Public Policy Brief

How Big Should the Public Capital Stock Be?

The Relationship between Public Capital and Economic Growth

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Preface

Amid the favorable economic news of the first half of 1998—low unemployment, low inflation, a budget surplus, and a healthy growth rate—concerns about an "infrastructure crisis," which first arose during the 1980s, have persisted. And there is reason to be concerned. Economic growth has pressed the capacity of our public capital systems, such as transportation, water, and education, because public capital investment has not kept pace with the growing economy.

At the same time, budget concerns have shifted from how to get rid of the federal deficit to what to do with the surplus. Should we pay down the national debt, cut taxes, or restore funding to some of the many spending programs that were cut in order to balance the budget? Research Associate David Alan Aschauer, of Bates College, suggests that maximizing economic growth can and should be a goal of federal budget policy. It is possible to estimate empirically the growth-maximizing levels of public capital and total government spending, and these estimates can be used as a guide for planning public expenditure.

According to Aschauer, there is a nonlinear relationship between public capital and economic growth. If there is too little public capital, there are too few roads, railways, and waterways to transport the nation's goods; too few schools to train the nation's workforce; and too few fire and police stations to protect the nation's citizens. But, if there is too much public capital, taxes will be too high for private industry to take full advantage of the public infrastructure. At some point between too much and too little, then, there is a growth-maximizing ratio of public capital to private capital. That level is what Aschauer believes public investment should try to achieve.

In this brief Aschauer uses data from the 48 contiguous states over the period 1970 to 1990 to estimate the optimal public capital ratio and the initial and long-run impacts on growth of permanent and temporary increases in public capital. He finds that the public capital ratio is far below the growth-maximizing level in most states. He also finds that the level of total government spending, which includes mostly noninvestment spending (such as defense spending and transfer payments), far exceeds the growth-maximizing level. He concludes that economic growth can be increased by increasing the public capital stock and by redirecting government expenditure from noninvestment consumption spending to public investment.

Aschauer's analysis sheds light on the process of determining an optimal level of public investment and a federal budget policy approach that may support economic growth. We hope you find his ideas interesting and welcome your comments.

Dimitri B. Papadimitriou
Executive Director
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The Relationship between Public Capital and Economic Growth

The United States, like all countries, invests heavily in its public capital stock—transportation systems, such as subways and highways; water treatment plants and sewer systems; and public buildings, such as schools, fire stations, police stations, and courthouses. Such investment is needed for a strong, flexible, and vibrant economy. Workers need to ride the subway or drive their car to get to work; companies need to ship goods; manufacturers need to use water and dispose of waste; future workers need to be educated; and businesses need to be protected from fire and crime.

Yet over the past three decades the level of public sector investment has slipped in the United States. The growth rate of state and local government capital stock illustrates the decline. As Figure 1 indicates, it climbed as high as 5.4 percent per year in the 1960s, but dipped as low as 1.5 percent in the 1980s and was only 2.3 to 2.6 percent per year in the 1990s. Meanwhile, growth in the country's private capital stock—equipment such as trucks, trains, and planes and structures such as office buildings, factories, and warehouses—has increased the demands placed on the available public infrastructure facilities. This drop in public investment led to the concerns about an "infrastructure crisis" that were prevalent in policy discussions of the 1980s.

A basic question of public finance is, How big should the public capital stock be? Put differently, is it possible to have too much as well as too little public capital? It is easy to recognize economic inefficiency stemming from too little public capital—from congested streets and highways, bursting water mains, crowded schools, and an overburdened criminal

Figure 1 **Growth Rate of State and Local Public Capital Stock**
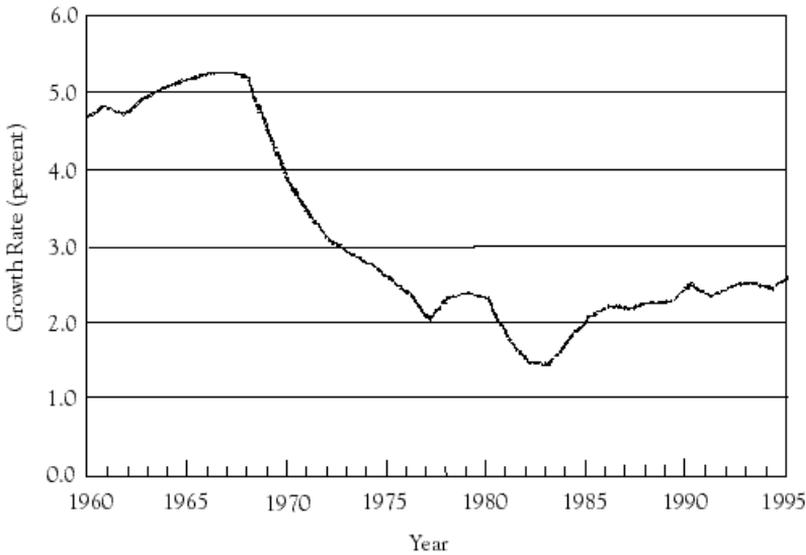
Source: "Improved Estimates of Fixed Reproducible Tangible Wealth, 1929–95," *Survey of Current Business,* May 1997, Table 15.

justice system. Economic inefficiency stemming from too much public capital is somewhat harder to detect, but is just as important. The tax burden associated with financing and maintaining public capital reduces the returns to private activity, which, in turn, may result in too few trucks in the nation's fleet, trains crawling along on wobbly tracks, factories full of antiquated or obsolete equipment, and airplanes pushing the limits of safety.

This brief reports the results of three statistical studies of the relationship between public capital and economic growth.[1] The method employed is an analysis of the relationship between economic growth and the ratio of public capital to private capital. Most previous studies of the effectiveness of public capital assume a linear relationship between public capital and output and so are incapable of estimating the optimal level of public capital spending. They can only estimate whether an increase in public capital spending will increase or decrease growth. The method employed in the studies on which this brief is based instead assumes a nonlinear relationship between public capital and economic growth, that is, a

relationship that is positive up to a certain level of public capital but turns negative at levels above that growth-maximizing point.

The brief is divided into three parts. The first discusses the theoretical model for determining the growth-maximizing size of the public capital stock and gives an overview of the empirical evidence of an optimal public capital ratio. The second examines the static and dynamic effects of an increase in the public capital stock. The third discusses the policy implications, arguing that one important goal of public policy should be to achieve the growth-maximizing level of public capital. The discussion is organized around a series of questions about the relationship between public capital and economic growth. The results can be summarized as follows.

