Transportation Spending and Economic Growth

The Effects of Transit and Highway Expenditures

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Prepared for:
American Public Transit Association
September 1991

Excerpts from the Report

IMPORTANCE OF TRANSPORTATION TO PRODUCTIVITY

"One way to generate higher productivity growth is to provide an appropriate environment to foster private capital accumulation. The results of this study suggest that one way to provide such an environment is through increased funding for transportation, in general, and for public transit in particular."

TRANSIT VERSUS HIGHWAY SPENDING

"Within the broad category of transportation spending, the evidence indicates that public transit spending carries more of a potential to stimulate long run economic growth than does highway spending. In turn, the benefit to cost ratios for transit spending in any particular year exceed those for highway spending to a considerable degree."

A GENERAL CONCLUSION

"It is evident that transit spending carries over twice the potential to impact productivity as does highway spending."

Introduction

Transportation spending has always been a major catalyst in the long term development of the United States economy. The Erie Canal, the Federal Road, and the Interstate Highway are a merely a few of the transportation projects which have been of significant importance to the nation's economic expansion since Colonial times.

However, the past couple of decades has witnessed a decline in the number of new transportation projects to only a few a year. For example, since 1960 highway spending by state and local governments has slid from nearly 2 percent of gross national product to just over 1 percent of output. This trend is reflective of a broader slump in public investment in infrastructure, with spending on a *core* infrastructure (including not only surface and air transportation but also water and sewer systems and electrical and gas facilities) falling from around 4 percent of output to just over 2 percent.

While investment in surface transportation facilities has slumped, the demand for such facilities climbs unabated. For example, on the nation's highways, travel by occupants of passenger vehicles has risen from less than 600 million miles in 1960 to 1.4 million miles in 1988. During the same period, motor vehicle freight carriage has climbed at 4.5 percent annual rate, from 200 to nearly 700 billion ·on-miles.

Similarly, public transit passenger trips have risen from 7.3 billion in 1970 to 9.1 billion in 1989, a 25 percent increase. An undesirable result of this imbalance between the supply of and the demand for facilities is increased congestion in the transportation network. The General Accounting Office reports that "traffic congestion is an escalating transportation problem in this country. An increasing proportion of both rural and urban interstate highways are operating under crowded conditions." In California, the Chamber of Commerce estimated that in 1988 travel delays cost each motorist over $230 per year. The Texas Transportation Institute puts the 1988 cost of traffic congestion in urban areas above $400 per registered vehicle. The congestion is particularly acute in the Northeast, where the total congestion cost per registered vehicle is above $750. Indeed, there is valid concern that traffic gridlock is in our future and that severe economic repercussions will result unless additional resources flow toward transportation. In the words of Fred Barnes, Senior Editor of the ***New Republic***, the "truth is that congested highways and crowded airports, harmful enough now, will be economically ruinous if not corrected."

A number of factors have contributed to the reduction in public spending on transportation. A substantial rise in transfer payments--especially social security--since the mid-1960's has squeezed spending on goods and services by the public sector in general and transportation in particular. The cost of building new transportation facilities has risen at a quicker pace than the general price level and has induced a shift in government spending patterns away from that area.

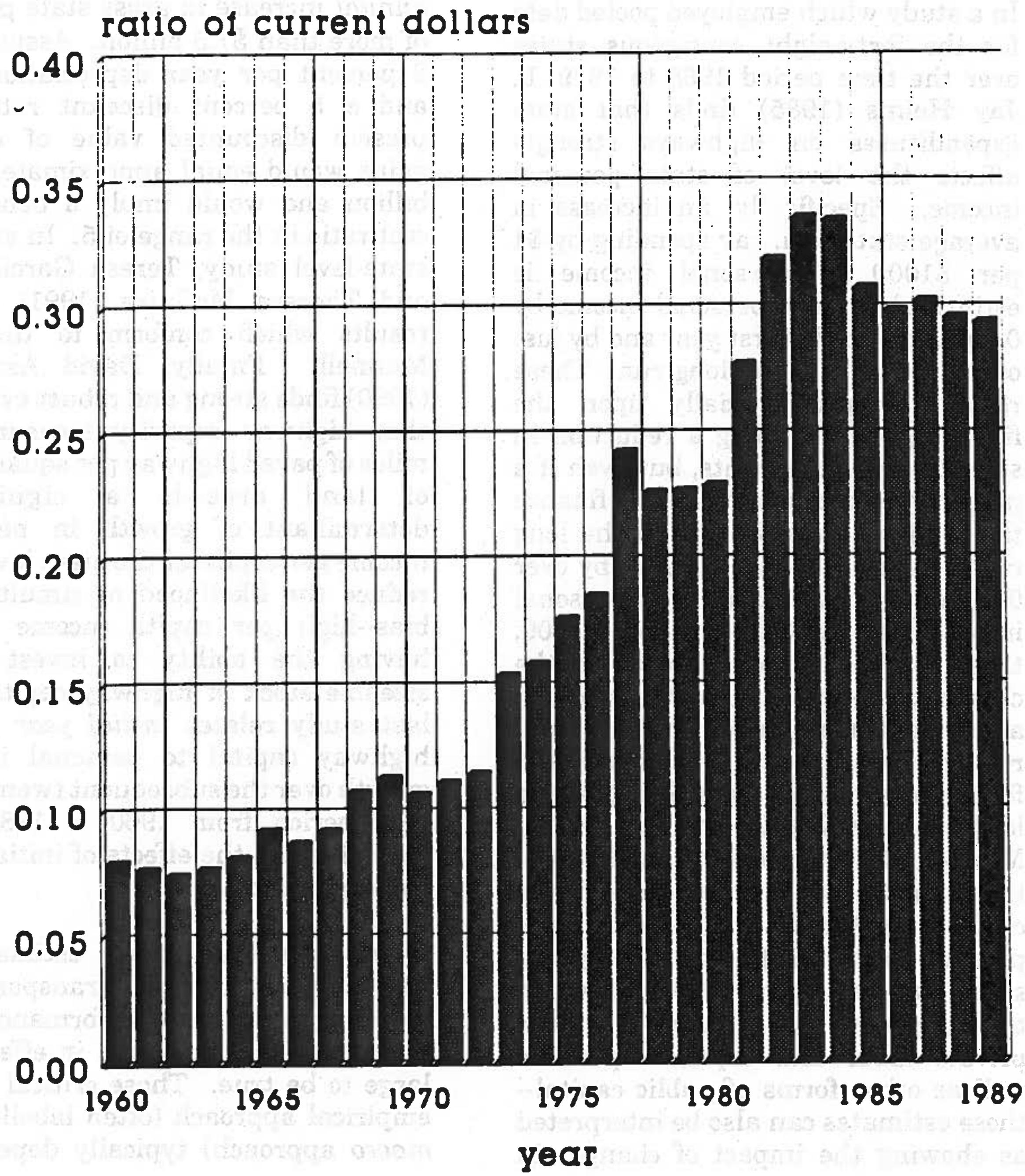
The conventional method of measuring the *economic feasibility* of a transportation facility involves a narrowly structured, partial equilibrium calculation of travel time savings, travel-generated revenue, and job creation (from input/output analysis) from a facility and comparing these benefits to the construction cost of the facility. Typically, benefit to cost ratios are developed to judge the feasibility of the facility. These traditional methods, *which tend to significantly underestimate the total economic value of transportation infrastructure*, can also be identified as a reason for the lack of commitment by federal and state governments to increased funding for transportation services.

