REGIONAL ECONOMIC PERFORMANCE AND PUBLIC INFRASTRUCTURE INVESTMENT

by

Nicolas O. Rockler
B.A. Regional Science
University of Pennsylvania, 1976

M.A. Regional Science
University of Pennsylvania, 1977

SUBMITTED TO THE DEPARTMENT OF URBAN STUDIES AND PLANNING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY IN URBAN AND REGIONAL STUDIES
AT THE
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

FEBRUARY 2000

Signature of Author: ______________________________
Department of Urban Studies and Planning
January 20, 1999

Certified by: ______________________________
Karen R. Polenske
Professor of Regional Political Economy and Planning
Dissertation Supervisor

Accepted by: ______________________________
Frank Levy
Professor of Urban Economics
Chairman, Ph.D. Committee
Department of Urban Studies and Planning

REGIONAL ECONOMIC PERFORMANCE AND PUBLIC INFRASTRUCTURE INVESTMENT

by Nicolas O. Rockler

Submitted to the Department of Urban Studies and Planning on January 20, 2000 in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Urban and Regional Studies

ABSTRACT

Three studies were conducted to analyze the relationship between public infrastructure investment and regional economic performance. The first study examines the literature on economic development and productivity growth. I show that conflicting results from studies by other analysts are the likely result of poor public capital data spanning to short an interval, and an inadequate modeling framework. Public investment may generate small improvements in productivity, but models understate economic impacts owing to the public goods character of some forms of public capital.

The second study explores the relationship between economic distress and public infrastructure investment. I use a sample of U.S. counties to analyze public investment according to level of economic distress. With simple investment models, I estimated infrastructure needs for counties with apparent shortfalls. I analyzed the needs-estimates in a series of case studies in which jurisdiction planning and budget personnel were consulted about the accuracy of the estimates. I show that short-run economic distress is not to be linked to public infrastructure investment. Over the long-run, investment varies by level of distress, but as a consequence of private residential investment. The needs-estimating models were reasonably accurate, but missing investment data proved troublesome. Counties proved to be a poor unit of analysis for infrastructure needs, as since significant variation was observed among jurisdictions within counties.

The third study demonstrates the need for better estimates of public infrastructure capital stock. I prepared new capital stock estimates for two regions using local investment data and survey-based public capital service lives. I surveyed one thousand jurisdictions in the New England region and the state of Texas. Survey-based service-lives seem to differ significantly from estimated lives. Stock estimates using local investment data and survey-based service-lives produce dramatic differences compared to estimated stocks at the state and regional level. The new data, however, performed just as poorly as other series when used to estimate aggregate production functions.

Prior analysts' understanding the relationship between economic performance and public infrastructure investment has been limited because of poor data, and inadequate appreciation of infrastructure's inherent complexity. The research presented here demonstrates that significant improvements are possible and worth undertaking.

Dissertation Supervisor: Karen R. Polenske

Title: Professor of Regional Political Economy and Planning

REGIONAL ECONOMIC PERFORMANCE AND PUBLIC INFRASTRUCTURE INVESTMENT

January 2000

Nicolas O. Rockler, Ph.D. Candidate
Department of Urban Studies and Planning
Massachusetts Institute of Technology

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

I would like to thank several individuals whose help allowed me to complete this research. Foremost among them are Karen R. Polenske, my academic and thesis advisor, and Diana Rietveld, my wife. Professor Polenske was invaluable in guiding this work and was enormously patient with my rate of progress. Over a long period, she was always helpful and encouraging, something for which I am very thankful. Diana's contribution was also one of patient encouragement, combined with great efforts in running the household, caring for our two children, *and* working a regular job. I suspect she had her doubts and deserves much credit for not acting them.

I would also like to thank Frank Levy and Kirk Bozdogan, dissertation committee members, who provided valuable advice and suggestions. (They may never view public works in the same light again.) I would also like to thank two people in the Department of Urban Studies and Planning who helped guide me through MIT, notably Sandy Wellford and Rolf Engler.

This dissertation started around the time our first son, Harmen, was born. He was followed two years later by Arno. Early on, both developed an interest in public infrastructure, as our many public transit trips will attest. They will soon be testing other forms of infrastructure, notably schools, and I hope their experiences are "productive."

This research was completed with financial support of a dissertation grant from the U.S. Department of Housing and Urban Development (HUD Grant H5938-SG), and through sponsored research funded by the U.S. Economic Development Administration (Project #99-06-07430). Their interest in this topic is gratifying. I hope they continue to sponsor work in this field, supporting students' research on topics for which there is, otherwise, a real shortage of funding.

Any errors, omissions, or deficiencies are strictly of my own making and none of the above persons shares responsibility for them.

Nicolas Rockler
Cambridge
January 2000

CHAPTER 1 - INTRODUCTION

This dissertation is comprised of three separate papers that concern regional economic performance and public infrastructure investment. Public infrastructure, at its core, is the capital needed to produce public goods and services. Production and delivery of these is the fundamental reason for the existence of the many governments that make up the public sector. At issue in this research is whether public investment plays an important role in the economic growth process. Can it be used as a development tool, and if so, what types of public investment promote growth?

The history of public infrastructure is as old as the first collective arrangements for supplying water, maintaining roads, developing harbors, providing protection, etc. These activities have been pursued by people around the world for thousands of years and it would seem as though we ought to have a pretty good idea by now as to whether they contribute to economic growth and development. In a general sense, we do, but not based on the analyses of data using formal economic models.

We know from a cursory understanding of history, for example, that canals improve accessibility and enhance the value of land and resources that were previously too distant for economic use. We know that such investments generate new opportunities for businesses to serve the population that owes its livelihood to the existence of the canals. Growing population and business opportunities, in turn, lead to ever greater concentrations of population and economic activity along the canals, initiating development of urban centers.

We know that urbanization made delivery of certain public services feasible, creating a sufficiently large market to offer education and public health services. We know that when projects such as these perform as planned, improved public welfare results. But, it is one thing to observe canal building and another to impute subsequent growth and development from this one public investment.

We know that not all public investments perform as planned. Some detract from future development by devaluing existing private assets and others fail to deliver on promises for reasons external to specific projects. We know that economic context plays an important role, just not how much.

It is surprising to realize that we still cannot draw definite conclusions as to whether infrastructure investments, in aggregate, enhance the productivity of an economy. Do they help a little bit, a lot, or not at all? In the late 1980s, widely publicized research argued for increased public investment as a means of stimulating productivity growth. Subsequent research, however, indicated that the effect was only very slight, and certainly not large enough to promote creation of an "infrastructure policy" by governments. What was striking then, as now, is how little understanding there is regarding how infrastructure investment is measured, how stocks are estimated, and how inexact is the basis for such estimates. Researchers employ figures that may completely misrepresent the available stock of capital, and then develop research results that can offer only weak support for what are essentially expressions of political ideology. The data are too poor to support more precise conclusions.

In these papers, I examine the role of infrastructure in *regional* economic performance. The regional perspective lets us examine hypotheses about functional relationships while varying economic context, where differences in history and development generate a range of outcomes. Distinctions among "older" regions, "industrial" regions, urban areas, etc. are found in regional data that are either not found in aggregate data or which become intractable when international comparisons are used.

In the first paper, presented in Chapter 2, I examine two separate streams of economic thought concerning infrastructure investment, those found in the literature on development and those on productivity. I connect these two because the productivity research offers no clear statement of theory or anticipated results, whereas infrastructure investment plays a large role in the development planning, at least as regards undeveloped areas. Also, the productivity literature presents an enormous range of output elasticity estimates. Most of the research treats public capital as a homogenous good, even though the differences in output effects between a utility generating plant, for example, and school facilities, are easy to recognize.

The development literature was reviewed in the hope that it would clarify the role of infrastructure and growth, but it is seen to be vague when it comes down to the types of investment that promote growth. This reflects the difficulty of generalizing about a very complex good, one whose own characteristics vary from case-to-case, and where the context determines the impact.

One of the fundamental tools of productivity research, the aggregate production function, yields conflicting results when viewed over the work of a number of researchers. In many instances, the estimated output elasticities do not make economic sense, but analysts do not examine these results. In this paper, I indicate the problems of using aggregate production functions, identifying characteristics of the data and conceptual problems of the models. One of my key findings is that the realities of infrastructure make estimating the economic role of infrastructure a very difficult task. Its lagged impacts, its generation of spatial externalities, its funding at levels that reflect political realities (but not market equilibria), and the poor quality of the data themselves create huge barriers to simplification with the aggregate technique.

Economic performance, as used here, is measured using output growth, unemployment rates, and per-capita personal income. These are conventional income-accounting measures (e.g., gross state product in the United States) and are not comprehensive indicators of economic impact. Gross product measures, for example, ignore the social costs and benefits that are often the sought-after consequences of public investment. Unemployment and personal income measures are used as eligibility criteria for some public works programs, and are key indicators for the research presented in Chapter 3.

In Chapter 3, I examine the use of so-called "short-cut" techniques to estimate infrastructure needs. It is intended that these be used to identify economically distressed places with sizeable needs. Distress is measured by high relative unemployment rates and low per-capita income levels. Public investment has a long history of use as a tool in fighting unemployment, but largely for its counter-cyclical effects. It has also been used in the United States for stimulating economic restructuring through provision of public capital to attract private investment. It is for this latter activity that analysts seek improved needs estimates.

In this research, I demonstrate that the basic premise, that places exhibiting high degrees of economic distress are infrastructure-deficient is false. Local investment data indicate that distress is not linked to public infrastructure over the short-run, and that over the long-run, the differences that are evident are the consequences of endogenous growth-responses to private investment, not the cause. The categories of public investment thought to stimulate growth and development, such as highways, water systems, and power utilities, did not perform as might be expected among places that successfully made the transition from being distressed to nondistressed.

Among the other important findings of my study is that imposing the use of a single standard geographical unit of analysis, counties in this case, will not work for short-cut infrastructure needs-estimation. Infrastructure is supplied by a broad range of overlapping jurisdictions, from the very local to multi-state regions. Aggregation to a county-level causes information losses that can lead to inaccurate assessment of needs. I also show that some of the data used for making these estimates (and those that are used currently for measuring public investment) fail to measure some infrastructure investments supplied as a part of residential development. To the extent that they are included in the value of residential investment, the data for both types are made inaccurate and misleading for infrastructure needs estimation purposes.

The final paper, presented in Chapter 4, concerns empirical estimates of public capital stock, the fundamental measure common to all three papers. Used by most analysts, the "Fixed Reproducible Tangible Wealth" data as prepared by Bureau of Economic Analysis (BEA) offer national-level data on publicly owned capital. These estimates combine time-series of gross investment with estimates of depreciation to produce net capital stocks using the perpetual inventory method. The public depreciation data, however, are either those of a functionally analogous private category, or an estimate with no empirical basis. In so much as *gross* investment the 1947-1989 period is estimated to have grown by 2.2% per year[1] (BEA, 1993), and the Department of Energy's (DOE) commercial building demolition rates show a 3% rate (DOE, 1985), we might expect to see a declining stock. Instead, we see BEA's net capital public stock growing at 2.3% over the period. A well-estimated removal rate (or service-life rate) becomes extremely important when the difference between positive and negative net growth hinge on accuracy of the investment and removals data.

For this analysis, I conducted a survey of 1000 jurisdictions in Texas and New England was used to estimate service-lives for different types of public capital. The survey results show significant differences in the lives of highways and water/sewer systems between the two regions. When used to

[1] Measured in constant dollars. The growth rates are calculated from data given in BEA (1993), pp. 332-339, 421 and DOE (1985), p. 9.

estimate capital stocks, regional investment data and empirical estimates for removals produce stock estimates very different that those obtained by "sharing-out" the BEA national estimates using state proportions. I demonstrate the feasibility of assembling empirical data, although I encountered difficulty with obtaining data from large jurisdictions.

Even with improved data, aggregate production functions for the two test-regions did not produce significant improvements or credible results when estimating infrastructure's output effects. The reasons for this might be that too short a history is used, combined with a lack of detail for different infrastructure categories.

There remain significant opportunities to expand our understanding of regional economic performance and public investment. Obviously, better data are key to distinguishing the infrastructure types and local conditions under which public investment is likely to have an impact on private productivity. Better data, based on empirical measurement and prepared using state and small-area investment data, will also improve the accuracy of needs-estimates, but it seems unlikely that sufficient detail will become available for sub-county jurisdiction-level analysis. Application for better estimates will probably be limited to regions comprised of counties and larger, an appropriate aggregation for some public services.

REFERENCES

Bureau of Economic Analysis. 1993. Fixed Reproducible Tangible Wealth in the United States, 1925-1989. Washington, D.C.: U.S. Government Printing Office.

U.S. Department of Energy. 1985. "Characteristics of Commercial Buildings 1983." Washington, D.C.: U.S. Government Printing Office.

CHAPTER 2 - REGIONAL ECONOMIC PRODUCTIVITY IMPACTS OF PUBLIC INFRASTRUCTURE INVESTMENT

INTRODUCTION

Over the last decade, economic analysts (e.g., Aschauer, Munnell, Morrison and Schwartz, etc.) have attracted the attention of planners with the finding that public infrastructure can generate regional productivity gains. The idea that infrastructure is able both to produce useful public services *and* stimulate productivity growth sounds very attractive, particularly for assisting underdeveloped and distressed regions. These findings have found a ready following among government agencies and lobbying groups interested in promoting additional public investment, and increasing the level public investment has since become a policy goal during much of the 1990s, and as noted in the *Wall Street Journal,*

> Spending on infrastructure-a word that was associated with crumbling bridges, roads and other public projects in the tax-spending debates of a few years ago-is hot. Because of heated competition between states for corporate plant and office relocations, more and more regions have better roads, sewers and transportation systems. [2]

While there may be "heated competition" among jurisdictions to offer high-quality infrastructure services, there remain questions as to whether such investments strengthen regional economies by raising productivity or merely sustain existing

---

[2] *Wall Street Journal.* August 12, 1997. P.2.

activity without providing a growth stimulus. The difference is important because net new investment carries with it the possibility of subsequent investment to exploit newly available services and, therefore, further development. Replacement of worn-out capital has much more limited development potential.

In this paper, I examine the linkages between public infrastructure investment, economic development, and productivity growth. In particular, I am interested in knowing three things:

1. What conditions determine whether economic growth is dependent on net growth in public capital in the context of a developed national economy?

2. What types of impacts do such investments have on existing productive factors (i.e., labor and capital)?

3. What is the likely size of such impacts? If the gains are of significant size and appear to occur with predictability, planners may want to incorporate productivity impacts in their cost-benefit analyses and capital planning programs.

First, I review two disparate streams of economic literature concerning infrastructure investment/economic development and infrastructure investment/productivity growth. Second, I examine how the use of disaggregated regional and infrastructure-type capital stock data affects the results. Third, I discuss measurement and modeling problems evident in the current research. Finally, I offer conclusions and notes key areas for further research.

THE ROLES OF PUBLIC INFRASTRUCTURE INVESTMENT IN ECONOMIC DEVELOPMENT AND PRODUCTIVITY GROWTH

Among economists, there is a widely held view that public investment in certain types of infrastructure capital is desirable. The earliest justifications are two-fold: First, some forms of infrastructure exhibit the characteristics of "pure" public-goods. Street-lighting and flood-control are examples wherein the beneficiaries of such facilities cannot be excluded from enjoying the service, and there is no practical limitation on the number of persons (within the lit area or protected flood plain) who can benefit. A second justification arises with "natural" monopolies, such as telecommunications, power generation/distribution, and some public utilities (e.g., water storage/distribution and sewage collection/and treatment.) These are often publicly regulated and sometimes publicly provided, so as to claim for the public the excess profits arising from monopoly and economies of scale.

Although the justifications for public provision are simple enough, little effort has been expended on development of a "general theory" as to the role of public infrastructure in economic development. Public capital is highly heterogeneous, usually defined to include transportation systems, water storage and distribution systems, energy generation and distribution systems, general government services related to public safety, and often health and education. It is the product of highly complex political and financial institutions that have evolved for its provision. Polenske and Rockler (1993) note its general characteristics as being: (1) its large scale and long service-life; (2) the significant role played by public institutions in its finance, production, and maintenance; (3) its propensity to generate external economies (both positive and negative) as its services are consumed, and (4) its networked structure. Batten (1996) identifies two additional factors that add to its complexity, most prominently the timescale to be applied to the analysis of infrastructures' interaction effects with the private economy and the dynamic nature of urban (and regional) environments.[3] One final feature worth noting is the incremental nature of infrastructure investment in developed economies. The economic impacts of additions to existing

[3] Batten also includes issues of qualitative versus quantitative effects, and the need for better accounting of social costs. To illustrate these latter points, Batten points to the changing dominance of different transportation modes over the past 150 years, with the shift from canal to rail, rail to road, and prospectively, road to air, as evidence that different forms of infrastructure yield different developmental outcomes. These outcomes are not limited to the technological impact of one transportation mode versus another, but of creating and altering path-

networks are difficult to gauge, but, as a general characteristic, they are very much smaller than the effects of the investments that occurred when that economy underwent initial development.

Infrastructure's inherent complexities have a profound effect on how widely applicable existing theory really is. Consider the first question, specifically under what conditions is economic growth dependent on net growth in public(-*goods*) capital? As planners, we would like to identify measurable regional characteristics that can determine when public capital investment stimulates productivity growth.[4] In wholly undeveloped regions, for example, it is conceivable that some forms of public investment (e.g., sewage collection and treatment) will have no impact on overall growth (measured using conventional income accounting), while others always (or nearly always) serve to stimulate new activity (e.g., roads or utilities). In congested, developed regions, however, adding public capital may produce completely opposite effects. Consider the effect of additional highway capacity that results in a larger volume of traffic on city streets, reducing accessibility there and driving down local productivity due to congestion. Clearly, economic growth or production models will need to include contextual measures if we desire to develop the "rules of thumb" to guide planning decisions.

---

dependent returns-to-scale at different locations

[4] Similarly, we want to know whether certain forms of public investment represent the likelihood of slowing overall regional growth by either

Even if we do not identify systematic links between economic growth and public-infrastructure investment, we still want to know if public investments tend to have a complementary and/or substitutive relationship with specific types of labor and private capital. Public water-system investment, for example, is clearly *substitutive* for the labor and capital required for private water provision. At the same time, however, it is *complementary* to other forms of private investment (and its respective labor and capital requirements) when business-needs dictate access to adequate sources of water for commercial or industrial purposes. Because public investments may be needed or desired *even in the absence of productivity enhancements*, it is important to consider these other impacts. We need to remember that asking whether public capital is complementary or substitutive to private capital and labor should be answered by identifying what specific types of private capital and which specific groups of labor are affected.

The Role Of Public Infrastructure In Economic Development

For development economists (e.g. Hirschman (1958), Nurkse (1967), and Rosenstein-Rodan (1959)), virtually all public investment is "productive" so long as it creates useful services and leverages private investment, so that entrepreneurs will attempt to profit from its availability. Under the right circumstances (and assuming it is neither misdirected nor ineffective in generating useful services), these analysts

---

imposing a tax burden for finance or by "crowding-out" private investment.

maintain that such an investment will initiate a chain-reaction, a series of private and public investments that sustain economic growth and development.

Recent research by a few analysts, such as that of Eberts (1990) and Rietveld (1989), rely on Hirschman (1958) to identify the general tendencies of infrastructure with respect to economic growth and development. Hirschman is credited with the idea of focusing investment in sectors with strong intersectoral linkage relationships with the potential to create investment inducing disequilibrium (the so-called "unbalanced" growth strategy). He provides a descriptive overview on the role of infrastructure in economic development, its variable impacts, and the mechanisms that stimulate growth.[5] The development process, he argues, is not one of defining (or discovering after the fact) an optimal growth path and investing to achieve it (since he notes that this is all but impossible), but of initiating an interplay of investment between "social overhead capital (SOC)," consisting of public infrastructure and public enterprises, and "directly productive activities (DPA)," comprised of private-sector industries. This interplay occurs with private investment designed to exploit imbalances in profitability and returns arising from external economies that are, in turn, generated by public or private activity, and

5. Hirschman's arguments are often made with reference to the problems evident in underdeveloped economies, particularly institutional ones, but are not limited to such cases. Identical arguments can be applied to developed economies, but the scale effects of disquilibria that are thought to promote investment and growth become smaller and smaller as development proceeds. This is useful to remember

public investment that both serves a wide variety of needs and helps create additional externalities due to indivisibilities and/or its public-goods character.

Hirschman does not elaborate on the tendencies of different public-capital types to stimulate development. SOC, as a group, delivers basic services without which private production cannot occur. These include legal, education, public health, transportation, communications, power, water supply, and agricultural irrigation and drainage. The "hard core" of SOC consists of transportation and power, availability of which are "preconditions" for development. Hirschman does identify general conditions under which public investment will generate productivity impacts, noting that the correct measure is that of "social marginal productivity," but given the difficulty in estimating this measure, he concludes

> The trouble with investment in SOC--or is it its strength?--is that it is impervious to the investment criteria that have been devised to introduce some rationality into development plans. The computation of capital-output ratios often presents almost insuperable statistical difficulties (as in the case of highways) and is moreover considered to be misleading anyway because of the igniting effect SOC investment is expected to have on DPA. As a result, SOC investment is largely a matter of faith in the development potential of a country or region. The fact that there is so little possibility of evaluating objectively how much investment in SOC is really indicated in any given

---

when considering the size of productivity impacts that might be anticipated in developed economies.

situation should give us pause. Such a situation implies at least the possibility of wasteful mistakes. (Hirschman, 1958, p. 84)

In advanced economies, the ability of public institutions to achieve productivity gains with specific public investments seems to be limited. Hirschman argues that both surpluses and shortages of SOC can have positive effects on the productivity of private capital. In some instances, development can be accelerated through SOC shortages that induce private investment in substitute capital. Even in a case of SOC-DPA equilibrium, a collective memory of SOC shortages might create a speculative response on the part of private firms to invest to overcome an impending SOC shortage. Hirschman notes (Hirschman, 1958, p. 95), "a moderate SOC shortage is not likely to do too much damage to a really dynamic developing area. In such a situation, industries will think nothing of bringing in their own diesel generators, of digging for their own water, and of building their own access roads and workers' houses."[6] On balance, a stable or declining net public capital stock may induce a net increase in private capital as substitutes.

In other instances, a surplus of SOC acts as a "permissive" factor to attract private investors to a region to exploit the availability of SOC inputs. It is, however, not always a simple task to engineer a surplus that yields productivity-increasing

[6] The rising incidence of "telecommuting", where workers substitute telecommunications technology for traveling to the workplace, may be a private response to an SOC shortage.

private investment. The problem lies with the fact that there are few mechanisms to signal public officials when too large a surplus investment is achieved and little assurance that private investors will perceive surplus public capacity as a means of securing a profit. Thus, both shortages and surpluses of public capital can contribute to slowing private productivity growth, but generalization beyond this is not helpful.

Hansen (1965) builds on Hirschman's description of capital as being directly productive (private) or overhead (public) by distinguishing two types of overhead capital, "economic" overhead and "social" overhead. Economic overhead, by Hansen's (1965, p. 5) definition "supports directly productive capital, and includes roads, bridges, harbors, power projects, and similar undertakings." Social overhead capital, on the other hand, functions to benefit society in a general way, through education, health, and social welfare functions. Hansen views economic overhead capital as being complementary to private activity (and presumably to both private capital and labor), but only in regions that are not "congested." Congestion is said to exist when the marginal social productivity of any new DPA is negative. The production relationship of SOC is indeterminate, owing to its role as a generator of externalities that can be alternatively substitutive and complementary to capital and labor, and depending on the specific nature of the DPA to which it is connected. In congested regions, additional overhead capital of either type is undesirable because it will be surplus. It will attract additional private capital investment because investors perceive additional public capacity as a basis for new growth, and are not concerned with social externalities, thereby aggravating congestion even more.

Hansen offers a hypothetical scenario in which the relationship between DPA and both forms of overhead capital investment change depending on the level of development. Unfortunately, levels of development are poorly defined in regional economics, being proxy measurements for an indefinite set of institutional and economic/social characteristics that few are willing to define in rigorous fashion.[7] Thus, Hansen's contribution extends Hirschman's apparent answer to the question of "How is regional growth dependent on public capital investment?" from being "it all depends on circumstances" to "it depends on the level of development." He does not, however, offer any theoretical arguments as to whether certain types of public capital do or do not influence regional economic development or growth.

In designing a theoretical regional economic development policy model, Leven, Legler, and Shapiro (1970) included type-disaggregated public capital in industrial production functions

[7] Rives and McHeany (1995) offer an index measure of development that is constructed from weighted values of income, employment, population growth and property value. Similarly, they compute an index measure of infrastructure availability using a weighted index of water, sewer, and highway stocks and distance-defined accessibility. They find a positive correlation between infrastructure and development, but do not attempt to determine whether growth in infrastructure is endogenous to the development process or vice-versa.

to estimate regional output. They use contemporaneous physical measures of public capital stock in the model, and suggest that "While literally hundreds of classifications might be needed for manageable physical measures of private capital, the public sector could probably be accommodated, at least by dozens, and perhaps by as few as eight or ten." (Leven and others., 1970, p. 44.) They exclude portions of public capital that do not figure directly into the industrial production functions. Excluded parts can be used as determinants of regions' "environmental quality," because they "could affect consumers' satisfactions that could influence the region's labor supply" (p. 44). This is consistent with Hansen's scheme of splitting overhead capital into EOC and SOC. Leven and others use the various types of EOC as factors in the context of conventional industrial production function. They are among the first to propose decomposition of capital to split public and private forms in the context of the Cobb-Douglas model, an important concession that recognizes that factor endowments are not uniform over space. They do not, however, appear to acknowledge that some forms of public capital are generators of externalities characteristic of public-goods; therefore, they retain the constant returns to scale assumed in the Cobb-Douglas formulation. Ignoring this latter problem for the moment, their attempt to integrate public capital into the production function is a valuable contribution to the theory.

Mera (1975) views the matter somewhat differently than Hansen and Leven and others when he examines social overhead infrastructure's relationship to the efficiency of private capital. He "assigns" certain forms of infrastructure to industrial sectors, such as public irrigation to the agricultural sector, vocational training facilities to the manufacturing sector, and transportation and communications to the transportation and communications sector, etc. Public capital that remains unassigned is treated like Hansen's social overhead category, consisting of education, health, and welfare services. These categories, taken separately at times for some industries and together at others, form an "environmental" variable, that he uses in a Cobb-Douglas relationship with labor and private capital.

Mera tries to find-out which, if any, of the various combinations of the sector-specific public capital are linked to private sector productivity, either directly or as environmental variables. Later, he uses a combination of public and private capital. As an empirical exercise, Mera concludes that the results for a cross-section of 46 Japanese prefectures are remarkably disappointing because of seemingly contradictory and inconsistent findings. Mera finds, for example, that increases in public capital stocks generally have a negative impact on agricultural sector productivity (e.g., the higher the quantity of soil conservation, irrigation, and flood control capital, the lower the agricultural labor productivity). Additionally, the estimated impact of various environmental variables that are intended to be proxies for urbanization and agglomeration economies (some of which are combinations of categories of public capital stocks) prove, in nearly all cases, to have opposite values from the expected ones. Mera did not attempt to devise an interpretation for the unanticipated findings. We will return to some of the specific findings in the next section.

With respect to the three major questions of this paper, the economic development literature is seen to be only somewhat helpful. It is clear from the earliest analyses that context matters a great deal. The development impacts of public investment, if any, are a function of the social and economic context in which they are located. They can be difficult to observe, even with good data, because of the incremental nature of investment and the networked structure of public infrastructure system. This also makes it very difficult to generalize about infrastructure's development tendencies.

Economic overhead capital, i.e., roads, power utilities, communication utilities, and water systems, is the most likely means of enhancing productivity growth. When its creation generates exploitable benefits that can be "captured" through a linked private-owned investment, economic growth is possible. It becomes difficult to tell, however, once some development has occurred, whether additional public investment is the cause of private investment or is brought forth to satisfy a demand for services imposed by the presence of private activity. Measured over a long enough time period, the causality question disappears, but, by the same token, so does the prospect of using public investment initiate a sequence of development.

Social overhead capital, notably education, health, public safety, and environmental service facilities, appears to enhance development potential by means of improving the "economic climate", i.e., by helping to improve health, learning, and safety. The mere presence of facilities, however, is no guarantee that such services are produced. Although it would be wrong to conclude from the economic development literature that social overhead capital does not matter in promoting growth and development, it is evidently less important than the economic overhead types of infrastructure.

The Role Of Public Capital In Productivity Growth

In the course of reviewing analyses of infrastructure's productivity impacts, Jorgenson claims:

> The good news is that economists have built up a set of techniques for analyzing infrastructure investment based on sound microeconomic principles and ample empirical data. (Jorgenson, 1993, p. 5.)

In this section, I review the nature of these techniques for application here. In the research covered below, the predominant method of analyzing public capital's role in economic growth is to treat public capital as if it were like any other productive factor, i.e., labor or private capital, and enter it into a production or cost function. Unlike those other factors whose prices (and underlying supply and demand interactions) are nearly all market-mediated, however, public capital is viewed as an unpaid factor. There are a variety of forms for production functions, and assumptions vary from one to another, but for the most part, public capital is treated as any other homogeneous production factor. This is clearly at odds with public capital's prominent idiosyncrasies, however, which I noted earlier.

In the development literature, no explicit expectation is given as to how large a role public capital plays in determining the level of output. Munnell (1990) notes that the shares of national income attributable to capital inputs (all types) are approximately 35%, leaving 65% for labor inputs. She implies that after including public capital, a combined capital figure that is close to the 35% might be reasonable. Obviously, departures from income shares would be expected when public capital acts, on the whole, in a nonneutral fashion with other factors (i.e., when it substitutes for or complements those factors.) However, no researchers have offered a precise *a priori* estimate for the elasticities. As I will show, the estimated values do cover a broad range, including some negative values for both private and public capital.

Production Functions

In Leven and others' model (1970) described above, a Cobb-Douglas production function is employed for analysis of infrastructure's productivity effects. The Cobb-Douglas is one of several forms of production functions that can be applied for specific industries or for aggregations of sectors, up to and including an entire economy.

Although the Cobb-Douglas form is useful for many purposes, it entails certain limiting assumptions that make it unsuitable for analyzing public capital's productivity relationships. To begin with, when used to estimate the shares of output attributable to different factor inputs, it is presumed that each factor is paid its marginal product. When factors' marginal products are market determined, this works well, but for public-goods, there is no market price. In fact, the absence of market discipline to meter the correct level of public investment can result in overinvestment, with a possible consequence being negative output elasticities.[8]

Walters (1963) indicates that output elasticities are generally limited to values greater than zero, despite the

---

[8] The lack of precision used to determine the level of public investment by political means is well illustrated by the comments of the California senate leader. When asked about a proposed highway investment level of $16 billion, Senator John Burton responded that it would have to be an amount that "would not scare the electorate…It could have been $12 billion, but that would have been too little. It could have been more, but that would be too much. [Sixteen billion] just seemed kind of there." (*Los Angeles Times,* March 8, 1999, p. A3.)

possibility of negative output effects at various times. Berndt (1991) cites the need to include negative marginal products in agricultural production as the driving force to develop the transcendental-logrithmic production function by Heady and Dillon (1961), while Lynde and Richmond (1992) employ the same rationale (i.e., the need to allow for negative marginal impacts) in recommending the use of a cost-function.

The Cobb-Douglas function is premised on constant returns to scale. Under this assumption, scalar increases in inputs yield identical scalar increases in output, so that, for example, doubling public capital, private capital, and labor inputs produces double the output and so on. The problem here is that it precludes public goods from acting like public goods. For "pure" public goods, i.e., those that are both nonexcludable and nonexhaustible as defined by Musgrave and Musgrave(1989), their presence in a productive activity cannot be presumed to have constant returns to scale. For example, once a roadway is illuminated, increasing the level of nighttime usage is cost-free.[9] The Cobb-Douglas function would have it otherwise, however. Another problem with the Cobb-Douglas function is best illustrated with an example: If one imagines a region in early stages of development and looks at water and energy utilities, it might be seen that at low levels of output, increasing returns to scale would be apparent with increasing private usage (and increasing private capital purchases and labor to facilitate this), followed by an output level at which constant returns might become a feature, followed by diminishing returns at very high levels of output. Similarly, regions with various rates of growth and development serviced by one energy or water system network might face such variable returns to scale. That a simple model like the Cobb-Douglas can fairly represent such regions for comparative analysis seems like too great a leap. Constant returns to scale is a poor representation for capital such as public facilities that are intentionally overprovided for long periods to provide sufficient capacity in order to accommodate growth.

Hakfoort (1991) notes that another difficulty with the Cobb-Douglas production function is that it is unclear as to which way the causality runs, i.e., it is unclear whether public capital-stock growth drives output growth or the other way around. This criticism could be applied to all production functions, however. Causality and production functions involving public capital remain controversial among economists, not so much for technical reasons, but largely for political ones related to the role of the state in shaping economic affairs.

