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Productive Highway Capital Stocks and the Contribution of Highways to Growth[1]

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Introduction

This research represents the next step in advancing our understanding of the contribution of highways to economic growth. In a previous research, Fraumeni constructed improved measures of highway capital stock (Fraumeni, 1999). As a result of this research and a paper by Beemiller (1999), the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce revised its highway lifetimes substantially downward from 60 to 45 years (Fraumeni & Bennet, 1999) as part of its 1999 comprehensive revision of the national accounts.[2] This change had a small, but measurable, affect on the official measure of Gross Domestic Product (GDP), which BEA produces.[3] The Fraumeni highway capital stock estimates are also publicly available for use in economic research and policy analysis.

The current research has four objectives directly related to measures of productive highway capital stock. First, it updates and extends the productive capital stock measures. Second, it addresses two important questions related to the stock measures: Have the parameters underlying the estimates changed significantly in the most recent period and what is the value-added of the Fraumeni measures compared to the BEA measures? The pavement curves are the focus of the parameter question. As BEA modified its asset lifetime measures during its 1999 comprehensive revision of the national accounts, perhaps the BEA stock estimates suffice? Third, it examines in a pilot study whether the highway structure stocks could be improved with growth rates from a quality-adjusted bridge measure. Fourth, it has the goal of making updating the productive stock measures a routine matter, producing detailed "cookbooks" that document how to update the research source files. Each of these objectives contributes to the value of the overall research.

The entirely new element in this research is the measurement of the contribution of highways to economic growth. From the perspective of national income accounting, there are three types of contribution: 1) The contribution of highway investment (capital outlays) to growth in GDP, 2) The contribution of highway capital input to growth in adjusted GDP, and 3) The contribution of highway gross output to growth in adjusted U.S. gross output. The data effort moves beyond productive capital stocks to assess the contribution of highways to economic growth; measures of capital input (which require rates of return), highway "industry" gross output, and U.S. gross output are needed. These contribution estimates provide a different perspective on the importance of highways for economic growth from those produced using different methodologies, which commonly employ econometric techniques.[4]

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[2] In this paper, the term "highways" refers to both highways and other public streets. The Bureau of Economic Analysis refers specifically to highways and streets.

[3] The increase in consumption of fixed capital, a component of GDP, was less than 1% of total U.S. consumption of fixed capital (Fraumeni and Bennet, 1999).

[4] For an example of estimates produced using an econometric model, see Nadiri and Mamaneus (1996).

The study reaches three conclusions using several different national income accounting measures:

- The rate of growth of highways is below the rate of growth of Gross Domestic Product (GDP),
- The nominal share of highways in (adjusted) GDP and (adjusted) U.S. gross output is small, and
- The contribution of highways to growth in (adjusted) GDP and adjusted U.S. gross output is small.

The last conclusion follows from the first two conclusions. National income accounting measures do not include spillovers, multiplier effects, or the use of highways by other than business or the government. Accordingly, the contribution estimates produced in the research are small compared to many alternative estimates. However, they can be directly compared to Bureau of Economic Analysis (BEA) contribution estimates.

This is the first time the contribution of highways to economic growth has been estimated using this method. In a report released in January of 1999 Fraumeni estimated productive highway capital stocks from 1929-1995.[5] The current study presents revised and updated the productive highway capital stocks through 2005 and estimates the contribution of highways to economic growth.

The study presents two conclusions about the revised and updated productive highway capital stocks:

- The pavement curve parameters have not changed significantly in recent years, and
- The Fraumeni productive capital stock estimates are preferred to those of BEA because the detailed break-outs capture the changing composition of highways outlays.

An experimental bridge stock is estimated. It results in a small, although significant, difference in the rate of growth of the productive highway structure capital stock.

Besides this paper, two volumes describe the research.[6]

[5] Fraumeni, January1999.