This paper represents an extension of previous work which is intended to avoid the pitfalls and limitations of partial equilibrium cost-benefit analysis. As such, it seeks to answer the following specific questions:

> Is there a strong, positive relationship between transportation spending and economic growth?
>
> From a general equilibrium perspective, are the benefits to an increase in transportation spending sufficient to outweigh the cost?
>
> What are the *relative* impacts of public transit spending and highway spending on productivity and economic growth?
>
> Do the general benefits to transit and highway spending outweigh their respective costs?

The latter two questions are of clear importance, particularly when viewed in relation to the recent trend in expenditures on public transit versus highways. As illustrated in Figure 1, after rising throughout the 1960's and 1970's, the ratio of public transit to highway spending has declined from approximately 34 percent in 1983 to 29 percent in 1989. To a large extent, this reversal of spending patterns is due to a 50 percent real decline in federal transit spending over the last decade. Unfortunately, there is little systematic evidence to assess whether this is a positive development from the perspective of our long run economic growth prospects. A general objective of this study is to fill this gap in our knowledge about the economic role of transportation spending.

Figure 1:
Transit versus Highway Spending



Discussion of Related Work

There is considerable evidence that transportation spending has a positive impact on long run economic growth. In a study which employed pooled data for the forty-eight contiguous states over the time period 1965 to 1979, L. Jay Helms (1985) finds that state expenditures on highways strongly affects the level of state personal income. Specific 'ly, an increase in average state hig...ay spending by $1 per $1000 of personal income is estimated to raise personal income by 0.2 percent in the first year and by just over 2 percent in the long run. These results depend crucially upon the financing source being a reduction in state transfer payments, but even if a property tax increase is used to finance the highway expenditure, in the long run personal income increases by over 0.6 percent. Assuming that personal income per capita averaged $8000, these results mean that even in the case of property tax financed spending an increase in highway spending would raise personal income per capita by $48 for every $8 of expenditure--implying a long run *multiplier* of 6. Alicia Munnell (1990a) presents estimates of the impact of an increase in highway *capital* on the level of gross state product for the forty-eight contiguous states over the period 1969 to 1986. As the empirical specification includes private labor and capital inputs--as well as other forms of public capital--these estimates can also be interpreted as showing the impact of changes in highway capital on labor productivity. Viewed in this manner, the estimates show that a 1 percent increase in the stock of highways (approximately $5 billion in 1980) would generate an *annual* increase in gross state product of more than $1.5 billion. Assuming a 2 percent per year depreciation rate and a 5 percent discount rate, the present discounted value of output gains would equal approximately $25 billion and would imply a benefit to cost ratio in the range of 5. In another state-level study, Teresa Garcia-Mila and Therese McGuire (1991) obtain results which conform to those of Munnell. Finally, David Aschauer (1990) finds strong and robust evidence that highway capacity--measured as miles of paved highway per square mile of land area--is a significant determinant of growth in personal income per capita at the state level. To reduce the likelihood of simultaneity bias--high per capita income states having the ability to invest in a sizeable stock of highway capital--the last study relates *initial year* (1960) highway capital to personal income growth over the subsequent twenty-five year period from 1960 to 1985 and controlled for the effects of initial year per capita income.

These empirically based estimates of the importance of transportation spending to economic performance have been criticized for being, in effect, too large to be true. Those critical of the empirical approach (often labelled the *macro* approach) typically depend on the lower estimates of economic impacts of transportation spending found in traditional cost-benefit (or *micro*) approaches. For example, Dale Jorgenson (1991) asserts that "cost-benefit studies...show modest or even negative payoffs to this form [i.e., physical infrastructure] of public investment."

It is true that the estimates contained in the studies above often yield a measure of the rate of return to public capital in the range of 50 to 60 percent--significantly higher than that on private plant and equipment of 10 to 15 percent. While rates of return to public investment in the 50 percent range are high relative to many of those estimated by conventional cost-benefit techniques, there is the distinct possibility--indeed, likelihood--that this is due to deficiencies in cost benefit methods which tend to understate the true return to public capital investments. Such defects in cost-benefit analysis could include:

the inherent difficulties involved in attempting to capture general equilibrium effects in a partial equilibrium, cost-benefit framework. According to research undertaken under the auspices of the National Academy of Sciences by James F. Hickling, Inc. (1990), even the "most proficient use of Benefit-Cost analysis creates the risk that the sum of all infrastructure decisions taken according to the strict rules of net present value maximization will fail to achieve the level and mix of transportation investments that maximize productivity, national economic growth, and welfare." Indeed, the empirical studies cited above strongly suggest that the broader the geographical scope of analysis, the larger the impact of public investment--specifically, public investment in infrastructure raises productivity at the *national* level more than at the *state* level, and more at the *state* level than at the *local* level. Alicia Munnell (1991) comments that "the most obvious explanation" for this result is that "because of leakages, one cannot capture all the payoff to an infrastructure investment by looking at a small geographic area."

the use of an inappropriate discount rate for public projects. In actual practice, cost-benefit analysis is often performed with relatively high discount rates. The Office of Management and Budget, for instance, requires the use of a 10 percent discount rate for evaluating federal projects. At first blush, a 10 percent discount rate may not seem too high when compared to recently experienced Treasury bond yields. Yet 10 percent is a high discount rate because typically in the present value calculations future benefits are expressed in real, inflation adjusted terms. Thus, the discount rate is properly interpreted as a *real* discount rate, and real interest rates on Treasury securities average well below 5 percent.

the actual practice of project selection. In a large number of circumstances, rather than particular projects being evaluated individually and being funded if they pass the cost-benefit test, the managers responsible for choosing projects have to face a budget constraint and, consequently, have a limited amount of resources to allocate. This leads to the distinct possibility that a number of projects which would be justified on economic grounds are left unfunded. Also, it may well be the case that in order to pass political muster, particular infrastructure projects need to be *self-financing* in the long run and not require an increase in tax rates. This implies that the project would need to generate enough additional tax dollars through economic growth to service any amount of debt issued to fund the project. Meeting this requirement necessarily implies a rate of return to the public project significantly above that on private investments. For example, if the applicable tax rate were 25 percent, the rate of return to the project would need to be in the range of 40 to 60 percent to be self-financing.

These counter-arguments justify a continuation of statistical research into the economic importance of transportation spending. In the current study, we formulate and, using state-level data for the period 1977 to 1986, estimate a dynamic economic model linking growth in labor productivity (measured as gross state product per laborer) to the level of transportation spending. The model also includes other variables which arguably affect productivity growth, such as initial per capita productivity (or income), the industrial composition of the economy, and overall measures of government spending.

Methodology

The analysis is premised on two fundamental ideas which have found support in previous empirical research. The first idea is that the commitment of a particular jurisdiction to its transportation infrastructure positively affects the profitability of private capital and, as a result, over the long term attracts new investment in plant and equipment. Evidence supporting this claim can be found at the aggregate (national) level in research undertaken by David Aschauer [(1988), (1989b)], Kevin Deno (1988), Catherine Lynde (1991), and Alicia Munnell (1990b).