Another form of production function that has been used for some empirical estimates is the transcendental-logrithmic production function, often called the "translog" production function, derived from the research of Heady and Dillon. With this function, a range of production technologies are possible,

---

[9] Cost-free in terms of both use-cost and social cost, until it becomes congested.

with input substitution responses possible for different levels of output, and with returns that can vary depending on output levels. This latter point is a desirable feature for infrastructure analysis, because the interplay of response-times can be long when new capacity is added, and utilization rates change over time with development. As with the Cobb-Douglas production function, the lack of price and market-discipline problems remains, however, and the absence of prices to signal the "correct" quantities of public service inputs will violate equilibrium conditions. This will have an effect on all the output elasticities, not just those for public investment.

Cost Functions

Another approach to capturing the external economies within an analytical model framework is to use a cost function, as suggested by Nadiri and Maumuneas (1991), Lynde and Richmond (1992), and Morrison and Schwartz (1992). The reasoning behind using a cost function is that if public capital investment has productive impacts, the cost-saving impacts on private firms should be apparent. Morrison and Schwartz specify a variable-cost model that includes capital (public and private), labor (production and nonproduction), and energy, and the relevant factor prices, e.g., wages, price of capital (a function of corporate tax rates, rates of return for capital, and depreciation rates), and energy prices. These are combined with capital stock, labor, and energy inputs to estimate a cost function whose parameter estimates can be used to compute elasticity measures for factors. In their empirical results, the analysts find that aggregate costs do tend to decline with investment, but not always. I note several of the exceptions in the next section. With market-determined prices and costs, it seems difficult to imagine a circumstance where investment in public capital increases aggregate production costs, but these unanticipated results might not prove to be altogether wrong.

EMPIRICAL RESEARCH FINDINGS

Much of the current interest in the subject of productivity effects of public infrastructure investment was sparked by research conducted by Aschauer (1989) concerning slow growth in aggregate national productivity and its links with public investment. Aschauer's findings of large output elasticities are both a source of astonishment and the object of severe criticism. The astonishment derives from the fact that few economists were cogniscent of the possibility that in an advanced economy, public capital investment might have a sizeable link with output. The results were criticized for a variety of reasons, summed-up by Faucett (1994, p.1) as "implausibly high returns to public investment and short payback periods."

Aaron (1991) offers a strong critique of the Aschauer work consisting of four main points: First, time series of the type used by Aschauer offer little information, as he employs annual data that are dominated by trends. Second, the size of the estimated public infrastructure elasticities are far too large, and if correct, would have astounding implications for public investment policy. Third, Aschauer's conclusion that too little public investment explains an otherwise unexplainable decline in U.S. productivity is unproven by the results. Finally, application of aggregate production functions to factors whose prices are not market-determined is inappropriate.

Jorgenson (1991), Tatom (1991), and Holtz-Eakin (1991) also criticize the findings on methodological grounds. Jorgenson questions the statistical validity of the findings, focusing on the issue of presumed stationarity in the regression estimates. He notes that neither the dependent variable, output, nor infrastructure investment is stationary, i.e., is the product of fixed underlying processes, over the interval 1949-1985. He notes that the solution for this type problem is to estimate for the differences in the dependant variable, output. Tatom questions the omission of energy price effects on productivity, since the interval is one marked by drastic swings in the real price of energy inputs. He also questions the omission of a time-trend in the estimates to act as a rate-of-change shift in technical progress. Holtz-Eakin's criticism concerns the lack of variation in the data altogether, having covered a period of productivity growth from 1949 to 1973 following by a period of decline thereafter.

The production function models I review fall into four general categories : (1) national estimates using national time-series data, (2) national estimates using regional cross-section data, (3) national estimates using regional cross-section/time-series, and (4) regional estimates using cross-section/time-series data (Table 1). A fifth set, disaggregated industry and infrastructure types is covered in a later section. I summarize the significant findings for the four types below.

National Estimates Using National Time-Series Data

The national time-series estimates reveal a broad range of estimated public capital output elasticities, from a low of 0.04 (and not significantly different from zero) estimated by Tatom to 0.39 estimated by Aschauer. Labor shows an equally wide range of elasticities, but the private capital estimates all fall into a narrower band, 0.18 to 0.26. It is surprising to find such wide variation across the different analysts' public capital and labor estimates considering all were estimated with essentially the same data. The two Ratner estimates are notable because the first estimate, 0.06, jumped to 0.28 when re-estimated by Tatom using revised data. I cannot understand how the relationships could change so drastically with only a revision of highly aggregate data. Tatom's own estimates use the first differences of the factor inputs in the model in an attempt to correct for the various Aschauer-type problems. Doing so yields the conclusion that the public-capital output elasticity is essentially zero. As the remaining national and regional data demonstrate, implausibly wide variation in the estimated elasticities is characteristic of the results found in the research, an indication of conceptual problems, data problems, or some combination of the two.

As with all of the time-series estimates shown in Table 1, analysts model the output response to investment as being a simultaneous (or, at least, contemporaneous) one. This is a clear misunderstanding as to how public-infrastructure investment occurs, both as an exogenous act and as an endogenous response to private investment. The same is true for private investment with respect to public investment. Given the long production period and response times of private investment to completed infrastructure projects, all of the time-series research would benefit from exploration of different lagged-responses to investment. In fact, the zero elasticity found by Tatom is partial confirmation of the need for lags, since no simultaneous correlation is reasonably expected and none is found.

National Estimates Using Regional Cross-Section Data

Da Silva Costa, Ellson, and Martin (1987) and Prud'homme (1991) developed cross-sectional estimates of the aggregate production functions. The cross-section imparts valuable information through variation in industrial structure, age of capital stock, demographic characteristics, resource endowments,

Table 1
Empirical Estimates of Infrastructure Output Elasticities

Author (Year)	Data Interval	Geographic Coverage	Function Type[1]	Type or Industry Detail
Aggregate Production Function				
Ratner (1983)	1949-1973	U.S.	C-D	None
Ratner, revised by Tatom (1991)	"	"	"	"
Costa, et al (1987)	1972	U.S.-48 states	T-L	"
Aschauer (1989)	1949-1985	U.S.	C-D	"
Munnell (1990)	1970-1986	U.S.-48 states	C-D	"
"	"	"	T-L	"
Holtz-Eakin (1991)	1969-1986	U.S.-50 states	C-D	"
"	"	"	"	"
"	"	U.S.-8 regions	"	"
"	"	"	"	"
Prud'homme (1991)	1988	France-22 regions	C-D	"
Tatom (1991)	1949-1989	U.S.	C-D	"
"	"	"	C-D	"
Kelejian & Robinson (1997)	1970-1986	U.S.-48 states	C-D	"
"	"	"	"	"
Sectoral Production Function				
Mera (1973)	1954-1963	Japan-7 regions	C-D	Agriculture, Forestry, Fisheries
"	"	"	"	Mining, Construction, Manufacturing
"	"	"	"	Services
Costa, et al (1987)	1972	U.S. 48 states	T-L	Manufacturing
"	"	"	"	Nonagricultural
Munnell (1990)	1970-1986	U.S.48 states	C-D	Infrastructure Type

1 C-D=Cobb-Douglas
T-L= Trans-Log

Table 1 cont.

Empirical Estimates of Infrastructure Output Elasticities

AUTHOR (YEAR)	Estimated Coefficient (Elasticity) Values			
	Labor	Private Capital	Public Capital	Other Variables
Aggregate Production Function				
Ratner (1983)	0.71	0.16**	0.06	0.02 (time trend)
Ratner, revised by Tatom (1991)	0.55	0.23**	0.28	0.13 (time trend)
Costa, et al (1987)	1.02	-0.16	0.20	
Aschauer (1989)	0.35	0.26**	0.39	0.01 (time trend), 0.43 (unemployment rate)
Munnell (1990)	0.59	0.31	0.15	-0.01 (unemployment rate)
"	0.69	0.22	0.16	-0.006 (unemployment rate)
Holtz-Eakin (1991)	0.50	0.36	0.20	-0.0005 (time trend)
"	0.69	0.30	-0.05	See Note 1
"	0.56	0.25	0.20	
"	0.72	0.27	-0.12	See Note 1
Prud'homme (1991)	0.80	0.23	0.01	
Tatom (1991)	0.61	0.26**	0.13	-0.05 (energy price), 0.02 (time trend), '-0.0001 (time trend)^2
"	0.74	0.22**	0.04*	-0.06 (energy price)
Kelejian & Robinson (1997)	0.55	0.34	0.15	-0.06 (unem. Rate), 0.41 (pop. dens.) ,-0.013 (neighbors' pub. cap.), 0.36 (neighbors' productivity), 0.0011*(time trend)
"	0.93	0.34*	-0.18	0.01* (unem. Rate), 0.10* (pop. Dens), 0.04* (neighbors' pub. cap.), 0.82 (neighbors' productivity), 0.002* (time trend)
Sectoral Production Function				
Mera (1973)	0.54	0.20	0.26[2]	0.0003 (land area), -0.0019 (all public capital), 0.268 (time trend)
"	1.08	0.12	-0.35[2]	0.14 (all public capital), 0.06(time trend)
"	0.73	0.40	0.51[2]	-0.64 (all public capital), 0.05 (time trend)
Costa, et al (1987)	0.77	0.11	0.19	
"	0.95	-0.15	0.26	
Munnell (1990)	0.55	0.31	See Other	0.06 (highway stock), 0.12 (water &sewer stock), 0.01 (other public stock), -0.01 (unemployment rate)

* Not significantly different from zero at %5

** Assuming constant returns to scale over all factors

[1] Independent variables transformed to deviations from state-level mean-values to minimize effects of missing state characteristics, e.g., size, density, location, natural endowments.

[2] Sector-specific public capital

cyclical conditions, etc. that occurs across regions. The major drawback is that using only one time period may yield misleading results if it is somehow an atypical one. As seen with the time-series results, a wide range of elasticities are estimated. Prud'homme's results fall in the range of those found in the national time series, but Da Costa Silva and others show extreme ones for labor and private capital. The unrealistically high labor elasticity of 1.02, and low -0.16 figure for private capital raise concerns about a mismatch between output and investment timing, a key risk with this model type. [10]

Da Costa Silva and others' translog specification permits some further analysis concerning relationships among factor inputs. The quadratic terms indicate that diminishing returns are present for labor and public capital as investment increases, but increasing returns with increases in private capital investment. The cross-product terms (not shown in Table 1) for labor and public capital show these to be complements, but none of the other interactions are statistically significant.

Da Costa Silva and others (1987) test three hypotheses concerning output elasticities and public capital endowments. The first one, advanced by Hansen, is that public capital will show diminishing returns as per capita public-capital stock increases. This is demonstrated to hold over the range of

[10] These are certainly unrealistic over a long-run, but not necessarily over a short period.

states. Another Hansen hypothesis is that output elasticities should at first rise with increasing family incomes, but then fall as congestion costs overwhelm gains from scale effects. This hypothesis was not validated in the results. A related hypothesis, that output elasticities should rise and then fall with increasing scale of agglomeration seems to have been untested. Despite claims to the contrary, Da Silva Costa and others' measure of agglomeration, state manufacturing value-added, is hardly a complete measure of agglomeration, since it ignores urbanization or localization externalities in favor of scale alone.

National Estimates Using Regional Cross-Section/Time-Series Data

An obvious way to overcome the shortcoming of strictly cross-sectional or time-series models is combine the two. Munnell (1990), Holtz-Eakin (1991), and Kelejian and Robinson (1997) have estimated models using state data. Unfortunately, all three researchers use the same public-capital stock estimates, i.e., those of Munnell, a set that has some significant flaws, as will be discussed later. Nevertheless, using a variety of data transformations and, in the case of Kelejian and Robinson, adding additional state data, alternative corrections for Aschauer-type problems are tested, as well as hypothesis testing concerning "spillover effects."

On the whole, using untransformed data fall within the ranges found for the national time-series data, i.e., output elasticity estimates for public capital are in the 0.15-0.20 range, still sizeable productivity impacts. With transformations, however, these estimates fall-away. For example, using annual percentage change figures, Munnell's public-capital elasticity measure drops to 0.11. Using each state's deviation from its own mean in one estimate,[11] and long-run percentage change (estimated using the range endpoints) in another, Holtz-Eakin obtains elasticities of -0.05 and -0.12. Although statistically significant, Holtz-Eakin concludes that public-capital's output elasticity is probably zero. Kelejian and Robinson see a similar effect from their use of state dummy variables and autocorrelation corrections that produce a public output elasticity of -0.14. They claim that the significance of these estimates disappears with spatial-correlation adjustments, although this is not demonstrated. From the set of estimates, the clear conclusion is that public capital has very little effect, if any, on output. There remain questions, however, as to whether measuring at the state-level using annual data in a contemporaneous fashion and using estimated capital-stock data, as done here, are appropriate for drawing this conclusion.

Holtz-Eakin's test of regional aggregation offers insight as to how estimated productivity relationships are affected by loss of data information and accuracy. The state-level data used for the national cross-section are aggregated to form a cross-section for eight regions. The idea is to internalize

[11] With the loss of cross-section effect as a consequence.

regional spillovers that are "missed" at the state level so that any benefits to neighboring states will be measured in the regional figures. Surprisingly, there was no effect on public-capital output elasticity at an 8-region level, but that may be because state data already internalize the benefits. Smaller political units for some forms of infrastructure are probably more appropriate than states. Biehl (1995) distinguishes "point" infrastructure and "network" infrastructure in regional development with respect to the breadth of services each offers. Network infrastructure, to the extent that it is indivisible for different classes of users, is largely space-serving, while point infrastructure is generally population serving. Road networks, telecommunication networks, and power grids service broad geographic areas and may be well measured by state areas. Schools, hospitals, and public safety facilities are mostly point forms, and may require smaller, not larger, areas of analysis.

Another effort to measure the effects of neighboring states' public-capital stock was included in Kelejian and Robinson (1997). In their study, they estimated the productivity of neighboring states' public capital as well as that of each states' own capital. They find that neighboring states' public capital has no significant effect on any given state's output. This finding is counterintuitive if one thinks of states that have significant commuter inflows from the suburbs of metropolitan areas, such as New York, the District of Columbia, and Massachusetts. It would seem that lower concentrations of infrastructure characteristic of the suburbs are possible because there is more infrastructure in the central cities to serve areas beyond its boundaries. This would tend to favor higher output in the central city. This appears to be the case using unadjusted data, but it subsequently became insignificant with corrections.

A final note on the regional cross-section/time-series results concerns scale effects and interactions among factors. Munnell's translog estimates for factor interaction (not shown in Table 1) indicate that both private capital and labor generate increasing returns, and that public capital appears to yield constant returns to scale. This latter finding is opposite to that of Da Silva Costa and others. Furthermore, she finds that private capital is a substitute for both labor and .public capital, a finding different from that of Da Costa Silva and others, who found that labor and public capital were complementary, with no other substitutive relationships being statistically significant.

Regional Estimates Using Regional Cross-Section/Time-Series Data

Munnell (1990) estimated regional elasticities for U.S. Bureau of the Census regions, using state-level cross-section/time-series data. As shown in Table 1, the estimates for public-capital output elasticity vary widely, with a low value of 0.07 in the Northeast to 0.36 in the South. The labor elasticities range from 0.36 in the South to 0.90 for the Northeast, while private capital elasticities range from 0.09 in the Northeast to 0.51 in the West. Wide ranges and odd-looking values, like those for Northeast labor and West private capital, might lead us to dismiss these findings as being poorly estimated because they depart from the suggested "normal" ones. Nevertheless, there is some value in examining certain of the relative relationships. For example, the public-capital output elasticity for the South is dramatically higher than that of the other regions. This is consistent with Hansen's notion that EOC is highly productive in uncongested regions, something generally true of the South during this period. At the same time, the Western region's relatively low public-output elasticity may fairly represent the productivity of capital in congested high-growth regions, something characteristic of many of the West's major metropolitan areas, particularly as regards roadways and water systems. It is evident that more research on regional timeseries models would be of benefit.

Alternative Views Of Infrastructure And Productivity Growth

As demonstrated from the various research results presented above, the evidence from several researchers is that the output elasticity of public capital generally ranges from zero to moderately large, i.e., up to about 0.20.[12] Aggregating

[12] The negative output elasticities observed in Table 1, if real, would seem unlikely to persist over a long period. The exception would be for regions where additional investment funded from outside the region was maintained somehow.

infrastructure into one category, however, might lead to the false conclusion that infrastructure has no productivity effects. Subcategories might evidence offsetting productivity effects, as might be the case for water and sewer systems, where the former stimulates private investment and growth, while the latter generates costs but no marketable output.

One of the most ambitious disaggregations was performed by Mera (1975), who not only separated infrastructure into several different categories distinguishing between EOC and SOC, but went on to classify these as to the user-sector, i.e., primary, secondary, and tertiary industry. Mera contends that public infrastructure can play a dual role, both as a direct contributor to sectoral productivity (as an unpaid factor of production) while forming a component part of external economies. Mera's estimated elasticity for each sector's own public capital is -0.35 for mining/construction/manufacturing, 0.26 for agriculture/forestry/fisheries, and 0.51 for services (Table 1). For some sets of "environmental" (SOC) categories, a positive relationship is found to benefit an industrial sector. For example, all public capital taken together accounted for an output elasticity of 0.14 in the mining/construction/manufacturing sector, which partially offset the -0.35 elasticity of that sector's own specific public capital. For services, the elasticity of aggregate public capital is -0.64 compared to 0.51

for its own public capital. For agriculture/forestry/-fisheries, the figure was negligible.

Mera is not alone in finding a range of elasticities for public capital, but both his, and those of Da Costa Silva and others (1987). have several extreme values that seem unlikely to be "final" long-run estimates. Munnell (1990) disaggregated not by industry, but by type of public capital itself, and estimated separate elasticities for each. Here, public capital elasticity is seen to decompose into 0.06 for highways, 0.12 for water and sewers, and 0.01 for other public stock. Also shown in Table 1 are the translog estimates for disaggregated public capital.

Using a cost function, Morrison and Schwarz (1992) find that a combination of highway and water/sewer capital stock accounts for between 15-30% of firms' production costs, depending on region in the United States., confirming findings from other studies that public-capital investment can have a sizeable impact on private sector costs, and hence, productivity. They also find decreasing returns in all U.S. regions except for the South, so that in the other regions, growth in the stock must exceed output growth to maintain a positive productivity relationship.[13]

Nadiri and Mamuneas (1991) apply a similarly constructed model (although the data inputs and derivations are different than those used by Morrison and Schwartz) to estimate separately

[13] The high return to Southern investment appears to confirm Munnell's finding that the South has a relatively high public-capital output elasticity. This is a good thing in so much as Munnell's data form the basis for Morrison and Schwartz's cost estimates.

but a willingness to overlook certain severe limitations that, if corrected, might significantly improve our understanding of the relationships. These are: (1) inappropriately short history applied to the analyses, (2) failure to disaggregate infrastructure types into meaningful categories, (3) poorly measured and unmeasured concepts, (4) use of mis-estimated perpetual inventory data for productivity analyses, and (5) failure to distinguish between publicly owned capital and public-goods capital. I discuss both the nature and consequences of these problems.

Inappropriately Short History

For U.S. regional income accounts data, time appears to "begin" around 1969, the starting point for BEA's gross state product estimates. These data are used as the dependent variable measures of output. By restricting themselves to these figures, analysts have a maximum coverage of 28 years. This period is barely adequate for capturing the interplay of investment, particularly for smaller geographic units where investment in individual infrastructure categories becomes more sporadic from year-to-year. If analysts were to consider the use of lags in the models, and there is good reason to think they should, 28 years begins to look even shorter. An alternative measure of output that comes close to value-added might be to use the components of personal income that are factor-related, i.e., wage and salary income for labor inputs

negative elasticity for general government capital investment.

and proprietor's income for capital inputs. State-level estimates of these data are available starting in 1929.

The other limiting factor with respect to data and modeling concerns the estimated capital stock. Type-specific subnational stock estimates do not exist for all types of public capital. For those that do exist, assembling the necessary time-series of investments to build stock time-series is a daunting task. Few researchers, with the exception of Eberts, have expended much effort in trying to build such series. The alternative approaches have been to distribute the national estimates to states. The problems with these techniques are that vintage characteristics are lost and the entire stock is depreciated at some uniform fixed rate for all regions. The absence of age-structure to the stock introduces homogeneity to the data, introducing bias into the estimates.

Infrastructure Type Disaggregation

Because of data availability problems, questions remain as to the productivity impacts of specific types of public capital. Efforts to distinguish among the different types must extend beyond the EOC/SOC distinction if planners hope to be guided in the channeling of public investment to areas that both produce useful services and enhance growth prospects. Mera's and Munnell's approaches of disaggregating by industry and facility-type are steps in the right direction, but not sufficiently detailed. It would be preferable to obtain data for at least the following types of infrastructure: streets, highways (limited access), water systems, sewer systems, educational/library facilities, hospital/health facilities, public safety, administration, power utility, and miscellaneous social service.

Unmeasured and Misclassified Infrastructure Creation

New commercial and residential development often includes investment in some forms of infrastructure that presently goes unmeasured or is misclassified as being part of some other capital investment. Rockler (1999) identifies these as including local roads/sidewalks/bridges, water systems, sewer system, and power/communications utility investments. The extent of the problem is unknown at present, but it is likely to occur in areas experiencing new growth (i.e., "greenfield" development) as opposed to development that is designed to fill-in or replace obsolete capital in established areas. Where such mismeasurement occurs, productivity parameters are likely to be misestimated and to contribute to the confusion concerning the size of any public infrastructure/productivity effect.

Improper Accounting for Depreciation in Capital-Stock Estimates

The capital stock data used in the models are gross stocks adjusted for estimated *depreciation*. These adjustments are intended to account for the lost value of future production that arise as a capital good ages. In contrast, for productivity analysis, analysts should use gross capital stocks adjusted for *retirements*. This type of estimate yields the current productive capacity of the capital stock in place. For an explanation of the differences in the two types of estimates, see Triplett (1996). To compound the data-quality issue, I note that the depreciation figures that are used to derive stocks are figures wholly fabricated from assumed service-lives and value-decay patterns. To the extent they have a basis in reality, these rates are drawn from data on private capital. Rockler (1999) demonstrates that empirically derived service-lives may be vastly different than the assumed ones, with possible significant impact on the stock estimates and imputed growth rates.

Confusion Between Publicly Owned and Public-Goods Capital

In general, the income and product accounts data measure publicly owned capital, while conceptually analysts probably want to estimate the impact of public-goods capital. To make matters more complicated, publicly owned capital can be used to generate private goods, and privately owned capital can generate public goods. Education, for example, has elements of "publicness" and "privateness" simultaneously, regardless of the ownership status of the structures where it is offered.

The distinction between the two forms of "public" capital is not a mere distraction. For many analysts working and writing on this topic, the differences are not made clearly enough, and the available data are a blend of both types of capital. They need to make the distinction because public-goods capital almost certainly generates significant externalities beneficial to a wide range of individuals and institutions. Publicly provided private goods have a much lower propensity to generate such externalities.

CONCLUSIONS

Public infrastructure is a complex form of capital, perhaps more so than many of the analysts conducting research in this field realize. The economic development analysts suggest that some public investment will stimulate higher levels of labor and/or private capital productivity, but not at all times or in all regions. Whether it is productive depends on what capital is already in place, whether sufficient private capital exists to be leveraged, and whether social returns remain (approximately) positive if the investment is made. As regions attain higher levels of development, the impacts are likely to become less pronounced, and not all forms of investment will generate positive productivity responses. Conjectures that negative productivity responses will result from congestion remain unproven using production-function estimates. However, consistent with expectations, public-infrastructure output elasticities decline with increasing levels of per capita public- capital stock.

Taken as a whole, the research on productivity using production-function models yields confusing and contradictory conclusions. When "properly estimated" (i.e., when the needed autocorrelation corrections and regional economic characteristics are controlled for), zero public-capital elasticities are typical, and, in extreme cases, negative ones occur. Cost- function results, however, contradict these findings with estimates that indicate a moderately positive (i.e., cost-reducing) response. The limited results on interaction of public capital with labor and private capital output elasticities turns-up no agreement either.

There is no question that research and analysis on this topic has been hampered by poor data availability. Researchers, however, have compounded these problems by confusing publicly owned capital and public-goods capital by treating them as a single capital form. In so doing, a portion of the measured capital stock consists of publicly provided private goods. The other portion, however, is for capital used in production of purely public goods. For this latter part, no market factors enforce efficiency constraints on the amount or types of public investment. Over- and under-provision are likely outcomes in different places and at different times, particularly when imperfect political systems govern funding availability and investment decision-making. Hence, negative output elasticity responses are not to be unexpected.

The data measuring U.S. capital stocks are national in scope, and estimated for purposes of wealth accounting, not productivity analysis. The data include adjustments for depreciation and decay that reflect the value of capital goods with respect to future production, not current production needs. Public capital is treated similarly, although the basis for estimating these rates, analogous private capital, appears to be unsound. The net result is that the regional estimates used by researchers are essentially shared-out based on fixed factors. No differences in age-composition and service-lives are incorporated in the estimates.[15]

Empirical analysis using aggregate production and cost function models offers a range of estimated productivity impacts of public investment. When researchers analyze public capital in a more disaggregated form and with regional distinctions, the range of output elasticities increases, and in some instances, becomes negative. This latter result, predicted in the literature, runs counter to the expectations of analysts whose modeling approach suggests that all publicly owned capital is governed by the same efficiency-criteria as is applied to private capital investment, and hence, very unlikely to have negative output elasticities at an aggregate level.

Finally, I note that productivity analysts appear to operate on the assumption that if public capital "is productive" in the sense of increasing output, the output response ought to occur during the same time period, i.e. in which public

---

15. An exception to this is the metropolitan area estimates prepared by Eberts (1986) which are constructed using area data.

investment occurs. The fact that the response is not simultaneous, however, is insufficient proof that public capital investment is not productive. The more accurate interpretation might be that public investment is not immediately productive, which does not preclude it from becoming so in subsequent years. It is an issue that remains for study.

The directions for future research on this topic are evident. Clarification of the problem at hand appears to be a good starting point. Once a clear delineation of "public" is given, preparation of a disaggregated capital-stock database (properly adjusted for aging-effects) to match the definition chosen would be useful. Productivity models may still yield more consistent results if various lag structures are employed.

There is ample literature on private investment cycles and economic growth, but scant research that includes detailed government investment cycles. Such research would go a long way in helping to identify and quantify the relationship between the two, and whether it tends to be a stable one or not. Analysts should be able to do better with the "ample empirical data" to which Jorgenson referred in improving our understanding of this subject. The principles may be sound, but their application has not yet reached the point where they are of much policy use.

REFERENCES

Aaron, Henry J. 1991. "Discussion" (Response to Paper of D.A. Aschauer)" in *Is There a Shortfall in Public Capital Investment?: Proceedings of a conference held at Harwich Port, Massachusetts, June, 1990.* Federal Reserve Bank of Boston, Conference Series, no. 34, pp. 51-63.

Aschauer, David. 1989. "Is Public Expenditure Productive?", Journal of Monetary Economics. No. 23 (March), pp. 177-200.

Batten, David F. 1996. "Infrastructure and the Complexity of Economic Development: An Exploratory Introduction," in Infrastructure and the Complexity of Economic Development, Batten, D.F. and C. Karlsson, editors. Berlin: Springer-Verlag.

Berndt, Ernest R. 1991. The Practice of Econometrics Classic and Contemporary. Reading, MA: Addison-Wesley Publishing Company.

Biehl, D. 1991. "The Role of Infrastructure in Regional Development", in Infrastructure and Regional Development, R.W. Vickerman (ed.). London: Pion.

Bruinsma, Frank, Nijkamp, P., and Rietveld, P. 1991. "Infrastructure and Metropolitan Development in an International Perspective: Survey and Methodological Exploration" in Infrastructure and Regional Development, R.W. Vickerman (ed.) London: Pion.

Da Silva Costa, Jose, R.W. Ellson, and R.C. Martin. 1987. "Public Capital, Regional Output, and Development: Some Empirical Evidence." Journal of Regional Science, no. 3, pp. 419-437.

Eberts, Randall W. 1986. "Estimating the Contribution of Urban Public Infrastructure to Regional Growth." Working Paper No. 8610, Federal Reserve Bank of Cleveland.

Jack Faucett and Associates. 1994. "Industry Studies of the Relationship Between Highway Transportation and Productivity." Final Report Submitted to the Federal Highway Administration. July, 1994.

Hakfoort, Jacco. 1991. "Public Capital, Private Sector Productivity and Economic Growth: A Macroeconomic Perspective," in Infrastructure and Regional Development, R.W. Vickerman (ed.) London: Pion.

Hansen, Niles. 1965. "Unbalanced Growth and Regional Development." Western Economic Journal, Vol. IV, No. 1. (Fall), pp. 3-14.

Heady, Earl O. and J.L. Dillon. 1961. Agricultural Production Functions. Iowa State University Press: Ames, IA.

Hirschman, Albert O. 1958. The Strategy of Economic Development. Yale University Press: New Haven.

Johansson, Börje and C. Karlsson. 1991. "Technology Development and Regional Infrastructure." Paper presented at the 38th North American Regional Science Association Meetings, New Orleans, LA.

Jorgenson, Dale W. 1991 "Fragile Statistical Foundations: The Macroeconomics of Public Infrastructure Investment." Paper presented at the American Enterprise Institute Conference on "Infrastructure Needs and Policy Options for the 1990s." Washington, D.C. February 4, 1991.

Kelejian, Harry H. and D.P. Robinson. 1997. "Infrastructure Productivity and Its Underlying Econometric Specifications: A Sensitivity Analysis." *Papers in Regional Science: The Journal of the RSAI.* Vol. 76, no. 1, pp. 115-131.

Leven, Charles L., John B. Legler, and Perry Shapiro. 1970. *An Analytical Framework for Regional Development Policy.* Cambridge: The MIT Press.

Lynde, Catherine and James Richmond. 1992. "The Role of Public Capital in Production." *Review of Economics and Statistics,* Vol. 74, No. 1, pp. 37-44.

Mera, Koichi. 1975. Income Distribution and Regional Development. Tokyo: University of Tokyo Press.

Morrison, Catherine and A. Schwartz. 1992. "State Infrastructure and Productive Performance." National Bureau of Economic Research, Working Paper No. 3981. Cambridge, MA: January, 1992.

Munnell, Alicia H. 1990. "How Does Public Infrastructure Affect Regional Economic Performance?" in *Is There a Shortfall in Public Capital Investment?: Proceedings of a conference held at Harwich Port, Massachusetts, June, 1990.* Federal Reserve Bank of Boston, Conference Series, no. 34.

Musgrave, Richard A. and P.B. Musgrave. 1989. *Public Finance in Theory and Practice.* McGraw-Hill, Inc: New York.

Nadiri, M. Ishaq and T. Maumuneas. "The Effects of Public Infrastructure and R & D Capital on the Cost Structure and Performance of U.S. Manufacturing Industries." National Bureau of Economic Research, Working Paper No. 3887. Cambridge, MA: October, 1991.

Nurkse, Ragnar. 1967. Problems of Capital Formation in Underdeveloped Countries. New York: Oxford University Press.

Polenske, Karen R. and Nicolas Rockler. 1993. "Issues Concerning the Relationship Between Infrastructure and Productivity." Multiregional Planning Research Staff Report No. 74 (June).

Prud'homme, Remy. 1996. "Assessing the Role of Infrastructure in France by Means of Regionally Estimated Production Functions" in Infrastructure and the Complexity of Economic Development, Batten, D.F. and C. Karlsson. 1996. Berlin: Springer-Verlag.

Ratner, Jonathan B. 1983. "Government Capital and The Production Function for U.S. Private Output. "*Economic Letters,* pp. 213-217.

Rietveld, Piet. 1989. "Infrastructure and Regional Development: A Survey of Multiregional Economic Models." *The Annals of Regional Science.* Volume 23, pp. 255-274.

Rives, Janet M. and Michael Heaney. 1995. "Infrastructure and Local Economic Development." *Regional Science Perspectives*, vol. 25, No. 1. pp. 58-73.

Rockler, Nicolas. 1999. "The Need for Empirical Measures of Public Infrastructure Stock for the Analysis of Regional Productivity." Draft, July 12, 1999.

Rosenstein-Rodan, Paul N. 1959. "How to Industrialize an Underdeveloped Area." Cambridge, MA: Center for International Studies, Massachusetts Institute of Technology.

Tatom, John A. 1991. "Public Capital and Private Sector Performance." *Review* (Federal Reserve Bank of St. Louis.) May/June.

Triplett, Jack E. 1996. "Depreciation in Production Analysis and in Income and Wealth Accounts: Resolution of an Old Debate." *Economic Inquiry*. Volume 34 (January).

Walters, A.A. 1963. "Production and Cost Functions: An Econometric Survey." Econometrica, Vol. 31, No. 1-2 (Jan.-Apr.)

CHAPTER 3 - IS THERE A RELIABLE SHORT-CUT APPROACH FOR ESTIMATING INFRASTRUCTURE NEEDS? PRACTICAL LESSONS FROM THE FIELD

INTRODUCTION

During the last decade, there has been renewed interest in policies regarding of public infrastructure investment. Largely the product of research concerning inexplicably low productivity growth in the United States compared to other advanced economies (Aschauer, 1989), this interest has broadened to include the role and function of infrastructure in promoting economic growth and development both at national and regional levels (Kressides, 1996, Eberts (1986), Munnell (1990), and Holtz-Eakin (1991)). "Infrastructure investment" is now a prominent element in many economic policy platforms, and it is perceived to be a key component for maintaining or improving competitiveness at whatever geographic coverage matches the political office in question. Among the recent analyses, however, empirical results are sometimes contradictory as to the specific types of infrastructure investments that promote productivity growth, and virtually no theoretical expectations are offered as to conditions under which infrastructure investment will promote growth and development.