[6] Fraumeni, Volume I and Volume II, October 2007. Volume II is a "cookbook" which describes in detail how the stock and contribution estimates are constructed. A five page summary of Volume I is available at http://www.fhwa.dot.gov/policy/otps/phcsmsumm08.htm .

Productive Highway Capital Stock Estimates

The productive highway capital stocks measure potential productive capacity. There is no stock utilization adjustment except in construction of pavement curves. (Utilization and other factors might affect the rate of return to the stock.)

The starting point for the construction of productive highway capital stocks is the collection of capital outlay. Total capital outlay data by system: Interstate, Non-interstate State, and Local, is collected from various tables in Highway Statistics (HS).[7] These outlays are outlays by any level of government on the specific system, e.g., the Local outlay total includes outlays on Local roads by Federal, State, and Local governments. Non-interstate State capital outlays are derived from the HS tables by subtracting Interstate from State capital outlays. These totals excluding not classified by system are then further subdivided into ROW (right-of-way) vs. non-ROW (pavement plus grading plus structures) capital outlays. Next, non-ROW capital outlays are divided into capital outlays for new construction or reconstruction vs. Other than new construction or reconstruction. Finally, the categories new construction or reconstruction and Other than new construction or reconstruction are further split into capital outlays for pavement, grading, and structures. The result is 21 possible capital outlay categories at the most detailed level as the following table below shows. The split of outlays differs year-by-year reflecting changes in how capital outlays are spent.

[7] Highway Statistics is online at http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.htm . System categorization is defined by who administers the road.

Disaggregation of Total Capital Outlay Classified by System				
Total, Excluding Not Classified by System	Interstate	ROW	ROW	ROW
		Non-ROW	New Construction or Reconstruction	Pavement
				Grading
				Structures
			Other Than New Construction or Reconstruction	Pavement
				Grading
				Structures
	Non-interstate State	ROW	ROW	ROW
		Non-ROW	New Construction or Reconstruction	Pavement
				Grading
				Structures
			Other Than New Construction or Reconstruction	Pavement
				Grading
				Structures
	Local	ROW	ROW	ROW
		Non-ROW	New Construction or Reconstruction	Pavement
				Grading
				Structures
			Other Than New Construction or Reconstruction	Pavement
				Grading
				Structures

The system capital outlay data is taken directly from HS, but other disaggregations require percentage splits to be estimated. ROW outlays are available for some years for Interstates and the Non-interstate State System.[8] For recent years ROW is estimated via a simple regression model that predicts the percentage that ROW outlay is of total capital outlay. For Non-interstate State, the average percentage that ROW is of Non-interstate State for 1956-1969 is held constant over the earlier years. For Local, the data on outlay for ROW is outlay on Local roads by Local governments only. Accordingly, the ROW outlay by any level of government on Local roads is determined as a function of the average percentage that local outlay for Local ROW is of outlay by any level of government for Local ROW.

A capital outlay split between outlays for new construction or reconstruction and outlays for Other than new construction or reconstruction is needed in all cases except in the case of the Interstate System prior to 1977. Reasonably it was assumed that all capital outlay for the Interstate System prior to 1977 was for new construction or reconstruction as these were the years of the construction of the Interstate System, and no other data was available to assume otherwise.[9] Obligation and center-line highway mileage data from HS by type is used in combination with percentages for pavement and grading from the 1997 Cost Allocation Study to obtain outlay by system type for pavements and grading. Type includes categories such as new route, relocation, reconstruction, major and minor widening, restoration & rehabilitation, and resurfacing. In the research summarized in the January 1999 report, it was assumed that all post-1976 Interstate capital expenditures were for Other than construction or reconstruction. The evidence from HS data is that this is not true, so this assumption is dropped in the current research. The percentage that bridge outlay is of pavement plus grading plus structures outlay is derived in a separate worksheet based on obligations.[10] The percentage that grading is of pavement plus grading outlays and the percentage that bridges are of pavement plus grading plus structures outlay are used in combination to develop all the percentages needed. The derivation of the 21 percentages for the outlay categories shown in the preceding table, excluding that for ROW, is complicated.