1. The relationship between public capital and economic growth is nonlinear.
2. The estimated growth-maximizing public capital stock is approximately 61 percent of the private capital stock.
3. The ratio of public to private capital (called the public capital ratio) falls short of the growth-maximizing level in 87.5 percent of the observed cases. The average state had a public capital ratio 26 percent below the growth-maximizing level.
4. The overall level of government spending is higher than the growth-maximizing level.
5. Both core and other public capital have positive growth effects, with urban infrastructure such as water and sewer capital having a particularly high impact.
6. A one standard deviation increase in the public capital ratio would cause an estimated 1.4 percent increase in the annual growth rate.
7. Public debt and taxes have a significant negative impact on growth. The negative impact reduces but does not reverse the positive impact of public capital on growth.
8. The impact of an increase in public capital stock on growth would have been greater in the 1980s when the public capital ratio was further from the growth-maximizing level than in the 1970s.
9. There are somewhat larger growth effects from public capital in the Snowbelt than in the Sunbelt.
10. Public capital has a persistent effect on economic growth and a substantial cumulative effect on output and employment.

Determining the Optimal Public Capital Stock

Is there a nonlinear relationship between public capital and economic growth?

The research reported in this brief focuses on the relationship between the ratio of public to private capital (the public capital ratio) and economic growth. The goal is to estimate the public capital ratio that maximizes growth. The theoretical relationship between the public capital ratio and the economic growth rate is nonlinear. The growth rate rises with the public capital ratio until it reaches a maximum—at the optimal public capital ratio—and then falls.

The explanation for the nonlinear relationship is simple. When the public capital ratio is lower than the optimal level, the positive effects of public capital dominate the adverse effects of methods of financing, resulting in an increase in private investment and economic growth. But, when the public capital ratio is higher than the optimal level, the adverse effects of financing overwhelm the stimulative effects of public capital, inducing a drop in private capital accumulation and the growth rate of output.[2] For instance, enhanced transportation, water, and sewer systems improve the efficiency of trucks, airplanes, and factories through the reduction in traffic congestion and the absence of water main breaks or sewer line backups. But, if the investment is financed by taxes and if taxes are overly burdensome on private firms, the firms will not be able to afford to purchase enough trucks to take advantage of an enhanced transportation system.

The data used in the empirical analysis cover the 48 contiguous states in the United States over the period from 1970 to 1990. The analysis proceeded by searching for the best-fitting nonlinear relationship between the public capital ratio and economic growth. The key parameter is the output elasticity of public capital: the percentage increase in output due to a percentage increase in public capital. The optimal public capital ratio was found to be 61 percent.

The data are tailored to allow analysis to capture the long-run effect of public capital on output and employment growth and to allow a role for

other determinants of economic growth. To accomplish this, a small panel data set is constructed by averaging the basic data over 10-year periods resulting in 96 total observations—enough to allow for separate state-specific and temporal effects while maintaining a focus on the long run.

Other researchers have obtained a wide range of estimates of the effectiveness of public capital. Some find the public capital stock to be too low, others find it to be at or near the optimal level, and others find it to be too high.[3] Of course, there are ways to reconcile these rather diverse results. For instance, public capital often links various geographical locations in a productive network; consequently, one would expect the effectiveness of public capital to be larger when a larger geographical area is being studied. For the most part, studies show a greater efficiency at the national level, less at the state level, and less still at the local level.[4]

What is the growth-maximizing public capital ratio?

The basic estimate of the optimal ratio of public capital to private capital is 61 percent. In other words, a public capital stock 61 percent the size of the private capital stock will maximize long-run economic growth. Because public capital affects both output and employment, it is of interest to calculate separately the output-growth–maximizing and employment-growth–maximizing public capital ratio. A range of estimates is obtained using various methods, but the range is fairly narrow, between 59.7 percent and 63.9 percent for the output-growth–maximizing ratio and between 56.8 percent and 61.3 percent for the employment-growth–maximizing ratio.

Does the actual public capital ratio fall short of the growth-maximizing ratio?

Across the 48 states, the average public capital ratio is 44.6 percent, 26 percent (or 16 percentage points) below the growth-maximizing level of 61 percent. Most states—87.5 percent or 84 of 96 possible cases (the 48 states in each of two decades)—have deficient public capital, that is, public capital ratios below 61 percent (see Figure 2). The gap between the growth-maximizing level and the actual level was as high as 68

Figure 2 Economic Growth and Public Capital Ratio
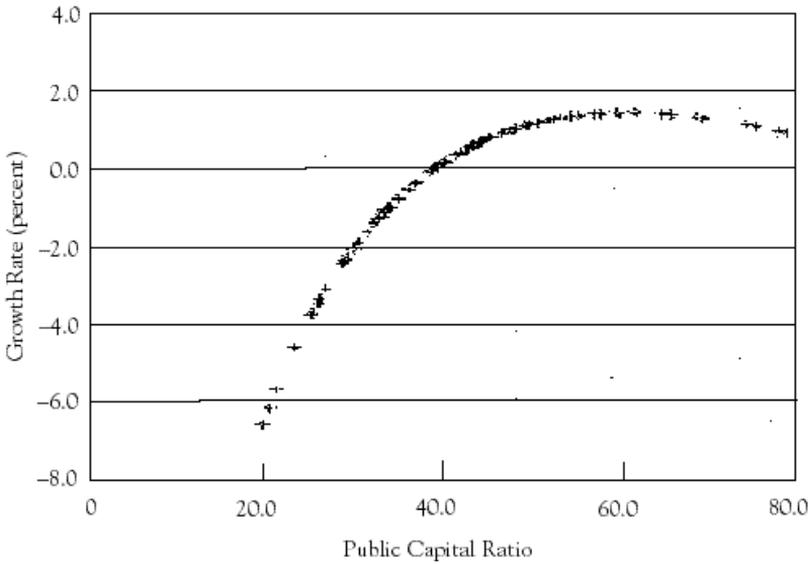
Source: Author's calculations.

percent in some observations. Still, 12 observations lie above the output-growth–maximizing level, suggesting that these particular states (during specific decades) might have increased economic growth by reducing the public capital stock. (Note that some states have negative growth rates in this and subsequent figures because there are factors other than the public capital ratio, such as unemployment, that are taken into account in the curve.)

Is the overall level of government spending too high?