Prior to this upsurge in interest, infrastructure investment policy was largely the concern of development economics in the context of underdeveloped regions and nations, dating back to Lewis (1955), Hirschman (1958), and Rosenstein-

Rodan (1959). As viewed by these analysts, the issues were not those of causality (unlike the current debate) because undercapitalized regional economies would almost certainly benefit from some exogenous infrastructure investment. Rather, the focus was on fashioning institutions that would make sustained growth and investment (and re-investment) more certain than under the prevailing conditions. As such, these analysts, like the contemporary ones, fail to offer prescriptive advice as to the types and amounts of infrastructure that would support growth and development, if any.

For various reasons, analysts have paid little attention to the different characteristics of infrastructure that affect development. They have not analyzed relationships between different forms of public infrastructure and private investment, nor the time-horizon over which these factors might influence the improvement in economic performance, nor the degree of structural change that can be achieved.

In this paper, I present findings from research that concerns precisely these issues. This research is derived from work conducted for the Economic Development Administration (EDA) of the United States Department Commerce. The EDA currently offers assistance to jurisdictions experiencing economic distress by funding public infrastructure projects. They believe that such assistance can stimulate job and income growth or help retain existing jobs by reducing barriers to economic development. In fiscal year 1997, the EDA budget for such projects totaled $165.2 million. EDA has two eligibility criteria for distress-related funding: (1) relatively high county unemployment rates and (2) relatively low county per-capita personal income. Examples of projects EDA funds include construction of water/sewer facilities to serve industrial and commercial sites, building access roads to transportation facilities, funding port improvements, and aiding business incubators. According to EDA, such projects should stimulate further industrial and commercial growth and investment, generate economic growth, reduce unemployment, and increase income (EDA, 1999).

EDA expressed an interest in knowing whether a "short-cut" method could be developed to identify the type and magnitude of infrastructure needs of distressed areas. The key finding presented in this paper is not that such a short-cut has been found, but that only certain infrastructure types are likely to aid the transition from economic distress to economic viability. This should be of keen interest to planners and practitioners responsible for public capital investment.

This paper is presented in five sections: (1) Review of the literature concerning economic distress and public infrastructure investment. (2) Empirical findings concerning historical public investment and distress status of a sample of

U.S. counties. (3) Estimates of infrastructure needs. (4) Case-study tests of needs-estimates. (5) Conclusions.

LITERATURE REVIEW

Evaluations of targeted investment programs intended to alleviate long-run or "structural" economic distress are seemingly few. A significant gap exists in the economic development literature concerning the past performance of public investment in altering the development path of lagging regions in developed countries. As a result, there is little empirical guidance on which to draw for the design and testing of quantitative infrastructure needs estimates. A study by Arthur D. Little (1974) is the only one of which we know that attempted to identify the role of public investment in aiding the transition of United States (U.S.) regions from long-term distress to stable growth. Their study, conducted on behalf of the EDA more than twenty years ago, was concerned precisely with this issue. However, the study was hampered by the lack of local economic data available at that time, a problem that has since become less severe, but not eliminated, particularly as regards inventory measures of public capital.

There exists an extensive literature on public investment and unemployment, but only as it concerns the relationship between cyclical unemployment and the use of public works investment as a means of countercyclical job creation. There are numerous studies analyzing the extent to which the infrastructure-creation process can generate three related impacts: (1) direct construction job growth, (2) indirect job growth in industries supplying materials/services, and (3) job growth through expenditures for consumption from the income earned both directly and indirectly. Among these, Haveman and Krutilla (1969), Rand Corporation (1977), Abt Associates (1979), and most recently, Rutgers University (1997) provide thorough discussions of the impacts and policy implications of generating short-run employment impacts. None of these, however, attempts to determine the extent to which public investment has furthered the transition of distressed areas to growth areas over a long time period.

Long-run job development through public infrastructure investment has never been an active topic in the regional economics literature, except peripherally in the current debate concerning the productivity effects of public-works investment. Aschauer (1989), Munnell (1990), Holtz-Eakin (1991), and others have focused on the infrastructure productivity impacts, concentrating on two central issues: (1) the magnitude of regional product growth linked to public investment, and (2) the direction of causality, i.e., whether it is public investment that acts as a stimulus to other sources of output growth or vice-versa. These analyses, described in Chapter 2, are still inconclusive on both questions, and have little to say about the types of infrastructure investment that are likely to aid regions at different stages of economic development. In general, there is scant detail concerning different types of infrastructure, and most analyses are limited to regions whose smallest units consist of states.

For policy purposes, the productivity tendencies of infrastructure investment identified in much recent research are a poor guide as to the type of investment a jurisdiction should undertake at any given time. Even highway investment, widely regarded as a key contributor to economic growth, can have a range of productivity impacts as noted by Rietveld (1989) and Boarnet (1997). They argue that projects that are incremental to the existing network offer virtually no gains in productivity from a national or regional perspective, but can still generate gains at a local level.

In the past, the topic of infrastructure investment and economic development is found in studies concerning underdeveloped regions in the earliest stages of economic development, as a country begins to go beyond agricultural and natural resource extraction activities. Research by Lewis (1955), Rosenstein-Rodan (1959), and Hirschman (1958) offer a range of positions on the ability of infrastructure investment (then usually described as "social-overhead capital") to stimulate economic investment. But these analysts were concerned mostly with institutional arrangements designed to achieve sustainable growth rather with than issues concerning infrastructure's role in development, since undercapitalized regional economies would almost certainly benefit from almost any exogenous infrastructure investment. As such, these analysts fail to offer prescriptive advice as to the types and amounts of infrastructure that would support growth and development.

Even as a part of the ongoing productivity-infrastructure debate, the theoretical linkage between productivity and unemployment is undeveloped. In comparing international productivity growth and unemployment rates, Gordon (1995), for example, hypothesizes on the existence of a productivity-unemployment tradeoff relationship. He argues that the persistently high European unemployment rates are a product of high capital investment that renders labor highly productive, hence, highly paid. These high pay levels, he posits, are responsible for lowering labor demand below what would otherwise be the case, and are further sustained by rigidities in the labor market.[16] The combination of capital investment and rigid labor markets only serve to aggravate unemployment. In the absence of these rigidities, additional labor would be coaxed into employment (either from being unemployed or by entering into the labor force) to take advantage of the higher wage. With the rigidities in place, however, the only way to return

[16] These rigidities stem from institutional limitations, such as those on the number of work-hours, shop opening hours, and occupational and spatial immobility.

employment to the equilibrium level is for capital disinvestment to occur.

Gordon claims that these rigidities are less evident in the United States than in Europe. By extension, they might still contribute to persistent unemployment in lagging regions of the United States, but this hardly seems to be a complete explanation for the disparities in employment opportunities in regions whose relative underdevelopment has been evident for decades. Whatever the reasons, the theoretical linkage between productivity and unemployment is not sufficiently developed to account for such wide gaps. Furthermore, the ambiguous role of public infrastructure in furthering productivity growth that we see in the recent literature seems not to have taken us much closer to a goal of formulating an infrastructure investment policy to combat structural unemployment.

The EDA funding-eligibility criteria do not distinguish between short-run and long-run unemployment distress. For places places with short-run distress, research by Ballard and Katz (1992) indicates that after a shock (e.g., oil crisis-type or defense spending cut-back), states' unemployment rates revert to their mean values over a period of 5 to 7 years. The unemployment rate reduction is achieved largely by out-migration. Wage rate reductions among job-seekers do occur, but apparently not of sufficient size to attract new employers. This is consistent with Gordon's argument about rigidities.

With a short-run shock, employer's are not about to relocate to exploit lower wage opportunities, given the costs and uncertainties that relocation entails. If employers tend to "ride-out" disruptions created by a significant shocks, then it seems unlikely that EDA's funding to create new infrastructure is likely to attract such firms.

Long-run distress is another matter. Whereas in the short-run, workers migrate for better job and income opportunities, places experiencing chronic unemployment appear to have mobility barriers, economic and social ones. Inadequate infrastructure appears may have little connection to these conditions and added public investment may not generate private responses because of the other factors at work. Investment designed to serve existing residents may still be enough reason to subsidize new capital, but other alternatives may also be considered, such as income subsidies, programs to aid relocation, or labor retraining programs. These latter options may be more appropriate in the long run, even if they signal a surrender to market forces.

The strongest arguments that can be made at present are that infrastructure is clearly necessary to support economic development processes, and that investment in infrastructure, at some times and in some places, may stimulate growth. As a general rule, however, infrastructure provision in and of itself is not a prescription for growth to follow. This view is supported in the findings of the A.D. Little (1974) research, which explicitly included tests of the hypothesis that "the availability and quality of infrastructure affects growth" by changing the comparative cost structure of transport, power, utilities, water and sanitation in places where the quantity is greater and the quality higher.

SAMPLE COUNTY INFRASTRUCTURE INVESTMENT BEHAVIOR AND HISTORICAL ECONOMIC PERFORMANCE

Perhaps the greatest problem facing researchers regarding public investment concerns the lack of data on the public capital stock for small geographic areas. Although national stock data have been compiled from the national income accounts, local data are unavailable. Researchers cited above have employed various schemes of "sharing-out" the national data using proxy measurements, usually to a state level. Little is known, however, about either the true quantity of public capital or its age characteristics for regions. Without such information, empirical analyses of public investment and regional economic performance have been hampered by implicit assumptions that local area capital stocks are homogenous with respect to technology and performance over space. This feature would appear to confound analyses of productivity from the outset. To overcome this data limitation in part, I used 30 years' of county-level, detailed construction activity data to compute per-capita investment estimates for a sample of counties.[17] With these, I cannot determine whether there are systematic differences in investment according to degree of economic distress, but we can estimate investment needs for different infrastructure categories based on economic and demographic characteristics. I infer these needs estimates from gaps between actual and expected investment, consistent with estimates prepared by Wyckoff (1984). Unfortunately, I still cannot analyze the effect of differences that might arise from having capital mixes of different ages at the start of the 30-year history, in so much as investment prior to 1967 is not included.

In order to distinguish distressed from non-distressed areas, I drew a random sample totaling 125 counties from the population of 3,140 U.S. counties, stratifying the sample into five groups of 25 counties, each intended to characterize ranges of increasing unemployment.[18] I describe these ranges as "very-low" (0-3.5% unemployed), "low" (3.6-4.6% unemployed), "medium" (4.7-5.9% unemployed), "high" (6.0-7.9% unemployed) , and "very-high (greater than 8.0% unemployed)." For simplicity,

---

[17] These are unadjusted for depreciation. The current Bureau of Economic Analysis estimated service-lives for government-owned capital ranges from 32 years for industrial buildings to 60 years for the nonstructures, including roads, water facilities, sewer facilities, and other (BEA, 1997). Educational, health, and other structures all have 50 estimated service-lives. Failure to depreciate the construction data will result in a slight over estimate of the available public capital per capita. This is offset to some unknown degree by the systematic under-reporting of small investments (projects below the $50,000 per project reporting minimum), and missed projects on the part of F.W. Dodge, the data source for public investment used here.

[18] I drew an additional sample of 50 counties for a separate analysis of military base closure and defense-industry downsizing analysis. These counties are included in the statistical modeling presented later.

I refer to the three lowest unemployment quintiles as "low-distress", and the two highest as "high-distress." Counties in the high-distress group are eligible for EDA funding, while those in the low-distress group are not.[19]

The database consisted of three data types: investment (including disaggregated public infrastructure and private investment in structures and facilities), government-operating expenditures, and county-level demographic and economic time-series data. For investment, I used detailed county-level construction statistics from the F.W. Dodge division of McGraw-Hill, Inc. These are proprietary data, developed from tracking construction activity covering all counties in the United States (in computer accessible form) starting in 1967.

Although the database coverage of projects is known to have gaps for small projects (i.e., ones under $50,000 per project) and for nonbid ("force account") contracting, the coverage of publicly bid construction is thought to be virtually complete. In the subsequent case-study work, however, I encountered several instances in which missing data were significant in their absence. Some were systematically excluded, but important, such as certain force-account work, and some are not covered at

---

[19] Eligibility for EDA public works grants is based on both unemployment and per-capita income. My use of unemployment to define distress was designed to achieve a fair distinction of distress for all counties. Per-capita income could also have been used for sampling. Income can be misleading across regions, however, unless cost-of-living adjustments are made. Such adjustments can be difficult to make at the county-level, complicating database development without reasonable expectation that the outcome of our feasibility tests would be materially altered. Per-capita income is highly correlated with unemployment rates. Counties with very low unemployment rates tend to have very high incomes, and vice-versa.

all, as with developer-provided infrastructure linked to new development.

It should also be noted that the F.W. Dodge data include some investment in private-sector substitutes for public infrastructure. Clear examples are private-school investment that serves nearly identical functions as its public counterparts, or private hospital investment that serves a community in identical fashion to public investment. Other less obvious, but still important categories include private telecommunication facilities and services, private warehousing and transportation systems, and private energy utilities. The Dodge data, however, cover only structures and not equipment for the 30 years. I use these private investment as explanatory variables in the investment estimating models.

The second set of relevant data covers governmental operating and maintenance expenditures on infrastructure. These data are published in censuses (every five years) as a part of the Census of Governments. I assembled these for 1977, 1982, 1987, and 1992 by functional category. (Bureau of the Census, 1977, 1982, 1987, 1992) The functions covered in these data include: education, libraries, public welfare, hospital, health, highways, other transportation, police, fire, corrections, protective inspection, natural resources, parks and recreation, other sanitation, administration, and utilities. The purpose of analyzing these data is to determine whether distressed areas incur different operating costs than nondistressed ones.

Finally, I used economic and demographic time-series data for the sample counties to determine whether industrial mix (i.e., sectoral employment), income levels/growth rates, or population levels/growth rates are linked to economic distress. I extracted these data from the Bureau of Economic Analysis' "Regional Economic Information System" (BEA, 1995).

Economic Characteristics Of Sample Counties

The 125 counties account for approximately 15.5 million persons (Table 1). This figure is the average population computed over the 1969-1995 period. The overall sample growth rate averaged 1.1% per year (very close to the 1.2% per year observed for the United States over the same period).[20] Counties in the sample range in size from Petroleum County, Montana, the sixth smallest county in the nation with an average population of 611 persons, to Los Angeles County, California, the largest county in the United States, with an average of 7.9 million persons. As a group, the sample counties experienced annual average growth in total employment and real per-capita personal income of 2.3%. The three quintiles with the lowest unemployment rate (the "low-distress" counties) showed a slightly lower population annual growth rate (1.0%) and a slightly higher employment annual growth rate (2.4%) than the

[20] Calculated from Bureau of the Census, *Statistical Abstract of the United States, 1995*, p. 8, Washington, DC. Superintendent of Documents, U.S. Government Printing Office.

high-distress counties, which had annual rates of 1.2% and 2.0%, respectively, for population and employment.

Table 1
Comparative Growth and Sectoral Employment Shares by County-Type

VARIABLE\COUNTY-TYPE	ALL COUNTIES	LOW-DISTRESS	HIGH-DISTRESS
Sample Size (Number of Counties)	125	75	50
Population Growth (%)	1.1	1.0	1.2
Per Capita Personal Income Growth ($1992, %)	2.3	2.3	2.3
Employment Growth (%)	2.3	2.4	2.0
Manufacturing Employment Growth (%)	3.8	3.9	3.6
Services Employment Growth (%)[21]	3.7	3.9	3.3
Manufacturing Share of Total Employment (%)	14.5	14.0	15.1
Services Share of Total Employment (%)	46.8	47.7	45.4

Source: MIT-Multiregional Planning Research Group, 1998

Over the 1969-1995 period, manufacturing and service sector employment for all sample counties grew at moderately strong annual rates of 3.8% and 3.7%, respectively. Low-distress counties had higher average annual manufacturing and services growth, while high-distress counties had lower rates for both.

---

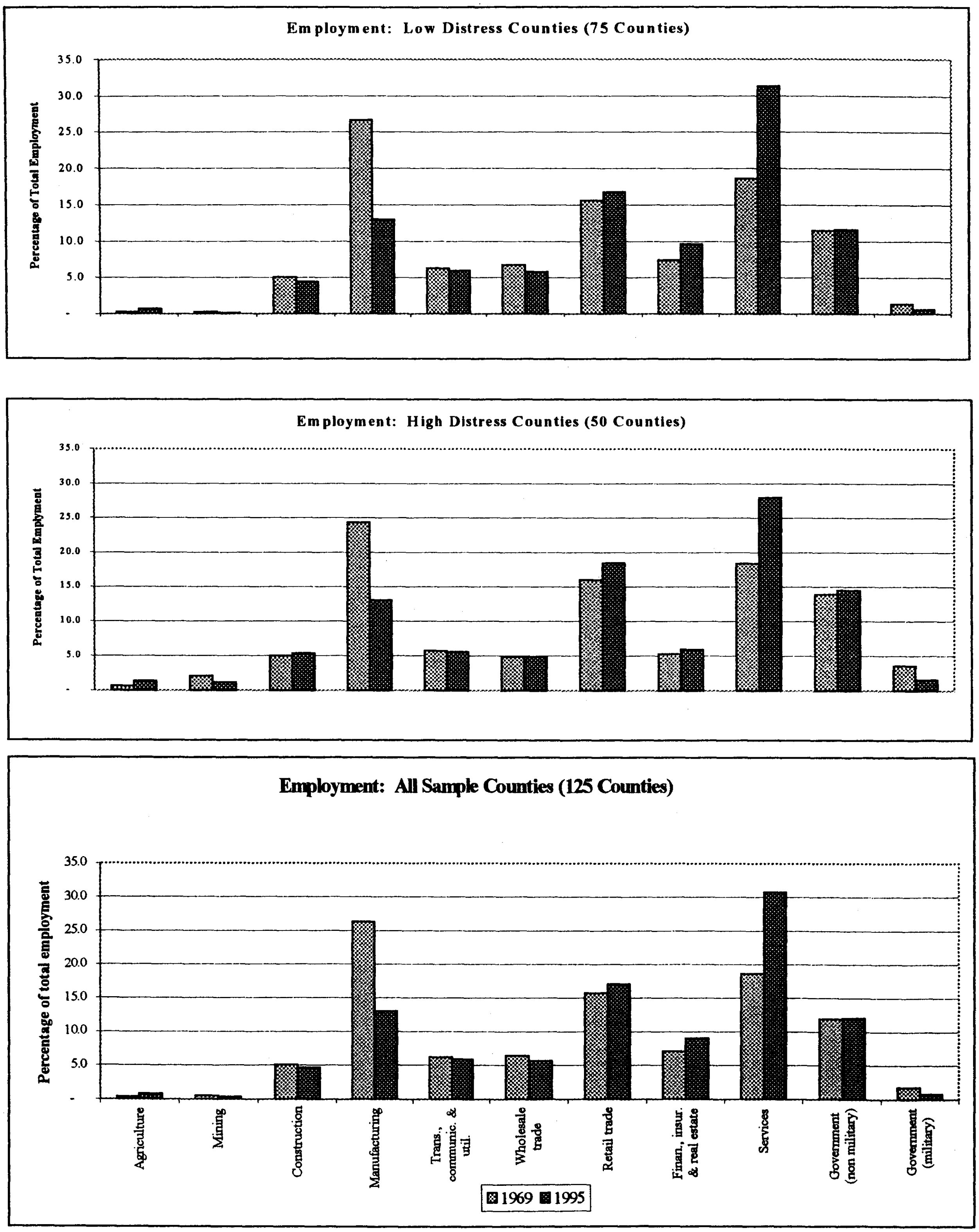
[21] Services includes the following industrial divisions of the *Standard Industrial Classification, 1987:* retail trade, wholesale trade, finance, insurance, real estate, transportation, communication, public utilities, and services.

Even so, the current composition of economic activity in the two county-types and the changes in structure that have occurred over the past quarter century are not drastically dissimilar to one another. As shown in Figure 1, services and retail trade are currently the largest sectors in each county-type based on percentage of total employment in each of the sectors. These are followed by nonmilitary government and manufacturing. I also note the declining importance of manufacturing and the rising importance structure/facility-type specific deflators. The cumulative value of services over the 1969-1995 is clearly evident for both county-types.

Although the two county-types have similar economic structures, broadly defined, they are distinct as to whether or not the counties were part of a metropolitan (MSA) area, as shown in Table 2. Eighty percent of high-distress counties are non-metropolitan, as compared to 63% of low-distress counties.[22]

[22] For reference, the United States, as a whole, consists of 817 metropolitan counties (26%) and 2279 non-metropolitan counties (74%). The population distribution among MSA and non-MSA counties is almost the reverse of the number of counties: Approximately 80% of the population resides in MSAs, while 20% resides in non-MSA areas.

Figure 1
Employment by Industry and Distress-Level



As will be shown later, these differences are responsible for variation in the amount of infrastructure investment per capita across the different county-types, since some public-service activities are predominantly urban ones.

In addition to having higher unemployment, distressed areas exhibit lower personal income than average. As shown in Figure 2, the high-distress unemployment group has real per capita personal income significantly below that of low-distress counties, averaging approximately $15,000 in 1995 versus $18,000, respectively.

Table 2
Location of Metropolitan Versus Nonmetropolitan Sample Counties

COUNTY TYPE	NUMBER IN METROPOLITAN AREA LOCATION (%)	NUMBER IN NON-METROPOLITAN AREA LOCATION (%)
All Counties	38 (30%)	87 (70%)
Low-distress	28 (37%)	47 (63%)
High-distress	10 (20%)	40 (80%)

Source: MIT-Multiregional Planning Research Group, 1998

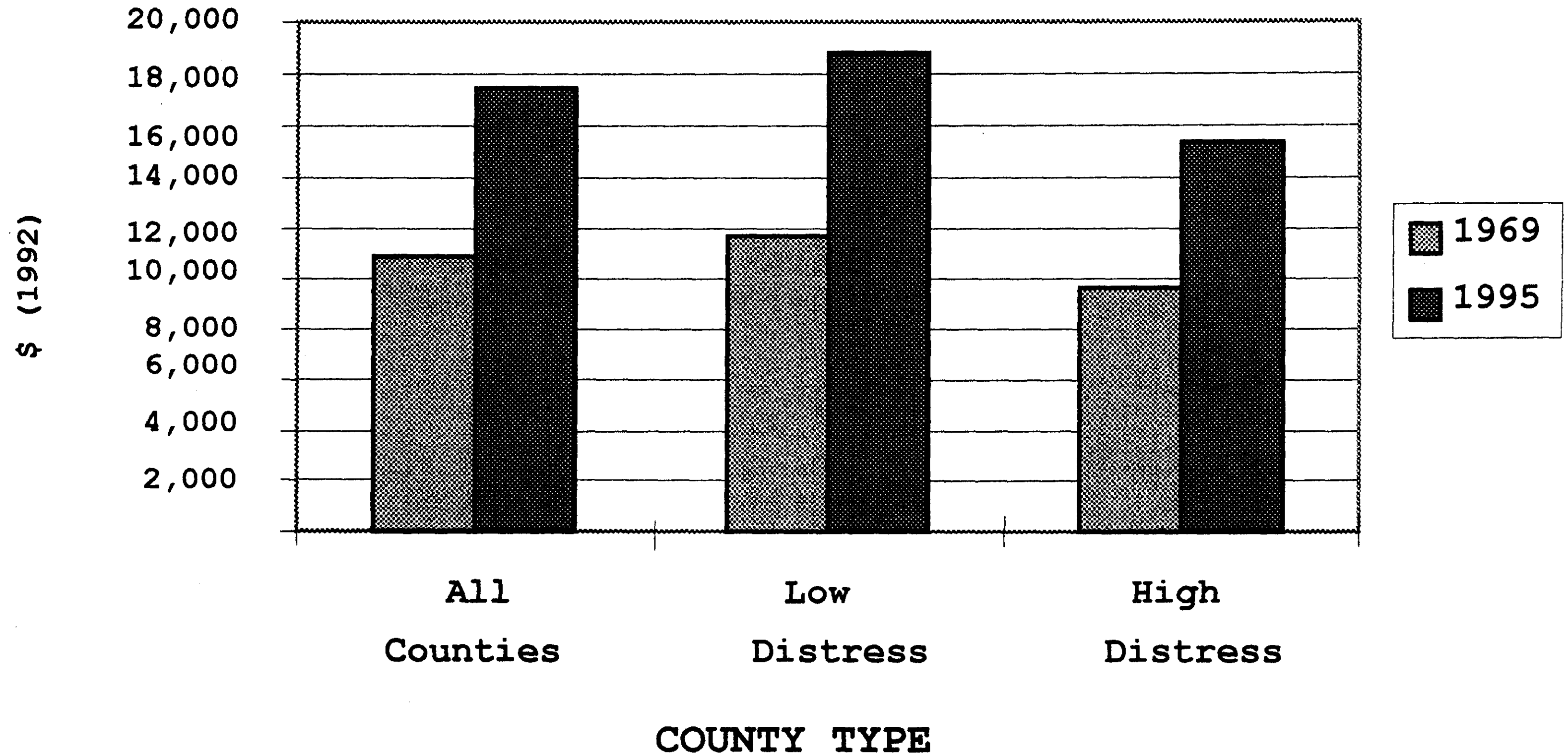
Infrastructure Investment Within The Sample Counties

For each of the sample counties, I estimated the real-value of infrastructure investment that occurred during the period 1967-1996 from the nominal-value investment series. These investments serve as a proxy for the stock of infrastructure, recognizing that I excluded pre-1967 infrastructure, and I did not account for removals or depreciation. Given that the best available information on the average service life of public infrastructure is 32-60 years (depending on type), a sizable portion of the stock for certain categories is likely to be missed, something not reflected in the needs estimates. My estimates will not reflect any differences in technology for older structures, such as those related to energy and environmental concerns.

Based on total U.S. investment figures, the stock estimates used here represent approximately 80% of the value as estimated by the Bureau of Economic Analysis (BEA, 1997).[23] In spite of this gap, these figures are relevant for three reasons. First, the estimates indicate the type-specific relative investment that has occurred over the past 30 years at the county-level. There is no a priori reason to suspect that

[23] See Bureau of Economic Analysis, 1997, p. 73, for capital services lives, and Tables 11 and 12 for data on stock of structures.

Figure 2
Per Capital Personal Income ($1992): 1969, 1995



the coverage of any one type of structure or facility is better than another. Second, the relative differences of the incremental infrastructure requirements for different county-types will still be accurate, having been estimated for county demographic and economic growth characteristics. Finally, the estimates are comprehensive in terms of coverage, with consistent estimates for all U.S. counties.

Short-Term Distress And Infrastructure Investment

I classify the cumulative 1967-1996 investment per capita, by county-type (short-run unemployment distress) and infrastructure category (Table 3). The $11,175 per person is approximately 80% of BEA's national stock estimate of $14,076 per person. Low-distress counties had slightly more investment than high-distress counties, but the differences were not statistically significant. This holds true for the other categorical differences in total investment, as well.

The key feature of the mean per-capita investment figures is that the low and high-distress counties are statistically undifferentiated. This suggests that distress-level, as measured by unemployment rates, is not closely linked to infrastructure investment. In view of the economic conditions prevailing during the 1995-1997 period over which unemployment was measured, and the long-held belief that economic distress

Table 3
Infrastructure Investment, Cumulative 1967-1996
(Mean per capita, $1992)

County-Type, Unemployment Distress Level	Sample Size	Total	Streets, Highways, & Bridges	Airport	Power Utilities	Communi-cations	Water	Sewer Systems	Hospital/ Health Care	Educa-tion	Public Adminis-tration, Public Safety, Miscel-laneous
All Sample Counties	125	11,175	5,237	105	129	11	543	800	791	1,367	2,192
Very Low	25	13,146	5,933	264*	210	26	522	995	1,006	1,573	2,617
Low	25	10,879	5,580	53	61	6	536	787	798	1,453	1,606
Medium	25	11,447	5,549	65	68	7	569	788	742	1,363	2,298
High	25	9,709	4,574	78	76	14	413	627	812	1,258	1,858
Very High	25	10,691	4,549	67	229	4	673	803	597	1,187	2,583

*-Value significantly different from baseline at .05 significance level (t-statistic).

Source: MIT-Multiregional Planning Research Group, 1998

can be reversed by public investment, this finding is surprising.

The favorable macroeconomic conditions that prevailed during that period would suggest that places with high unemployment had structural problems that might have a connection to infrastructure inadequacy. If it is true that infrastructure stock is linked to distress, however, it is not apparent in these data. Absent such a link, the models for estimating infrastructure-needs rely on demographic, economic growth, and other structural characteristics, including private capital investment.

Income levels and unemployment rates are inversely related with respect to per capita infrastructure investment. Per capita investment, calculated according to income quintiles, looks nearly identical to that of unemployment, except in the cases of sewer systems and healthcare (Table 4). For these two categories, both very-low and very-high distress counties evidence significantly different per capita investment compared to the entire sample, with the very-low distress counties having nearly three times the per capita investment of the very-high distress counties. Once again, this distinction appears related to the fact that certain infrastructure types, sewer and health care in this case, are primarily found in metropolitan areas, also areas with the lowest income distress.

Table 4
Infrastructure Investment, cumulative 1967-1996
(Mean per capita, $1992)

County-Type, Income Distress Level	Sample Size	Total	Streets, Highways, & Bridges	Airport	Power Utilities	Communications	Water	Sewer Systems	Health Care	Education	Public Administration, Public Safety, Miscellaneous
All Sample Counties	125	11,175	5,237	105	129	11	543	800	791	1,367	2,192
Very Low Inc. Distress	24	13,252*	4,839	249*	102	30*	477	1,263*	1,242*	1,911*	3,140*
Low Inc. Distress	30	10,801	5,038	103	170	8	577	82	926	1,327	1,800
Medium Inc. Distress	25	10,254	4,480	36	225	6	606	768	799	1,335	2,000
High Inc. Distress	21	9,923	5,045	67	55	5	372	642	544	1,208	1,988
Very High Inc. Distress	25	11,601	6,777	72	71	7	646	458*	394*	1,056	2,118

*-Value significantly different from baseline at .05 significance level (t-statistic).
Source: MIT-Multiregional Planning Research Group, 1998

The other difference worth noting is that very low-income distress counties have significantly greater education and public administration/public safety/miscellaneous investment than the baseline. Both of these categories have per capita investment nearly 40% higher than the baseline values. This distinction may be the product of the highly localized nature of taxation and decision-making regarding investments for these two categories. High-income counties (i.e., low income-distress) appear to use their greater fiscal capacity to invest in schools and other public facilities at a far greater rate than counties with lower income levels. At the other end of the income scale, the opposite effect is not observed, and school and public facilities investment in the very high income distress counties are not statistically different from the all-sample values.

Long-Term Unemployment Distress And Infrastructure Investment

One of potential problems with the EDA unemployment and income-distress eligibility criteria is the short time-period over which the distress determination is made. Eligibility for EDA funding is based on unemployment rates calculated over a 24-month period and income measurements from the most recent annual BEA estimates. It is evident that some counties might become eligible for funding based on cyclical rather than structural distress. To test whether distressed areas have made successful transitions over long time-periods, I used unemployment rate data from the 1960 Census of Population to classify the distress status of the sample counties, and I identified shifts in distress levels. From these data, a very different and surprising picture emerges as to the extent to which distress and infrastructure investment are related. I discuss these results for unemployment and per-capita income below.

The 1960 unemployment data yield quintiles defined by the unemployment rates (Table 5). The very-low and low unemployment quintiles are close to the 1996 definitions described earlier, but the higher-distress groups span a somewhat wider range, with higher end-points than their 1960 counterparts. The degree of distress is thus relative to a particular time period. For purposes here, these are sufficiently comparable to gauge development progress. Of the 125 sample counties, 36 experienced reduction in distress-level of one or more quintiles, 47 showed no change, and 42 showed increased distress.[24]

In Table 6, I show the mean per-capita investment by structure/facility type for these counties. For all but one of the eleven structure/facility types shown, counties experiencing long-term distress reduction of one or more quintiles had larger per-capita investment levels than those that had no change or had increased levels of distress. For five structure/facility types, the differences were significant at a 5% significance

---

[24] Changes in distress-level, even when estimated over a thirty-year interval, may reflect cyclical influences. A cyclical peak or trough occurring at the measurement times may yield larger estimates of distress-change than would be obtained in the middle of the cycle. Neither 1960 nor 1990 was a peak or trough at a national level.