The second idea is that the attained level of labor productivity--output per worker--is directly related to the amount of capital available to workers. This follows in a straightforward way from the economists' notion of a *production function*, a technical expression linking labor and capital (factor inputs) to output of goods and services. An improvement in the stock of machinery and structures, given the labor force, enhances the ability of workers to produce commodities and, thereby, raises their productivity. As a direct corollary, the *growth rate* of productivity is directly related to the *growth rate* of the capital stock. This idea, fundamental as it is to the economists' theory of the firm, has found strong support in a variety of empirical studies such as those of William Baumol, Sue Anne Batey Blackman, and Edward Wolff (1989), Stephen Dowdrick and Duc-Tho Nguyen (1989), and Angus Maddison (1982).

Once estimated, the dynamic model can be used to simulate the impact of changes in transportation spending on the growth rate of the capital to labor ratio as well as the growth rate of labor productivity. These simulations assume:

a ***baseline*** of i) a constant level of output per worker over the thirty year period from 1990 to 2019 equal to an inflation-adjusted $34,813 and ii) growth in employment equal to 0.6 percent per year;

an ***enhanced spending*** case where transportation spending in general, and transit and highway spending in particular, are increased by $10 billion per year over the ten year period from 1990 to 1999--for a total of $100 billion. This represents an annual 17.3 percent increase in transportation spending from the 1989 level of just under $60 billion.

Research Findings

When interpreting the results of the empirical simulations to follow, it is important to remember that the results pertain to average values across all states' economies. For example, the finding that a rise in transportation spending induces a rise in productivity levels by $100 would represent a rise of that magnitude in the average level of output per worker across *all* states. Consequently, to determine the impact on national output it would be necessary to multiply the $100 by the national employment pool. If this pool were 120 million workers, the impact of the transportation spending would be to raise national output by $1.2 billion.

General Transportation Spending

The estimated impact of the enhanced level of transportation spending on average productivity levels over the thirty year period from 1990 to 2019 is illustrated in Figure 2. Relative to the baseline case, the initial effect is for productivity to rise at an increasing pace. By the year 1999 the level of productivity has risen by $399 dollars, or by 1.1 percent over the initial productivity level of $34,813. After the year 2000, when transportation spending is returned to the baseline level, the rate of annual productivity growth slows to some degree; for example, the increment to productivity equals $48 in the year 2009 versus $69 in the year 1999. Still, the dynamics of the model are such that productivity continues to rise through the year 2019, at which time the cumulative increase in productivity stands at $1,357. This represents a 3.9 percent increase in the level of productivity from its initial value.

Transportation spending has such substantial impacts on the long run level of productivity and output because of the relatively sluggish convvergence of annual productivity gains back to the baseline path. The structure of the dynamic model is such that transportation spending raises the pace of private capital accumulation which, in turn, raises the rate of productivity growth for a substantial period of time. Specifically, the number of years for the level of productivity to move halfway from its initial value, before an increase in transportation spending, to an ultimate, higher value--is about sixteen and one-half years (the half-life for productivity in the estimated model). This allows for significant productivity increases to persist, and cumulate, for a lengthy period of time.

The effect of the higher transportation spending on total output is obtained by multiplying the productivity impacts against the forecasted level of employment in future years. This calculation generates a stream of benefits which can be compared to the costs of the transportation program. In any particular year, the discounted value of these benefits is given by the formula:

$$DB_j = \frac{\Delta y_j}{[1+d]^j}$$

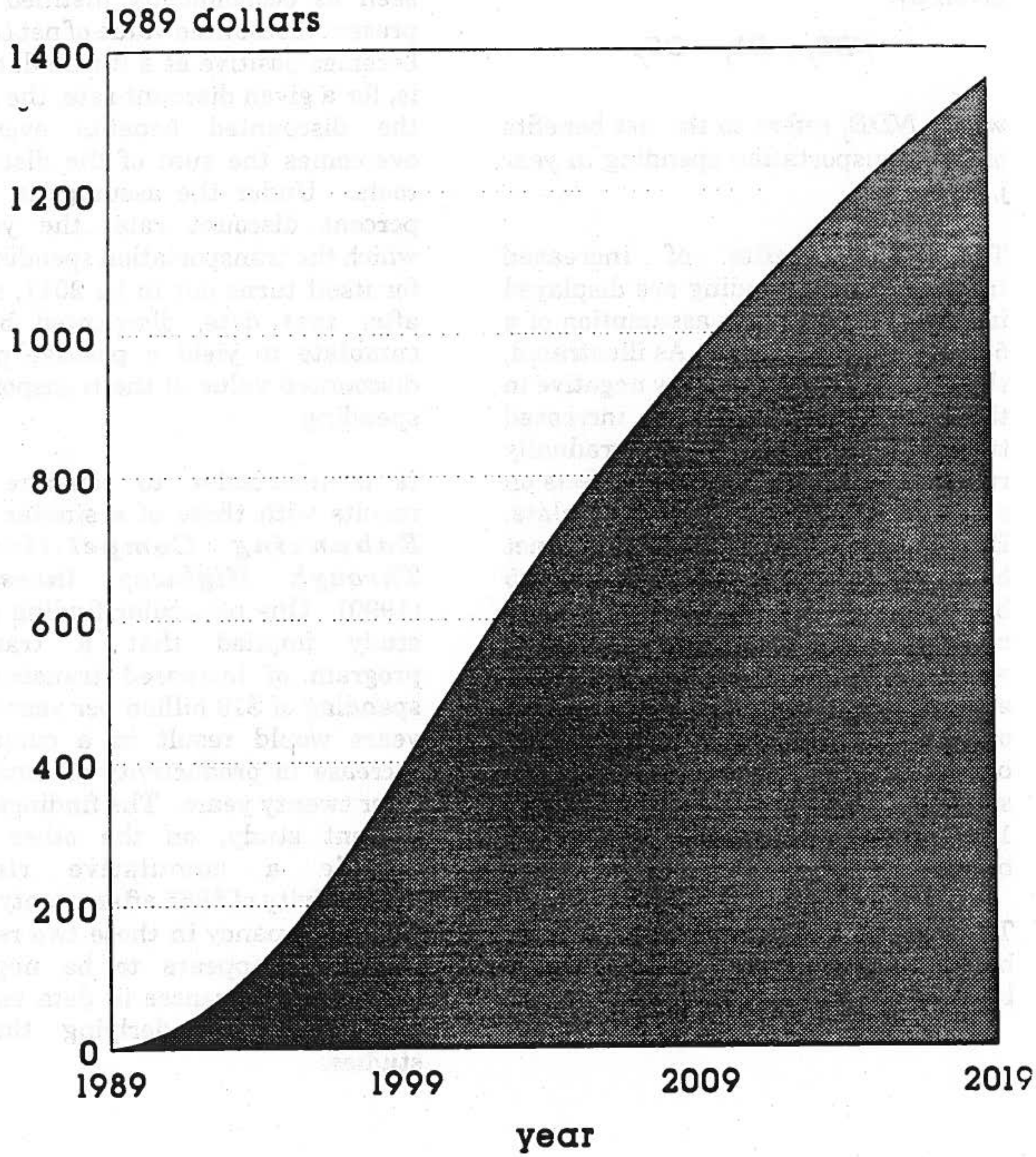
where DB_j refers to the discounted value of the benefits in a particular year (indexed by j), Δy_j refers to the increments to output in the same year, and d is a discount rate.