Investment is only a small portion of total government spending. The rest of government spending, such as the salaries of military personnel and transfer payments to retirees, is defined as current consumption spending and is not expected to have the same positive effects on economic growth as investment spending. A number of researchers have found that economic growth rates are adversely affected by higher levels of total government spending. This research suggests that government spending is either unproductive by nature or, if productive, has been taken well beyond its growth-maximizing level. The growth-maximizing ratio of total government spending to private capital was

Figure 3 **Economic Growth and Ratio of Government Spending to Private Capital**
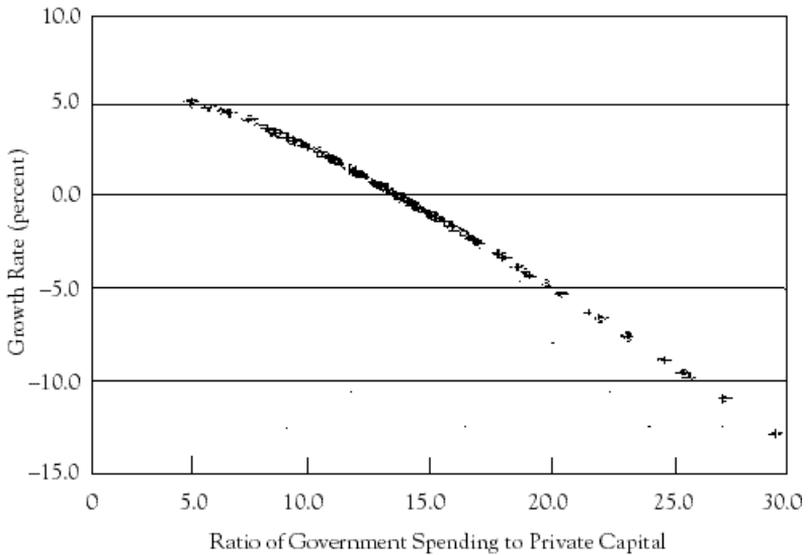
Source: Author's calculations.

estimated to be 4 percent.[5] Figure 3 reveals that the ratio in all 48 states in both decades (all 96 observations) was above the growth-maximizing level.

What is the relative importance of core public capital and other public capital?

Different types of public capital have a different impact on economic performance. Core public capital (such as streets and highways, water and sewer systems) may have a larger impact on growth than other public capital (such as educational buildings, hospitals, and conservation projects, and development structures).[6] Figures 4 and 5 show the relationship between economic growth and the ratios of core public capital and other public capital to private capital. These figures imply growth-maximizing values of core public capital and other public capital of 44 and 31 percent, respectively, compared with actual sample average values of 27 and 18 percent. The data indicate a deficient level of core public capital for 94 of the 96 observations and a deficient level of other public capital for 90 of the 96 observations, suggesting that for the

Figure 4 **Economic Growth and Ratio of Core Public Capital to Private Capital**
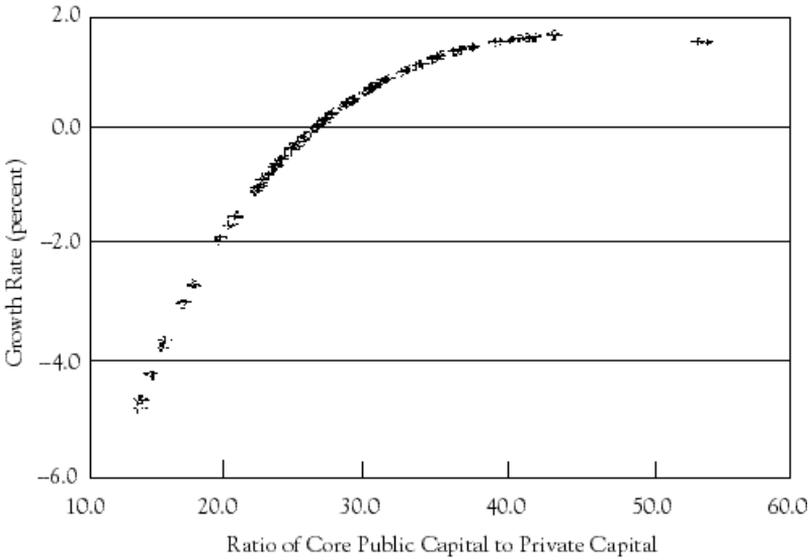
Source: Author's calculations.

Figure 5 **Economic Growth and Ratio of Other Public Capital to Private Capital**
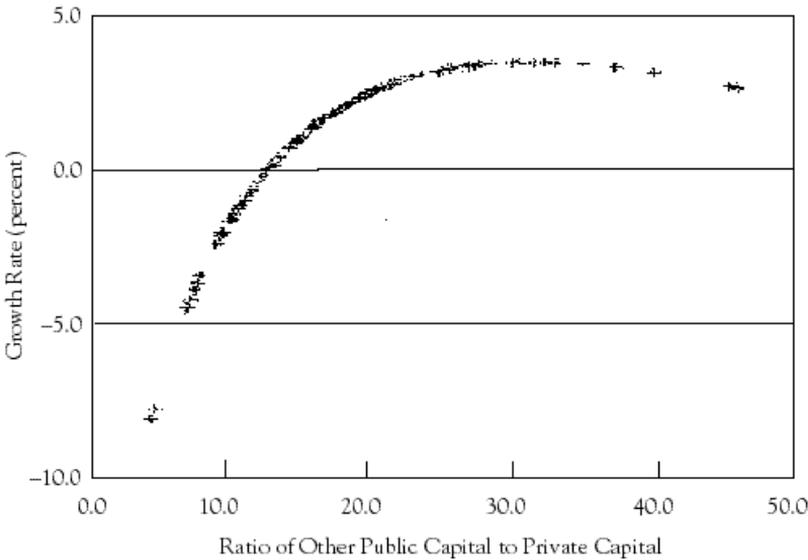
Source: Author's calculations.

average state in the sample the growth effects of other public capital slightly exceed the effects of core public capital.

Static and Dynamic Effects of an Increase in Public Capital on Output and Employment

Given the deficiency of the public capital stock estimated above, the analysis now turns to the effects of an increase in the public capital ratio. Increases have both static and dynamic effects. Static effects are the initial impact on output and employment; the dynamic, or subsequent, effects depend critically on the degree to which output and employment growth are related to their initial levels and the extent to which they interact with one another over time. The static effects arise because the increased productivity of private capital and labor cause immediate increases in private capital accumulation and growth in the labor force. Enhanced transportation, water, and sewer systems encourage construction of new industrial enterprises, while improved schools attract additional laborers to the local employment pool.