Table 5
Unemployment Rate Quintile Ranges
(%)

Quintile	1960	1996
Very Low Unemployment	0-3.5	1.6-3.5
Low Unemployment	3.5-4.3	3.6-4.6
Moderate Unemployment	4.4-5.2	4.7-5.9
High Unemployment	5.3-6.8	6.0-7.9
Very High Unemployment	6.9-13.3	8.0-15.6

level. The five categories (education, miscellaneous structures, sewer systems, social services, and airports) had vastly larger averages than the "no change or increase" group. For example, counties with reduced distress had an average annual per-capita educational structures investment of $1,779 compared to $1,085 for those whose distress level remained stable or increased. Sewer systems investment per-capita was $1,137 for reduced distress counties and $667 for stable or increased distress ones. With the exception of airports, however, investment in these categories, is generally a consequence of significant private residential investment and

Table 6

Infrastructure Investment Per-Capita by Structure/Facility Type and Change in Unemployment Distress Level, 1960-1990

STRUCTURE/FACILITY TYPE	PER-CAPITA INFRASTRUCTURE INVESTMENT BY CHANGE IN UNEMPLOYMENT DISTRESS-LEVEL, 1960-1990 (Mean per Capita, $1992)		
	No Change or Increased By One or More Quintile	Decreased by One or More Quintile	Decreased by Two or More
Number of Counties (MSA Counties)	88	36	15
Administration, Public Safety, Miscellaneous	511	654	908
Education	1,085	**1,779**	**2,387**
Water	547	542	589
Hospitals	223	263	323
Miscellaneous	421	**903**	1,344
Power Utilities	136	110	176
Streets, Highways, Bridges	5,292	5,139	6,237
Sewer Systems	667	**1,137**	**1,300**
Social Services	197	**338**	**513**
Airports	67	**200**	**390**
Communications	9	18	**35**

Boldface figures are significantly different than "No Change or Increased by One or More Quintile Group" at 5% significance level.

Source: MIT-Multiregional Planning Research Group, 1998

local population growth, and not the growth stimulus itself. Interestingly, streets/highways/bridges, water systems, and power utilities, all categories popularly perceived to lead development, do not appear to show significant differences in per-capita investment in areas that have seen reduced unemployment distress. This is not to say that these categories are unimportant to the development process, only that areas with long-run unemployment changes do not have markedly different investment behavior for these categories. It is likely that the incremental nature of infrastructure investment and the back-and-forth interplay of public and private investment precludes the emergence of single categories of infrastructure investment as a cause of growth.

It might be suspected that counties with high unemployment distress in 1960 that experienced substantial improvement over the next 37 years were also ones that became parts of metropolitan areas, and, in so doing, had investments that were more typical of urban areas than rural ones, such as hospital, sewer, and water systems. This does not appear to be the case, however. Of the 36 counties that had reduced distress, 26 remained nonmetropolitan as of 1997, about 70% of the total, which is identical to the overall share of nonmetropolitan counties in the sample regardless of distress conditions.

As I noted earlier, low income-distress areas tended to be accompanied by higher per-capita infrastructure investment and vice-versa. In a critical departure from both this and the long-term unemployment relationship just described, the sample data reveal that counties that had rising per-capita incomes had reduced per-capita investment levels, significant for miscellaneous structures, power utilities, social services, and airports. I derive the income below (Table 7), and I use them to group the sample to obtain the per-capita investment figures (Table 8).

The exact reasons for this pattern are not clear. Possible explanations include: (1) Counties that experienced strong income growth had sufficient infrastructure capacity to accommodate additional economic growth, or (2) whatever shortfall in infrastructure that resulted from apparent underinvestment (or delayed investment) is not critical for economic growth. It should be noted that the stronger per-capita income growth was in nonmetropolitan areas. These are places that do not offer services characteristic of higher population densities, such as water systems, sewer systems, hospitals, social services, and airports. It is clear evidence, however, that not all income growth is linked to infrastructure investment, consistent with my earlier observation that the causality relationship between investment and economic growth may not run exclusively in one direction or the other.

Table 7
Per-Capita Personal Income Quintile Ranges
($ 1960, $ 1992)

Quintile	1960	1997
Very Low Per-Capita Income	77-1,082	6,084-9,225
Low Per-Capita Income	1,087-1,294	9,240-10,420
Moderate Per-Capita Income	1,296-1,471	10,460-11,425
High Per-Capita Income	1,484-1,812	11,500-12,273
Very High Per-Capita Income	1,835-2,629	12,725-21,091

INFRASTRUCTURE-RELATED OPERATIONS AND MAINTENANCE EXPENDITURES

Infrastructure-service provision requires jurisdiction expenditures of two types: (1) the investment of physical capital described above, and (2) expenditures linked to utilization of capital needed to deliver services. These latter expenditures consist of both operations and maintenance (O&M) expenditures.[25] The accounting and reporting of these

[25] The distinction between capital and operations/maintenance account expenditures is not always clear. Repairs can appear in either account, usually (but not always) dependent on the funding source and financing method. For example, a large stretch of leaky water main might be replaced as part of a redevelopment plan funded under a capital budget using a revenue or general obligation bond. A short stretch of leaky water main may be replaced to effect a repair, funded under the water department's operating budget. The work is essentially the same, differing only in the scale. The repairs made by a large metropolitan area under its operations and maintenance accounts may dwarf the capital-account investments of smaller jurisdictions.

Table 8

Infrastructure Investment Per-Capita by Structure/Facility Type and Change in Per-Capita Income Level, 1960-1990

STRUCTURE/FACILITY TYPE	PER-CAPITA INFRASTRUCTURE INVESTMENT BY CHANGE IN INCOME LEVEL, 1960-1990 (Mean per Capita, $1992)			
	No Change or Decreased by One or More Quintile	Increased by One or More Quintile	Increased by Two or More Quintiles	Increased by Three or More Quintiles
Number of Counties (MSA Counties)	74	50	29	15
Administration, Public Safety, Miscellaneous	555	548	481	598
Education	1393	1129	1160	1114
Water	581	493	578	556
Hospitals	239	228	192	234
Miscellaneous	672	**396**	**343**	**284**
Power Utilities	176	59	55	**24**
Streets, Highways, Bridges	5670	4622	4760	4255
Sewer Systems	894	670	656	486
Social Services	285	**168**	**125**	**118**
Airports	130	70	**41**	**38**
Communications	16	5	1	**2**

Boldface figures are significantly different than "No Change or Increased by One or More Quintile Group" at 5% significance level.

Source: MIT-Multiregional Planning Research Group, 1998

88

expenditures is generally done separately from investment. Interpretation of expenditures per capita is not simple. If the expenditures per capita or unit of infrastructure are relatively high, this may indicate the presence of outmoded, high-maintenance capital, on one hand, or the results of deferred maintenance in earlier times. There is no way to tell. On the other hand, low expenditures per capita may indicate a budget constraint, too little capital, or the presence of cost-efficient capital. To illustrate this, I show data on an average annual O&M expenditure per capita and per unit of investment (Table 9). These are based on data prepared by the Bureau of the Census as a part of the Census of Government Finance, presenting expenditure figures for 1977, 1982, 1987, and 1992, transformed to real (1992) dollars per capita.

The most important features of the O&M expenditures are the lower amounts expended in high-distress counties compared to the entire sample, especially in the transportation terminals and water systems categories. Only in social services are the expenditures higher than the sample average. To see whether these figures are disproportionately large, I computed the ratio of O&M expenditures to total invested capital for the four infrastructure categories were computed (Table 10). None of the average investment figures shown for the two distress groups are significantly different from the sample average.

Table 9
Average 1977-1992 Operations and Maintenance Expenditures by Infrastructure Category and Unemployment Distress Level (Investment Per capita, $1992)

COUNTY-TYPE	Administration	Education	Hospital/ Health	Miscellaneous	Public Housing	Roads	Sewer	Social Services	Transportation Terminals	Water	TOTAL
All Counties	50	835	70	12	21	137	38	55	10	128	1357
Low-distress	52	846	74	12	23	147	42	51	15	154	1416
High-distress	47	820	64	12	17	122	32	62	3	91	1269

Source: MIT-Multiregional Planning Research Group, 1998 and Bureau of the Census, Census of Governments, 1977, 1982, 1987, 1992.

Table 10
Ratio of Average 1877-1992 Operations and Maintenance (O&M) Expenditures to Infrastructure Investment, By County-Type and Infrastructure Category ($ O&M/Investment)

COUNTY-TYPE	Combined	Health & Education	Transport, Water, Power Utilities	Social, Administrative, Public Safety, and Miscellaneous	Sewer Systems
All Counties	0.124	0.419	0.045	0.053	0.048
Low-distress	0.127	0.398	0.049	0.053	0.049
High-distress	0.120	0.457	0.040	0.054	0.045

Source: MIT-Multiregional Planning Research Group, 1998 and Bureau of the Census, Census of Governments, 1977, 1982, 1987, 1992, and F.W. Dodge Division, McGraw-Hill, Inc.

Summary of Investment and Expenditures

The data on investment fail to support the notion that economically distressed counties have underinvested in infrastructure. Based on cumulative investment, the economically strongest counties invest more than others in the short-run (by approximately 20%, on a per capita basis), but the weakest counties are, in contrast, little different than the remainder of the sample. Over the long run, counties that made the transition from being distressed do have higher investment rates than those in persistent distress, but only in categories that respond to new residential investment growth. These categories (sewers, social services, education, and airports) are not the ones normally thought to have strong development-stimulating potential, such as streets/highways, power utilities, and water systems.

Even though counties that are economic distressed show no evident link to underinvestment in infrastructure, the short-cut needs estimation technique for targeting investment to regions can still be useful. Whether for restructuring local economies, as EDA hopes to do, or allocating federal aid for other policy purposes, there remains a need to provide an equitable, rational means of allocation. Estimated shortfalls may be such a means, provided they can be estimated with reasonable accuracy. Thus, I test the short-cut estimation method with a view towards application for larger areas. For this purpose, I developed simple, county-level cross-sectional models to estimate investment shortfalls. I tested the accuracy of these against information gained from case-studies conducted in six of the sample counties. A description of the models and case-study results are presented in the following section.

STATISTICAL MODEL DEVELOPMENT AND ANALYSIS

In order to estimate county-level infrastructure needs, I used our 175-county database[26] to develop multiple-regression models of infrastructure investment for separate categories of infrastructure. The models use sample counties' economic and demographic characteristics to estimate infrastructure investment. These models incorporate some of the basic determinants of investment levels and growth, but by no means all such factors. I restricted these to readily available public-domain data for the independent variables, consistent with EDA's objectives of ease-of-use and simplicity, including population, population growth rate, sectoral and total employment (and relevant growth rates), and private investment of various types.[27]

From these models, I prepared estimates of the expected investment for each county and compared them to the actual investment for each county, based on county characteristics.

---

[26] This database includes the 125 county sample, as well as 50 counties selected for research concerning needs of counties experiencing defense cut-backs or military-base closures.

[27] Also included is a military-base closure dummy variable, because a different portion of the analysis was concerned with infrastructure needs of areas undergoing defense-related downsizing of facilities. This variable would generally not be used for the short-cut approach in future estimates.

The difference between the actual investment and the expected investment, when negative, constitutes an estimate of "shortfall" and when positive, constitutes a "surplus." For each category, I identified economic and demographic variables that have a plausible connection to the infrastructure investment category and then used a "stepwise" regression procedure to identify the specific variables that generate statistically significant coefficients when fitted using the multiple linear regression technique. I screened the resulting equations for any evident multicollinearity problems, and I then revised and re-estimated the models. The resulting equations are shown in Table 11. Only for social/administration/public safety/- miscellaneous public investment were unemployment rates good predictors of needed investment. Similarly, income failed to be a good predictor of investment levels, except in the case of roads. This is consistent with my analysis-of-variance tests discussed above that indicated that few forms of infrastructure investment varied significantly by the level economic distress.

With the exception of the public utilities category, the models are moderately accurate in estimating public investment as a function of county characteristics. (Public-utility investment is sporadic and highly variable in magnitude. Nearly one-fifth of the sample counties showed no investment in power

Table 11
Public Infrastructure Investment Models: Coefficient and Goodness of Fit
(175 Sample Counties, Coefficients significant at 5%-level shown in boldface)

EXPLANTORY VARIABLES[1]	INFRASTRUCTURE TYPE[2]								
	Roads (Incl.streets, bridges,etc.)	Admin.,Public Safety, Misc.	Schools	Sewer Systems	Hospitals/ Health Care	Water Systems	Power Utilities	Airports	Communication Utilities
MFGSHR	**-188**	**-47**					**-9**	**6**	
SVCSHR	**-184**			**10**	**17**	**-7**	**-9**	**-4**	
TOTEMPGR					**-88**				
MFGGR	**-89**			**-12**					
SVCGR	**138**								**-6**
PCI	**0.30**								
PCIGR						**-63**	**-107**		
POP				**-0.00012**	**-0.00014**				
POPGR						**64**		**-61**	
MSA	**-1673**					**-105**			
BASE-CLOSURE	-1,481	**861**							**30**
SEWER						**0.15**			
PRIV-COMML		**-31.00**		**0.31**	**0.14**		**0.04**		
PRIV-TRANPRT								**4.70**	
PRIV-UTIL	**-7.70**								
PRIV-MISC			**0.14**	**0.13**					
PRIV-RES			**0.04**	0.02				**0.02**	**0.002**
UNEMP		**142**							
Constant	**12,762**	**1,470**	**758**	**25**	**-61**	**846**	**859**	**197**	**6**
GOODNESS OF FIT (By Infrastructure Type)									
Adjusted-R2	0.38	0.30	0.40	0.39	0.47	0.27	0.11	0.66	0.48
F-statistic	12.87	17.98	55.95	21.32	35.64	12.38	4.26	52.89	33.08

1-See Appendix 2 for Complete Definitions of Categories
2-Explanatory Variables and Units of Measure

BASE-CLOSURE-Dummy Variable (0=No closure in county,1=closure in county)
MFGSHR-Manufacturing Employment Share of Total Employment (Average, 1969-1994, %)
MFGGR-Manufacturing Employment Growth Rate (1969-1994, %)
MSA-Dummy Variable (0=nonmetropolitan area, 1=metropolitan area)
PCI-Per Capita Personal Income ($1992)
PCIGR-Per Capita Personal Income Growth Rate (1969-1994, %)
POP-Population (Average, 1969-1994)
POPGR-Population Growth Rate (1969-1994, %)
PRIV-COMML-Investment, Private Commercial Structures ($1992 per capita)
PRIV-MISC-Investment, Private Miscellaneous Structures ($1992 per
PRIV-RES-Investment, Private Residential Structures ($1992 per capi
PRIV-TRANSPORT-Investment, Private Transportation Facilities ($1992 per capita)
PRIV-UTIL-Investment, Private Utility Structures ($1992 per capita)
SEWER-Investment, Public Systems ($1992 per capita)
SVCGR-Services Industries Employment Growth Rate (1969-1994, %)
SVCSHR-Services Industries Employment Share of Employment (Average, 1969-1994, %)
TOTEMPGR-Total Employment Growth Rate (1969-1994, %)
UNEMP-Unemployment Rate (1995-1997, Average, %)

utilities during the 30-year period). In general, public and private investment are positively related to each other, highlighting their generally complementary nature. For each of the infrastructure categories listed in the first column of Table 11, the user can read across the rows to identify the coefficient estimates for the variables shown at the column heading. For example, to find the equation for schools, read across the school row. If a cell is empty, I did not include the variable shown in the column heading in the model. The school equation includes two variables, private miscellaneous investment ("PRIV-MISC") and private residential ("PRIV-RES") investment. The coefficients are shown to be 0.14 and 0.04, respectively. The constant term is 758 (i.e., $758 per capita), and the R^2 value is .40 indicating that these two variables "explain" 40% of the variation in county-level per capita school investment.

I used models to estimate each county's "expected" investment per capita. I then subtracted this fitted from the county's actual investment. I compared the estimates of surplus and shortfall against those obtained from the case-study research to test whether infrastructure needs were accurately identified.

CASE STUDIES AND KEY FINDINGS

Case studies were conducted within six of the sample counties to verify the accuracy of the needs estimates. Two other members of the Multiregional Research Planning staff of the Massachusetts Institute of Technology's Urban Studies and Planning Department and I conducted a series of interviews with capital planners, budget officers, and various other representatives of jurisdictions in six counties were conducted. In preparation, we identified six broad lines of inquiry to explore to gauge what types of information-loss would occur when needs are estimated only with the short-cut technique. These topics included:

- Known infrastructure (or related) barriers to private business growth.
- Recent fiscal events that might be departures from historical pattern concerning development and investment.
- Infrastructure capacity limitations likely to affect near-term private investment decisions.
- The nature of capital budgeting and planning in the jurisdiction.
- Local perception on the linkages between infrastructure and private investment.
- Any apparent overlaps or duplication of services in base-closure counties, or special investment requirement to make base facilities attractive for re-use by public or private parties.

We selected six case-study sites, one in each of the six EDA regions. Five sites (Darke County, OH, Martin County, FL, Taylor County, IA, Crittenden County, AR, and Riverside County, CA) had relatively high investment shortfalls for aggregate investment, and one (Suffolk County, MA) had a large surplus. Each of the six sites encompassed multiple political jurisdictions operating within county boundaries responsible for infrastructure provision.

The case studies afforded an opportunity to gauge expected infrastructure investment behavior against the realities faced by local jurisdictions in terms of priorities, budget, affordability, and political pressures. I summarize the findings below. Readers interested in detailed information obtained from the case-studies should see Appendix B.

The case studies offer ample evidence of four problems with my approach. These problems, in order of severity are: (1) Counties are inappropriate political units as the sole basis for estimating infrastructure needs. (2) Capital investment levels and capital budgets reflect the intersection of needs and means to pay for them, not the intersections of actual and desired investment. (3) Private infrastructure provision is not accurately measured in some of the existing investment data, and it is probably misclassified in other parts of the data. (4) The needs-estimating models should be revised to capture additional important demographic features. This can be accomplished without great additional expense and make the estimates useful for broad regional budget planning, or for evaluation of investment patterns for other large areas.

Counties As The Unit Of Analysis

Counties, as a political unit, have varying degrees of responsibility for the provision of infrastructure, and proved highly problematic for the analysis. They share responsibilities with states, cities, towns, and special purpose districts for infrastructure provision. With more than 70,000 political jurisdictions in the United States, there are multiple jurisdictions operating in each county, with varying responsibility for capital investment. Counties, as an areal unit over which to aggregate or consolidate needs-estimates for all jurisdiction-types, are generally not sufficiently homogenous to permit an aggregate-needs measure to serve for all the jurisdictions operating therein.

There is no practical, low-cost way of knowing what proportion of infrastructure services are delivered by the capital resources from within a county without collecting data from all operating jurisdictions regarding the quantity, quality, and adequacy of capital resources and the service area (and population) served by capital within that county. Such data collection would be very costly, requiring consultation with local capital planners and administrators for accurate information.

Because a significant amount of infrastructure is funded using local resources, particularly schools, streets, bridges, water, and sewer treatment, infrastructure needs should be geared to the political units which do the funding. However, sticking to this concept makes the notion of an "economical shortcut method" of needs-estimating infeasible. Jurisdiction-level analysis is tremendously time-consuming, and appropriate data on the economic and demographic characteristics are sparse.

"Needs" Versus Budgeted Investment

The second case-study finding is that participants found the distinction between current investment levels and current investment needs to be purely academic. None of the interviewees were prepared to quantify needs beyond the scope of their current capital plans, plans that were designed to meet their "needs", subject to the prevailing budget constraint.

The use of historical investment rates, in view of the weak linkage with unemployment rates (particularly the short-term measures now in use), indicates that investment rates are not a sufficient proxy indicator for needs. For this reason, we believe additional research aimed at identifying "adequate" capital stocks and service-levels would be highly valuable.

Unmeasured Infrastructure Investment

In three of the case-study locations, a sizable proportion of residents received infrastructure services from private infrastructure resources. For the most part, these take the form of water treatment, wastewater treatment, and roadway investments that serve new residential developments. These investments, however, are not tracked separately from residential construction expenditures, and the costs are generally incorporated in the selling prices of the houses. Therefore, the infrastructure portions remain invisible to both public and private agencies that attempt to record such investments. The incidence of this problem over the entire country is not known, nor is the value of the untracked investment. In the case studies, it was only observed where new residential growth was apparent, but it conceivable that small-scale nonresidential developments have a similar feature. This form of infrastructure provision bears closer analysis, and is discussed further under the "Recommendations" section.

Needs-Estimating Model Revisions

The models currently used to estimate county-level infrastructure needs could be improved with the addition of more detailed economic and demographic data. In some of the cases, the estimates are not sufficiently sensitive to depict accurately the needs of areas with unusual population age-profiles and/or density characteristics. Such variation can influence the type and quantity of public investment required. For example, in areas characterized by a significant proportion of farm, elderly, or seasonal population, the use of dummy variables will improve the accuracy of the investment. For the most part, these data are available at the county-level and could easily be accommodated in the models to generate the improved needs-estimates. Some increase in the sample-size would be desirable to provide for sufficient observations to account for such effects.

CONCLUSIONS AND RECOMMENDATIONS

Both the literature and my empirical results indicate that infrastructure investment is essential for economic growth but is not, by itself, sufficient to alleviate economic distress. There is little difference in the pattern of investment across counties of varying degrees of short-run economic distress (the period used by EDA to determine eligibility), a clear indication that economic growth rates are not tied directly to public infrastructure investment. Measured over a long-run period, some infrastructure investment is positively related to reductions in unemployment distress, but not to increases in relative per capita personal income. The three categories usually thought to have a strong impact on development, streets/highways/bridges, water, and power utilities, do not show significant differences in per-capita investment by degree of distress, whereas education, social services, and sewer systems, do show significant differences. This appears to be a lagged response to other private investment, probably residential.

Infrastructure is a fundamental ingredient to support certain forms of private investment and economic activity. For regions that have a history of distress, public investment can eliminate a critical capacity constraint and can be a valuable precursor to alleviating distress. By itself, however, it does not guarantee that growth or development will necessarily follow. Economic growth (and the consequent alleviation of economic distress) requires productivity increases, and engineering these is evidently a more complex proposition incremental improvement in the public capital stock. This remains an area for future research.

My attempt to find a reliable, simple, and economical method of estimating infrastructure needs at a county-level was unsuccessful. In large measure, this is due to the difficulty of applying county-wide needs-estimates for specific infrastructure services to all the jurisdictions operating within a county. While it remains possible to that jurisdiction-level needs-estimates, i.e., for cities, metropolitan areas, counties, etc. can be estimated with reasonable accuracy once the data are assembled, the secondary data needed to do this remains a critical barrier. The concept of infrastructure-needs itself sounds straightforward, but as a practical matter, it is not. Case-study participants looked upon needs as being nearly synonymous with their budgets. They design their budgets to meet their needs, all subject to their budget constraint.

This research, while failing to demonstrate the feasibility of employing our proposed method on a broad-scale, did yield insights into infrastructure investment and measurement problems that have been previously unobserved. Specifically, the incidence of developer-supplied infrastructure does not appear to be measured at present by either public or private agencies, and goes unmeasured or misclassified. Research on this topic is clearly needed, as there is no way to tell at present how widespread a problem it is, nor what the implications are for public investment policy.

APPENDIX A - F.W. DODGE PROJECT-TYPE DEFINITIONS

F.W. Dodge Project Type/-Structure Groups	Infrastructure Categories
Airports	Transportation Facilities
Amusement, Social, Recreational	Administration, Public Safety, Miscellaneous
Apartments	Residential
Auto Service, Parking Garages	Administration, Public Safety, Miscellaneous
Bridges	Roads
Capitols, Court Houses	Administration, Public Safety, Miscellaneous
Communications Buildings	Communications Facilities
Dams, Reservoirs	Administration, Public Safety, Miscellaneous
Dormitories	Residential
Gas Utilities	Power Utilities
Government Services	Administration, Public Safety, Miscellaneous
Hospitals, Health Care, Nursing Homes	Health Care
Hotels, Motels	Hotels
Laboratories, Manufacturer-Owned	Manufacturing Buildings
Laboratories, Nonmanufacturer-Owned	Administration, Public Safety, Miscellaneous
Libraries	Administration, Public Safety, Miscellaneous
Manufacturing Plants	Manufacturing Buildings
Miscellaneous Nonbuilding	Administration, Public Safety, Miscellaneous
Miscellaneous Nonresidential	Administration, Public Safety, Miscellaneous
Offices, Privately-owned	Commercial Buildings
Offices, Publicly-owned	Administration, Public Safety, Miscellaneous
One-Family Housing	Residential
Power Generating Plants	Power Utilities
River, Harbor Facilities	Administration, Public Safety, Miscellaneous
School, Colleges	Educational Buildings
Sewer Systems	Sewer
Space Facilities	Administration, Public Safety, Miscellaneous
Stores and Restaurants	Commercial Buildings
Streets, Highways	Roads
Two-Family Housing	Residential
Warehouses, Manufacturer-Owned	Manufacturing Buildings
Warehouses, Nonmanufacturer-Owned	Commercial Buildings
Water Systems	Water Systems
Worship, Houses of	Administration, Public Safety, Miscellaneous

APPENDIX B - CASE STUDIES

Three members of the Multiregional Planning Research group of the MIT Urban Studies and Planning Department conducted case studies in 6 counties, interviewing representatives of 35 jurisdictions. We met with representatives of the largest jurisdiction in each of the following 6 counties:

Crittenden County, Arkansas
Darke County, Ohio
Martin County, Florida
Riverside County, California
Suffolk County, Massachusetts
Taylor County, Iowa

Of these six counties, one (Riverside, CA), was distressed and experienced both base realignment and defense-cutbacks. Of the six counties selected, five counties display sizable shortfalls of total public investment based on our models, and one, (Suffolk, MA) has estimated surpluses of public investment. In preparing for the interviews, we used our estimates and a set of open-ended questions to guide the discussion on infrastructure needs. Both quantitative and qualitative assessments are included. The quantitative tests involve a review of the jurisdiction's capital budget to derive annual average investment per capita over the budget period by infrastructure category, and the jurisdiction's best estimate of capacity utilization of existing facilities. The qualitative analysis centers around the jurisdiction's self-assessment of existing infrastructure condition and quality of services. These features cannot be included in the needs-estimating procedure, but may be important factors in leading jurisdictions to seek EDA funding for specific projects.

In this section, we describe the topics of discussion and analysis included in the case studies and then present a general summary of the case-study findings.

Questions And Issues

Based on our estimates of infrastructure needs and prior experience regarding infrastructure impact estimation, we identified the following series of questions and issues for all distressed counties, as well as specific ones for base-closure and defense-cutback areas. These are listed below.

1. In view of our finding little evidence linking the degree of economic distress (unemployment) and levels of infrastructure investment, we wanted to answer the following questions for each case study:

   (a) Are there specific instances where firms that were once major employers have closed or relocated for locational reasons (i.e., ones specific to this jurisdiction), such as taxes, labor costs, energy costs, market factors? Were these "nonbasic" firms, i.e., serving outside markets?

   (b) If any reasons in (a) above have an infrastructure component, probe further as to how it influenced the firms' operating decisions.

(c) Have any firms been in contact with the jurisdiction about setting-up a new establishment? If yes, did they identify or inquire about specific types of infrastructure services or rates?

2. To the extent that economic structure is a more important determinant of infrastructure-needs than distress-level, what changes have occurred recently that have either strained the jurisdiction's existing capacity or financial ability to maintain the capacity it already has. Are there specific industries that have experienced large upward or downward employment levels that affected available infrastructure service capacity?

3. Are there specific categories of infrastructure for which the jurisdiction has little or no additional capacity?

4. Capital budget review: For each of the categories shown in 3 above, what are the sizes and growth rates of planned capital investment over the period covered by the budget?

5. What changes in public services appear to be needed to enhance the jurisdiction's attractiveness?

6. For base-closure counties, which municipal services were or are currently provided to the base? What percentage of local capacity does this represent? Are there any services or infrastructure on the base that could augment the jurisdiction's capacity for similar services? Does the base infrastructure require additional investment to meet code requirements? Is

there a development plan for base-reuse? What are the estimated needs and what is the current estimate of costs?

Case Study Reports

Darke County, Ohio

Darke County appears to be adequately served in its infrastructure needs, with the possible exception of roads. The county does significant amounts of force-account bridge and sewer work that, if properly accounted for, would offset some of the estimated investment shortfall. These investments go unrecorded in the F.W. Dodge data and are not likely to be recorded in any future data.

CASE STUDY SUMMARY

Darke County is located approximately 40 miles northwest of Dayton, Ohio, bordering on eastern Indiana. It is accessible to Dayton and surrounding areas by undivided state highways and smaller secondary roads. The predominant land-use is rural, but manufacturing dominates industrial employment (by place of residence), with nearly one-third of the labor force working in manufacturing industries as of 1990. The county population numbered 54,000 in 1992 and declined slightly over 1980-1992 at a rate of -0.2% per year. Nearly half of the population resides in and around Greenville, the county seat, and there are several other smaller towns scattered around the county. In general, the county is fairly typical of others in Ohio: The unemployment rate measured over 1995-1997 was 5.1%, and the average income was $11,600 per capita, slightly below the state average of $12,600 per capita.

Darke County has more manufacturing employment as a percentage of the labor force and less services employment than the state as a whole. A significant percentage of manufacturing employees commute to work in neighboring Miami and Montgomery counties. Miami County is traversed by Interstate 75 and has numerous large plants. Montgomery County, in which the City of Dayton is located, has several immense automobile and transportation parts manufacturing facilities. In contrast, Darke County's manufacturing activity is limited generally to smaller branch plants, but the county does have several plants with employment ranging from 750-1000 persons, including Allied-Signal and Corning Glass. The county lacks the access required for high-frequency, high-volume shipping found nearby in other counties. At present, it has no interstate and divided state highway access. There is limited short-line rail service through Greenville, and the CSX Corporation's rail lines pass through the county, but have no sidings. Prior to deregulation of interstate truck transport rates, the county was the main location of one of the nation's largest trucking firms, Carl Subler, Inc., but this firm went bankrupt following deregulation, and more than one case-study interviewee conjectured that poor road access may have played a part in the firm's failure.

INFRASTRUCTURE INVESTMENT SUMMARY

For this case study, we interviewed the Darke County Board of Supervisors, the county engineer, the mayors of Greenville and Versailles, and the Greenville School Board treasurer and capital planner. As a jurisdiction, Darke County is only responsible for roads and bridges. The city of Greenville (population 12,000) is responsible for its own water system, sewer system, parks, public administration, and safety. Power utility and health-care services are privately delivered. The same is true of Versailles (population 2,000), except that they do bulk purchasing of electricity for sale by its own utility department. The Greenville school district operates independently of the city, and the rest of the county is served by a township-based school system. There are twenty townships within Darke County. Table 1 shows the per capita Dodge-based infrastructure investment by type for calendar year 1996 and the 1996-1999 actual and planned investment per capita (1997-2003) obtained from county sources. The estimated shortfalls (called "model residuals") are derived from our regression-based model. As shown, the largest investment in 1996 (consolidated for the interviewed jurisdictions), is roads, followed by sewer and water. We normally anticipate some discrepancies between the actual investment figures obtained on-site and those from F.W. Dodge owing to different reporting periods for fiscal-year

Table 1
Actual 1996 and Planned 1997-2003 Infrastructure Investment
Darke County, Ohio

Infrastructure Category	1996 F.W. Dodge ($, current)	1996 Actual ($, current)	Model Residual Average Annual ($1992, per capita)	Rank	Planned Investment-1997-2003 ($1998, average annual per capita)	Rank
Education	432,000	NA	-910	3	243	1
Roads	4,362,000	3,312,453	-2370	1	119	2
Water	684,000	850,000	-242	5	22	3
Sewer	242,000	900,000	-367	4	9	5
Power Utility	0	0	-147	6	15	4
Administration/safety	772,000	0	-1,243	2	1	6
Total	6,060,000	5,062,453	-5,279		410	

Source: F.W. Dodge Inc. and MIT-Multiregional Planning Research Group, 1998 figures in Ohio (year ending June 30) and the calendar years in the Dodge data. In addition, we expect the on-site derived figures to fall below the Dodge ones because there were a number of small jurisdictions for which we did not collect data at all. For this reason, the total investment differences, $6.1 million from Dodge versus $5.1 million from on-site data look reasonable. However, the Darke County highway department engages in a substantial amount of "force-account" work, meaning that it does its own construction work using public employees of the jurisdiction. The work is not offered for public bidding, and is rarely, if ever, reported in the Dodge statistics. This leaves a gap between the Dodge data and the actual investment, understating the former. To a lesser extent, force-account work is used in the water and sewer categories, as well, with Greenville City using this type of construction for system upgrades and replacements of small portions of the system.

The estimated rank-order importance of needed investment compared to planned investment between 1997-1999 indicates that there was some disagreement between our model and perceptions in the County. The model identifies roads, public administration/safety/miscellaneous, and education as the categories with the largest shortfalls in descending order. The planned expenditures, however, indicate that education, roads, and water systems are the highest priorities. Some of the discrepancies could be reduced, no doubt, by improving the model specifications to reflect the county's rural land-use and low-density development. However, the problem associated with force-account work cannot be easily eliminated, and in this sense, we will always face a systematic under-reporting of local investment.

Nevertheless, various representatives clearly identified roads and highways as being the category of highest need. Because the county is accessible only by 2-lane, undivided highways, they felt that the present road system was an impediment to additional private investment in new manufacturing facilities. The model did identify this as the area of greatest shortfall, but the problem appears to be a reluctance at both the state and local levels to fund additional highway construction at a time when the county economy is already performing reasonably well. The fact that local officials view development potential as most easily accomplished with road investments (in contrast to education, for example) is understandable. Large tracts of land presently in agricultural production would be transformed into land suitable for nonagricultural uses if it were accessible to the regional (and national) highway network. No such direct consequences can be attached to educational facility investment. Their view, of course, does show a bias that may or may not be justified.