The discounted value of the costs of the increased transportation spending is obtained by the analogous formula:

$$DC_j = \frac{\Delta c_j}{[1+d]^j}$$

where DC_j refers to the discounted value of the increased transportation spending and Δc_j refers to the increments to the level of

Figure 2:
Transportation Spending and Productivity



transportation spending.

Finally, the *net* discounted value of the benefits of increased transportation expenditure in a given year j is then given by:

$$NDB_j = DB_j - DC_j$$

where NDB_j refers to the net benefits of the transportation spending in year j.

The net benefits of increased transportation spending are displayed in Figure 3 under the assumption of a 5 percent discount rate. As illustrated, the net benefits are sharply negative in the first few years of increased transportation spending, but gradually rise over time as the positive effects on economic growth begin to cumulate. By the year 2000, the annual net benefits become positive at about $5.5 billion, and only gradually decline as a result of the discounting process as well as the gradual convergence of the economy to an higher level of long run output. In the year 2019 the net benefits due to the transportation spending which occurred during the 1990's remains somewhat above $1 billion.

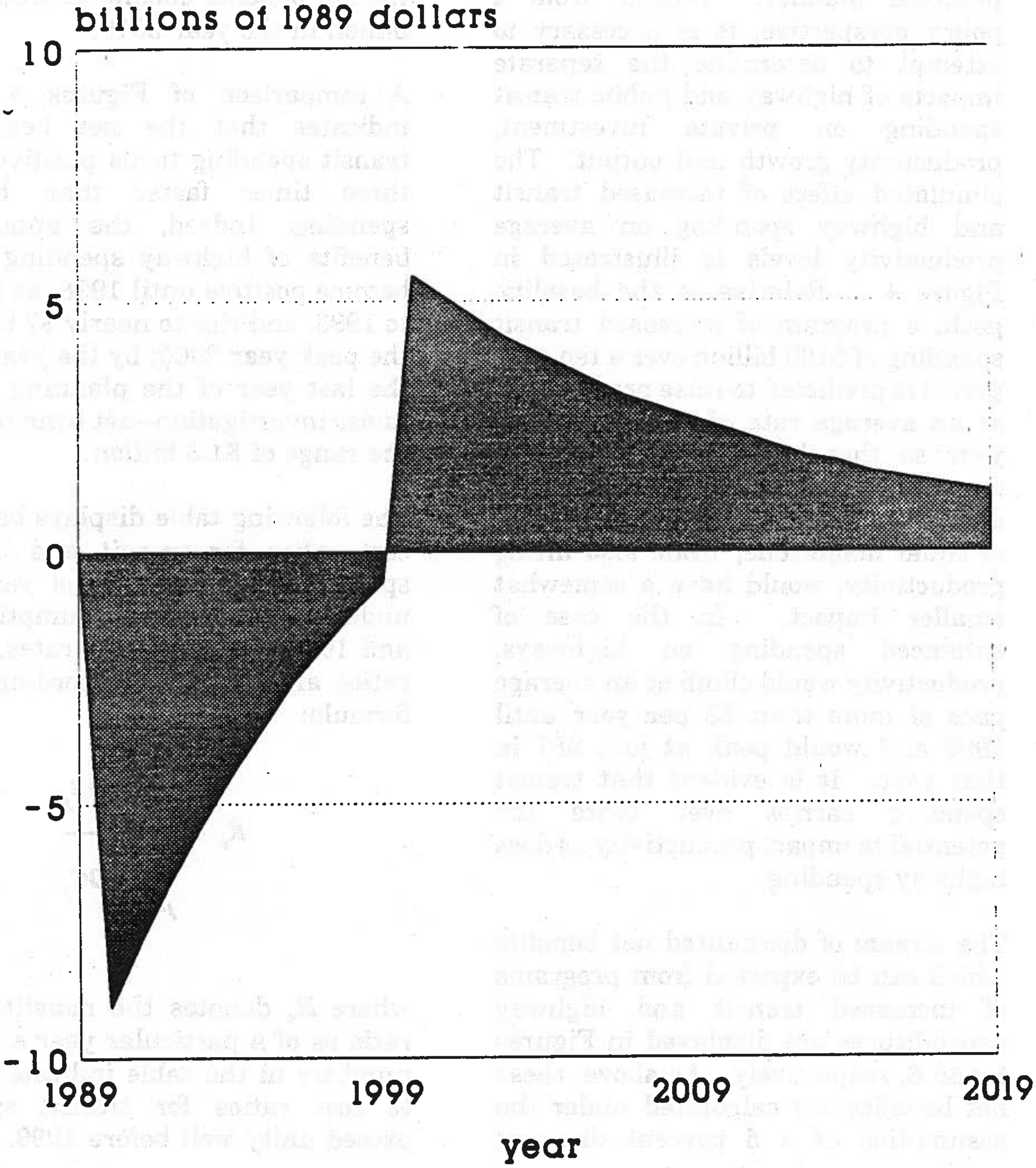
The present discounted value of net benefits as of any future year (indexed by s) is given by the expression:

$$PV_s = \sum_{j=1990}^{s} NDB_j$$

The transportation spending can be seen as economically justified if the present discounted value of net benefits becomes positive at a future date; that is, for a given discount rate, the sum of the discounted benefits eventually overcomes the sum of the discounted costs. Under the assumption of a 5 percent discount rate, the year in which the transportation spending pays for itself turns out to be 2011, so that after that date, discounted benefits cumulate to yield a positive present discounted value of the transportation spending.

It is instructive to compare these results with those of a similar study, ***Enhancing Competitiveness Through Highway Investment*** (1990). One particular finding of that study implied that a transitory program of increased transportation spending of $10 billion per year for ten years would result in a cumulative increase in productivity of some $920 after twenty years. The findings of the present study, on the other hand, include a cumulative rise in productivity of $965 after twenty years. The discrepancy in these two results--some $45--appears to be negligible given the differences in data sets and methodologies underlying the two studies.

Figure 3:
Net Benefits of Transportation Spending



Transit versus Highway Spending

The finding that additional transportation spending would be advantageous to economic growth may not be sufficient to guide policy in a practical manner. Indeed, from a policy perspective, it is necessary to attempt to determine the separate impacts of highway and public transit spending on private investment, productivity growth and output. The simulated effect of increased transit and highway spending on average productivity levels is illustrated in Figure 4. Relative to the baseline path, a program of increased transit spending of $100 billion over a ten year period is predicted to raise productivity at an average rate of about $18.50 a year so that by the year 2000 the annual increment to productivity peaks at $185. A highway spending program of equal magnitude, while also lifting productivity, would have a somewhat smaller impact. In the case of enhanced spending on highways, productivity would climb at an average pace of more than $8 per year until 1999 and would peak at just $87 in that year. It is evident that transit spending carries over twice the potential to impact productivity as does highway spending.

The stream of discounted net benefits which can be expected from programs of increased transit and highway expenditures are displayed in Figures 5 and 6, respectively. As above, these net benefits are calculated under the assumption of a 5 percent discount rate. The net benefits of transit spending are negative for three years, but swing positive and climb for the remainder of the 1990's. After peaking at about $15 billion in the year 2000, the net benefits decline to around $3.3 billion in the year 2019.