The dynamic effects of public capital depend, in a complicated way, on the initial movements in output and employment. For instance, as the private capital stock rises over time, the returns to private capital tend to contract, but the returns to labor tend to expand; as output depends on the services of both private capital and labor, the combined influence of these forces on economic growth is ambiguous. Consequently, there are many different potential paths for output and employment over time. Increases in public capital can have either temporary or permanent effects on output and employment growth. Small static effects of public capital may accumulate to large dynamic effects or large static effects may accumulate to small dynamic effects. Therefore, it is important to understand the static and dynamic effects to understand fully the impact of public capital on economic performance.

Static Effects

The model estimates the effects on both output growth and employment growth. The equation for each depends on the public capital stock expressed as a ratio to the private capital stock, on initial levels of output and employment, and on the unemployment rate.

What is the magnitude of the growth effects of public capital?

The magnitude of the growth effects of public capital depends on the output elasticity of public capital (estimated to be 0.30) and on the degree of inadequacy of the public capital stock, or how far its value diverges from the optimizing level of 61 percent. The results imply that, for the average state in the sample, a one standard deviation increase in the public capital ratio from its sample average value (from 45 to 58 percent) would result in a 1.4 percent per year increase in the annual growth rate of output per worker. This is a substantial result, suggesting that for many states an insufficient level of public investment may have been responsible for relatively sluggish productivity and economic growth in recent decades.[7]

What are the effects of public debt and taxes on economic growth?

In order to understand the relationship between government capital and economic growth, it is important to take into account the means of financing both the original acquisition of capital and the maintenance of capital over its useful lifetime. Here we assume that the original acquisition of capital is financed by municipal bonds and the maintenance of capital is financed by taxes. Both debt and taxes are found to have a negative effect on output and employment growth. The net effect of public capital on the economy is calculated by subtracting the financing impact from the gross impact of public capital. The net effect of a 5 percentage point increase in public capital is 0.4 percent per year for output and 0.2 percent per year for employment—considerably below the growth effects calculated below of 0.8 and 0.3. The financing of public capital clearly matters for economic performance, but the growth impacts of public capital, however financed, are still large and positive.

Was the impact of an increase in public capital stock on economic growth different in the 1970s than the 1980s?

As other studies have confirmed,[8] the public capital stock did not keep pace with the private capital stock during the 1970s and 1980s. The public capital ratio slid from 47.2 percent in the 1970s to 42.0 percent in the 1980s, causing the gross and net growth effect of public capital to increase for both output (from 0.256 to 0.327 percent and 0.071 to 0.142, respectively) and employment (from 0.090 to 0.122 and 0.031 to 0.063, respectively). In other words, the impact on growth of an increase

in the public capital stock would have been greater in the 1980s, when states were farther from the optimal level, than in the 1970s. This confirms statistically the notion, prevalent in the policy discussions of the 1980s, of an "infrastructure crisis" in the United States.

Does the impact of public capital stock on growth differ in the Snowbelt and the Sunbelt?

The public capital ratio is considerably higher in the Snowbelt (the 21 states in the northeastern and midwestern regions) than in the Sunbelt (the 27 states in the southern and western regions). The estimated net output growth effect is calculated to be 18.2 percentage points lower in the Snowbelt than the Sunbelt and the net employment growth effect is 4.4 percentage points lower, implying that increased infrastructure investment in the Sunbelt would increase growth. However, there may be different sensitivities of economic growth to public capital in the two regions of the country arising from geography, population density, and other factors. After the necessary calculations, it turns out that the output and employment growth effects are nearly the same across regions. In particular, the output growth effect is 0.6 percentage point higher and the employment growth effect only 0.8 percentage point lower in the Snowbelt than in the Sunbelt. The net growth effects for the average state in both the Snowbelt and Sunbelt are positive, which justifies increased public capital investment in both regions of the country.

What are the static effects of an increase in core and other public capital on economic growth?

One might expect certain portions of the other public capital category to be important for employment growth and output growth at the state level. For instance, a large portion of other public capital is local and higher educational facilities, which can be expected to have a direct effect on employment growth and at least an indirect effect on output growth. Similar arguments can be made for electric and gas utilities, mass transit, air transport, and water transport. Indeed, once financing is taken into account, the net output and employment growth effects are positive for other, but not for core capital. Apparently, schools and hospitals have been underprovided relative to highway, water, and sewer systems. Intuitively, core capital seems to be more important to economic performance than other capital. Yet a reconciliation between the empirical

results and one's intuitive reaction might be found in the fact that high-ways are disproportionately funded by federal grants; that is, they are financed from outside rather than inside the jurisdiction, which may well have induced an excessive level of investment in core public capital.

Summary of static effects

For the average state over the 1970s and 1980s, the gross static impact of a 5 percentage point increase in the public capital ratio (approximately a 10 percent increase in the public capital ratio) is an increase in output growth of around 0.8 percent per year and in employment growth of some 0.3 percent per year. The net effect is an increase of 0.4 percent per year in output growth and 0.2 percent per year in employment growth.

Dynamic Effects

The dynamic impact of public capital on economic growth depends on whether and how fast output and employment converge to their long-run or steady-state values.[9] Applying a convergence rate of 2 percent per year[10] to the preceding results suggests that a 5 percentage point increase in the public capital stock eventually will cumulate to a sizable 8 percent increase in output per worker, assuming employment growth is exogenous. However, allowing for a joint relationship between output growth and employment growth makes a number of outcomes possible.

What, if any, is the cumulative effect of public capital on output and employment?

The impact of the change in public capital on economic growth is quite persistent. Figure 6 shows the impact of a permanent 5 percentage point (10 percent) increase in the public capital ratio (as before, from 45 per-cent, near its sample average, to 50 percent) on the growth rates of out-put and employment. (A permanent increase in the public capital ratio requires an increasing level of public investment rather than a one-time increase in public capital to match the rising private capital stock.) As is evident from the figure, the growth rate of output initially rises by 0.8 percent per year and the growth rate of employment climbs by a smaller 0.3 percent per year, confirming the analysis of the static impacts of pub-lic capital. Interestingly, output and employment growth continue to expand for some time. The output growth effect peaks at 0.9 percent per year after 9 years, and the employment growth peaks at 0.5 percent per