Martin County, Florida

- Martin County has large seasonal population and employment changes that distort the estimated shortfall estimates.

- Certain shortfall estimates appear to be overstated, such as those for education and healthcare. These can be remedied with the addition of more detailed data to the models. True shortages in capacity, specifically road capacity, are intentional on the part of the county, being used as a growth management tool.
- Data on water, sewer, and roads fail to measure developer-provided infrastructure. These are thought to be sizable, in so much as both municipal water and sewer systems are operating well-below engineering capacity.
- The county has an ample taxbase, and any additional capital needs are not likely to be a product of inadequate county means.

CASE STUDY SUMMARY

Martin County is located on the east coast of Florida, approximately 75 miles north of West Palm Beach via Interstate 95. It had a population of 104,000 persons in 1992 and experienced rapid increases in recent years, with a compound annual growth rate of 3.8% per year between 1980 and 1992. This rate is significantly greater than Florida's already high rate of 2.5% per year over the same period. Martin County has the seemingly paradoxical characteristic of having relatively high unemployment over the 1995-1997 period (7.4%, 33rd highest among our sample of 175 counties), and very high real ($ 1992) per-capita income of $20,328 in 1997, the fourth highest among the 175 counties in our sample. This feature made it an attractive area to include as a case-study site to see what, if any, was the link between its economic conditions and infrastructure investment.

In the course of the site visit, we learned that the county has two notable economic/demographic characteristics: First, there is very strong seasonality to much of its economic activity, with a large tourism component and a prominent agricultural sector concentrated in citrus growing and citrus processing. These activities reach a seasonal peak during the middle of the winter. The county also has a large seasonal population for climatic reasons, with an influx beginning in November and an outflow that starts in March. This temporary population increase, based on anecdotal accounts, consists of wealthier-than-average retirees who augment the resident population levels by 30% during the winter months. Combined with agricultural seasonality, the county experiences strongly seasonal employment swings across a range of industries, pushing unemployment rates up during the spring, summer, and early fall.

The second significant characteristic is that the county has a large percentage of the total county population aged 65 and older, namely 25%, compared to 18% for Florida as a whole. The large elderly population is thought to be comparatively wealthy and reported by local officials to purchase significant service-sector outputs, including medical, finance, insurance, and real estate services.

For our purposes, these atypical characteristics have important effects on the estimated infrastructure requirements. First, the resident population estimates, developed from U.S. Bureau of the Census' Census of Population measurements as of April 1, 1990, do not accurately reflect the true population served by the county for most public services, which is actually much greater in the winter months. The *per-capita* historical investment data would be substantially lower if they reflected the actual population served, and our *aggregate* estimates of demand and shortfall would both be increased because of the larger base population. Second, the age-composition of the population, presently undifferentiated in the investment models, probably overstates the demand for educational services and understates demand for health and hospital services. These are features that could be readily corrected in a revised set of investment estimates.

As we indicated, the county's economy is noted for its agriculture and tourism industries. There is no significant manufacturing activity in the county, with services (broadly defined to include wholesale and retail trade, finance insurance, and real estate, personal services, and state and local government) comprising the bulk of employment. Population is widely distributed across the county at a relatively low density. There is only one city of significant size, Stuart, with approximately 12,000 persons. The rapid growth of population has resulted in construction of high-rise apartment buildings along the coast and low-density housing developments inland. The high volume of construction in this latter category has had major implications for public infrastructure investment and its measurement because it is generally reported to be the practice for residential developers to provide water plants and water lines, and sewer plants and lines sized for the development, as well as roads and utility connections. Because the F.W. Dodge data on public infrastructure investment data are collected using building permit data and/or architects as the primary sources of information, it is likely that most of the small-scale public infrastructure investments that serve these residential areas go unmeasured. This may exaggerate shortfall estimates for Martin County (and other counties with similar growth and development practices that have housing and infrastructure combined in tract-type residential development.)[28]

According to local planners, neither airport facilities, water, nor sewer systems are operating at their rated capacities presently. Recent water and sewer investments were designed to update treatment methods to a higher standard, rather than to expand capacity. By all accounts, Martin County does not suffer from a significant shortage of public infrastructure except where

[28] At the same time, the estimated investment in older metropolitan areas that have seen growth in re-developed areas, or increased density from additional development may be accurately captured when supplied by contracted work by public authorities, data generally "captured" by Dodge. This, however, creates a bias in the data that would seem to underestimate public investment in fast-growth areas relative to slow-growth, established areas, and give the (probably false) impression that fast-growth areas are significantly more

expressly the intent of growth-control oriented planners. All of the case-study participants indicated that both the quantity and quality of county public services delivered were adequate to meet the county's needs at present and in the near future, and none indicated that infrastructure, or lack of infrastructure, hampered the county's economic development prospects, except in the case of roads. County planners explicitly limit new road construction so as to limit growth in undeveloped agricultural areas. Neighboring counties to the north and south, such as those, for example, around Orlando and West Palm Beach, have experienced rapid growth and sprawl conditions that are viewed negatively by Martin County planners. The county government is fiscally conservative as evidenced by direct expenditures of approximately $1,000 per capita in 1987 versus $1,400 for the State of Florida and $1,500 for the nation as a whole (U.S. Bureau of the Census, 1994) even though Martin County has significantly greater personal income per capita than either larger area. There seems to be little question that if county conditions deteriorated sufficiently to cause political pressure to increase infrastructure investment, the county has the fiscal resources to add to the infrastructure base.

What then of the county's high unemployment rate? County officials indicate that it is largely a product of seasonal layoffs. The grapefruit harvesting season runs from October through early summer, and the resulting summer layoffs are

---

under-served with public infrastructure than they otherwise might be.

probably too short for workers to go elsewhere for employment. The layoffs are, however, significant in size. This, too, can be said of the service layoffs tied to the drop-off in tourism during the summer. For the most part, the recorded unemployment rate of 7.4% during the 1995-1997 period is viewed as nearly full employment in the context of the employment seasonality in Martin County.

INFRASTRUCTURE INVESTMENT SUMMARY

Planning officials for Martin County were interviewed for this case-study. The county provides infrastructure services for all types of infrastructure except utilities (power and communications) and hospitals, all of which are privately provided in the county. Table 2 shows the per capita Dodge-based infrastructure investment by type for calendar 1996, the county reported investment for 1996, the estimated shortfalls derived from the model, and the rank-order of planned investment during the 1997-1999 period.

The Dodge data, shown in the table, are calendar-year figures, while the Martin County data are for fiscal years, with the year running from October 1 through September 30. In view of possible timing differences, the data shown for 1996 appear to be accurate except for the missed educational investment by Dodge in 1996 of $9,000,000. This difference by itself would not have a great impact on the estimated shortfall of total infrastructure investment over the 30-year history with which we are working.

Table 2
Actual 1996 and Planned 1997-2003 Infrastructure Investment
Martin County, Florida

Infrastructure Category	1996 F.W. Dodge ($, current)	1996 Actual ($, current)	Model Residual Average Annual ($1992, per capita)	Rank	Planned Investment-1997-2003 ($1998, average annual per capita)	Rank
Education	0	9,000,000	-1,877	2	114	3
Roads	8,610,800	10,870,000	-2,953	1	576	1
Water	4,567,200	2,898,000	-124	6	17	6
Sewer	2,902,000	3,727,000	-1,639	3	27	4
Administration/safety	1,476,300	4,636,000	-1,467	4	114	2
Airport	0	0	-537	5	10	6
Total	17,556,300	31,131,000	-8,597		858	

Source: F.W. Dodge Inc. and MIT-Multiregional Planning Research Group, 1998

122

(If Dodge had not missed the $9 million, the shortfall estimate would fall by about $4 per person.) Our models show roads, education, and sewer infrastructure to have the largest shortfall values. The county's annual planned expenditures include roads, public administration/safety, and education as its highest priority investments, with sewer systems being the fourth highest. In view of the problems with the Dodge data in capturing the residential sewer and water "package" plants, however, we are reluctant to claim that even the rank ordering of the shortfall, as estimated by our model, would be accurate. In view of the local authorities' claims that there are no significant infrastructure shortage conditions in the county, we regard our estimates in this case as poor ones even with improvements in the models with respect to measurement adjustments for seasonal population and local demographic conditions, we think it is unlikely that our models will accurately capture the infrastructure investment requirements of such a county.

Suffolk County, Massachusetts

- For water, sewer, and the airport, Suffolk County is part of a larger special-purpose district. This makes simple per-capita calculations infeasible and vastly distorts the degree of surplus. Significant regional capacity is being constructed in Suffolk County.
- Analysis of infrastructure investment in Suffolk County is hampered by several large-scale, long-deferred, one-time projects related to highways, water, sewer, and airport construction. As a result, current infrastructure

investment is not representative of recent or future investment trends.

- Legislation and regulations mandate some of these projects, not physical obsolescence.
- The highest planned per capita annual investments are the very same categories that show, according to our model, the highest surpluses: administration/safety, roads, and hospitals. The unusual size and length of construction on several enormous projects distorts most of the capital expenditure numbers.

CASE STUDY SUMMARY

Suffolk County is located in eastern Massachusetts and is comprised mainly of the City of Boston. In 1990, over 86 percent of the county's population resided in the City. Boston is connected to the national highway system through surface arteries and three interstate highways. An extensive public transportation network reaches into the City's various neighborhoods, linking them to the commuter rail system. Population in the City declined steadily from 647,000 in 1960 to 63,000 in 1980, and has, since the early 1990s, stabilized around 570,000.

Boston is an old city, with a rich and varied economic and social history. The nature of its economic base has changed considerably in the recent past. In 1960, close to 39 percent of the jobs were in manufacturing, while only 30% were in the finance and service sectors. Today, the finance, health care, and education sectors, along with other services, account for the majority of the city's and county's jobs. In 1996, 17 percent of the city's jobs were in manufacturing, while 60 percent were in the service sector. The city presents one of the highest concentrations of employment and income in the United States. Boston's unemployment rate peaked in 1991 at 9.3 percent, but in February, 1998, it was down to 3.4 percent.

Because it is an urban region, the county has a population density of 10,926 per square mile. Median household income in the county was $29,399 in 1989 just below the U.S. average, while per-capita income was $15,414, about 7% higher than the U.S. average. The City's poverty rate was 20.2 percent in 1980, and had fallen slightly to 18.7 percent by 1990. While nearly one quarter of the county's population over the age of 25 had not finished high school in 1990, almost one-third had a college degree.

INFRASTRUCTURE INVESTMENT SUMMARY

The current level of infrastructure investment in Suffolk County is higher than it has been in several years. This is due primarily to the implementation of a few large and long-deferred projects. The two main projects currently affecting the economy are the Central Artery/Third Harbor Tunnel project and the Boston Harbor Treatment Facility project. Both are funded primarily by the Federal government, with the Commonwealth of Massachusetts covering the remaining costs. The Central Artery project is the largest public works project in the country, estimated to cost $10.8 billion. The Boston Harbor Treatment

Facility project, run by the Massachusetts Water Resources Authority, is one of the largest wastewater treatment plants in the nation, constructed at a cost of $3.7 billion. Other plans under way in the county include a plan to develop the East Boston and South Boston seaport districts, a plan to improve parks and neighborhoods to connect them to residents to the waterfront areas, and plans (construction now completed) for a new federal courthouse in South Boston.

Officials from the City Budget Office, the Logan Airport Budget Office, and the Massachusetts Water Resources Authority Capital Planning Office were interviewed for this case study. Table 3 depicts the per capita Dodge-based infrastructure investment by type for 1996, the case-study derived investment per capita for 1996, the surplus estimated by our regression models, and the anticipated per capita investment for 1999-2003. The rank order of the residuals and planned investment are also shown.

The investment figures from F.W. Dodge and the figures obtained from the case study differ markedly. For the roads category, for example, the Dodge figure is nearly 20 times the actual investment figure. According to Dodge, the administration/safety figure is six times the actual investment figure. Dodge data show investments to be greatest in roads, administration/safety and sewers, while actual investments show

Table 3
Actual 1996 and Planned 1997-2003 Infrastructure Investment
Suffolk County, Massachusetts

Infrastructure Category	1996 F.W. Dodge ($000, current)	1996 Actual ($000, current)	Model Residual Average Annual ($1992, per capita)	Rank	Planned Investment-1997-2003 ($1998, average annual per capita)	Rank
Education	24,068	32,657	1,158	4	121	4
Roads	547,739	20,643	2,725	2	292	2
Water	10,982	40,000	661	6	42	5
Sewer	92,903	310,000	1,156	5	41	6
Power Utility	2,834	0	286	8	0	
Communication Utility	320	0	65	9	0	
Hospital	4,293	3,395	1,163	3	22	7
Administration /safety	190837	28,404	5,557	1	238	3
Airport	3,979	71,065	324	7	327*	1*
Total	877,955	506,164	$15,087.00		1,083*	

Source: F.W. Dodge Inc. and MIT-Multiregional Planning Research Group, 1998

* per capita values computed using county population—defining the jurisdiction of the airport, which serves a large region, is not feasible.

the highest figures in sewers and the airport. The immense investment in sewers can be attributed to the Boston Harbor Treatment Facilities project. Overall, the total actual infrastructure investment for 1996 represents only 56 percent of the Dodge investment figure.

A comparison of the perceived needs (according to our model) and the actual planned investment shows a great disparity between the two. Our model shows a surplus in all categories, and, in most instances, this surplus is higher even than the planned annual per capita investment by a factor of ten or more. The sharpest difference is in administration/safety, with our model projecting an average annual per capita investment of $5,557 and actual planned investment only at $238. Most importantly, the highest per capita planned investment is precisely in the categories that, according to our model, demonstrate the greatest surplus: administration/safety, roads and hospitals.

City officials pointed out that a lot of the needs assessment their budget department conducts is fairly intuitive, although backed by research and data. Given the political nature of their work, they are often guided by the various initiatives of the Mayor's office. Each year, one or two particular issues take the political forefront, and extra funds need to be budgeted to cover them. Many of these initiatives come under the categories of public safety, education, or health. These departments are frequently given priority as it is politically difficult to reject their requests for public funds. A large portion of the budget for the next couple of years, for example, is earmarked for new police headquarters and high school renovations.

In addition to being compelled by political factors, certain investments are mandated by legislation and environmental regulations. Logan Airport, for example, faces several legislative mandates. The airport must contribute considerable funds toward the Central Artery project, as well as for a South Station-Logan connection. In addition, environmental regulations, such as those regarding contaminated fuel, compel certain investments. The largest investment in the County driven by environmental regulations is the Boston Harbor Cleanup project, mandated by court order. The Safe Drinking Water Act and other regulations issued by the Environmental Protection Agency and the Department of Environmental Protection play heavily in the reasons for investment in the water and sewer sectors. In the 1980s, the biggest issue for the water authority was the quantity of water supply. A conservation effort and investment in leak stoppage reduced concern in that area, and since the early 1990s, the new issue has been in water quality.

To a certain extent, there is a "no growth" assumption in some of the budget offices of the region. Boston's physical space is limited, and the City's population is stable. As a result, most of the infrastructure investment in the City is budgeted for maintenance and repair. With the exception of the Central Artery project, in which several road segments are being placed underground, there is limited new road construction. Similarly, as it would be difficult to find a suitable site for a new school, most of the focus in education is on maintenance, rather than new construction. At Logan Airport, the main factor driving investment is a modernization program designed to rehabilitate the aging facility. Finally, the Massachusetts Water Resources Authority assumes that its service area will not be expanded. Capital projects in water and sewers will taper off after the current large projects are completed. With the exception of the airport budget office, the people interviewed for the case study indicated that there are no plans that cannot move forward for lack of funding. In fact, inadequate funding was never mentioned as a problem. On the contrary, city budget officials believe than more could be achieved if project financing were considered in a more comprehensive manner.

Taylor County, Iowa

- Taylor County is economically distressed due to low income and limited nonagricultural production activity. The county unemployment rate understates the real level of underemployment because laid-off nonagricultural workers usually leave the labor force and resume farm work.
- The condition of the county's road network is poor. Access to major metropolitan areas and the highway

network can be difficult. Street-paving is an area of significant need for several towns.

- The county has only recently been connected to the regional water system, resulting in the need for an extraordinarily large investment in water systems in recent years. Prior to the connection, parts of the county suffered from severe water shortages.

CASE STUDY SUMMARY

Taylor County is located in southwestern Iowa, approximately 100 miles southwest of Des Moines and 110 miles north of Kansas City. It is one hour's drive from the interstate highway system (I-29), connected by two-lane undivided highways. It is not served by either railroad or commercial air carriers. It is almost entirely rural, with almost all land dedicated to agricultural activities. The county population was approximately 7,100 persons in 1992 and has been declining. The economy is almost entirely focused on agriculture and agricultural services. Fully 25 percent of the population resides on farms, nearly the highest percentage in a state characterized as agricultural. The primary agricultural products of the county are row crops (corn and soybeans) and livestock.

Because of its agricultural concentration, the population density is among the lowest in the state, with 13 persons per square mile in 1992. The county experienced significant loss of population between the 1980-1990 period, declining by nearly 17 percent, one of the larger losses for any county in the state.

The county is also characterized by very low income levels. Median family income in 1989 was $22,800, nearly the lowest of any county in the state, and per capita personal income was $14,500 (78% of the U.S. average for 1990). The county exhibits low rates of educational attainment (one quarter of the population has not completed high school), and there is a high rate of families living in poverty, 14% in 1989. Although the unemployment rate of 5.6% for the 1995-1997 period is too low to be indicative of "distress" by EDA threshold values, there appears to be limited employment opportunity "off-the-farm" for many of the younger residents This accounts for the sizable outmigration of a portion of the population. When people lose nonagricultural jobs, local officials believe that most return to family-owned farms for work, thus leaving the labor force and lowering the measured unemployment rate.

The two largest towns are Bedford and Lenox, with 1,500 persons and 1,300 persons, respectively. Both towns offer a limited range of commercial activities and services, including banking, retailing, and personal services. The largest employers in Bedford are apparel sewing-plants, each with several dozen employees, and there is one tool and die making shop. The largest employer in Lenox is an egg-processor, employing several hundred production workers. Both towns were founded more than one-hundred years ago, and, by appearances, have not seen much new private investment for several decades with the sole exception of the Lenox egg-processing plant. Both towns look to be similar in the sense of being well-worn. Vacant storefronts and buildings in poor states of repair are numerous. The streets and sidewalks are not in good condition near the town centers, and at the periphery of the towns, streets are unpaved altogether.

The county government, located in Bedford, is responsible for provision of highways and prisons. The towns are responsible for streets, water, sewer, power utilities (in Lenox), libraries, public safety, internet connections, and general public administration. Both towns have independent school boards that are responsible for their own facilities, and neither town has a hospital, being served by small clinics (and limited to one or two physicians) offered on a scheduled, part-time basis.

INFRASTRUCTURE INVESTMENT SUMMARY

The county clerk, city officials for Bedford and Lenox, and Lenox utility manager were interviewed for the case study. As these towns are small, it is unlikely that major projects went unreported during the course of the discussions. Table 4 shows the per capita Dodge-based infrastructure investment by type for calendar 1996, the case-study derived investment per capita for

Table 4
Actual 1996 and Planned 1997-2003 Infrastructure Investment
Taylor County, Iowa

Infrastructure Category	1996 F.W. Dodge ($000, current)	1996 Actual ($000, current)	Model Residual Average Annual ($1992, per capita)	Rank	Planned Investment-1997-2003 ($1998, average annual per capita)	Rank
Education	0	0	-1,002	3	86	3
Roads	206	175	-2,197	1	89	2
Water	1,630	350	-651	4	89	2
Sewer	0	1,300	-299	6	146	1
Power Utility	0	12	-208	8	2	4
Communication Utility	0	5	-37	9	1	4
Hospital	0	0	-615	5	0	4
Administration/ safety	0	0	-1,119	2	0	4
Airport	0	0	-267	7	0	4
Total	1,836	1,842	-6,395		413	

Source: F.W. Dodge Inc. and MIT-Multiregional Planning Research Group, 1998

1996, the shortfall estimated by our regression models, and the anticipated per capita infrastructure investment for years 1997 through 1999 prepared by summing the estimated annual infrastructure investment and dividing by the average population of 7,981. The rank order of the residuals and planned investment are also shown.

As shown, the investment figures from F.W. Dodge and the case-study based figures for 1996 are close in total, but the Dodge data apparently misclassify a large sewer project as being a water project. The perceived need for investment in the 1997-1999 period is significantly different than that estimated by the models, both in terms of scale for the total ($6,395 versus $413 per capita), by the relative differences between infrastructure types, and rank of importance by infrastructure type. In our models, the greatest shortfall is for roads, followed by administration/safety, and education. The actual plans are for sewer systems, water, and roads. In the case of the sewer and water systems, the need to meet regulated performance standards for treatment and quality is compelled by state and federal authorities. The lack of available water supply had been detrimental to the county as a whole, but this year, the threat of critical water shortages has been averted through connection of the county to the regional water authority. (There were documented cases in recent years in which water had to be trucked in to the county during summer months owing to constrained local supplies.)

The condition of many of the local roads is poor, and local government representatives believe the roads need significant improvement in the future. For the time being, however, the water and sewer investments are needed to meet environmental regulatory requirements. Financing this work draws a significant proportion of the jurisdictions' fiscal capacity. Taking into account that the shift in local priorities is compelled from outside the county, the large needs accorded to administration/safety and education estimated by our models versus actual plans points to the difficulty of short-cut methods. We can envision no simple way to pull together regulation-induced investment needs in a short-cut approach, even when these dominate a jurisdiction's near-term investment plans.

In the case of Taylor County, our estimates could be improved by taking into account the county's low population density. This would likely reduce the estimated administration and safety needs estimates. Further, if we accounted for the prevailing low crime rates, the estimated needs for public safety and prison facilities would be reduced. Nevertheless, Bedford and Lenox represent difficult economic development cases from the standpoint of infrastructure investment. Clearly, these are needed to continue to supply services to residents, but as a means to stimulate nonagricultural investment, there seems to be little prospect of success. Bedford officials noted their interest in funding additional street work and replacement of an old fire station if funds were to become available, but it would be difficult to see how the latter investment would greatly enhance the town's attractiveness to potential new private investors.

Crittenden County, Arkansas

- Crittenden County faces several critical barriers to economic development, the most important of which is low educational attainment. Educational building capacity and condition may contribute to this, and our models identify this category as having a large investment shortfall. Schools are overcrowded and badly in need of renovation.
- Infrastructure needs are not uniform across the county. In part of the county, residents benefit from access to Memphis, Tennessee's infrastructure. More remote (and highly rural parts) have no such access.
- Investment data fail to measure some sewer system investment related to residential development, but appear correctly to identify the presence of the shortfall. Officials from the two largest cities in the county, West Memphis and Marion, both identified the need and cities' plans to increase investment.
- The county's economy has a significant concentration in distribution and warehousing activities. The two largest cities plan to continue investing in roads to utilize the regional advantages created by the junction of two interstate highways in the county, as well as

access to the Mississippi River, and three major railroad lines.

CASE STUDY SUMMARY

Crittenden County is located in northeastern Arkansas in the Memphis Metropolitan Statistical Area. The county is bordered on its east side by the Mississippi River, just across from Memphis, Tennessee. Many of the residents work in Memphis or the surrounding counties and almost one-half of the labor force commutes to work outside of Crittenden County. Two major interstate highways intersect the county, I-55 which runs north-south across the entire country from Illinois to Louisiana, and I-40 which extends east-west across the United States between North Carolina and California. The county is served by nearby Memphis International Airport, which is within 20 minutes of 70% of the county's population and the homebase of Federal Express, the parcel delivery company that has one of its largest distribution centers there. The city of West Memphis, the largest city in the county, also maintains a small municipal airport. Both Union Pacific and Burlington Northern Railroad serve the county, and Union Pacific is currently building an intermodal facility in the county.

The county population was approximately 49,600 persons in 1996, a stable figure over the last two decades. The largest city, West Memphis, has approximately 27,000 residents. The second largest city, Marion, with almost 7,000 residents, is experiencing rapid growth, up nearly 60% since 1990. Some of this growth is from new arrivals to the county and some from relocation within the county. Population density varies widely over the county, from a low of 16 persons per square mile in the rural areas, to a high of more than 6,000 persons per square mile in West Memphis.

Crittenden County, despite having very low unemployment (3% currently), is economically distressed because of its low personal and family incomes. In 1990, personal income per capita averaged $9,334, only two-thirds of the national average of $14,300. Median family income was $20,900 in 1989, also two-thirds of the national figure of $31,000. In certain parts of the county, the deviations from the national rates are even larger. Earle, a town of 3,400 residents had a median family income of $12,400 in 1989, about 40% of the national figure. Marion, on the other hand, had a family income of $31,400, slightly more than the U.S. value for 1989. Over 27% of the population lived in poverty in 1990, with the range by city varying from 7% in Marion to 53% in Crawfordsville.

One possible explanation for the county's low-income status may be found with its low-educational attainment. Approximately 60% of the population over age 25 had completed high school by 1990, and only 10% had completed a bachelor's degree. For reference, the U.S. rates are 75% and 20%, respectively. High school graduation rates by city ranged from 40% in Earle to 76% in Marion.

The economy of Crittenden County is diverse, but not dramatically different from the state of Arkansas as a whole, except for a somewhat greater concentration in construction, transportation, and distribution activity in the county. Most of the county's commercial activity is located in West Memphis, where trade (wholesale and retail combined) accounts for one-quarter of total employment. The largest employer in West Memphis is a steel mill, which opened in 1992 and now employs 250 workers with an average pay of $40,000 per year. The largest employer in Marion is the county government, as Marion is the county seat. The Union Pacific Intermodal Facility, which is nearing completion, is located within the city of Marion. It will add to the concentration of distribution and warehousing, and is expected to employ over 2,200 low-skilled workers by 2003, becoming the largest employer by that time. The county is looking to attract even more warehousing and distribution activity to take advantage of extraordinarily good transportation access and low-wage labor.

INFRASTRUCTURE INVESTMENT SUMMARY

Eight officials representing the county and several jurisdictions were interviewed regarding recent planned public investment, including the County Judge, the Director of West Memphis' Office of Economic Development, the head of West

Memphis Utility Commission, the Director of the West Memphis Metropolitan Planning Organization, the Mayor of Marion, the Economic Development Administrator of Marion, Marion's School Superintendent, and an Engineering Consultant to the City of Marion. Our models indicate that Crittenden County exceeded the expected overall investment per capita for a county of its size and growth rate, but that this was due to a high volume of roadway investment. These were offset to a large extent by the combined lower than expected amount of school, sewer, and hospital/health care investment. Our interviews confirmed this to some extent, although complete data on sewers and hospital/health care would make it easier to assess the quality of our estimates.

We estimated a surplus of roadway investment totaling $3,809 per capita, as shown in Table 5. Local officials expected that additional investments in the road network would occur to improve existing roads and build new arterials and loops to make the region more attractive to industry requiring accessibility. Many officials indicated a need to keep traffic flowing within and around the county. Plans include roads for truck-use to separate trucks from commuters heading to Memphis and the surrounding region. The $139 per capita planned investment shows this to be the second largest investment category, and attests to the county's commitment to draw in warehousing and distribution facilities.

Table 5
Actual 1996 and Planned 1997-2003 Infrastructure Investment
Crittenden County, Arkansas

Infrastructure Category	1996 F.W. Dodge ($000, current)	1996 Actual ($000, current)	Model Residual Average Annual ($1992, per capita)	Rank	Planned Investment-1997-2003 ($1998, average annual per capita)	Rank
Education	0	0	-828	1	139	3
Roads	3,809	NA	2106	9	177	2
Water	408	400	124	8	42	6
Sewer	1,830	900	-353	3	34	7
Power Utility	0	0	-20	5	50	5
Communication Utility	0	0	-13	6	0	8
Hospitals/Health Care	0	0	-763	2	NA	8
Administration/safety	7,962	NA	95	7	80	4
Airports	0	0	-110	4	186	1
Total	14,009	NA	238		NA	

Source: F.W. Dodge, Inc. and MIT-Multiregional Planning Research Group, 1998

NA-Data Not Available

We estimated that the greatest shortfall is in educational facility investment, and local officials acknowledged this to be correct. Data we gathered indicated that Marion is budgeting for new schools, with planned per capita investment of $139 over the next five years. Although Earle, West Memphis and Turrell have no current plans to invest in school infrastructure, the County judge felt that there is a good chance that Crawfordsville will probably do so once tax revenues generated from operations at the intermodal facility and related developments are flowing.

The shortfalls in sewer system investment were difficult to assess in view of incomplete information. However, the likely inclusion of some sewer system investment under residential development construction might account for part of that shortfall. The shortfall in hospitals/healthcare are similarly difficult to assess, but as there is good access to Memphis and it's medical facilities, this may be not a severe problem.

West Memphis is the only jurisdiction in the county to operate its own power-generation facilities. Profits from these operations are used to fund water and sewer facilities. In 1996, no investment was made in new power utility infrastructure, confirming the F.W. Dodge numbers. Power utilities were seen as having a shortfall in our model. This is confirmed by West Memphis' plans to build a new electrical substation over the next five years at a cost of $2.5 million, or $50 per capita. This is primarily to service a new industrial park in the city, as well as to try and attract businesses from Memphis.

In 1996, there was no airport infrastructure investment. Overall, the models indicated a shortfall, but this fails to recognize the proximity of the county to Memphis, where air transportation services are easily accessed at Memphis International Airport. There are plans to invest substantially in the Crittenden municipal airport over the next five years. The infrastructure investment figures of $186 per capita between 1997 and 2002 translate into nearly $10 million in total. This investment is seen as essential to serve the warehousing and distribution industries that the county is trying attract. The airport would be improved with added runways and direct access to the highway. In addition to transporting goods between places, the city hopes that the airport will serve commuters and corporate executives.

Riverside County, California

- Riverside County covers a large land area, greater than Connecticut and Rhode Island combined. Its large size and numerous jurisdictions (more than thirty-five) creates unusual difficulties in preparing a detailed analysis of aggregate county infrastructure investment. Our models identify roads and education as categories with the largest shortfalls. Local planning officials tended to agree with these findings.

- In addition to having large infrastructure investment shortfalls, Riverside County is also a base-closure and defense-cutback area. Neither of these have had a significant negative impact on the county, however, and the county continues to grow at a very strong rate. Its unemployment rate fell to 6% in March, 1998.
- Residential developers are required to fund a significant amount of the water, sewer, and road construction linked to their developments.
- The county uses a voter-approved local sales tax to finance road and transportation improvements. More than half of the county's total expenditures in these categories are funded using this mechanism.
- Shortages of educational infrastructure are largely the product of voter-enacted limitations on property taxes, but these can be overridden with adequate support from residents in affected school jurisdictions.

CASE STUDY SUMMARY

Riverside County is located in southern California. It is very large, covering 7,300 square miles stretching from the Colorado River along its eastern border to Orange County, 200 miles to the west. It is larger in area than Connecticut and Rhode Island combined. The western end of the county is largely urban and accessible by a well-developed network of interstate and other divided highways. The eastern end, primarily rural in character, has more limited access, being served only by Interstate 10 and small state/local roads. The two largest cities, Riverside and Corona, are served by commuter rail services to Los Angeles and Orange counties, and the county is also served by freight and passenger rail service. Moderate-sized airports are located in the city of Palm Springs, as well as nearby Ontario, and Orange counties. Other cities of notable size include Moreno Valley in the northwestern corner of the county and Temecula in the southwestern corner, adjacent to rapidly growing San Diego.

Between 1980 and 1990, Riverside County population grew faster than any other county in the state. In 1996, the population reached approximately 1.4 million persons. Since 1990, the growth rate moderated somewhat, but still averaged nearly 3% per year over the 1990-1996 period. Population density averages approximately 200 persons per square mile, but varies widely across the county. In the City of Riverside, it reaches as high as 3000 persons per square mile, while in the rural areas of the eastern part, it falls to just 10 persons per square mile.

Economic activity in the county is concentrated in the various services industries, with approximately 60% of total employment being in trade, personal services, and government. Nearly one-third of the labor force commutes to work outside the county. Most of these workers commute to San Diego, Orange, or Los Angeles counties. Military employment is down to 5,300 persons in 1995 from nearly 10,000 persons in 1969. The March Airforce Base realignment in 1993 has helped focus new economic development activity on light manufacturing and distribution activity to take advantage of growing trade with Mexico.

At the county level, Riverside County is not presently economically distressed. The unemployment rate fell to 6% in March, 1998, down from 8% in 1996. The 1989 median family income of $37,700 is higher than the U.S. median by approximately 7%, although it does vary significantly for different parts of the county. Riverside County's poverty rate in 1989 stood at 12%, 2% below the national average. Educational attainment in the county is somewhat lower than the national average as of 1989 but is improving. Nearly 25% of the county population have not completed high school and less than 15% have completed a college degree. The corresponding national figures are 25% and 21%, respectively.