A comparison of Figures 5 and 6 indicates that the net benefits of transit spending turns positive nearly three times faster than highway spending. Indeed, the annual net benefits of highway spending do not become positive until 1998, as opposed to 1993, and rise to nearly $7 billion in the peak year 2000; by the year 2019--the last year of the planning horizon under investigation--net benefits are in the range of $1.5 billion.

The following table displays benefit to cost ratios for transit and highway spending for a number of years and under the alternative assumptions of 5 and 10 percent discount rates. These ratios are computed according to the formula:

$$R_s = \frac{\sum_{j=1990}^{s} DB_j}{\sum_{j=1990}^{s} DC_j}$$

where R_s denotes the benefit to cost ratio as of a particular year s. As the numbers in the table indicate, benefit to cost ratios for transit spending exceed unity well before 1999.

Figure 4:
Productivity Effects of Transit and Highway Spending

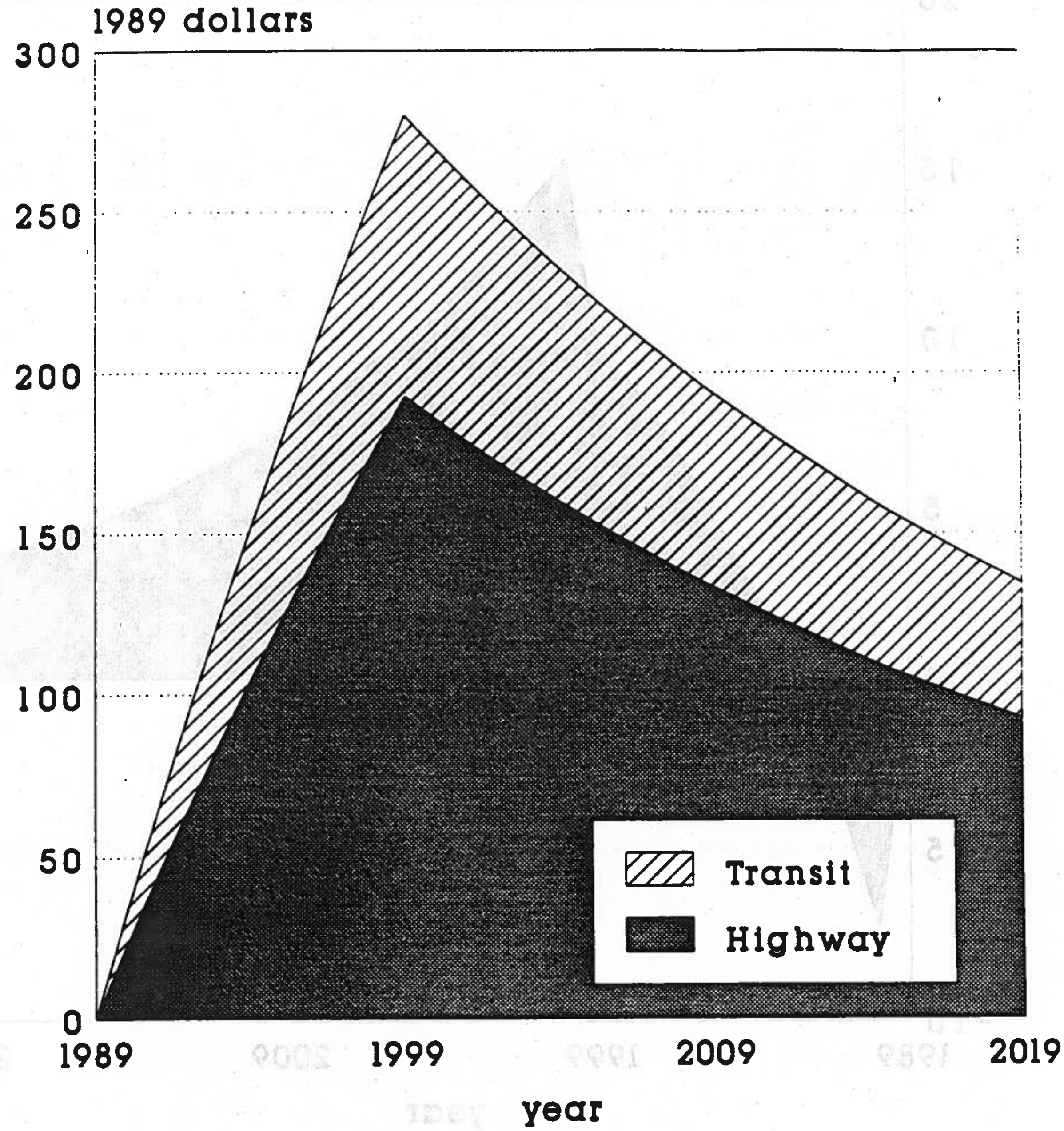


Figure 5:
Net Benefits of Transit Spending

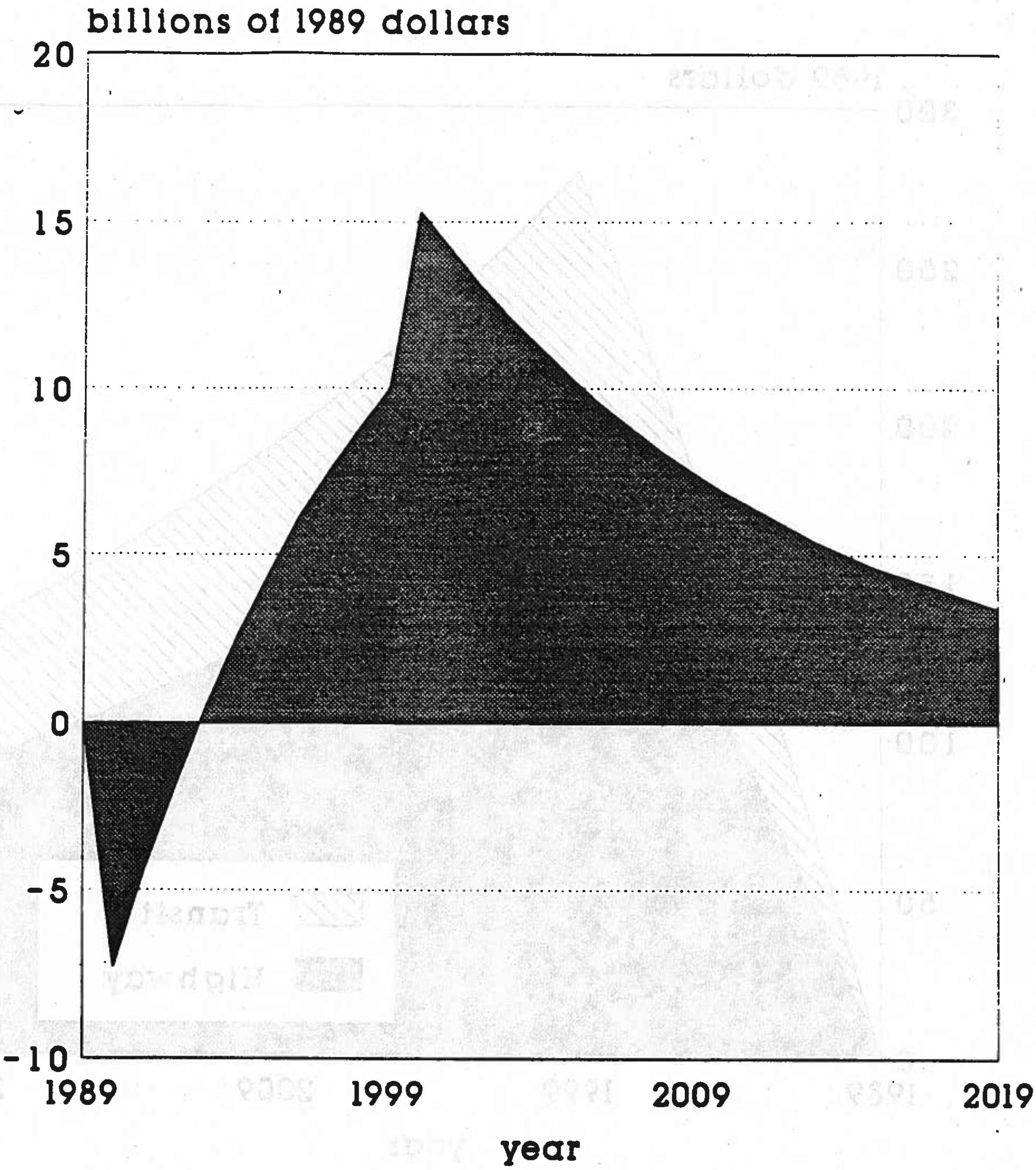
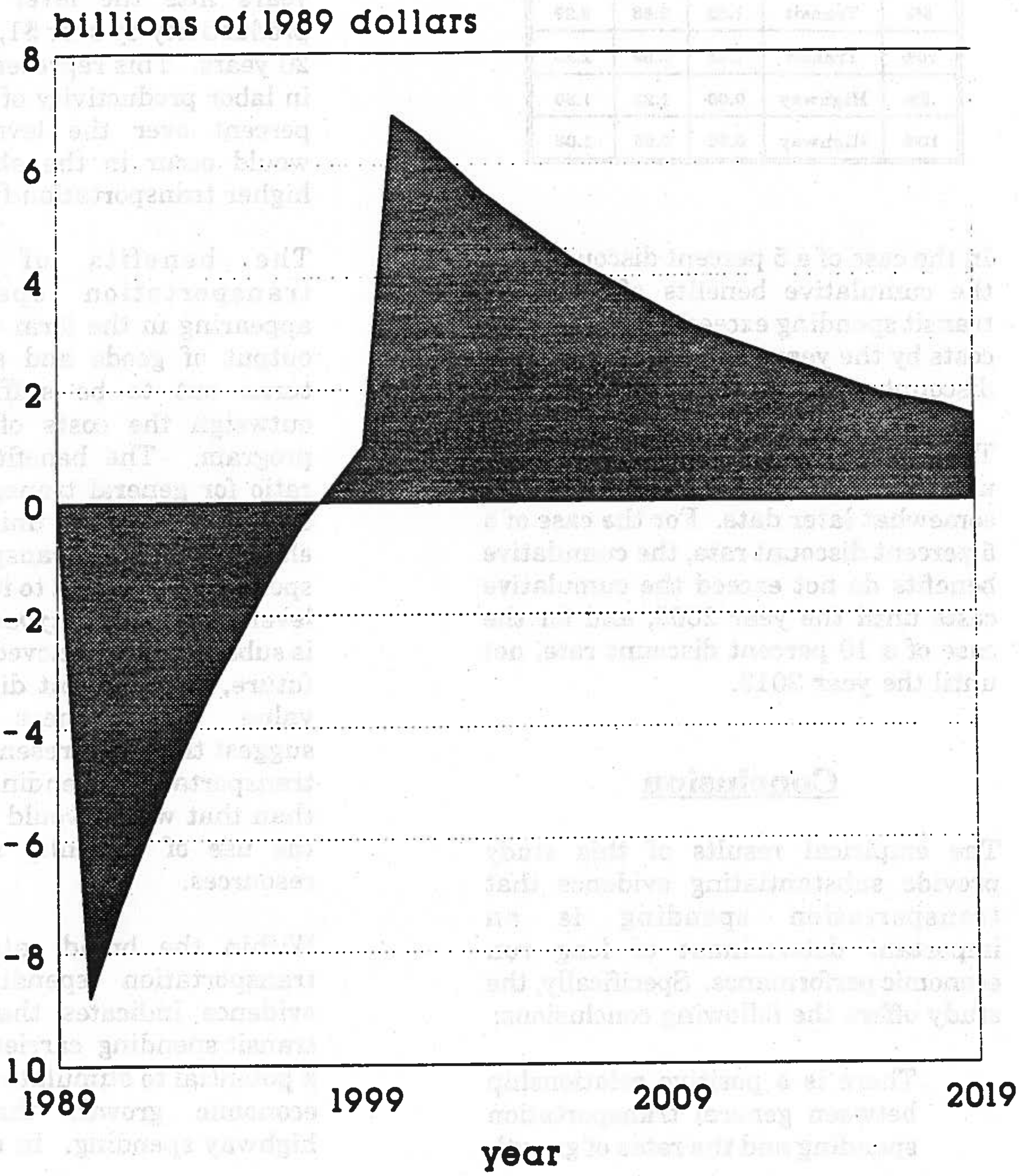


Figure 6:
Net Benefits of Highway Spending



Benefit to Cost Ratios				
		Year		
d	Mode	1999	2009	2019
5%	Transit	1.32	2.68	3.29
10%	Transit	1.23	2.09	2.33
5%	Highway	0.60	1.22	1.50
10%	Highway	0.56	0.95	1.06

In the case of a 5 percent discount rate, the cumulative benefits of increased transit spending exceed the cumulative costs by the year 1996; for a 10 percent discount rate, by the year 1997.

The benefit to cost ratios also exceed unity for highway spending, but at somewhat later date. For the case of a 5 percent discount rate, the cumulative benefits do not exceed the cumulative costs until the year 2005, and for the case of a 10 percent discount rate, not until the year 2013.

Conclusion

The empirical results of this study provide substantiating evidence that transportation spending is an important determinant of long run economic performance. Specifically, the study offers the following conclusions:

There is a positive relationship between general transportation spending and the rates of growth of private plant and machinery, the productivity of the workforce, and output. An increase in transportation spending of $10 billion for ten years lifts the level of labor productivity by over $1,300 after 20 years. This represents a rise in labor productivity of nearly 4 percent over the level which would occur in the absence of higher transportation funding.

The benefits of higher transportation spending--appearing in the form of higher output of goods and services--turns out to be sufficient to outweigh the costs of such a program. The benefit to cost ratio for general transportation spending exceeds unity some eleven years after transportation spending is reduced to its former level. While this *payback* period is substantially removed into the future, on a present discounted value basis, these results suggest that the present level of transportation spending is less than that which would optimize the use of currently available resources.

Within the broad category of transportation spending, the evidence indicates that public transit spending carries more of a potential to stimulate long run economic growth than does highway spending. In turn, the benefit to cost ratios for transit spending in any particular year exceed those for highway spending to a considerable degree.