Figure 6 Growth Effects of a Permanent Increase in the Public Capital Ratio
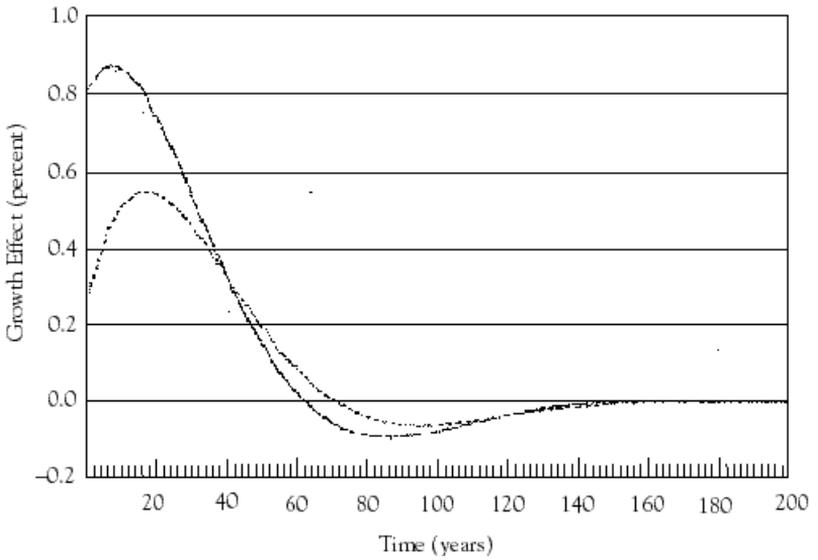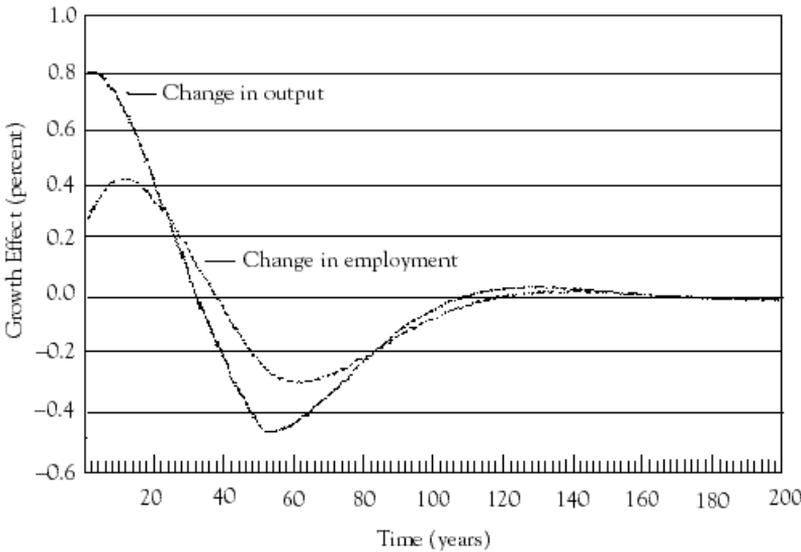

Source: Author's calculations.

Figure 7 Cumulative Growth Effects of a Permanent Increase in the Public Capital Ratio
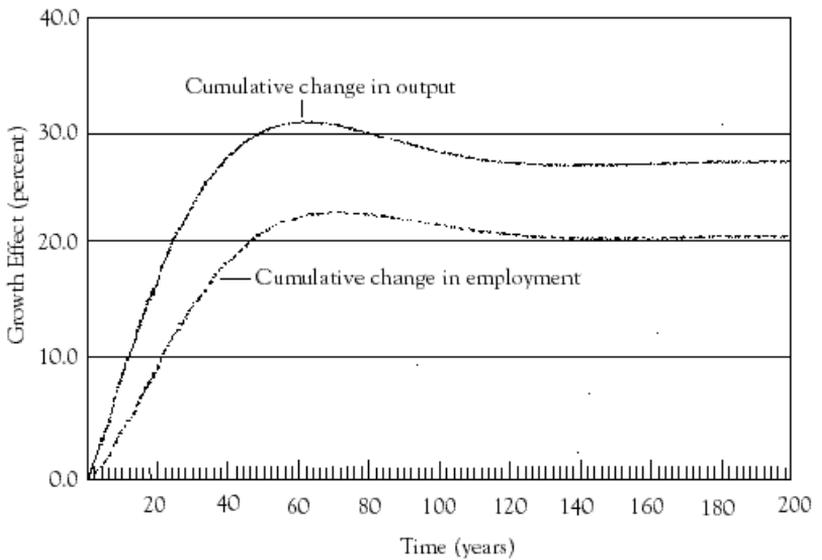
Source: Author's calculations.

Figure 8 **Growth Effects of a Temporary Increase in the Public Capital Ratio**

Source: Author's calculations.

year after 18 years. Even though output growth peaks more rapidly, it remains above employment growth, generating persistent productivity gains. Output growth remains above 0.4 percent per year (half of the initial impact) for nearly 40 years.

Figure 7 illustrates the cumulative effect of a 10 percent increase in the public capital ratio on the level of output and employment. Output climbs by 27.2 percent, nearly three times the percentage increase in the public capital ratio. Over three-quarters of the increase in long-run output comes from gains in employment (which increases by 20.8 percent), with less than one-quarter arising from capital accumulation and productivity improvements (which increase 6.4 percent).

To some readers, the magnitude of these effects may seem implausibly large. In response, four points may be made. First, the fundamental reason for the substantial cumulative effects is not to be found in the initial increase in output and employment growth as much as in the persistence of the increase in growth rates.

Figure 9 Cumulative Growth Effects of a Temporary Increase in the Public Capital Ratio
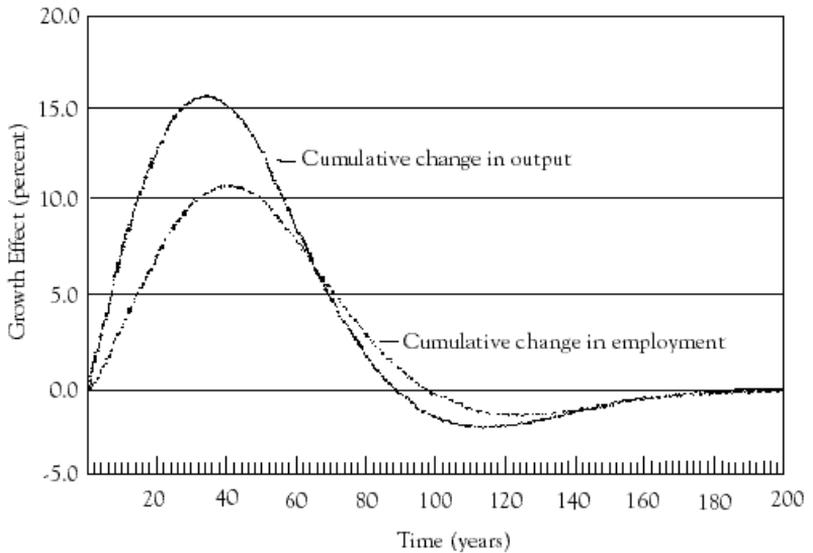
Source: Author's calculations.