INFRASTRUCTURE INVESTMENT SUMMARY

Numerous interviews were conducted with planning and budget officers representing Riverside County and its constituent jurisdictions. Interviews with representatives of county departments included officials from the Economic Development Agency, the Transportation and Land Management Agency, the Transportation Commission, the Planning Department, and the Office of Education. Interviews were also conducted with officials from the three largest cities, Riverside, Corona, and Moreno Valley, and with representatives of March Air Force Base. Nevertheless, because of the county's size and complex jurisdictional structure, we were unable to obtain complete figures on infrastructure investment. Table 6 shows the per capita Dodge-based infrastructure investment by type for calendar 1996, interview-based investment per capita for 1996, the shortfall of public investment as estimated by our regression models, and the anticipated per capita investment for years 1997 through 2002.

The 1996 figure for educational investment was obtained from EdSource, a California research organization. This figure includes all bonded school construction approved in fiscal year 1996, and is close to the figure obtained from Dodge. Despite the large absolute volume of new school construction, officials in the county still see a huge shortfall in investment in schools. The inadequacy of available space is somewhat offset by the use of temporary classroom structures. In terms of planned construction, growing enrollments and mandated class-size reductions will result in a need for $915 million in new construction and major renovations over the 1999-2002 period. Of this, $665 million would be for new school construction and $250 million for major renovations.

Our models indicate that Riverside County (as well as all other California counties in the sample) have total infrastructure investment shortfalls per capita, ranging from $-2,100 to $-5,400. Much of this is concentrated in the roads category. County officials acknowledged a severe problem with roads, especially at peak travel-times on highways in and around Riverside and Corona. The general feeling among county and local officials is that the situation will get worse as people continue to move to the county because of relatively attractive home prices while, at the same time, they will continue to commute to work in San Bernardino, San Diego, Los Angeles, and Orange counties. This strain on the transportation infrastructure could be partially relieved by job growth within the county that reduces commuting volume, and some increase in roadway investment. Nevertheless, the present shortfall in capacity is not producing economic distress, but may act as a restraint to even faster growth.

Table 6
Actual 1996 and Planned 1997-2003 Infrastructure Investment
Riverside County, California

Infrastructure Category	1996 F.W. Dodge ($000, current	1996 Actual ($000, current)	Model Residual Average Annual ($1992, per capita)	Rank	Planned Investment- 1997-2003 ($1998, average annual per capita)	Rank
Education	20,229	26,500	-781	3	349	1
Roads	117,298	106,225	-2,835	1	173	2
Water	30,483	NA	-289	5	NA	NA
Sewer	48,680	NA	-822	2	NA	NA
Power Utility	1,187	NA	-316	4	NA	NA
Communications Utility	280	NA	-34	8	NA	NA
Hospitals/Health Care	434	NA	-7	9	NA	NA
Administration/safety	120,729	NA	-171	27	NA	NA
Airports	1,090	NA	-173	6	NA	NA
Total	340,410	NA	-5,428		NA	NA

Source: F.W. Dodge Inc., EdSource, and MIT-Multiregional Planning Research Group, 1998

NA-Data Not Available

REFERENCES

Abt Associates, Inc. 1980. "Evaluation of the Local Public Works Act, 1976 and 1977." Report submitted to the Economic Development Administration. Cambridge, MA.

Arthur D. Little, Inc. 1974. "Economic Transition of Distressed Communities-An Analytical Study", Report submitted to the Economic Development Administration. Cambridge, MA.

Aschauer, David A. 1989. "Is Public Expenditure Productive?" Journal of Monetary Economics, Vol. 23 (March), pp. 177-200.

Blanchard, Olivier J. and Lawrence Katz. "Regional Evolutions." Brookings Papers on Economic Activity, 1992-1, pp. 1-75.

Bureau of Economic Analysis. 1995. "Regional Economic Information System." U.S. Department of Commerce. Washington, D.C. (CD-ROM)

Bureau of Economic Analysis. 1997. Survey of Current Business, Vol. 77, No. 5, May, 1977, p.73.

Bureau of the Census. 1994. County and City Databook: 1994. Superintendent of Documents, U.S. Government Printing Office. Washington, D.C. 1994.

Center for Urban Policy Research, Rutgers University. 1997. "Public Works Program-Performance Evaluation." Report submitted to the Economic Development Administration.

Eberts, Randall W. 1986. "Estimating the Contribution of Urban Public Infrastructure to Regional Growth." Federal Reserve Bank of Cleveland. Working Paper 610.

Economic Development Administration. 1998. "Public Works Development and Facilities Program." Website: http://www.doc.gov/eda/html/pwprog.htm

Gordon, Robert J. 1995. " Is There a Trade-Off Between Unemployment and Productivity Growth?" National Bureau of Economic Research. Working Paper No. 5081. Cambridge, MA.

Haveman, Robert and John Krutilla. 1968. Unemployment, Idle Capacity, and the Evaluation of Public Expenditures. John Hopkins University Press, Baltimore, MD.

Hirschman, Albert O. 1958. The Theory of Economic Development. Clinton, MA: The Colonial Press, Inc.

Holtz-Eakin, Douglas. 1991. "Public-Sector Capital and the Productivity Puzzle." National Bureau of Economic Research (NBER), Working Paper No. 4122. Cambridge, MA: NBER.

Lewis, W. Arthur. 1955. The Theory of Economic Growth. London: George Allen and Unwin, Limited.

Munnell, Alicia H. 1990. "Why Has Productivity Growth Declined? Productivity and Public Investment." New England Economic Review (January/February), pp. 3-22.

Polenske, Karen R., Nicolas Rockler, Anne Kinsella-Thompson, and Anjali Mitter. 1998. "Demand for Economic Development Infrastructure. Report to the Economic Development Administration, Department of Commerce. Cambridge, MA.

Rietveld, Piet. 1989. "Infrastructure and Regional Development." The Annals of Regional Science, vol. 23, pp. 255-274.

Rosenstein-Rodan, Paul N. 1959. "How to Industrialize an Underdeveloped Area." Cambridge, MA: Center for International Studies, Massachusetts Institute of Technology.

Wyckoff, Paul G. 1984. "Measuring Infrastructure Needs." REI Review, vol. 2, no. 1 (November), pp. 19-29.

CHAPTER 4 - THE NEED FOR EMPIRICAL MEASURES OF PUBLIC INFRASTRUCTURE STOCK FOR THE ANALYSIS OF REGIONAL PRODUCTIVITY

INTRODUCTION

Over the last decade, numerous analyses of the relationship between public infrastructure and regional economic productivity have been performed. For the most part, these have relied on what may be poor estimates of public capital stock, often inappropriately estimated for the uses to which they are put. Most regional stock estimates are constructed by "sharing-out" national stock estimates, incorporating no subnational data on public capital service-lives or service-decay functions. Although scant attention is paid to public capital stock estimation in the literature, the conclusion that it is an unimportant or minor segment of the nation's capital would be wrong. Public capital (primarily buildings and structures) is a very large part of the stock, comprising one-third of the 1997 total U.S. nonfarm, nondefense capital (BEA, 1999.) In view of its size and the generally inadequate understanding of its economic function, a broad range of research opportunities exist.

Some of the analyses of public capital stock and productivity involve cross-sectional comparisons of international data, and some focus on regions comprised of states or metropolitan areas. The results from both types, however, are inconclusive regarding the role of public capital as a source of productivity growth. Part of this might stem from the complex nature of public capital, but part may also result from the data. Because U.S. data may be faulty, it is worth re-evaluating some of the results with improved data and estimates. In this paper I examine some of these issues in the context of U.S. regions, presenting the first known empirical estimates of capital service-lives and public capital stock for two regions.

With few exceptions, prior researchers have based their analyses on stock estimates derived from BEA's national estimates used for the national income and product accounts. No public agencies produce comprehensive estimates of subnational capital-stock series, so that researchers are forced to employ various means of distributing the national figures to local areas. I demonstrate that there are sizeable differences between the shared-out estimates and those developed using a combination of survey-based data combined with local investment data. Despite the improvements in data, however, estimated production functions for the two regions fail to produce credible results. This may indicate that there are conceptual problems to be overcome in the field of small area production function estimation.

I begin the analysis with a brief review of the relevant literature concerning public capital stock and its estimation. Second, I describe a survey of jurisdictions and the database used to estimate stocks for two regions and present summary data to compare the different estimates. Third, I present production function estimates and compare them to other research results. Finally, I offer conclusions and recommend topics for further research.

LITERATURE REVIEW

Among the least discussed aspects of public capital stock estimation are the data adjustments used to transform accumulated gross capital investment into net capital stock. Because there has never been a comprehensive census of public capital, estimates and estimation procedures are of critical importance. The BEA estimate of net stocks has generally been the starting point for many researchers. The BEA prepares stock estimates based on the perpetual inventory technique. This technique entails assembling timeseries of annual investment in public capital to which two adjustments are made: First, the investment series are deflated to constant real dollar values. Second, the real-value investment series are adjusted for losses in value due to asset-aging. There are differing opinions as to how these adjustments should be approached, as discussed below.

Deflating Current-Dollar Investment

Deflators related to investment come in several forms. As noted by Gordon (1967), there are significant content differences among them, as well as limitations on the accuracy of with respect to capital stock estimation. The five basic types include:

- Fixed-weight output and price indices
- Project-price indices
- Component (subassembly) price indices
- Input cost indices
- Composite cost indices

Prior to 1997, BEA used fixed-weight price indices to develop deflators used to convert current income and production measures to a real basis. For investment deflators, BEA uses construction-cost indices, which are, in turn, derived from cost monitoring performed by private firms.[29] In general, these are developed from project-price indices. This technique has shortcomings for structures whose typical content changes dramatically over time, but it is preferable for cases where the constituent parts of buildings and structures show moderate variation. Since 1997, BEA has adopted the "chained-weight" price index approach to estimating investment (and other) deflators, hoping to reduce the distortion associated with changing input composition over time. However, unlike producer and consumer price indices which have a composite structure, construction is deflated directly, with no weighting scheme. The most recent BEA capital stock estimates are based on real investment estimated with chain-weighted deflators.

[29] Except for residential construction, which is a fixed-weight composite index of housing input prices prepared by the U.S. Census Bureau.

Although project-price deflators are the preferable type for most construction categories, there are still problems with these for regional applications. With the exception of water and gas system construction, none are reported on a regional basis. This is no different than most other cost indices and real-valued capital stock estimates, but it is worth remembering that the capacity and quantity of services potentially generated *per dollar* of infrastructure investment will vary greatly by region, reflecting differences in construction costs (principally labor costs) in different regions. There is, however, no movement to standardize these regionally, something that would require development of a whole new set of cost indices, which is likely to be very costly.

Depreciating Prior-Year's Investment Value

The complexity of adjustments needed for asset-aging depends on the purpose to which the final estimates are put. For purposes here, it appears as though the simplest method is also the correct one. There is, however, significant confusion concerning these adjustments, termed "depreciation" by Hulten and Wykoff (1981) and Fraumeni (1997.) The confusion surrounds the precise definition of depreciation, distinguishing between such related concepts as deterioration, exhaustion, obsolescence (both physical and technological), retirement, and capital consumption. Some view depreciation as a measure of capital inputs to production and others view it as a component cost of capital services. Triplett (1996) has clarified the situation to a great extent by delineating the differences between adjustments made for income-accounting purposes and adjustments made for productivity analysis. He demonstrates that the definitions are close in meaning, but not identical.

As used in income and wealth accounting, depreciation is the measure of capital used-up in production. It is shown in the accounts as "capital consumption", and it is used to adjust gross product to yield net product. It can be measured both as a physical adjustment and an economic one. It measures capital goods' productive services generated during a time-period and, at the same time, the amount of capital that requires replacement in order to keep the stock of capital intact from one period to the next.

In production analysis, depreciation is *a component cost* of producing capital services, not the measure of capital services per se. Capital-service adjustments linked to the aging process have two parts, the loss of future capital services due to "decay" in a given time period and the losses due to "retirements" (or "withdrawals" or "removals") in that period. Together, Triplett describes these as "deterioration." This differs from capital consumption in that deterioration affects current period capital-service flows, but it is not an estimate of total lifetime reduction in services derivable from capital. Following Triplett's example, consider a light bulb that will last for 10 years. After one year, production potential is reduced to 9 years. The lost year is viewed as capital consumption by economic accountants and deducted from the gross capital stock. From the point of view of the productivity analyst, after one year, nothing has changed, i.e., there is no measurable service-flow change. This remains true until the bulb either dims or burns-out, i.e., until there is a measurable reduction in the value of services produced or the bulb is retired. In order to estimate a time-series of capital stocks, it is therefore necessary to have cohorts of capital of similar type and age (i.e., homogeneous cohorts) to which estimates of decay and retirements can be applied.

For both public capital decay rates and service-lives, BEA uses figures presumed to be close to the actual ones. No data concerning public structures have been assembled to prepare the BEA estimates.[30] As a rule, the values have either been borrowed from the closest-sounding private capital type, as in the case of office buildings, industrial buildings, etc., or the values have been made-up, as in the case of water, sewer, and transportation systems. Private capital service-lives have been empirically estimated by the Department of the Treasury (1947), and later by Hulten and Wykoff. For the time-decay rates, BEA uses patterns derived from Winfrey (1967), in which the age-

[30] The only empirical research that deals with building service-lives was done by the Department of Energy (DOE), as a part of its nonresidential energy consumption surveys (DOE, 1979 and 1982). These data, however, are of limited value to us because although they disaggregate buildings by function (e.g., commercial, office, educational, hospital, etc.), they do

distributions around the mean service lives are either bell-shaped or asymmetrical with a higher proportion of discards occurring before the mean service-life. The latest BEA estimates have incorporated Hulten and Wykoff's decay patterns

Which Measure of Net Capital Stock to Use?

I noted earlier that Triplett (1996) argues that in productivity analysis, analysts should employ a net capital stock based on adjustment for deterioration. In fact, Gordon (1967) argues for nearly the same thing. Gordon noted that analysts should measure gross real capital stocks, for which there is "no deduction for depreciation." Rephrased in terms of Triplett's definitions, Gordon argues for a zero-decay adjustment over each vintage of capital's service-life. This is the familiar "one-hoss shay" concept of depreciation. He argues that

> ...a machine's value is not proportional to its current ability to produce services but to the discounted value of future services and would decline rapidly with passing time even if the machine's ability to produce physical service-hours did not change at all with age. Nor in calculating capital stock should we deduct for deterioration which is the decline in the capital services obtainable from a machine over its lifetime as lower speeds are required when parts become worn, as fewer service-hours per year are possible because of increased maintenance,

---

not distinguish as to public or private ownership. Further, they only cover buildings and not other structures or facilities.

> and as equipment is shunted aside to standby duty, only to be required during periods of peak demand.

Note that Gordon's "deterioration" is used with the same meaning as Triplett's "decay.")

For this analysis, it is clear that a zero-decay rate is appropriate, particularly for structures and systems that have only a small fraction of their value comprised of integrated technical systems, examples of which would be power-generation or sewage-treatment equipment. For service industries, of which government is one, the connection between capital depreciation and productivity seems relatively unimportant, particularly as regards deterioration of buildings and structures. For some service industries, such as retailing, equipment deterioration has an obvious impact on productivity. For office-related functions, however, the aging of the structure itself would seemingly have no effect on labor productivity.[31]

Other researchers, notably Munnell (1990), Aschauer (1989), Eberts (1986), and Holtz-Eakin (1993), have all opted for BEA net stock estimates (at a national level) or applied the BEA methodology to their perpetual inventory method. As characterized by Triplett, these estimates are better suited for

[31] In extreme cases, building-system failures might interrupt workflow and some productivity impact might be observable. Also, advancement of building-system technologies can increase the relative operating costs of older structures over time. Even so, equipment remains a small component in the value of most buildings, and the capital productivity effects are likely to be small.

SURVEY DESIGN, DATABASE DEVELOPMENT, ESTIMATED PUBLIC-CAPITAL SERVICE-LIVES, AND CAPITAL-STOCK ESTIMATES

Because there are no private firms or public agencies performing capital censuses, researchers are forced to make their own or use the estimates of others. Frenken (1992) identifies two techniques that can be used to make estimates, the perpetual-inventory method or the "direct observation" method. The former is widely applied and inexpensive to do. For each structure or facility, it requires only a timeseries of completed construction and a timeseries of capital decay and retirements. Where historical timeseries are insufficiently long to capture all of the capital still in existence, a starting benchmark is required, as well.

For direct observation, researchers have to sample representative firms or public jurisdictions at regular intervals to obtain stock information. This approach is costly and potentially difficult for assets whose values or physical quantities are hard to measure. It is a technique, however, unburdened by the layering of assumptions and estimates required for the perpetual inventory method as presently applied, and in the few cited cases where it is used, appears to yield usable results. It appears particularly useful for estimating stocks of equipment and machinery with comparatively short service-lives. In such cases, it appears as though the perpetual-inventory method tends to overestimate the stock. In Frenken's research, direct-observation for buildings yields slightly different results than perpetual inventory. For nonindustrial-nonresidential buildings, direct-observation estimates are approximately 90% of the perpetual-inventory ones. For industrial buildings, a direct-observation estimate yields 110% of the perpetual-inventory estimate.[32] Frenken suggests that direct observation be used in conjunction with the perpetual-inventory approach, particularly for verifying the accuracy of benchmarks used with the inventory approach.

In the survey conducted for this research, I tried to obtain an initial set of direct-observation results, but failed to produce enough useable responses to develop complete estimates. I did fare better, however, in obtaining the other data needed to use the perpetual-inventory method, the details of which are summarized below.

For this research, benchmark estimates for five broad categories, streets/highways/bridges, water/sewer, other public buildings/public works combined, manufacturing structures, and nonfarm-nonmanufacturing structures were derived. (The specific year of the benchmark depends on the starting date of the construction timeseries, ranging between 1924 and 1937.) The state-level construction (investment) statistics were assembled on a disaggregated-basis by structure type (i.e., type of building or public works function, such as public-administration

---

[32] Average calculated from Frenken's data over 16 industrial sectors, unweighted by size of stock.

building, school building, highway, water system, etc.) These proprietary data were obtained and are used with special permission from F.W. Dodge division of McGraw-Hill, Inc. To estimate retirements, a survey of jurisdictions was conducted, which I describe briefly below.

Survey Design and Response

To obtain data on public-capital service-lives, I conducted a survey for a sample of jurisdictions in two regions, New England and Texas. I selected these regions because of their vastly different economic development history and economic structures. They were of equivalent population in the mid-1970s (12.1 million and 11.8 million for New England and Texas, respectively) when the large jumps in energy prices caused New England's economic growth to slow dramatically and that of Texas to accelerate. Between 1930 and 1997 (the approximate range of the construction timeseries), New England's population had a compound annual growth rate of 0.7% per year, less than half of Texas' 1.6% per year (Bureau of the Census, 1999.) Other differences worth considering are physical size, climate, and access to national and international markets. New England is one-forth the size of Texas, has a snow-belt climate, and also has an eccentric location with respect to the nation as a whole.

I distributed a mail survey at the beginning of 1998 to obtain data for 1997. (The complete questionnaire is shown in Appendix A.) In addition to information on removals of public capital, I used the survey to gather each jurisdiction's self-appraisal of the adequacy of public capital on several parameters, the use of capital budgets, if any, and whether respondents thought that there were direct linkages between public and private investment projects that were undertaken in 1997.

Sixteen percent of the surveys were completed and returned, but primarily from small jurisdictions. This may introduce bias into the estimates of both service-lives and, consequently, estimated capital stocks (discussed later). The response rate weighted by population was 9% for New England, and 15% for Texas.

I collected data for each region for different types of infrastructure shown in Table 1. Investment in these categories accounts for approximately 95% of nondefense public capital, the balance being equipment (see Katz and Herman, 1997, Table 11) In addition to these structure categories (all treated as public, although some may have private ownership), I assembled data on private manufacturing and nonfarm/nonmanufacturing structures investment, the latter including commercial, religious, and miscellaneous structures, and electrical, gas, hydroelectric power-utility facilities. For these private categories, however, I did not survey regional service lives, and there may be differences across regions and compared to the BEA estimates.

Capital Stock Estimation

In addition to service-life information, I required two additional types of information to implement the perpetual-inventory method. First, starting, or "benchmark," estimates of the stock for each category are needed. Second, an annual series of construction investment is needed to match those same categories.

The investment timeseries start in either 1925 or 1931, depending on the structure/facility type. Therefore, I needed the starting stock values (i.e., for year-end 1924 or 1930). These are particularly important for New England, which already had significant population centers using public infrastructure well before the mid-1920s. Without undertaking additional data gathering, I estimated these using the historical construction data time series.

To estimate starting-stock values, I calculate the time series of cumulative investment adjusted for removals. Using the "complete" part of the series, (i.e., when the series consists entirely of the investment data assuming the one-horse

Table 1
INFRASTRUCTURE CATEGORIES FOR SURVEY

CATEGORY	INCLUDED STRUCTURE/FACILITY TYPES	BENCHMARK/STOCK CATEGORY
1. Office	Office buildings, administration buildings	Other Public Buildings/Structures
2. Schools	Schools (primary, secondary, post-secondary, vocational, colleges,) school auditoriums, gymnasiums, field houses	Other Public Buildings/Structures
3. Hospitals, Health Care, Nursing Homes	Clinics, hospitals, nursing homes, convalescent facilities, other health treatment	Other Public Buildings/Structures
4. Social Services	Museums, amusement/recreational facilities, exhibit halls, theaters, libraries, stadiums	Other Public Buildings/Structures
5. Highways, Streets, Bridges	Roads, sidewalks, tunnels (pedestrian, vehicle), bridges, roadway lighting, bridges (pedestrian, vehicle, railroad)	Streets/Highways/ Bridges
6. Water Systems	Water treatment plants, water lines, pumping stations, reservoirs, tanks/towers	Water and Sewer
7. Sewer Systems	Sewage treatment plants, sanitary sewers, storm sewers, lines, pumping stations,	Water and Sewer
8. Energy and Communication Utilities	Power plants (hydro, nuclear, fossil fuel), gas manufacturing and distribution systems, gas tanks, heating and cooling plants, electric substations, electric power lines, communications lines and towers,	Nonfarm/Nonmanu facturing
9. Dams, Reservoirs	Dams (hydroelectric, flood control, water supply), river and harbor development (including docks and piers), flood-control structures	Other Public Buildings/Structures
10. Trans-portation Facilities	Public transportation terminals and facilities (including airports, ground transport, marine terminals, bus stations), related maintenance facilities	Other Public Buildings/Structures
11. Public Safety	Police buildings, fire stations, jails, prisons, armories	Other Public Buildings/Structures
12. Miscellan-eous	Parking garages, pools, laboratories, park structures, warehouses	Other Public Buildings/Structures

shay removal rate), the starting value is based on the based on the stock growth rate for that category and region. I adjust this figure, one for which there is no specific age-structure, for removals, using either the BEA or the survey-based depreciation rate.

For shorter service-life categories, such as manufacturing (which has a 31-year service-life), I have a fairly long set with which to work, 43 observations measured over the 1956-1998 period. (The investment series covers 1925-1998.) For longer-lived categories, such as our survey-based New England water-system figure of 67 years, I measure growth rates over a two-year interval, 1997-1998.

Note that all of the estimates are for nonmachinery, nondefense capital, and where necessary, I made adjustments to the Dodge data to remove defense-related investment using BEA national income accounts data on the annual shares investment for defense purposes (BEA, 1999.)

The investment series, the F.W. Dodge *Construction Potentials,* offer consistent state-level coverage beginning in 1925.[33] They measure construction contract awards and include the value of the facility, not including site- (or land-) acquisition costs, any stand-alone equipment, or the costs of engineering design work. These data are known to have two systematic deficiencies. First, the data do not cover "force

---

[33] State-level data are limited to the 37 states east of the Rocky Mountains until 1960, when full 50 state coverage was introduced.

account" work, that is when a jurisdiction uses its own personnel and equipment to build a structure or facility without a public bidding process. Second, there are instances when newer residential developments (and possibly commercial ones, as well) include construction of small water supply-systems, sewage, and other utility systems without use of separate contracts. (Polenske et al., 1998) These occur with unknown frequency, and the value of unmeasured investment is therefore also unknown. The resulting public stock estimates are downward-biased. There is reason to believe that the bias has a regional variation, since Texas has a much higher rate of new residential construction than New England. Hopefully, this missing part of public investment will not be critical to the analysis.

Estimated Public-Capital Service-Lives

In this section, the survey results for public-capital service-lives are given. These have direct application here, but may also prove useful in capital-project evaluation, where the service-life is sometimes used to compute internal rates of return for testing the financial feasibility of projects. Shortening the service life-times, as is the case of the figures shown, raises the periodic repayment required to finance a project, and may increase the needed net cash-flow.[34]

[34] Alternatively, service-lives are often ignored in favor of a standardized period used to obtain debt financing, such as 30 or 50 years.

The average age of removed structures was 52 years, very close to the BEA estimated service-life of 50 years for nonindustrial public buildings (Table 2). This is, however, significantly longer than the average service-life of approximately 33 years (assuming straight-line depreciation from a demolition rate of 3 percent per year) that was observed from a survey conducted by the U.S. Department of Energy (DOE) in 1983 (DOE, 1983), one of the few such surveys conducted. There were no statistically significant differences between the two regions, with average service-lives of 53 and 52 years for New England and Texas, respectively.

Table 2
PUBLIC-CAPITAL SERVICE-LIFE COMPARISON
(Boldface Values Significantly Different Than Mean Value [95% confidence])

Capital Type	**Survey-Based Service Life**				**BEA (Yr)**	**Treasury Bulletin F (Yr)**
	Number of Cases	**New England (Yr)**	**Texas (Yr)**	**Combined (Yr)**		
Public Buildings (incl. health, education, administration)	*17*	53	52	52	50*	57
Street, Highway, Bridge	*44*	30	22	26	60	NA
Water System	*23*	**67**	**31**	45	60	NA
Sewer Systems	*25*	**56**	**32**	41	60	NA
Dams, Harbors, Ports	*2*	23	-	23	60	NA

* BEA takes 85% of the Treasury figure as an assumed service-life. Treasury makes no estimates for public structures, and BEA assumes lifetimes to be identical to private sector structures of similar function.

Sources: Author, BEA (1977), Jorgenson and Sullivan (1981)

For streets/highways/bridges, water systems, sewer systems, and dams/reservoirs, the observed service-lives are less than or equal to the BEA service-life, with several substantial differences. Streets/highways/bridges showed a combined service-life of 26 years, less than half the BEA assumed rate of 60 years. Water systems showed a combined average life of 45 years, only three-fourths the BEA rate of 60 years, and there are significant differences between New England and Texas, with average life-times of 67 years and 31 years, respectively. Similarly, sewer systems showed significant regional variation, with New England at 56 years (close to the BEA rate of 60 years) and Texas at 32 years. The combined average of 41 years, however, is still much below the BEA rate. Finally, dam and reservoir removal and replacement were represented by only two cases, not enough to warrant further analysis.

These figures indicate that prior notions of public-capital service lives may be seriously flawed. More extensive regional coverage may show that more regions exhibit differences in service-lives from the national rates. Although my figures cover only a single point-in-time, these service-lives may have cyclical dimensions, as well. Cycles might result from a combination of factors that include historical development timing (long-run age effects), economic and fiscal performance behavior (economic cycles), regulatory effects (e.g., need for more stringent service-quality levels as regions reach a certain size/density, or as technological change warrants, as with newly imposed requirements for removal of specific hazardous pollutants from drinking water.

It should also be noted that replacements may not be like-for-like exchanges when it comes to system content or components. For example, streets/highways/bridges bridge replacement usually involves road resurfacing and/or bridge-deck replacement. These are not complete replacement operations, in so much as site-clearance, road-bed preparation, and structural construction are not required to achieve full rehabilitation. In the survey, I did not obtain information about component-replacement within the different capital types, but this is worth considering for future work, given the heterogeneity of replacement possibilities within each category, and the frequent opportunity to recycle portions of existing systems.

It should also be noted that the service-lives and subsequent stock estimates were developed from a set of responses that are biased to small- and medium-size jurisdictions. On one hand, the respondents may provide highly accurate information because they manage relatively few capital projects in the course of the year. Respondents, therefore, have a greater likelihood of knowing many of the details concerning projects' histories than would be the case in a large city. On the other hand, high density, large-scale, congested urban environments may produce vastly different services-lives than found in small towns. High use-intensity and strained maintenance budgets may shorten service-lives, offset to some degree by institutional neglect that effectively lengthens these beyond the normal times for replacement. If the service-lives are overestimated because of the bias towards small jurisdictions, the resulting stocks will be too low. Conversely, if large city service-lives prove to be drastically shorter, the estimates will be too high. Again, this is an area where future research can resolve the issue.

CAPITAL-STOCK ESTIMATES

By combining a starting-stock estimate with subsequent investment and adjustments for removals, two sets of perpetual-inventory estimates for New England and Texas are derived. The first set (Table 3) is based on the current BEA service-life estimates with ownership-specific geometric depreciation patterns. Ownership is either public or private. The second set, (Table 4) is based on survey-based service-lives for public capital, and BEA estimates for private capital. (The depreciation method differs for private categories in the second set, as well.)

Based on the BEA service-lives, New England had $71 billion of nonmachinery, nondefense capital in 1938, nearly 50% more than Texas, with $52 billion. The gap between the two regions diminishes over time, as the Texas' growth rate exceeded New England's in each interval shown in the table by more than 1

Table 3
REAL NET STOCK OF NONMACHINERY CAPITAL: 1938, 1958, 1978, 1998; NEW ENGLAND AND TEXAS
BEA Service-Lives for All Categories
[Zero Economic Depreciation of Public Stock;
BEA Declining-Balance Depreciation of Private Stock]

CATEGORY\YEAR	Stock at Year-End ($ million, 1992)				Annual Growth Rate Over Interval (% , annual)			
	1938	1958	1978	1998	1938-1958	1958-1978	1978-1998	1938-1998
NEW ENGLAND								
Street/Highway/Bridge	14,065	22,910	40,479	56,648	2.5	2.9	1.7	2.3
Water and Sewer Systems	3,596	6,651	16,294	27,821	3.1	4.6	2.7	3.5
Other Public Structures/Facilities*	32,697	44,007	83,823	116,498	1.5	3.3	1.7	2.1
Manufacturing	5,912	10,104	13,237	13,578	2.7	1.4	0.1	1.4
Nonfarm, Nonmanufacturing	15,132	22,650	43,887	66,433	2.0	3.4	2.1	2.5
STATE TOTAL	**71,403**	**106,321**	**197,721**	**280,978**	**2.0**	**3.2**	**1.8**	**2.3**
Population Estimate (000)	**8,427**	**10,219**	**12,284**	**13,430**	**1.0**	**0.9**	**0.4**	**0.8**
TEXAS								
Street/Highway/Bridge	9,937	18,516	43,085	72,761	3.2	4.3	2.7	3.4
Water and Sewer Systems	5,173	8,379	17,094	33,588	2.4	3.6	3.4	3.2
Other Public Structures/Facilities*	18,160	31,051	67,635	124,343	2.7	4.0	3.1	3.3
Manufacturing	5,559	14,342	27,285	28,617	4.9	3.3	0.2	2.8
Nonfarm, Nonmanufacturing	12,694	23,516	57,318	103,591	3.1	4.6	3.0	3.6
STATE TOTAL	51,523	95,804	212,417	362,901	3.2	4.1	2.7	3.3
Population Estimate (000)	**6,301**	**9,252**	**13,500**	**19,386**	**1.9**	**1.9**	**1.8**	**1.9**

* Includes publicly- and privately-owned utilities (energy, communications), railroads, and institutional structures.

Table 4

REAL NET STOCK OF NONMACHINERY CAPITAL: 1938, 1958, 1978, 1998; NEW ENGLAND AND TEXAS
Survey-Based Service-Lives for Public Categories; BEA Service-Lives for Private Categories[Zero Economic Depreciation over Service Life for All Categories]

CATEGORY\YEAR	Stock at Year-End ($ million, 1992)				Annual Growth Rate Over Interval (%, annual)			
	1938	1958	1978	1998	1938-1958	1958-1978	1978-1998	1938-1998
NEW ENGLAND								
Street/Highway/Bridge	7,121	14,847	27,025	26,393	3.7	3.0	-0.1	2.2
Water and Sewer Systems	2,215	5,619	15,523	27,131	4.8	5.2	2.8	4.3
Other Public Structures/Facilitie	32,780	44,206	84,057	117,676	1.5	3.3	1.7	2.2
Manufacturing	9,482	14,675	16,997	15,361	2.2	0.7	-0.5	0.8
Nonfarm, Nonmanufacturing	20,705	28,638	59,062	87,881	1.6	3.7	2.0	2.4
STATE TOTAL	72,304	107,986	202,665	274,441	2.0	3.2	1.5	2.2
TEXAS								
Street/Highway/Bridge	4,256	12,046	31,665	39,905	5.3	5.0	1.2	3.8
Water and Sewer Systems	1,872	5,630	12,989	24,182	5.7	4.3	3.2	4.4
Other Public Structures/Facilitie	18,205	31,159	67,761	124,466	2.7	4.0	3.1	3.3
Manufacturing	7,613	19,991	33,386	36,706	4.9	2.6	0.5	2.7
Nonfarm, Nonmanufacturing	15,745	28,572	74,819	139,772	3.0	4.9	3.2	3.7
STATE TOTAL	47,690	97,397	220,621	365,032	3.6	4.2	2.5	3.5

* Includes publicly- and privately-owned utilities (energy, communications), railroads, and institutional structures.

percentage point. (Texas' total stock passed New England's in 1975, based on the Table 3 estimates.) The only subcategory in which New England showed higher overall growth than Texas was for water and sewer system growth, although in the latest period, Texas surpassed New England in this category, as well. The substantial difference in the region's total stock growth, after factoring-in the effect of compounding over 60 years, is very large.