There are valid reasons, however, for exercising caution in the use of these results for policy purposes. From a theoretical perspective, economists have only a rough notion of what factors are crucial to long run growth and of the speed of adjustment, or rate of convergence, of the economy after a shock to the growth process occurs. Hence, the results of this paper may be open to theoretical interpretations somewhat different than that presented here. From an econometric perspective, it is always possible that in the process of empirically implementing the model of this paper, one or more variables that also have important influences on private capital accumulation and long run economic performance have been omitted. Still, such an omission would only reduce the estimated importance of various types of transportation spending if there was a close *positive* association between the omitted variable and expenditures on transportation. The most likely such variable would appear to be other government spending--on education, water and sewers, and so forth--which we have been careful to introduce into the empirical model.

Irrespective of concerns over analytical procedures, it remains true that in the face of an aging population and slower growth in the labor force and employment, the maintenance of growth in living standards is going to become increasingly dependent on strong growth in the productive efficiency of the labor force. Indeed, merely to sustain growth in per capita incomes at the levels to which we have become accustomed in recent years will require growth in productivity well above the current rate of around 1 percent per year. One way to generate higher productivity growth is to provide an appropriate environment to foster private capital accumulation. The results of this study suggest that one way to provide such an environment is through increased funding for transportation, in general, and for public transit in particular.

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Technical Appendix

The model estimated in this study is an extension of earlier research undertaken by the author in Aschauer [(1988), (1990)]. The basic notion is that the rate of return to private capital within a particular area depends positively on the capacity of the infrastructure and transportation network. For example, Aschauer (1988) presents regression results which indicate a positive relationship between the nonmilitary public capital stock and gross and net rates of return to the stock of private capital equipment and structures. Analogously, Aschauer (1990) contains results which indirectly establish a positive relationship between highway capacity--measured as miles of paved road per square mile of land area--and the return to capital.

It is well established that investment in new plant and equipment depends positively on the return to capital. Thus, we posit that the growth rate in the private capital to labor ratio, Δk, depends positively on the capacity of the local transportation network as in

(1) $\Delta k = f(g; z_{\Delta k})$

where g = a measure of the capacity of the transportation network and $z_{\Delta k}$ refers to other influences on private investment rates.

It is also well accepted that the level of labor productivity depends on the amount of capital equipment and structures available per worker; a better stock of equipment and structures raises the productive efficiency of the typical worker. Further, it is the case that--across samples of individual states and nations--labor productivity levels tend to *converge* [see, for instance, Baumol, Blackman, and Wolff (1989), Dowdrick and Nguyen (1989), and Barro (1990)]. That is, over time countries which have a particularly low level of productivity (or per capita income) tend to *catch up* with countries with higher productivity levels. Following Dowdrick and Nguyen (1989), we postulate the production relationship

(2) $p_t = a + \phi t + \alpha k_t + \beta f_t$

where: p_t = the (natural) logarithm of the level of labor productivity in period t; a is a constant term; t = time; k_t = logarithm of the private capital stock in period t; and f_t = a productivity *catch up* function. The notion is that ϕ represents the rate of growth in labor productivity of the technologically superior economy; growth in f_t represents additional growth in other, technologically inferior economies. Converting this expression to period-by-period growth rates yields

(3) $\Delta p_t = \phi + \alpha \Delta k_t - \beta p_{t-1}$

where it is being assumed that the rate of growth of the *catch up* function is inversely related to the level of productivity attained in the previous period. For values of β lying in the interval (0,2), equation (3) represents a stable first-order difference equation. Solving this equation for the average period-by-period rate of growth of labor productivity between an initial period "0" and a final period "T" yields

$$(4)\quad \Delta p = z_p + \{\alpha[1-(1-\beta)^T]/\beta T\}\Delta k - \{[1-(1-\beta)^T]/T\}p_0.$$

Equations (1) and (4), representing a nonlinear (in parameters) dynamic model, are estimated jointly using Zellner's Seemingly Unrelated Regression (SUR) technique.

The estimation results are to be found in Tables TA.1 through TA.4 below. Three separate models are estimated: for total transportation spending, transit spending, and highway spending, respectively.

In Table TA.1, the effect of transportation spending on the growth rate of the private capital to labor ratio, θ, equals .166 and is highly statistically significant (T-ratio of 5.19). This estimate implies that a $10 billion increase in transportation spending spread across the forty-eight contiguous states would result in a $2.05 billion rise in the private capital stock in the same year.

The model of the third through sixth columns of Table TA.1 include a measure of the industrial composition of states' economies given by

$$z = \sum_{j=1}^{9} \eta_j \Delta y_j$$

where η_j is the share of total output in a particular state which is generated by sector j, Δy_j is the growth rate of output of sector j, and there are nine primary (single-digit SIC) industrial classifications. Thus, if total output in, say, mining grows at a particularly slow pace then z is particularly low for states heavily dependent on mining. An analogous variable has been found to be important to economic growth in previous studies [e.g., Barro and Sala-i-Martin (1990)]. The coefficient linking the sectoral composition variable, z, to productivity growth is labelled c in the table; as can be seen from the results, there is a strong, positive relationship between the sectoral composition variable and productivity growth.

Previous work [e.g., Kormendi and Meguire (1989)] has shown that government spending acts as a drag on economic growth for a broad sample of countries. The idea is that *unproductive* government spending must be matched (in the long run) by distorting taxes. These taxes, in turn, reduce the incentive to engage in market activities and dampen economic growth rates. Accordingly, the model of the last two columns include a measure of total government spending relative to total state output. This variable is defined to be inclusive of transfer payments but *exclusive of* transportation spending so as to separate out the role of transportation

Table TA.1: Transportation Spending and Productivity Growth

Dependent Variable: Growth in Output per Laborer

β	.031 (.009)	.032 (.009)	.035 (.008)	.035 (.009)	.042 (.009)	.042 (.009)
θ	.166 (.032)	.166 (.032)	.166 (.032)	.166 (.032)	.166 (.032)	.166 (.032)
α	.812 (.140)	.747 (.222)	.598 (.135)	.545 (.212)	.533 (.135)	.486 (.211)
c	—	—	.617 (.209)	.652 (.239)	.612 (.200)	.587 (.234)
γ	—	—	—	—	-.605 (.294)	-.593 (.316)
ne	—	.088 (.300)	—	-.022 (.279)	—	.067 (.273)
mw	—	-.178 (.173)	—	-.127 (.160)	—	-.070 (.157)
w	—	.084 (.206)	—	-.157 (.209)	—	-.021 (.214)
R^2	.452	.409	.487	.453	.523	.479
σ	.006	.006	.006	.006	.006	.006

Standard errors in parentheses. Model also contains constant terms.

spending from total spending. The coefficient connecting total government spending to productivity growth is labelled γ in the table. Evidently, there is a negative relationship between total government spending and economic growth, although the statistical significance of the relationship is weaker than for the other variables of the model.

The estimates of the convergence parameter, $\beta = .042$, and of the elasticity of output with respect to capital, $\alpha = .486$, in the last column of Table TA.1 imply that the contemporaneous rise in the private capital stock of over $2 billion would induce a rise in the level of output per worker of just over $8 and in the total level of output of $960 million in the same year. It is to be emphasized, however, that because of the slow rate of convergence of output to a new *steady state* the ultimate rise in output would equal some 28.1 times the initial rise in output, or some $27 billion.