Second, the results pertaining to a permanent increase in the public capital ratio may differ from a permanent increase in the absolute level of public capital which, in the context of a growing private capital stock, translates into a temporary increase in the public capital ratio. A permanent increase in the public capital ratio requires a series of increases in the public capital to keep up with the growing level of private capital. Figure 8 illustrates the impact of a temporary rise in the public capital ratio on the growth rate of output and employment. The initial effects on the growth rates of output (at 0.8 percent per year) and of employment (at 0.3 percent per year) are nearly the same as in the case of a permanent increase in the public capital ratio (see Figure 7). However, the growth rate of output begins to fall after 2 years (compared to 9 years in the case of a permanent rise in the public capital ratio), and the growth rate of employment builds to only 0.4 percent per year over 12 years (compared to 18 years). Output growth and employment growth turn negative after the initial rise but eventually return to their original level.[11] Output growth and employment growth begin to rise after the public capital ratio has stabilized at its original level. Figure 9 shows the corresponding cumulative impact on the levels of output and employment. The

Figure 10 Cumulative Growth Effects on Output of a Permanent Increase in the Public Capital Ratio
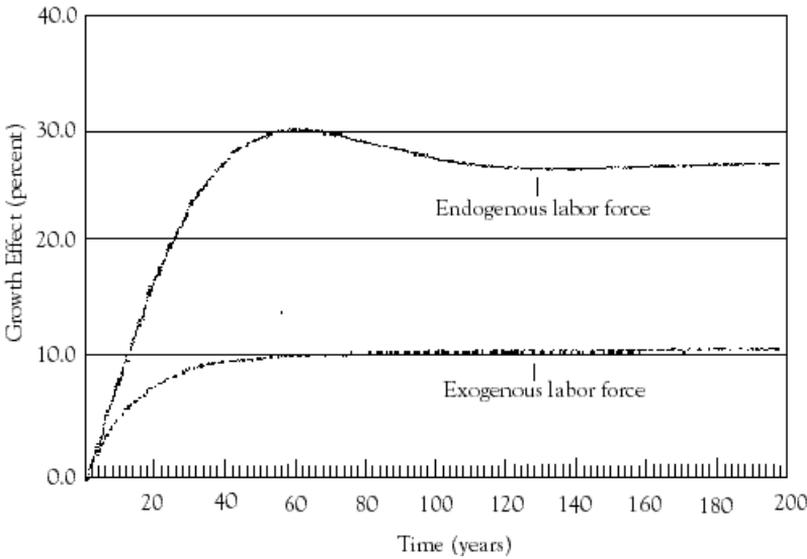
Source: Author's calculations.

maximum cumulative gains are 15.7 percent for output and 11.0 percent for employment. However, because the model assumes stability, output and employment eventually decline back to their original levels.

Third, the above results depend on the assumption of an endogenous labor force. An exogenous labor force means that the size of the labor force is fixed and all increases in employment must come from decreases in unemployment; an endogenous labor force means that growth can attract labor from other areas. Much of the increase in output in the above examples can be attributed to an increase in the labor force, which is likely if the rise in the public capital stock is isolated in a particular state and attracts labor migration from other states. However, if the rise in the public capital stock is regional or even national in scope, there would be less migration and the effects on output and employment growth would be much more modest. Figures 10 and 11 compare the cumulative effect on output and employment when the labor force is exogenous to when the labor force is endogenous. In the exogenous labor force model the cumulative gains in output and employment are

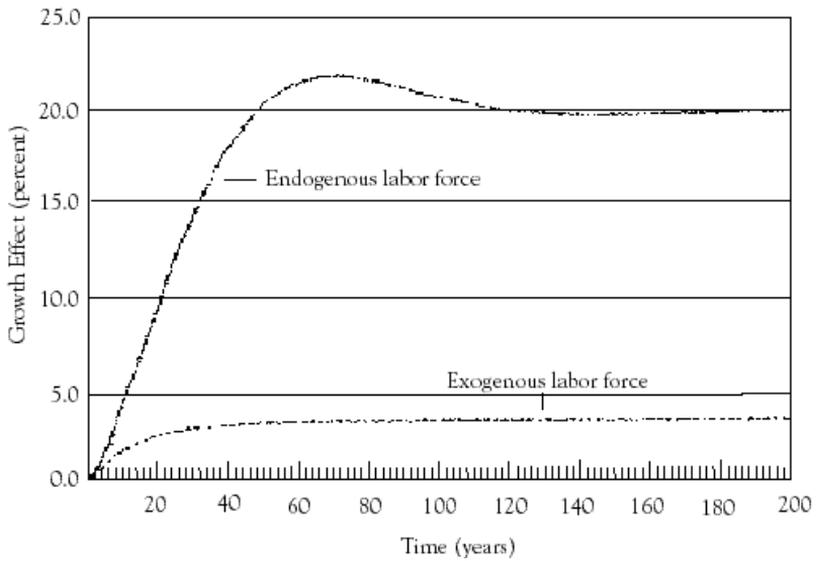**Figure 11 Cumulative Growth Effects on Employment of a Permanent Increase in the Public Capital Ratio**

Source: Author's calculations.

11.2 percent and 3.5 percent, respectively, 16.0 and 16.2 percentage points below the corresponding gains in the endogenous growth model.[12]

Fourth, public capital must be financed in some manner (such as by debt, taxes, grants, or user fees) that can be expected to have an adverse impact on economic growth. Consequently, the net effect of public capital on long-run economic performance may turn out to be somewhat smaller. Figure 12 illustrates the impact of a permanent 5 percentage point increase in public capital on the growth rates of output and employment in an exogenous labor force model with public debt and taxes. The initial increases in output and employment growth are equal to 0.4 and 0.2 percent per year, respectively. After a few years of rather volatile movements, the growth rates follow smooth paths to the long-run equilibrium. Figure 13 shows the corresponding paths for the cumulative effects on the long-run levels of output and employment in an endogenous labor force model. The net effects, allowing for taxes and public debt, are much smaller than the gross effects of public capital illustrated in Figures 7 and 8. The rise