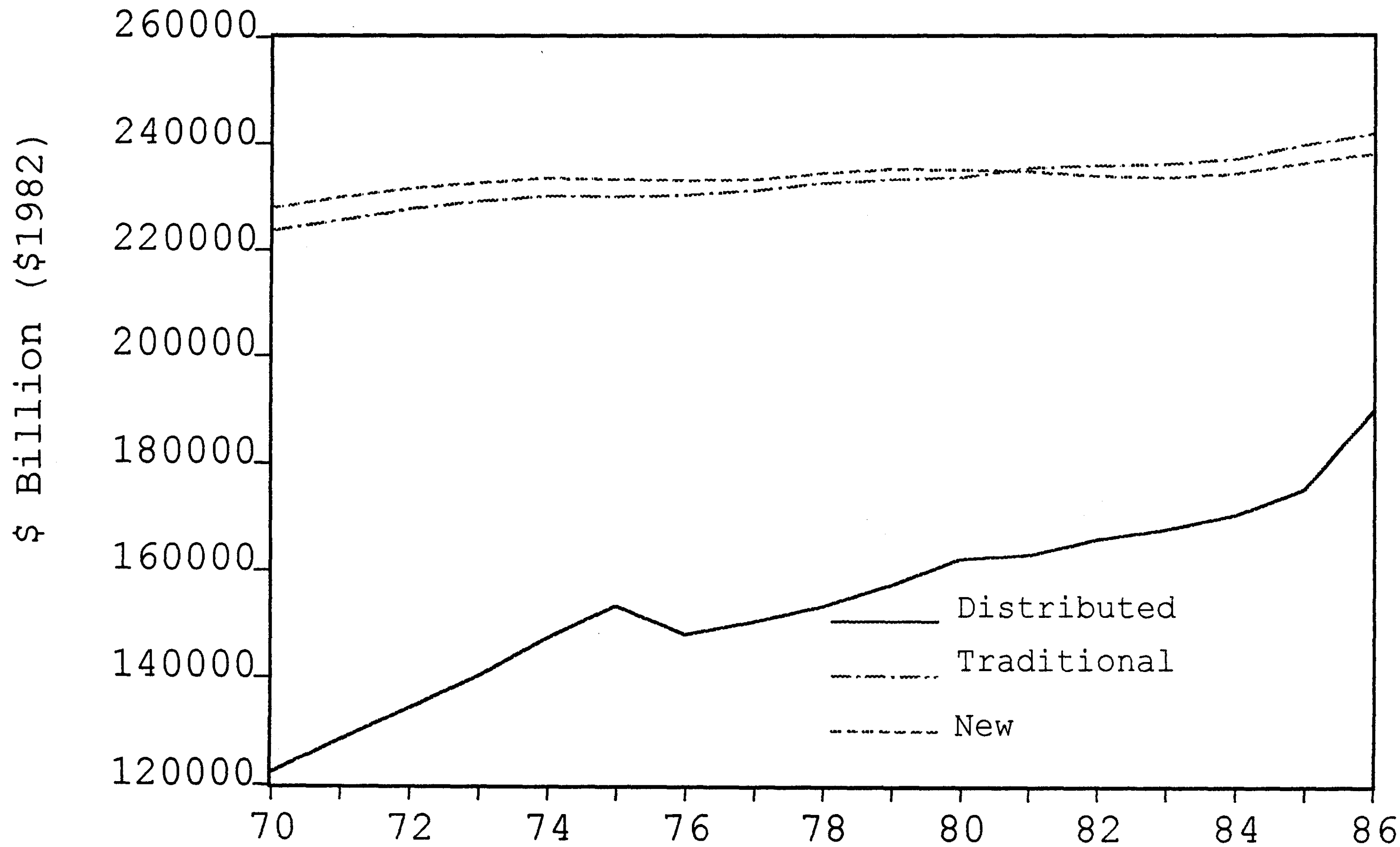
Except for strong New England water and sewer system growth, all other categories experienced a significant slow-down in growth over the interval shown, the two decades from 1978-1998. Manufacturing, for example, had almost no growth between 1978-1998, at a mere 0.1% per year. Other public structures and streets/highways/bridges also had low rates, at 1.7% per year for both. Texas, on the other hand, shows moderately strong growth in all categories except manufacturing, which, like New England, was nearly static at 0.2% per year between 1978-1998.

For reference, I call the above estimates of capital stock "traditional," in so much as the service-lives (and depreciation rates of the two private-ownership subcategories) are like those used by BEA. Using the survey-based service-lives and zero-rate depreciation to our estimates, a different picture of the capital-stock time-series is seen, both in terms of levels and growth rates (Table 4). In general, the levels of new *total* capital-stock estimates are close to the traditional ones, within 2%. For New England, the new total is slightly lower, while for Texas, the new total is slightly higher. Compared to the distributed national estimates, however (Figures 1 and 2), the two new total stock estimates differ significantly from the distributed one, with New England's values being about twice the distributed ones, and Texas' being about half.

Within the subcategories, there are some major differences among the two estimates. Street/highway/bridge stocks in both regions, and water and sewer system stock for Texas display levels and growth rates of the traditional and new estimates that differ substantially from one another. As an example, the new street/highway/bridge stock in 1998 for New England is slightly less than one-half the traditional figure ($26.4 billion versus $56.6 billion). Obviously, differences appear in the growth rates for this category, as well, but not perhaps as much as we might expect based on the change in levels. For New England, moderately strong early growth in stock is seen using the new estimates as compared with the traditional, but later, the growth rate turns negative in the new series, whereas the slower depreciation of the traditional estimate results in a low, but still positive rate.

For Texas' street/highway/bridge category, the new estimate for 1998 stock is slightly greater than one-half the traditional

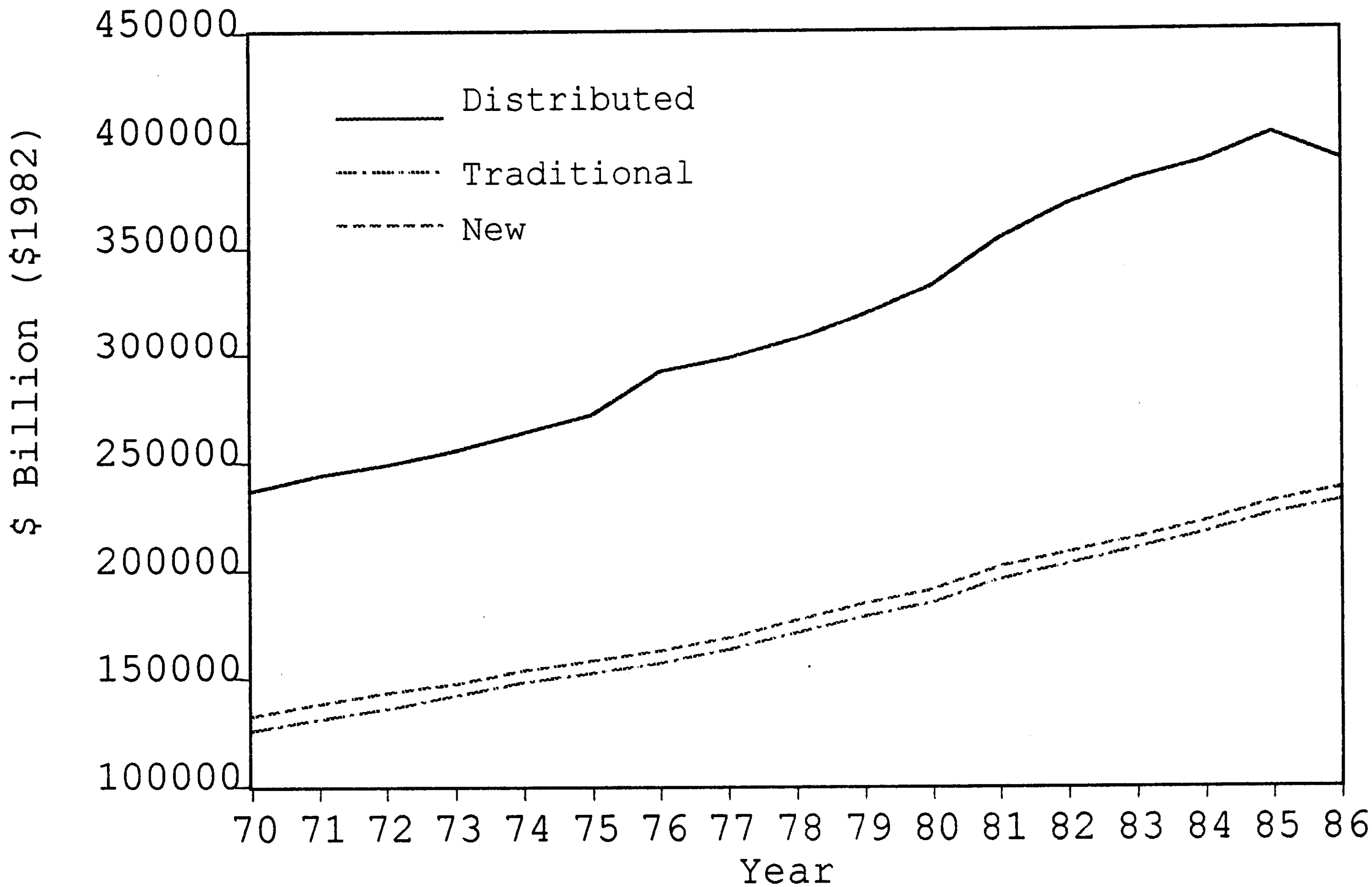
Figure 1
New England Total Nondefense Capital Stock: 1970-1986
New Estimates versus Distributed National Data



Sources: Author, Munnell (1990)

Figure 2

Texas Total Nondefense, Nonmachinery Capital Stock: 1970-1986
New Estimates versus Distributed National Data



Source: Author, Munnell (1990)

figure ($39.9 billion for the new versus $72.8 billion for the traditional), but the growth pattern differs between the two sets of estimates. With the traditional estimates, the growth rate increases and then decreases over the three intervals shown, but it decreases over all intervals in the new estimates. Dramatic differences are seen for New England streets/highways/bridges and manufacturing, both of which showed absolute declines in capital stock during 1978-1998 due to the higher depreciation rates attributable to shorter service-lives and zero-rate depreciation. Instead of merely slow growth for New England highways and manufacturing at 1.7% per year and 0.1% per year, respectively, the new estimates show growth of -0.1% and -0.5% per year. In contrast to the Table 3 estimates, Texas achieved higher growth for streets/highways/bridges and water/sewer systems early-on in the historical data, with growth of at least 5% per year for both categories during the 1938-1958 period. This time period is concurrent with the growth of significant new manufacturing capacity, seen to be 5.0% per year during the 1938-1958 period.

In considering whether the differences in the two sets of estimates are sufficient to justify the opinion that new regional capital stock estimates are needed, the reader should consider the last two intervals shown in Tables 3 and 4, which are the most valuable because the earlier estimates are apt to be influenced by the starting values which may not be correct.

In this regard, the differences in the street/highway/bridge, water and sewer systems, manufacturing, and nonfarm/nonmanufacturing estimates are all strong evidence that a combination of regional decay rates and actual investment data generate substantially different stocks than what is derived from fixed shares of the national total. Levels, growth rates, composition by subcategory, and any derived ratios (e.g., capital-output) will be significantly different.

IMPACT OF NEW ESTIMATES IN PRODUCTIVITY ANALYSIS

One way I use the new estimates to demonstrate the importance of accurate stock estimation is to compare results obtained with the different data sets in an identical modeling framework. Here, I can compare the results obtained using three data sets can be compared: Munnell's shared-out data, our "traditional" estimates using empirical regional investment data with the assumed BEA service-lives, and the survey-based estimates.

Munnell (1990) followed Aschauer (1989) in using a Cobb-Douglas production function with two capital inputs, private and public capital. In logrithmic form, this function is written as:

$$Q = \ln MFP + a \ln K + b \ln L + c \ln G$$

Where Q = output
MFP = multifactor productivity
K = private capital

L = labor

G = public capital

a, b, c = output elasticities

To this equation, Munnell adds a term for the unemployment rate to "reflect the cyclical nature of productivity", a proxy for capacity utilization. For the 48 U.S. states, the fitted coefficients obtained by regressing *K, L, and G on gross state product measured* over the 1970-1986 period are .31, .59, and .15 for private capital, labor, and public capital, respectively, The equation has a high multiple correlation coefficient (R^2), and the coefficients are significantly different from zero. The coefficient on the unemployment rate is small, -0.007. When the production function is estimated for the Northeast Region (composed of the New England and Mid-Atlantic census regions), and the South, Munnell obtains the following results:

Region	lnMFG	alnK	blnL	clnG	dUnemp.
Northeast	**8.8**	**0.09**	**0.90**	**0.07**	**-0.01**
South	**3.2**	**0.38**	**0.36**	**0.36**	**-0.02**

(Coefficients with values different from 0 at 95% confidence are show in ***boldface.)***

As in the 48-state case, the equations fit well, and all coefficients are significant. The very high labor coefficient on Northeast labor and concurrently low capital coefficients pose a difficulty for interpretation, however. Even if, as Munnell argues, a case can be made for human-capital differentials from one region to the next, such a vast difference is hard to explain, and could not persist for long where labor and capital have long-run mobility.

When Munnell's data are used to estimate the coefficients for the New England region (as a whole) and the state of Texas, the estimates lose some credibility. These estimates, made without the benefit of a large cross-section of states, have problems with coefficient values, signs, and significance-levels. Here we obtain:

Region	lnMFG	alnK	blnL	clnG	dUNEMP	R^2
New England	**4.1**	**0.56**	-0.40	0.70	-0.01	.97
Texas	1.2	-0.03	0.58	-0.13	0.59	.99

(Coefficients with values different from 0 at 95% confidence are show in ***boldface.****)*

I found little useful information concerning the productivity of public capital in the above results because none of the estimated elasticities are significant except the one for New England private capital. Furthermore, the results I obtained by replacing private and public estimates of capital-stock yield some different results, but still are characterized by poor parameter estimates and wrong signs. For each region, I show the regression results fitting the production functions using both the traditional estimates of capital stock (using BEA depreciation rates) and the new estimates using survey-based public-capital-stock estimates. Both sets incorporate actual nondefense, nonmachinery capital investment data.

New England	lnMFG	alnK	blnL	clnG	dUNEMP	R^2
Traditional	**-5.4**	**2.03**	-0.38	-0.09	**-0.02**	.99
New	**-6.9**	**2.51**	**-0.86**	-0.10	**-0.03**	.99

Texas	lnMFG	alnK	blnL	clnG	dUNEMP	R^2
Traditional	**0.9**	-0.23	**0.66**	**0.72**	-0.01	.99
New	0.5	-0.12	**0.54**	**0.75**	-0.01	.99

(Coefficients with values different from 0 at 95% confidence are show in ***boldface.****)*

Although the alternative estimates for both regions' production functions represent an improvement from the standpoint of having more significant parameter estimates than can be obtained with the distributed stock estimates, the estimated coefficients are still difficult to interpret. For example, I note that for both alternative New England estimates, private capital is significant, but has too large an elasticity (i.e., a 1 percent increase in private capital yields a 2 percent increase in gross state product for the traditional estimate and a 2.5 percent increase with the new estimate.) Labor, significant for the new estimate, has a large negative elasticity, and public capital is not significant. In almost the opposite fashion, Texas' estimates indicate that private capital is not significant, but that both labor and public capital have large (and significant) positive elasticities.

Problems with Production Function Estimates

The above estimates of the production relationships have problems that can be examined using the data presented here. One of the problems is that is that stock time-series data generally show little in the way of period-to-period changes relative to the other economic series. As a result, the multiple correlation coefficients are misleadingly high. Another problem is that the investment/output response for public infrastructure is presumed to be contemporaneous, when in reality, there should be some lag between investment and positive outputs due to relatively long production requirements.

Several analysts (e.g., Tatom (1991), Holtz-Eakin (1993)) have made the criticism that stock timeseries are not stationary, i.e., they are not the product of fixed underlying processes. The suggested solution is to use first-differences of both the dependent and independent variables. Unfortunately, at the regional level, such estimates made with these data prove not to be helpful. Only one of the coefficients in the four equations I estimated is significantly different from zero. These results are shown below:

New England	ΔlnMFG	ΔalnK	ΔblnL	ΔclnG	ΔdUNEMP	R^2
Shared-out	0.05	0.00	0.00	-0.17	-0.00	.73
New	0.05	0.00	0.00	-0.35	0.00	.73
Texas						
Shared-out	0.06	0.20	0.67	-1.47	0.00	.76
New	-0.05	0.20	**1.03**	0.65	0.00	.73

*(Coefficients with values different from 0 at 95% confidence are show in **boldface.**)*

My results in estimating the lag relationships are not much better than the differences. For New England, no fix-point lag (up to 8 years), improved on the unlagged relationship with respect to coefficient significance or sign. The series remained serially correlated. For Texas, the results were somewhat better, although not entirely acceptable, either. Here, with a one-year lag on private capital investment and seven-year lag on public investment, labor and public capital have roughly the same output elasticity. The coefficient on private capital is not significantly different from zero.

Texas	**lnMFG**	**alnK**	**blnL**	**clnG(-5)**	**dUNEMP**	**R2**
Shared-out	1.48	0.00	**0.60**	0.52	-0.01	.99
Texas	**lnMFG**	**alnK(-1)**	**blnL**	**clnG(-7)**	**dUNEMP**	**R2**
New	2.02	0.15	**0.41**	**0.45**	**-0.01**	.99

It might be the case that for both New England and Texas, my time framework is too short to derive a general relationship. Unlike the cross-sectional estimates using many states to estimate production relationships (presumably with some variation as to growth dynamics) my timeseries is limited to 17 years, and the estimates depict a limited set of conditions. Thus, what I see is a small piece of the long-run regional development path, so that the current dynamic factor contributing to the slow-growth New England region is private capital investment, while for the fast-growth Texas economy, labor-dependent industry development and public capital investment are the driving factors. What I still have to do here, then, is to see how these estimates change in response to estimation over a longer time horizon.

SUMMARY AND CONCLUSIONS

Public-capital estimates have been ignored for too long by economic analysts. Recent research concerning public-capital productivity impacts are based on poorly formulated estimates. In this paper, I reviewed the characteristics of the capital-stock estimates used by a number of researchers. I found that much of prior research is based on BEA or similar capital-stock estimates that are better suited for national income and product analysis, rather than regional productivity analysis. Furthermore, I demonstrated that the manner in which aging capital is treated in the stock-estimation process has a significant impact on the size of the estimate. I used a mix of survey-based public infrastructure service-lives, and those employed by BEA for private capital. These estimates of public-capital service-lives are important, if only because they are the first empirical, regional estimates, demonstrating that these data can be developed without incurring huge costs.

Significant differences in the service-lives of certain forms of public capital are seen from the two-region survey. Water and sewer systems and streets/highways/bridges both display large differences that affect the estimated stock. With more comprehensive regional coverage and follow-up studies, analysts can develop a better understanding of how public infrastructure affects private capital and labor productivity. In a comparative analysis of with prior research, short time-series estimates for regions offer misleading estimates of factor elasticities with respect to output. Substitution of my new estimates for the old ones had little impact of this outcome, which indicates that other data may be missing from the analysis or that the analysis period is too short. I suspect the latter may be true, given the long lag time that can be observed between the incidence of public investment and private-sector responses, and vice-versa. Despite this problem, better public-capital data would prove useful to analysts in this field and should be developed further.

APPENDIX A - INTRODUCTORY LETTER AND SURVEY QUESTIONNAIRE

Introductory Letter

NICOLAS O. ROCKLER **(617) 924-2436**
129 HILLSIDE ROAD
WATERTOWN, MASSACHUSETTS 02172
E-mail: norockle@mit.edu
December 1, 1997

Jurisdiction Representative
Anywhereville, New England or Texas

Dear Sir/Madam:

I am conducting research on the topic of public infrastructure and economic productivity as a Ph.D. candidate at the Massachusetts Institute of Technology. I am writing to ask for your help by answering the questions found on the enclosed survey. Your answers to these questions are critical to development of new estimates of the service-lives of public infrastructure, as well as helping me characterize the condition and adequacy of public infrastructure.

This questionnaire should be completed by jurisdiction personnel knowledgeable about public facilities, such as public works managers, town managers, or department managers. I would appreciate your filling-out this questionnaire for your jurisdiction or forwarding it to the appropriate person(s) for completion. If your jurisdiction is a special purpose one, please respond just for the specific facilities for which your jurisdiction is responsible.

This questionnaire is being mailed to jurisdictions throughout the six-state New England region and the State of Texas. The results will appear in aggregated form and no individual jurisdiction information will be published, except to identify those participating. Please return your completed questionnaire using the enclosed envelope (or to the address shown above) by Friday, January 16, 1998. Your help is greatly appreciated. If you have any questions or comments, please call or write me at the phone number or addresses shown above.

Sincerely,

Nicolas Rockler

enclosures

Questionnaire

Public Infrastructure and Economic Productivity Questionnaire

The questions below concern the age and condition of the physical infrastructure owned by your jurisdiction. Physical infrastructure is comprised of public buildings, such as administration buildings, schools, hospitals, etc. as well as related facilities and structures such as warehouses. Also included are roads, bridges, water systems (transportation, distribution, storage, and treatment), sewage systems (collection and treatment), energy utilities (electric and gas), public transportation terminals (rail, boat, bus, air) and related service facilities, waterway and waterfront structures and facilities, and flood control structures and facilities. Please examine the last page (p. 14) for examples of structures and facilities included in each category.

Our primary interest is in estimating the average service-lives of the various general categories of public infrastructure. We ask that you be precise as possible, recognizing that in some instances, precision may entail a significant effort to contact the most knowledgeable persons for that infrastructure category. Your best estimates as to dates, sizes, etc. would be appreciated if other sources are unavailable or time is limited. Your responses will be combined with others and no jurisdictions or their representatives will be identified by name, except to list those who elected to participate. Please return your responses in the enclosed envelope no later than January 15, 1998. Thank you for your participation and effort.

---

1. Does your jurisdiction maintain administrative records *for each* of your public buildings, facilities, or systems? (Check one)

_____Yes (Answer A and B, below)

_____No (Go to Q.2)

A. Who (and/or where are) these records maintained by your jurisdiction? (Check all that apply)

_____Maintained centrally
_____Maintained departmentally
_____Maintained by facility
_____Varies by department or function
_____Other (Please describe briefly)______________________________

B. In the table below, please indicate the types of information, listed by row, that are recorded for each facility or structure, listed by column? (Check all that apply. For detailed definition of facilities and structures, see last page of questionnaire.)

DATA ITEMS FOUND IN RECORDS	**FACILITY OR STRUCTURE (Enter a Check Mark if Data Items are on Records for Each Facility or Structure)**			
	1. Offices	2. Schools	3. Hospitals, Health Care, Nursing Homes	4. Social Services
a. Construct-ion Date				
b. Size/Capacity (e.g. sq. ft., pupils, gals. per day, etc.)				
c. Date of sale, abandonment, or demolition				
d. Date(s) of major addition(s)				
e. Original Cost ($)				
f. Cost of Addition(s) ($)				
g. Annual Maintenance and Repair Expenditures ($)				

DATA ITEMS FOUND IN RECORDS	FACILITY OR STRUCTURE (Enter a Check Mark if Data Items are on Records for Each Facility or Structure)			
	5. Highways, Streets, Bridges	6. Water Systems	7. Sewer Systems	8. Energy and Communication Utilities
a. Construct-ion Date				
b. Size/Capacity (e.g. sq. ft., pupils, gals. per day)				
c. Date of sale, abandonment, demolition				
d. Date(s) of major addition(s)				
e. Original Cost ($)				
f. Cost of Addition(s) ($)				
g. Annual Maintenance and Repair Expenditures ($)				

DATA ITEMS FOUND IN RECORDS	FACILITY OR STRUCTURE (Enter a Check Mark if Data Items are on Records for Each Facility or Structure)			
	9. Dams, Reservoirs	10. Public transportation terminals and facilities incl. mass transit, air, bus, marine	11. Public Safety	12. Mis-cellaneous
a. Construct-ion Date				
b. Size/Capacity (e.g. sq. ft., pupils, gals. per day)				
c. Date of sale, abandonment, demolition				
d. Date(s) of major addition(s)				
e. Original Cost ($)				
f. Cost of Addition(s) ($)				
g. Annual Maintenance and Repair Expenditures ($)				

C. Are these records maintained in computer accessible form?

_____Yes

_____No (Go to Q.2)

If yes, how many years of history are available and with what frequency? _____Starting year_____Frequency (e.g., monthly, semiannually, annual, other)?

2. Does your jurisdiction assess real property for purposes of taxation?

____ Yes

____ No (Go to Q. 3)

a. Do your assessment records include descriptions of taxable and nontaxable property?

____ Yes

____ No

b. Please indicate the types of information found on your assessment records: (Check all that apply)

____ Description of current use (e.g. retailing, office, etc.)

____ Size of lot

____ Size of structure

____ Age of structure or construction date

____ Age of major additions or date of additions

____ Condition of structure

____ Occupancy status (e.g. abandoned, occupied)

c. Are these records maintained in computer accessible form?

_____ Yes

_____ No

3. Does your jurisdiction require a permit for demolition of private commercial or institutional buildings?

_____No (Go to Q. 4)

_____Yes A. Please return a blank permit application or indicate which of the following information are included on a permit (Check all that apply):

Check all that apply	**Data Found on Demolition Permit**
_____	1. Construction Date
_____	2. Size/Capacity (e.g. sq. ft., pupils, gals. per day)
_____	3. Date of sale, abandonment, demolition
_____	4. Date(s) of prior major addition(s)
_____	5. Original Cost ($)
_____	6. Cost of Addition(s) ($)

B. Are the demolition records maintained in computer accessible form?

_____Yes

_____No (Go to Q.4)

If yes, how many years of history are available and with what frequency? _____Starting year_____Frequency (e.g., monthly, semiannually, annual, other)?

4. In calendar year 1997, were any of your jurisdiction's **public buildings removed from service** because of demolition, sale, abandonment, or casualty loss (e.g. fire, hurricane, flood, etc?)

_____Yes

_____No (Go to Q. 5)

A. If yes, please provide the following information for each structure that was sold, abandoned, or destroyed. Please be as accurate as possible. If no administrative records are available, please provide your best estimate or contact the most knowledgeable person(s) responsible for each removed building.

Description of Property (e.g., police station, library, office building, etc.)	**Reason for Loss** (e.g., fire, sale, demolition, obsolescence, etc.)	**Age of Property When Removed** (Years)	**Size of Property** (sq. ft. or indicate Units)	**Percentage of Juris-diction's Capacity Removed** (% of total for similar facilities*	**Did you or will you replace this structure in 1997 or 1998?** (Y or N)
1.					
2.					
3.					
4.					
5.[35]					

* For example, if your jurisdiction closed and demolished a 75,000 square foot elementary school building due to old age and your total school space amounted to 300,000 square feet prior to the demolition, the lost capacity was 25%, i.e. 75,000/300,000.

[35] If more than 5 in 1997, please list additional structures and relevant details on additional sheet.

5. In calendar year 1997, was all or part of your **road/highway system, water system, sewer system, or any dams/reservoirs** ***permanently lost*** **(but not replaced)** because of obsolescence or casualty loss (e.g. hurricane, flood, earthquake etc?)

_____Yes
_____No (Go to Q. 6)

A. If yes, please provide the following information for each facility was abandoned or destroyed. Please be as accurate as possible. If no administrative records are available, please provide your best estimate or contact the most knowledgeable person(s) responsible for each removed property.

For example, your jurisdiction took a water pumping station permanently out-of-service in 1997 with no new capacity required to meet current needs. Please indicate the capacity, age, and approximate percentage this removed facility represents of total capacity in your jurisdiction

System Type	**Reason for Loss or Abandonment,** e.g., fire, storm damage, obsolescence, etc.)	**Average Age of System** (Years)	**System Size** (Indicate units, e.g., miles, gals. per day, etc.)	**Percentage of Capacity lost** (% of total system)
1. Road/Highway				
2. Water System				
3. Sewer System				
4. Dams, Reservoirs				

6. In calendar year 1997, was all or part of your **road/highway system, water system, sewer system, or any dams/reservoirs** ***removed and replaced*** because of obsolescence or casualty loss (e.g. hurricane, flood, earthquake etc?) Please include such normal replacement activities as road/highway reconstruction and resurfacing, bridge-deck replacement, sidewalk and curb replacement, and water and sewer line replacement, as well as less frequently performed replacements.

_____Yes
_____No (Go to Q. 7)

A. If yes, please provide the following information for each facility removed and replaced. Please be as accurate as possible. If no administrative records are available, please provide your best estimate or contact the most knowledgeable person(s) responsible for each removed property.

For example, your jurisdiction replaced several streets' worth of water lines in 1997. Please indicate the number of feet, age, and approximate percentage this amount represents of similar lines in your jurisdiction.

System Type	**Reason for Replacement** e.g., storm damage, obsolescence, etc.)	**Average Age of Replaced Component** (Years)	**Amount Replaced** (Indicate units, e.g., miles, gals. per day, etc.)	**Percentage of Overall Capacity Replaced** (%)
1. Road/Highway				
2. Water System				
3. Sewer System				
4. Dams, Reservoirs				

7. Does your jurisdiction employ a formal evaluation program for your infrastructure services (e.g. capacity, demand ,congestion, service outages, maintenance and repair scheduling, cost of service and/or user-fees?

_____Yes
_____No (Go to Q.8)

a. If yes, please provide a brief description of the evaluation, its frequency, planning horizon, etc.

8. Does your jurisdiction maintain capital budgets?

_____Yes
_____No (Go to Q. 9)

a. If yes, for how many years into the future do your budgets extend?

_____(Number of years)

9. For each of the following facility types, please indicate **the number of structures** (or other relevant measure, such as miles, gals. per day, etc.) **and adequacy of capacity** for facilities owned by your jurisdiction at the beginning of calendar 1997. (For detailed definition of facilities and structures, see last page of questionnaire.)

FACILITY	Number of Structures or Capacity	CAPACITY ADEQUACY RATING (Check One for Each Row)			
		Inadequate	Adequate	More than Adequate	Greatly Excessive Capacity
1. Offices					
2. Schools					
3. Hospitals & Health Care					
4. Social Services					
5. Highways, Streets, Bridges					
6. Water Systems					
7. Sewer Systems					
8. Energy Utilities					
9. Dams, Rivers, Reservoirs					
10. Transportation Facilities					
11. Public Safety					
12. Miscellaneous					

GO TO NEXT PAGE

10. For each of the following facility types, please rate the adequacy of your present infrastructure with respect to **capacity relative to current needs**. For each facility type, check the value in the column that best describes current adequacy. (For detailed definition of facilities and structures, see last page of questionnaire.)

FACILITY	CAPACITY ADEQUACY RATING (Check One for Each Row)				
	Severely Inadequate	Inadequate	Adequate	More than Adequate	Greatly Excessive Capacity
1. Offices					
2. Schools					
3. Hospitals & Health Care					
4. Social Services					
5. Highways, Streets, Bridges					
6. Water Systems					
7. Sewer Systems					
8. Energy Utilities					
9. Dams, Rivers, Reservoirs					
10. Transportation Facilities					
11. Public Safety					
12. Miscellaneous					

GO TO NEXT PAGE

11. For each of the following facility types, please rate the adequacy of your present infrastructure with respect to **service quality, e.g. congestion, service disruptions, etc.** For each facility type, check the value in the column that best describes current adequacy. (For detailed definition of facilities and structures, see last page of questionnaire.)

FACILITY	SERVICE QUALITY RATING (Check One for Each Row)				
	Very Low Quality	Low Quality	Adequate	More than Adequate	Very High Quality
1. Offices					
2. Schools					
3. Hospitals & Health Care					
4. Social Services					
5. Highways, Streets, Bridges					
6. Water Systems					
7. Sewer Systems					
8. Energy Utilities					
9. Dams, Rivers, Reservoirs					
10. Transportation Facilities					
11. Public Safety					
12. Miscellaneous					

GO TO NEXT PAGE

12. For each of the following facility types, please rate the adequacy of your present infrastructure with respect to **safety, e.g. risk of injury or property damage** associated with use due to such things as fire, accidents, water borne disease, etc. For each facility type, check the value in the column that best describes current adequacy. (For detailed definition of facilities and structures, see last page of questionnaire.)

FACILITY	Safety Rating (Check One for Each Row)	
	Inadequate	Adequate
1. Offices		
2. Schools		
3. Hospitals & Health Care		
4. Social Services		
5. Highways, Streets, Bridges		
6. Water Systems		
7. Sewer Systems		
8. Energy and Communication Utilities		
9. Dams, Rivers, Reservoirs		
10. Transportation Facilities		
11. Public Safety		
12. Miscellaneous		

GO TO NEXT PAGE

13. For each of the following facility types, please rate the adequacy of your present infrastructure with respect to **operating cost relative to users ability to pay**. For each facility type, check the value in the column that best describes current adequacy. (For detailed definition of facilities and structures, see last page of questionnaire.)