These estimates of the convergence parameter, β, are close to those found by Barro and Sala-i-Martin (1990) for the United States as well as for a sample composed of 98 countries over the period 1950 to 1985. These authors point out that such sluggish rates of convergence to shocks is only compatible with the neoclassical growth model if capital is thought of in a broad sense to include human as well as physical capital. This is because a small capital-share coefficient (here, α) implies strong diminishing returns to capital and a more rapid rate of convergence. It is revealing that the present estimates of the elasticity of output with respect to capital--which, under competitive market assumptions would equal the share of total output accruing to capital--are much higher (e.g., $\alpha = .486$ to $.812$) than implied by standard calculations of capital's share (e.g., $\alpha = .30$).

Finally, as is clear from the second, fourth, and sixth columns of Table TA.1, it matters little whether or not regional dummy variables are included in the empirical specification of the model. This would suggest that other regional variables which may have been omitted from the model are not particularly important for explaining economic growth across states.

Results for the effect of transit spending on long run growth can be found in Table TA.2. The fundamental difference from the previous table is the estimate of the impact of public transit spending on the growth rate of the capital to labor ratio; the coefficient θ equals .384 (T-ratio = 4.3) which is well over twice the impact of general transportation spending. The other coefficient estimates are in close proximity to those in Table TA.1 and warrant the same conclusions as before.

Results for the effect of highway spending on long run growth, in turn, are contained in Table TA.3. In this instance, the fundamental difference

Table TA.2: Transit Spending and Productivity Growth

Dependent Variable: Growth in Output per Laborer

β	.032 (.009)	.032 (.009)	.036 (.008)	.035 (.008)	.042 (.009)	.041 (.009)
θ	.384 (.090)	.384 (.090)	.384 (.090)	.384 (.090)	.384 (.090)	.384 (.090)
α	.887 (.169)	.790 (.191)	.651 (.158)	.615 (.182)	.629 (.203)	.584 (.236)
c	—	—	.585 (.210)	.598 (.243)	.521 (.166)	.487 (.192)
γ	—	—	—	—	-.594 (.318)	-.580 (.344)
ne	—	.144 (.226)	—	-.023 (.200)	—	-.075 (.223)
mw	—	-.190 (.169)	—	-.136 (.160)	—	-.073 (.159)
w	—	.043 (.198)	—	-.153 (.201)	—	-.026 (.210)
R^2	.424	.404	.463	.439	.483	.448
σ	.006	.006	.006	.006	.006	.006

Standard errors in parentheses. Model also contains constant terms.

Table TA.3: Highway Spending and Productivity Growth

Dependent Variable: Growth in Output per Laborer

β	.029 (.007)	.028 (.007)	.033 (.007)	.029 (.007)	.042 (.009)	.041 (.009)
θ	.231 (.047)	.231 (.047)	.231 (.047)	.231 (.047)	.216 (.047)	.216 (.047)
α	.686 (.132)	.435 (.182)	.576 (.120)	.379 (.177)	.530 (.133)	.475 (.205)
c	—	—	.469 (.145)	.363 (.161)	.624 (.188)	.592 (.224)
γ	—	—	—	—	-.626 (.284)	-.599 (.311)
ne	—	.485 (.245)	—	.357 (.239)	—	.077 (.265)
mw	—	-.196 (.197)	—	-.168 (.166)	—	-.069 (.157)
w	—	.176 (.197)	—	.002 (.203)	—	-.226 (.217)
R^2	.381	.401	.396	.398	.503	.457
σ	.007	.006	.007	.006	.006	.006

Standard errors in parentheses. Model also contains constant terms.

with the previous results is that the coefficient showing the impact of highway spending on capital accumulation is much smaller than in Table TA.2, ranging between .216 (T-ratio = 4.6) and .231 (T-ratio = 4.9). By implication, benefit to cost ratios as reported in the main text are significantly smaller for highway spending than for transit spending.

The case in which the estimation model contains both transit spending and highway spending simultaneously could, of course, also be considered. A difficulty, however, is that these types of spending are themselves highly correlated which leads to multicollinearity in the estimated relationships between transportation, capital accumulation, and productivity growth. The expected result is high standard errors associated with the coefficients linking the two types of transportation spending to growth in the capital stock. It is still the case, however, that the coefficients values themselves are of the same order of magnitude as in Tables TA.1 and TA.2 and are statistically significant at the usual 5 percent level.

There remains the possibility that the relationship between transportation spending of various sorts and productivity growth may be the result of a *reverse causation*, with high productivity growth countries be able to afford a high level of transportation spending. This potential should be virtually eliminated by the presence of the initial level of productivity in the productivity growth expression (4) since the *level* of productivity (or per capita income) would be a better measure of *ability to pay* than the growth rate of productivity. Nevertheless, Table TA.4 reports instrumental variable estimates of the empirical model to further insure that the correlations are not mere evidence of a reverse causation. In the present case, a valid instrumental variable would be one which is highly correlated with the particular transportation spending variable yet not be caused by the rate of productivity growth. We follow Aschauer (1991) and posit that the ratio of total state and local debt to output as of end of the year 1976 qualifies as a valid instrument. The budget constraint of state and local governments would lead to the expectation that the amount of debt carried from the period before 1977 over to the period 1977 to 1986 will impact spending levels during the latter period--leading to a correlation with the transportation spending variables. While it might also be expected that *past* productivity growth would be a determinant of current debt levels, it is difficult to argue that *current* productivity is a determinant of *past* debt. In this sense, past the past debt ratio is a predetermined variable.

Scanning the results of Table TA.4 indicates that any bias that may have been introduced by a simultaneous relationship between productivity growth, capital accumulation, and transportation spending is such as to cause the estimates in Tables TA1.

Table TA.4: Transportation Spending and Productivity Growth
Instrumental Variables Estimates

	Total			Transit			Highways		
$\breve{\beta}$	.030 (.007)	.033 (.007)	.044 (.009)	.030 (.007)	.033 (.007)	.044 (.009)	.030 (.007)	.033 (.007)	.044 (.009)
θ	.192 (.067)	.192 (.067)	.175 (.069)	.486 (.169)	.486 (.169)	.443 (.174)	.325 (.113)	.325 (.113)	.296 (.117)
α	.843 (.222)	.684 (.189)	.718 (.229)	.843 (.222)	.684 (.189)	.718 (.229)	.843 (.222)	.684 (.189)	.718 (.229)
c	___	.448 (.144)	.571 (.183)	___	.448 (.144)	.571 (.183)	___	.448 (.144)	.571 (.183)
γ	___	___	-.695 (.278)	___	___	-.695 (.278)	___	___	-.695 (.278)
R^2	.301	.331	.461	.301	.331	.461	.301	.331	.461
σ	.007	.007	.006	.007	.007	.006	.007	.007	.006

Standard errors in parentheses. Model also contains constant terms.

through TA.3 to *understate* the importance of transportation spending to productivity growth. Indeed, the estimates of the primary effect of transportation spending on capital accumulation, represented by θ, are some 10 to 30 percent higher in Table TA.4 than in the previous tables. This implies that benefit to cost ratios as reported in the text may underestimated to a similar degree.