Figure 12 **Growth Effects of a Permanent Increase in the Public Capital Ratio, Financed by Taxes and Public Debt, with Exogenous Labor Force**
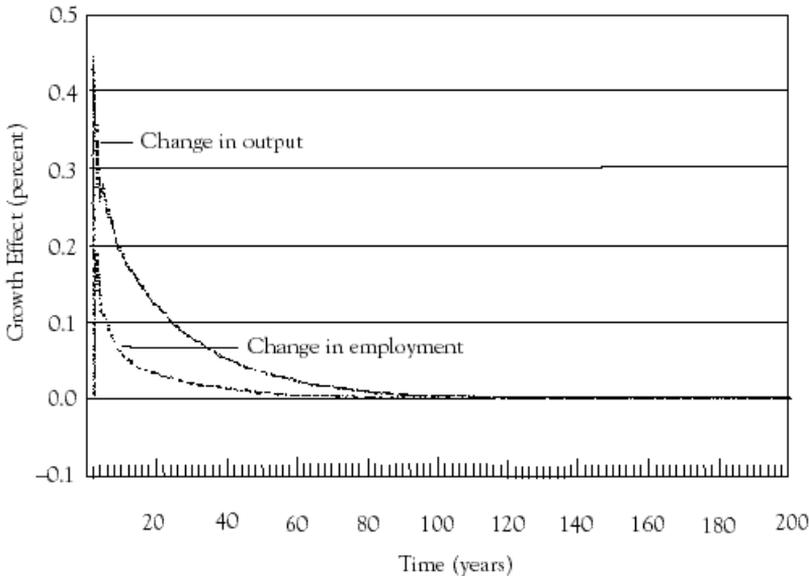
Source: Author's calculations.

Figure 13 **Cumulative Growth Effects of a Permanent Increase in the Public Capital Ratio, Financed by Taxes and Public Debt, with Exogenous Labor Force**
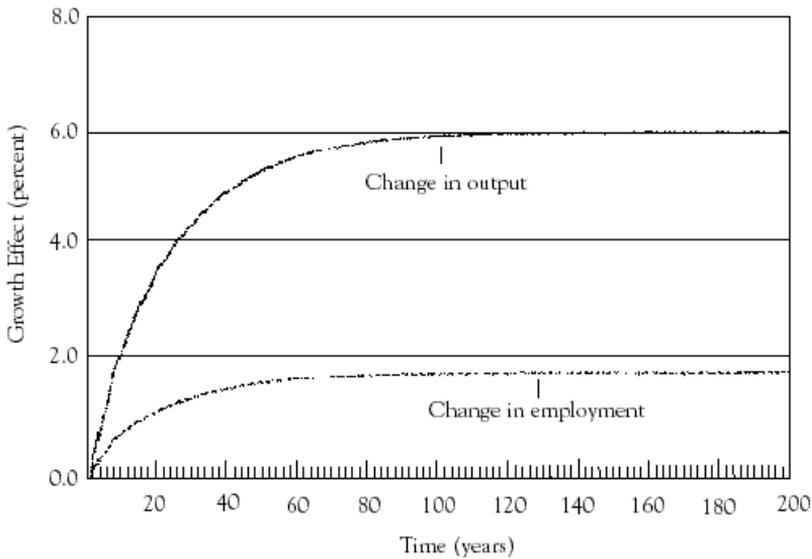
Source: Author's calculations.

in the long-run levels of output and employment is about half as large as before. About one-third of the reduction can be attributed to diminished initial growth rates and about two-thirds to quicker convergence rates.

Summary of dynamic effects

A complete analysis of the long-run impact of public capital must be decomposed into the impact of public capital on initial growth rates—the static effects—and the subsequent increases in output and employment—the dynamic effects. In particular, depending on the potency of feedback effects, a small initial effect of public capital can accumulate to a large long-run effect or a large initial effect can accumulate to a small long-run effect. The cumulative effects of public capital are much larger for an endogenous labor force model than for an exogenous labor force model. The cumulative effects are significantly reduced but still positive even when the means of financing is taken into account.

Attaining the Optimal Level of Public Capital

The empirical results reported here indicate that in most areas of the United States during the 1970s and 1980s the levels of public capital were below the levels that would have maximized the rate of economic growth. Given that there has been no great change since then, the public capital stock, in this sense, is too small. The growth-maximizing ratio of public capital to private capital is estimated to be 61 percent, while the actual sample average is 45 percent. Similarly, the optimal levels of core and other public capital are estimated to be 44 and 31 percent, respectively, while the actual averages across the sample are the lesser values of 27 and 18 percent. The empirical results suggest that for the average state a one standard deviation increase in overall public capital, core public capital, or other public capital would stimulate an increase in output growth per worker of somewhere between 0.3 and 1.4 percent per year.

One way to boost the growth rate of output is through an increase in the public capital stock, with the initial acquisition of public capital financed by debt and the maintenance of public capital financed by

ongoing taxes. The public capital stock augments growth by providing services to the private sector, while the associated higher taxes detract from growth by reducing the returns to private economic activities. However, the analysis of static and dynamic effects indicates that for nearly all states the positive effect of the increase in the public capital stock dominates the negative effects of financing by taxes, with the net result of an increase in economic growth from an increase in public sector capital.

At the same time, the analysis suggests that for nearly all states the actual levels of government spending were above the levels that would have maximized output growth. In that sense the overall level of government spending is too high. While the growth-maximizing ratio of government spending to private capital is estimated to be 4 percent, the sample average ratio is a much larger 14 percent, suggesting that for the average state a one standard deviation increase in government spending would decrease output growth per worker by 1.3 percent per year.

Therefore, another way to boost the growth rate of output is through a decrease in the overall level of government spending, with an associated cut in taxes. The overall level of government spending stimulates growth much the same way that investment spending stimulates growth, except that the adverse effects of financing dominate the stimulative effects of spending at a much lower level. The empirical results show that the growth-maximizing level of total spending is only 4 percent. All states in the sample are above that level of spending, meaning that a decrease in overall government spending would cause an increase in economic growth.