FACILITY	RELATIVE OPERATING COST RATING (Check One for Each Row)				
	Very Low Cost	Somewhat Low Cost	Appropriate Cost	Somewhat High Cost	Very High Cost
1. Offices					
2. Schools					
3. Hospitals & Health Care					
4. Social Services					
5. Highways, Streets, Bridges					
6. Water Systems					
7. Sewer Systems					
8. Energy Utilities					
9. Dams, Rivers, Reservoirs					
10. Transportation Facilities					
11. Public Safety					
12. Miscellaneous					

GO TO NEXT PAGE

GO TO NEXT PAGE

14. During calendar 1997, did your jurisdiction fund any new or rehabilitation construction projects that resulted in a subsequent private investment, such as a new shopping center linked to improved highway access or a new residential development tied to a sewer system extension? (Check One)

____ No (Go to Q.15)

____ Yes. Please describe briefly, citing value of projects or size of projects, if known:

15. During calendar 1997, did your jurisdiction fund any new or rehabilitation construction projects that became necessary because of an identifiable private investment, such as a new school to serve a large new residential development, or water system extension to serve a new industrial park (Check One)

____ No (End)

____ Yes. Please describe briefly, citing value of projects or size of projects, if known:

16. Please enter the name, phone number, and e-mail address (if available) for the person to contact in the event of questions regarding your jurisdiction's responses to the questionnaire.

Name____________________________________

Address (if different than enclosed letter)

____

Phone ( ) - ext. ____________

E-mail address_________________________

YOU HAVE COMPLETED THE QUESTIONNAIRE. THANK YOU FOR YOUR TIME AND EFFORT.

Infrastructure Categories

The table below lists the 12 infrastructure categories used throughout the questionnaire and examples of structures or facilities that should be included under each. Please note that when classifying mixed-purpose facilities, such a combined school and administrative building, classification should be determined by the predominant use of space. Thus, if a building consists of 20,000 square feet of classrooms and 3,000 square feet of offices, that structure should be treated as a school building.

CATEGORY	INCLUDED STRUCTURE/FACILITY TYPES
1. Office	Office buildings, administration buildings
2. Schools	Schools (primary, secondary, post-secondary, vocational, colleges,) school auditoriums, gymnasiums, field houses
3. Hospitals, Health Care, Nursing Homes	Clinics, hospitals, nursing homes, convalescent facilities, other health treatment
4. Social Services	Museums, amusement/recreational facilities, exhibit halls, theaters, libraries, stadiums
5. Highways, Streets, Bridges	Roads, sidewalks, tunnels (pedestrian, vehicle), bridges, roadway lighting, bridges (pedestrian, vehicle, railroad)
6. Water Systems	Water treatment plants, water lines, pumping stations, reservoirs, tanks/towers
7. Sewer Systems	Sewage treatment plants, sanitary sewers, storm sewers, lines, pumping stations,
8. Energy and Communication Utilities	Power plants (hydro, nuclear, fossil fuel), gas manufacturing and distribution systems, gas tanks, heating and cooling plants, electric substations, electric power lines, communications lines and towers,
9. Dams, Reservoirs	Dams (hydroelectric, flood control, water supply), river and harbor development (including docks and piers), flood control structures
10. Transportation Facilities	Public transportation terminals and facilities (including airports, ground transport, marine terminals, bus stations), related maintenance facilities
11. Public Safety	Police buildings, fire stations, jails, prisons, armories
12. Miscellaneous	Parking garages, pools, laboratories, park structures, warehouses

YEAR	TABLE B.1 - ESTIMATED STOCKS ($ 1992, billion)(BEA Service-Lives, Zero Economic Depreciation of Public Stock; BEA Declining-Balance Depreciation of Private Stock)					
	Street, Highway, Bridge	Water & Sewer	Other Public Buildings & Public Works	Manufacturing Capital	Nonfarm, Nonmanufacturing	TOTAL
	New England					
1938	14,065.5	3,595.6	32,697.4	5,912.0	15,132.4	71,402.8
1939	14,303.4	3,932.3	33,241.2	5,930.4	15,145.1	72,552.3
1940	14,577.5	4,167.4	33,594.7	6,240.4	15,418.9	73,998.9
1941	14,872.3	4,370.9	33,708.5	6,938.3	15,757.1	75,647.2
1942	14,927.8	4,602.7	33,485.3	7,684.5	16,072.4	76,772.6
1943	14,859.6	4,657.0	33,166.7	7,783.5	16,030.4	76,497.3
1944	14,780.0	4,669.7	32,828.7	7,771.7	15,761.2	75,811.3
1945	14,730.8	4,681.9	32,565.5	8,022.5	15,714.0	75,714.7
1946	14,909.9	4,795.2	32,605.7	8,445.5	16,175.5	76,931.8
1947	15,032.0	4,935.1	32,902.2	8,589.6	16,528.1	77,987.0
1948	15,327.3	5,031.8	33,275.3	8,627.3	16,835.9	79,097.6
1949	15,542.8	5,189.8	33,898.7	8,508.2	17,047.5	80,187.0
1950	16,033.7	5,332.8	34,975.4	8,484.0	17,456.5	82,282.3
1951	16,305.3	5,466.8	35,990.0	8,846.1	17,670.4	84,278.5
1952	16,694.6	5,607.9	36,622.7	8,860.1	17,925.1	85,710.4
1953	16,998.9	5,788.7	37,278.0	8,941.3	18,470.0	87,476.9
1954	17,777.9	6,045.9	38,554.3	9,163.3	19,138.7	90,680.1
1955	19,742.4	6,175.3	39,763.1	9,439.9	19,977.3	95,098.0
1956	21,087.0	6,319.1	41,176.0	9,725.8	20,849.5	99,157.4
1957	21,809.3	6,448.2	42,449.2	10,098.0	21,698.7	102,503.3
1958	22,909.6	6,651.1	44,007.3	10,103.8	22,649.6	106,321.4
1959	24,032.5	6,878.5	45,082.5	10,386.4	23,379.7	109,759.6
1960	24,694.7	7,035.9	46,617.9	10,564.7	24,293.1	113,206.3
1961	25,561.0	7,209.7	48,155.5	10,663.0	25,041.0	116,630.2
1962	27,378.2	7,417.3	49,652.0	10,747.5	26,096.3	121,291.3
1963	28,747.1	7,738.4	51,547.7	10,911.1	27,061.6	126,006.0
1964	29,769.2	7,940.2	53,591.8	11,034.5	27,770.0	130,105.6
1965	30,814.5	8,215.1	55,527.6	11,380.4	28,717.9	134,655.4
1966	31,955.3	8,512.4	58,060.4	12,025.3	30,074.8	140,628.2
1967	33,001.5	8,838.7	60,794.8	12,347.3	31,493.4	146,475.7
1968	33,720.5	9,259.4	63,593.5	12,720.1	33,827.9	153,121.4
1969	34,846.2	9,740.3	52,768.8	13,120.0	35,379.9	145,855.2

YEAR	TABLE B.1 - ESTIMATED STOCKS ($ 1992, billion)(BEA Service-Lives, Zero Economic Depreciation of Public Stock; BEA Declining-Balance Depreciation of Private Stock)					
	Street, Highway, Bridge	Water & Sewer	Other Public Buildings & Public Works	Manufacturing Capital	Nonfarm, Nonmanufacturing	TOTAL
1970	35,538.9	10,344.4	69,527.0	13,113.0	37,157.7	165,681.0
1971	36,047.5	11,125.6	72,419.6	13,038.2	38,479.0	171,110.0
1972	36,928.7	11,776.5	74,659.7	12,969.0	40,005.9	176,339.8
1973	37,604.5	12,593.1	76,658.1	13,021.7	40,987.3	180,864.8
1974	38,270.7	13,430.8	78,715.2	13,169.1	41,185.2	184,771.0
1975	38,821.5	14,032.9	80,026.7	13,200.3	41,112.8	187,194.2
1976	39,319.5	14,719.2	81,179.9	13,098.6	41,645.0	189,962.2
1977	39,942.5	15,517.1	82,439.0	13,106.4	42,517.8	193,522.8
1978	40,478.7	16,294.2	83,823.1	13,237.2	43,887.4	197,720.6
1979	41,087.2	16,779.0	85,051.0	13,478.5	44,536.2	200,931.9
1980	41,545.6	17,334.9	86,233.8	13,673.6	44,889.9	203,677.8
1981	41,949.5	17,686.9	86,317.9	13,728.8	46,440.6	206,123.8
1982	42,451.8	18,069.6	87,081.5	13,734.1	47,081.2	208,418.2
1983	43,075.1	18,420.4	88,159.6	13,795.5	48,191.7	211,642.3
1984	43,970.2	18,895.9	89,072.7	14,029.0	49,738.9	215,706.7
1985	44,689.2	19,379.6	90,212.8	14,421.8	51,959.0	220,662.4
1986	45,393.7	19,959.8	91,215.5	14,508.4	54,109.2	225,186.6
1987	46,079.3	20,671.7	92,855.7	14,539.8	56,418.0	230,564.5
1988	46,947.1	21,329.8	94,539.4	14,635.0	58,909.5	236,360.9
1989	47,638.7	21,943.5	96,726.9	14,525.7	60,793.7	241,628.5
1990	48,125.5	22,677.1	99,089.5	14,261.3	61,438.8	245,592.2
1991	48,878.4	23,582.0	100,265.1	14,033.0	61,699.6	248,458.1
1992	49,881.7	24,343.9	102,502.0	13,986.2	61,982.1	252,696.0
1993	50,814.5	25,115.3	104,920.5	13,798.1	62,598.9	257,247.2
1994	51,479.6	25,623.5	107,428.4	13,668.3	62,934.3	261,134.1
1995	52,723.2	26,014.5	109,876.5	13,628.5	63,560.8	265,803.5
1996	53,772.9	26,665.8	112,089.7	13,605.2	64,246.8	270,380.4
1997	56,296.0	27,467.9	114,626.4	13,678.7	65,273.3	277,342.4
1998	56,648.4	27,820.6	116,498.3	13,577.6	66,433.2	280,978.2
	Texas					
1938	9,936.8	5,172.8	18,159.7	5,559.3	12,693.8	51,522.6
1939	10,091.3	5,148.9	18,377.6	5,564.8	12,707.9	51,890.6
1940	10,346.2	5,168.1	18,830.5	5,895.0	12,846.4	53,086.1
1941	10,651.0	5,282.2	19,289.4	6,373.4	13,378.0	54,974.1
1942	11,049.8	5,800.6	19,459.8	9,049.6	14,497.6	59,857.4

YEAR	TABLE B.1 - ESTIMATED STOCKS ($ 1992, billion)(BEA Service-Lives, Zero Economic Depreciation of Public Stock; BEA Declining-Balance Depreciation of Private Stock)					
	Street, Highway, Bridge	Water & Sewer	Other Public Buildings & Public Works	Manufacturing Capital	Nonfarm, Nonmanufacturing	TOTAL
1943	11,026.3	5,899.1	19,462.8	9,433.3	14,599.9	60,421.4
1944	11,059.0	5,954.0	19,341.2	9,739.4	14,411.1	60,504.7
1945	11,100.2	6,013.1	19,350.2	10,299.5	14,592.3	61,355.3
1946	11,404.9	6,124.3	19,477.2	10,794.3	15,079.0	62,879.7
1947	11,780.6	6,228.9	20,069.3	11,146.4	15,349.4	64,574.6
1948	12,064.8	6,388.3	21,109.6	11,239.8	15,904.5	66,706.9
1949	12,414.5	6,502.8	21,879.4	11,244.9	16,140.3	68,181.9
1950	12,839.9	6,765.4	22,848.5	11,317.4	16,994.0	70,765.2
1951	13,153.1	6,916.6	23,726.9	11,916.6	17,917.6	73,630.9
1952	13,657.3	7,088.3	24,787.7	12,745.4	18,394.1	76,672.8
1953	14,085.2	7,236.5	25,471.9	13,160.4	19,260.4	79,214.4
1954	14,700.5	7,413.1	26,376.4	13,082.0	20,049.9	81,621.9
1955	15,516.7	7,573.3	27,460.3	13,455.6	20,901.7	84,907.5
1956	16,459.2	7,765.9	28,587.8	13,843.1	21,839.3	88,495.3
1957	17,395.2	8,051.5	29,734.2	14,052.9	22,582.4	91,816.2
1958	18,515.6	8,379.1	31,051.1	14,342.1	23,516.1	95,804.1
1959	19,588.3	8,672.9	32,223.4	14,558.3	24,324.3	99,367.1
1960	20,685.1	8,963.5	33,587.7	14,898.9	25,419.4	103,554.6
1961	21,686.8	9,227.6	34,927.9	15,233.7	26,546.8	107,622.9
1962	23,086.4	9,623.6	36,500.5	15,553.1	27,720.5	112,484.2
1963	24,255.0	9,956.4	37,961.6	15,829.5	28,831.2	116,833.7
1964	25,612.0	10,348.3	39,564.6	16,119.7	30,022.9	121,667.5
1965	26,856.8	10,722.0	41,308.7	16,514.8	31,502.4	126,904.7
1966	28,570.8	11,017.8	43,251.8	16,908.4	32,503.0	132,251.8
1967	30,022.5	11,265.5	45,395.9	17,451.7	33,725.2	137,860.8
1968	31,542.6	11,580.5	47,406.2	18,392.3	35,200.9	144,122.5
1969	33,261.6	11,949.0	49,235.0	18,559.4	37,119.0	150,124.0
1970	34,429.4	12,287.8	51,143.7	19,244.1	39,229.8	156,334.7
1971	35,899.3	12,608.1	52,802.7	19,031.5	42,212.7	162,554.4
1972	37,123.0	13,209.5	55,055.6	18,788.3	44,651.2	168,827.6
1973	38,230.4	13,932.0	57,242.0	19,785.4	46,905.5	176,095.3
1974	38,959.7	14,604.2	59,850.3	21,893.6	48,547.3	183,855.1
1975	39,711.4	15,130.0	61,677.4	23,041.1	49,925.0	189,484.9
1976	40,567.4	15,695.5	63,647.0	23,291.5	51,811.7	195,013.1
1977	41,871.6	16,428.4	65,534.4	24,901.8	53,918.7	202,655.0
1978	43,084.9	17,094.0	67,634.5	27,285.4	57,317.8	212,416.6
1979	44,575.5	17,681.3	69,921.2	27,455.5	62,147.4	221,780.9

YEAR	TABLE B.1 - ESTIMATED STOCKS ($ 1992, billion)(BEA Service-Lives, Zero Economic Depreciation of Public Stock; BEA Declining-Balance Depreciation of Private Stock)					
	Street, Highway, Bridge	Water & Sewer	Other Public Buildings & Public Works	Manufac-turing Capital	Nonfarm, Nonmanu-facturing	TOTAL
1980	45,751.2	18,283.7	72,088.1	27,499.9	66,195.7	229,818.6
1981	46,551.4	18,919.0	74,106.1	29,383.3	74,288.7	243,248.5
1982	47,548.8	19,432.8	76,791.0	29,188.5	78,976.6	251,937.6
1983	48,782.0	20,107.9	79,390.7	28,610.9	83,638.8	260,530.3
1984	49,906.0	20,910.1	82,146.8	28,539.0	88,255.6	269,757.6
1985	52,010.6	22,059.0	85,093.4	28,078.4	93,153.9	280,395.2
1986	53,986.8	23,326.1	88,051.3	27,527.9	94,963.3	287,855.4
1987	56,083.5	24,399.8	90,975.6	27,197.6	95,645.8	294,302.4
1988	57,569.1	25,292.3	93,331.3	26,791.0	96,320.0	299,303.7
1989	58,886.2	25,928.1	95,713.3	28,844.0	96,075.8	305,447.5
1990	59,944.0	26,563.6	98,198.5	28,357.5	96,317.4	309,380.9
1991	60,884.0	27,342.2	100,251.3	28,306.9	96,318.1	313,102.5
1992	61,978.3	28,193.6	103,013.4	28,616.0	96,389.9	318,191.2
1993	63,664.2	28,971.6	106,367.5	28,347.3	96,489.4	323,840.0
1994	65,316.1	29,755.5	109,727.2	27,949.9	97,071.8	329,820.5
1995	67,423.1	30,668.6	113,045.0	28,493.0	97,996.3	337,626.1
1996	69,080.8	31,696.8	116,701.0	28,527.5	98,949.5	344,955.6
1997	70,912.6	32,655.1	120,330.2	28,807.1	100,553.1	353,258.0
1998	72,761.3	33,588.2	124,343.3	28,616.7	103,591.1	362,900.6

YEAR	TABLE B.2 - ESTIMATED STOCKS ($ 1992, billion)(Survey-Based Service-Lives, Zero Economic Depreciation of All Stock)					
	Street, Highway, Bridge	Water & Sewer	Other Public Buildings & Public Works	Manufac-turing Capital	Nonfarm, Nonmanu-facturing	TOTAL
New England						
1938	7,120.7	2,215.5	32,780.3	9,482.0	20,705.2	72,303.6
1939	7,415.8	2,572.1	33,332.8	9,497.7	20,577.1	73,395.4
1940	7,747.7	2,826.8	33,694.6	9,811.6	20,723.9	74,804.6
1941	8,101.0	3,049.7	33,816.3	10,528.8	20,955.1	76,451.0
1942	8,215.7	3,300.5	33,600.8	11,321.7	21,184.6	77,623.3

YEAR	TABLE B.2 - ESTIMATED STOCKS ($ 1992, billion)(Survey-Based Service-Lives, Zero Economic Depreciation of All Stock)					
	Street, Highway, Bridge	Water & Sewer	Other Public Buildings & Public Works	Manufacturing Capital	Nonfarm, Nonmanufacturing	TOTAL
1943	8,207.2	3,373.6	33,289.4	11,496.4	21,077.4	77,444.1
1944	8,187.8	3,404.8	32,958.3	11,568.4	20,754.4	76,873.9
1945	8,199.4	3,435.3	32,701.8	11,907.8	20,658.7	76,903.0
1946	8,439.5	3,566.5	32,748.4	12,432.1	21,082.3	78,268.8
1947	8,623.0	3,724.2	33,051.0	12,695.5	21,419.4	79,513.1
1948	8,980.0	3,838.4	33,429.9	12,861.7	21,731.2	80,841.2
1949	9,257.5	4,013.6	34,058.9	12,876.6	21,964.8	82,171.3
1950	9,810.5	4,173.6	35,140.8	12,986.9	22,411.1	84,522.9
1951	10,000.5	4,324.3	36,160.4	13,487.1	22,682.0	86,654.3
1952	10,205.1	4,481.9	36,797.9	13,654.5	23,008.5	88,147.9
1953	10,298.7	4,679.0	37,457.8	13,893.4	23,640.7	89,969.5
1954	10,827.4	4,952.3	38,738.4	14,279.6	24,418.8	93,216.4
1955	12,539.9	5,097.4	39,951.2	14,730.9	25,391.7	97,711.1
1956	13,585.6	5,256.8	41,368.0	14,719.8	26,426.6	101,356.8
1957	13,972.9	5,401.2	42,644.8	14,862.8	27,467.5	104,349.2
1958	14,846.8	5,619.3	44,206.4	14,675.1	28,638.3	107,986.0
1959	15,747.3	5,861.6	45,284.9	14,760.7	29,618.6	111,273.1
1960	16,116.5	6,033.7	46,823.3	14,615.8	30,806.9	114,396.2
1961	16,780.8	6,222.0	48,363.8	14,668.3	31,859.0	117,893.8
1962	18,266.5	6,443.9	49,863.0	14,864.7	33,242.9	122,681.0
1963	19,430.5	6,779.1	51,761.3	15,225.7	34,569.3	127,765.8
1964	19,973.6	6,994.7	53,807.6	15,480.5	35,668.8	131,925.3
1965	20,696.0	7,283.3	55,745.6	15,997.0	37,031.4	136,753.3
1966	21,479.7	7,594.0	58,280.5	16,850.2	38,832.5	143,036.9
1967	22,150.0	7,933.6	61,016.8	17,338.0	40,734.4	149,172.8
1968	22,734.2	8,367.4	63,817.2	17,864.2	43,592.9	156,376.0
1969	23,850.7	8,861.2	67,055.4	18,446.8	45,731.8	163,946.0
1970	24,547.3	9,478.1	69,753.8	18,577.8	48,140.7	170,497.6
1971	25,031.1	10,271.8	72,647.7	18,350.6	50,142.5	176,443.7
1972	25,660.9	10,935.1	74,889.0	17,731.3	52,387.8	181,604.0
1973	26,143.9	11,763.9	76,888.5	17,163.5	54,130.5	186,090.2
1974	26,445.8	12,613.6	78,946.5	17,317.7	54,818.9	190,142.5
1975	26,713.5	13,227.5	80,258.9	17,470.2	55,217.0	192,887.0
1976	26,654.6	13,925.4	81,412.7	17,230.4	56,083.9	195,307.0
1977	26,941.3	14,734.8	82,672.5	16,918.5	57,218.5	198,485.6
1978	27,025.1	15,523.2	84,057.1	16,997.3	59,061.9	202,664.6

YEAR	TABLE B.2 - ESTIMATED STOCKS ($ 1992, billion)(Survey-Based Service-Lives, Zero Economic Depreciation of All Stock)					
	Street, Highway, Bridge	Water & Sewer	Other Public Buildings & Public Works	Manufac-turing Capital	Nonfarm, Nonmanu-facturing	TOTAL
1979	27,267.6	16,019.2	85,285.4	17,294.2	60,269.0	206,135.5
1980	26,886.5	16,586.1	86,468.6	17,710.0	60,943.9	208,595.1
1981	25,266.8	16,949.0	87,701.2	17,902.2	62,932.6	210,751.9
1982	24,366.8	17,342.4	88,937.3	17,662.4	63,684.5	211,993.4
1983	24,211.2	17,703.7	89,072.8	17,817.0	65,015.6	213,820.2
1984	23,950.7	18,189.6	89,901.3	18,079.5	66,992.1	217,113.2
1985	23,636.6	18,683.5	91,362.8	18,366.6	69,738.2	221,787.7
1986	23,873.1	19,273.8	92,459.9	18,299.6	72,262.9	226,169.3
1987	23,913.8	19,906.2	94,022.2	18,163.6	75,248.7	231,254.5
1988	23,226.5	20,529.8	96,074.3	17,998.4	78,286.8	236,116.0
1989	22,814.4	21,072.7	98,225.7	17,987.5	80,574.5	240,674.7
1990	22,591.9	21,690.9	100,040.0	17,542.4	81,757.0	243,622.2
1991	22,649.4	22,698.4	100,973.5	17,221.6	82,331.6	245,874.5
1992	22,754.2	23,467.5	102,955.3	17,150.8	82,774.7	249,102.5
1993	22,880.0	24,459.2	105,234.1	16,948.8	83,422.3	252,944.4
1994	23,136.9	25,059.7	107,725.0	16,718.7	83,908.6	256,548.9
1995	23,475.0	25,310.3	110,239.0	16,610.4	84,865.5	260,500.4
1996	24,182.7	25,960.0	112,689.6	16,292.2	85,514.9	264,639.3
1997	26,421.7	26,722.6	115,512.0	15,761.1	86,817.3	271,234.8
1998	26,392.5	27,131.3	117,675.6	15,361.2	87,880.7	274,441.2
Texas						
1938	4,256.2	1,872.2	18,204.6	7,612.7	15,744.7	47,690.4
1939	4,461.0	1,873.4	18,427.1	7,624.2	15,683.5	48,069.3
1940	4,766.8	1,918.2	18,884.5	7,965.8	15,757.2	49,292.5
1941	5,123.1	2,058.3	19,347.7	8,471.1	16,237.4	51,237.7
1942	5,573.9	2,603.0	19,522.2	11,194.2	17,328.5	56,221.8
1943	5,602.9	2,728.2	19,529.1	11,713.6	17,439.4	57,013.2
1944	5,688.4	2,810.0	19,411.3	12,172.2	17,271.3	57,353.1
1945	5,782.7	2,896.3	19,423.9	12,898.8	17,477.5	58,479.3
1946	6,140.9	3,034.9	19,554.3	13,582.2	18,002.5	60,314.8
1947	6,570.3	3,167.2	20,149.7	14,142.6	18,331.4	62,361.2
1948	6,908.3	3,354.4	21,193.1	14,459.4	18,959.6	64,874.8
1949	7,312.1	3,497.0	21,966.0	14,694.9	19,289.2	66,759.1
1950	7,791.6	3,787.7	22,937.9	15,001.8	20,249.8	69,768.8
1951	8,130.3	3,967.2	23,819.0	15,841.4	21,308.3	73,066.2

YEAR	TABLE B.2 - ESTIMATED STOCKS ($ 1992, billion)(Survey-Based Service-Lives, Zero Economic Depreciation of All Stock)					
	Street, Highway, Bridge	Water & Sewer	Other Public Buildings & Public Works	Manufacturing Capital	Nonfarm, Nonmanufacturing	TOTAL
1952	8,606.4	4,167.2	24,882.4	16,933.0	21,949.4	76,538.5
1953	8,906.5	4,343.9	25,569.1	17,640.3	22,998.7	79,458.4
1954	9,364.7	4,549.0	26,475.9	17,870.6	23,998.9	82,259.1
1955	9,974.9	4,737.8	27,562.0	18,553.9	25,086.8	85,915.3
1956	10,628.2	4,959.1	28,691.6	19,127.6	26,287.2	89,693.7
1957	11,225.5	5,273.4	29,839.9	19,504.3	27,322.1	93,165.2
1958	12,046.5	5,629.7	31,158.7	19,990.7	28,571.6	97,397.1
1959	13,070.5	5,952.1	32,332.7	20,208.7	29,724.1	101,288.1
1960	14,014.5	6,271.4	33,698.7	21,424.4	31,188.9	106,597.9
1961	14,997.3	6,564.1	35,040.5	21,976.7	32,718.2	111,296.8
1962	16,427.4	6,965.9	36,614.5	21,890.8	34,326.6	116,225.3
1963	17,518.3	7,295.3	38,076.9	22,548.1	35,905.8	121,344.5
1964	18,606.6	7,695.7	39,681.3	22,971.3	37,598.1	126,553.0
1965	19,639.4	8,057.0	41,426.5	23,781.2	39,612.1	132,516.2
1966	21,042.3	8,322.9	43,370.7	24,568.4	41,188.1	138,492.3
1967	22,134.4	8,562.4	45,515.9	25,350.5	43,014.4	144,577.6
1968	23,202.2	8,868.2	47,527.1	26,576.0	45,128.4	151,301.9
1969	24,892.3	9,196.0	49,356.7	27,108.9	47,724.2	158,278.1
1970	25,976.4	9,495.8	51,266.2	28,133.5	50,563.8	165,435.8
1971	27,355.2	9,773.9	52,926.0	27,959.6	54,331.5	172,346.2
1972	28,225.5	10,267.9	55,179.5	27,591.6	57,632.2	178,896.7
1973	28,909.6	10,579.8	57,366.5	26,245.4	60,812.6	183,913.7
1974	29,308.3	10,944.0	59,975.3	28,251.8	63,209.4	191,688.8
1975	29,664.8	11,351.4	61,802.8	29,430.9	65,336.9	197,586.7
1976	30,051.0	11,821.4	63,772.8	29,487.1	67,961.8	203,094.2
1977	30,998.5	12,467.7	65,660.6	30,960.4	70,677.6	210,764.8
1978	31,665.1	12,988.6	67,761.0	33,386.3	74,819.5	220,620.5
1979	32,686.3	13,406.4	70,047.9	33,922.7	80,462.8	230,526.1
1980	33,206.2	13,801.3	72,214.9	34,425.6	84,667.6	238,315.7
1981	33,150.5	14,198.9	74,233.1	36,702.8	93,437.0	251,722.3
1982	33,166.5	14,493.2	76,918.0	36,433.2	98,945.4	259,956.3
1983	33,425.8	14,940.1	79,517.8	35,527.8	104,775.0	268,186.5
1984	33,392.3	15,578.1	82,273.9	35,498.9	110,507.5	277,250.6
1985	34,416.6	16,513.1	85,220.3	35,560.7	116,938.0	288,648.8
1986	35,342.8	17,564.3	88,178.2	35,069.8	119,832.5	295,987.5
1987	36,585.1	18,417.8	91,102.3	34,757.5	121,697.9	302,560.7

YEAR	TABLE B.2 - ESTIMATED STOCKS ($ 1992, billion)(Survey-Based Service-Lives, Zero Economic Depreciation of All Stock)					
	Street, Highway, Bridge	Water & Sewer	Other Public Buildings & Public Works	Manufacturing Capital	Nonfarm, Nonmanufacturing	TOTAL
1988	36,848.4	19,076.8	93,457.8	34,525.1	123,957.9	307,866.0
1989	37,223.7	19,376.1	95,839.6	36,654.6	124,749.8	313,843.8
1990	37,235.2	19,671.6	98,324.5	36,374.2	126,003.0	317,608.4
1991	37,291.1	20,179.7	100,377.1	36,384.2	126,999.3	321,231.3
1992	36,993.4	20,747.5	103,138.8	36,748.4	127,990.5	325,618.7
1993	37,299.3	21,186.5	106,492.5	36,550.3	129,104.1	330,632.9
1994	37,607.5	21,637.2	109,851.9	36,249.2	130,582.1	335,927.8
1995	38,038.4	22,207.4	113,169.3	36,854.5	132,436.3	342,706.0
1996	38,522.0	22,853.2	116,824.8	36,855.0	133,974.3	349,029.4
1997	38,986.3	23,442.9	120,453.5	37,091.7	136,187.5	356,161.9
1998	39,904.9	24,182.5	124,466.1	36,705.9	139,772.4	365,031.9

REFERENCES

Aschauer, David. 1989. "Is Public Expenditure Productive?" Journal of Monetary Economics, No. 23, pp. 177-200.

Bureau of Economic Analysis. 1999a. National Income and Product Accounts annual data from www.bea.doc.gov.

Bureau of Economic Analysis. 1999b. Estimates of Fixed Tangible Wealth, 1929-1997. www.bea.doc.gov.

Eberts, Randall. 1986. "Estimating the Contribution of Urban Public Infrastructure to Regional Economic Growth." Federal Reserve Bank of Cleveland, Working Paper No. 8620.

Frenken, Jim. 1992. "How to Measure Tangible Capital Stock." Paper presented the International Association for Research in Income and Wealth, 22nd General Conference, Flims, Switzerland. August 30-September 5.

Fraumeni, Barbara M. 1997. "The Measurement of Depreciation in the U.S. National Income and Product Accounts." *Survey of Current Business*, Volume 77, No. 7 (July).

Jorgenson, Dale and M.A. Sullivan. 1981. "Inflation and Corporate Capital Recovery" in Depreciation, Inflation, and the Taxation of Income from Capital, edited by Charles Hulten. Washington, D.C: The Urban Institute Press.

Gordon, Robert. 1967. "Problems in the Measurement of Real Investment in the U.S. Private Economy." Ph.D. Dissertation. Cambridge, MA: Massachusetts Institute of Technology.

Holtz-Eakin, Douglas. 1991. "Public Capital and the Productivity Puzzle" The Maxwell School, Syracuse University, Metropolitan Studies Program, Occasional Paper, No. 147.

Holtz-Eakin, Douglas. 1993. "State-Specific Estimates of State and Local Government Capital." *Regional Science and Urban Economics. Vol. 23, No. 2.* North Holland, pp. 185-209.

Hulten, Charles R. and Frank C. Wykoff. 1981. "The Estimation of Economic Depreciation Using Vintage Asset Prices." *Journal of Econometrics*, Vol. 15, no. 3 (April), pp. 367-396.

Katz, Arnold J., S.W. Herman. 1997. "Improved Estimates of Fixed Reproducible Tangible Wealth, 1929-1995." *Survey of Current Business*, Volume 77, No. 5 (May), pp. 69-76.

Morrison, Catherine and A.E. Schwartz. 1992. "State Infrastructure and Productive Performance." Working Paper No. 3981, National Bureau of Economic Research. Cambridge, MA.

Munnell, Alicia. 1990. "How Does Public Infrastructure Affect Regional Economic Performance?" in: Alicia Munnell, ed., Is There a Shortfall in Public Capital Investment? Boston, MA: Federal Reserve Bank of Boston.

Polenske, Karen R., Nicolas Rockler, Anne Kinsella-Thompson, and Anjali Mitter. 1998. "Demand for Economic Development Infrastructure. Report to the Economic Development Administration, Department of Commerce. Cambridge, MA.

Tatom, John A. 1991. "Public Capital and Private Sector Performance." *Review* (Federal Reserve Bank of St. Louis.) May/June, pp. 3-15.

Triplett, Jack E. 1996. "Depreciation in Production Analysis and in Income and Wealth Accounts: Resolution of an Old Debate." *Economic Inquiry*. Volume 34 (January), pp. 93-115.

Winfrey, Robert. 1967. "Statistical Analysis of Industrial Property Requirements." Bulletin No. 125, Engineering Research Institute, Iowa State University.

Wulf, Henry, Chief, Finance Branch, Governments Division, Bureau of the Census. Personal communication.

U.S. Department of Energy. 1985. Nonresidential Building Energy Consumption Survey: Characteristics of Commercial Buildings 1983. Washington, DC.