Thus, one sure way to boost growth would be through a reorientation of government spending at the state and local level away from government consumption to government investment. Consider, for instance, what the empirical results of this brief have to say about a permanent $100 per capita reduction in government consumption spending and an equal $100 per capita increase in expenditures on physical public capital. The permanent $100 increase in government investment is capable of supporting a permanent increase in the public capital stock of, perhaps, $1,000; assuming a real interest rate on municipal bonds of 4 percent per year, a physical depreciation rate of 5 percent per year, and a population

growth rate of 1 percent per year, to service the debt associated with the purchase of the public capital requires $40 per capita, while to maintain the public capital against physical depreciation and growth in the labor force requires $60 per capita. In 1996 the state and local net public capital stock amounted to $13,392 per capita and the net stock of private nonresidential capital was $31,392. Consequently, the $100 per capita switch from public consumption to public investment implies a 7.5 percent rise in the public capital stock per capita and a 6.8 percent increase in the ratio of public to private capital. Using the empirical results of this brief, such a switch would cause an initial increase of 0.33 percent in the annual growth rate of output per worker and a cumulative rise in output per worker of 3.0 percent after some 40 years.

Placed in proper historical perspective, these results shed light on appropriate federal policy for the coming years. Over the period from 1960 to 1996, the total value of national wealth—including tangible assets such as plant and equipment, inventories, residential structures, consumer durables, and land and intangible assets such as education and research and development—expanded from $16.8 trillion to $57.7 trillion (in 1996 dollars), at an average rate of 3.4 percent per year.[13] During the same time, federally financed wealth grew from 2.2 to 4.3 trillion, at an average yearly rate of 1.9 percent. Thus, if federal investment had kept pace with overall investment, the nation's stock of assets would be higher by some $3 trillion.

Furthermore, looking within the various categories of federally financed investments, the source of this drag on national wealth building can be isolated to be physical capital, such as infrastructure, rather than intangible capital, such as education and research and development. While federally financed physical capital grew by 1.1 percent per year, well below the growth rate of national capital, education and research and development capital rose at annual rates of 6.1 and 4.2 percent, well above the growth rate of national capital. As a general rule, then, since 1960 the federal commitment to expanding educational capital and research and development capital has far exceeded its commitment to augmenting physical capital.

State and local governments have done much better than the federal government in providing funding for physical capital facilities such as

streets and highways, water and sewer systems, and other structures. From 1960 to 1996 state and locally financed physical capital advanced from $900 billion to $2.6 trillion, which represents a yearly rate of growth of 2.9 percent. Yet even this more substantial commitment was not enough to maintain the public capital stock against growth in the private capital stock, with the result that the ratio of public capital to total national capital had been declining by 0.5 percent per year.

Recently, both the administration and Congress have placed a new emphasis on adequately funding education—investment in our nation's human capital stock. This is, without doubt, good economic policy, as the available empirical evidence shows that the stock of human capital is well below the optimal level in the United States. However, the empirical evidence summarized here suggests that a parallel emphasis on adequately funding infrastructure also constitutes good economic policy, one that will require a reversal of the current and projected future policy stance regarding our nation's public capital stock.

Notes

1. Readers interested in a detailed econometric analysis should see Aschauer 1997a, 1997b, 1997c.
2. This explanation was given by Barro (1990) and, by extension, Aschauer (1997a). Another related reason is that at any particular point in time the aggregate capital stock is misallocated unless the marginal product of public capital equals the marginal product of private capital (see Arrow and Kurz 1970). Both of these arguments imply that there is an optimal public to private capital ratio, one that maximizes output and employment growth.
3. Aschauer (1989a), Fernald (1992), and Kocherlakota and Yi (1996) find that the public capital stock is too low; Munnell (1990) finds it to be near its optimal level; and Eberts (1986) and Holtz-Eakin (1994) find it to be too high. Finally, a few researchers, such as Evans and Karras (1994) and Hulten and Schwab (1991), detect a negative marginal product of public capital—seeming to imply that the nation would be better off, at least from a production standpoint, simply destroying a portion of the public capital stock!
4. Many authors have used state-level data to look at the importance of infrastructure to productivity (Munnell 1990), to costs of production in manufacturing sectors (Morrison and Schwartz 1996; Nadiri and Mamuneas 1994), and to overall economic growth (Holtz-Eakin and Schwartz 1995). Aschauer (1989a) found an output elasticity of 0.39 at the national level, Munnell (1990) found 0.15 at the state level, and Eberts (1986) found 0.04 at the local level.

5. For example, using cross-country data over the period 1960 to 1985 Barro (1990) and Barro and Sala-i-Martin (1995) find that a one standard deviation (6.5 percentage point) rise in government consumption spending is associated with a drop in the growth rate of 0.7 percent per year. Note that the overall level of government spending is the sum of government consumption and investment spending. One could examine government consumption spending rather than the overall level of spending. However, because investment is a relatively small portion of total spending, the distinction is not too important, and the results would likely be similar. One could interpret the results as saying that although the overall level of government spending is well above its growth-maximizing level, the investment portion is below its growth-maximizing level.

6. See Aschauer 1989a and Munnell 1990. Morrison and Schwartz (1996) define public infrastructure to include "only highways, water, and sewers" and state that the estimated impact of public capital on costs of production in the manufacturing sector "is somewhat smaller if we include 'other' public capital, apparently largely containing government buildings which do not augment efficiency."

7. The magnitude of the impact of public capital on economic growth is calculated under a particular set of maintained assumptions that may not accurately describe actual policy in the various states. In particular, it is assumed that the public capital is expanded immediately, rather than gradually; it is increased permanently, rather than temporarily; it is financed by debt, rather than by current taxation; and it has a persistent, rather than a transitory effect on economic growth. A discussion of the importance of these assumptions—the violation of which may raise or lower the actual impact of public capital on economic growth—is contained in the working papers (Aschauer 1997b, 1997c).

8. See, for example, Aschauer 1989a.

9. Many authors, using data on the United States, have documented a convergence in per capita output and income. For example, Barro and Sala-i-Martin (1991, 1995) estimate a convergence rate for personal income per capita of between 1.75 and 2.20 percent per year over the period from 1980 to 1990; however, they also find that the convergence rate became much less significant in the 1970s and 1980s.

10. A rough average of the convergence rates found by Barro and Sala-i-Martin.

11. This results from the model's assumed convergence rate of 2 percent.

12. The implied drop in unemployment of 3.5 percentage points appears reasonable. However, a linear extrapolation would suggest that a significantly larger increase in the public capital ratio might require a much larger drop in unemployment—which would reduce the unemployment rate to "unreasonable" levels (such as, perhaps, 1 or 2 percent). From this perspective, it might be preferable to include the unemployment rate in the model in a nonlinear fashion to allow a diminishing impact of growth on unemployment. However, including the unemployment rate in a linear way is done to ease computations.

13. These and subsequent wealth statistics are from the *Budget of the United States Government. Fiscal Year 1998. Analytical Perspectives* (Washington, D.C.: Office of Management and Budget, 1998),Table 2–4.

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