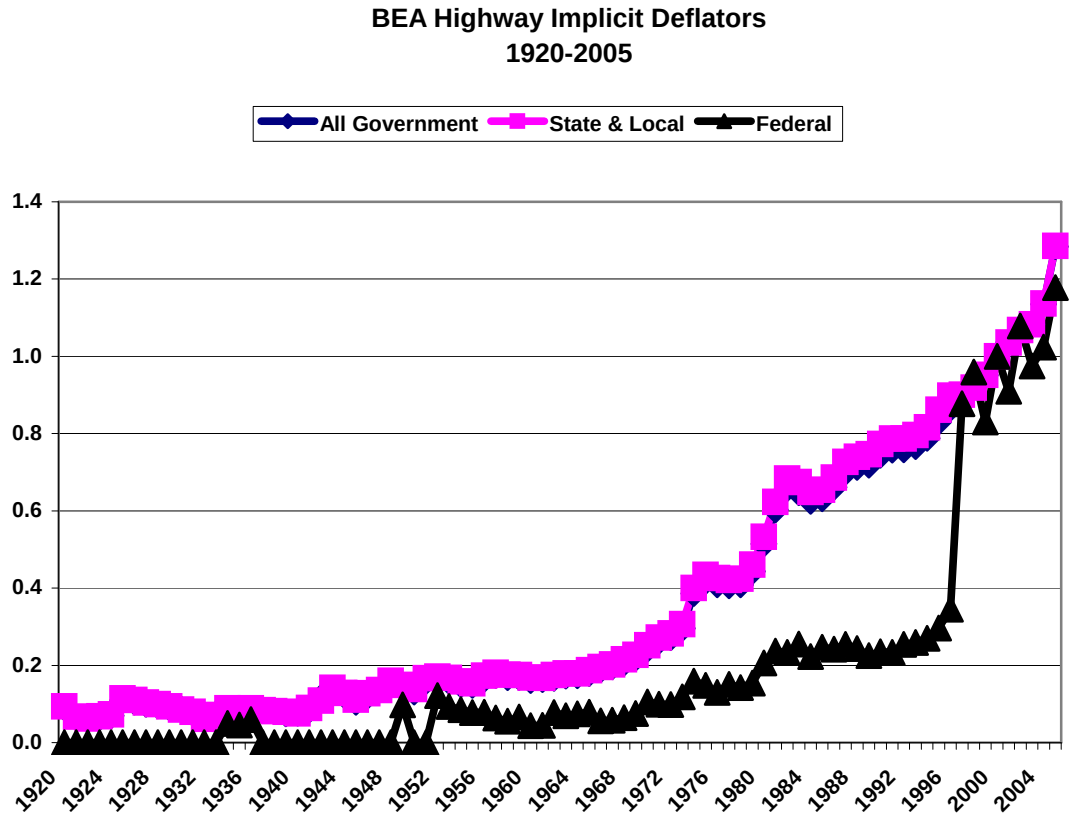
Deflators used throughout this research are derived from BEA data on highway investment. The implicit deflator is derived by dividing BEA historical cost investment by the chained quantity index for highways and streets. Deflators are derived for all government, Federal, and State and Local. Since the research that was reported in the January 1999 volume, BEA changed the number of significant digits it reports for historical cost investment. Historical cost investment has one significant digit to the right of the decimal; the chained quantity index has three significant digits to the right of the decimal. At times the historical cost investment is zero and the chained quantity index is a positive number, so the implicit deflator is zero. Other times, small changes create

[8] The data for 1981-2 is not used, as it is frequently suspect. In general, 1981-2 HS data is not used in any research calculations.

[9] Some roads are transferred into the Interstate System from the State System in the form of capital stocks in the early years of the construction of the Interstate System.

[10] It assumed that all structures are bridges in the percentage split estimates even though some clearly are not.

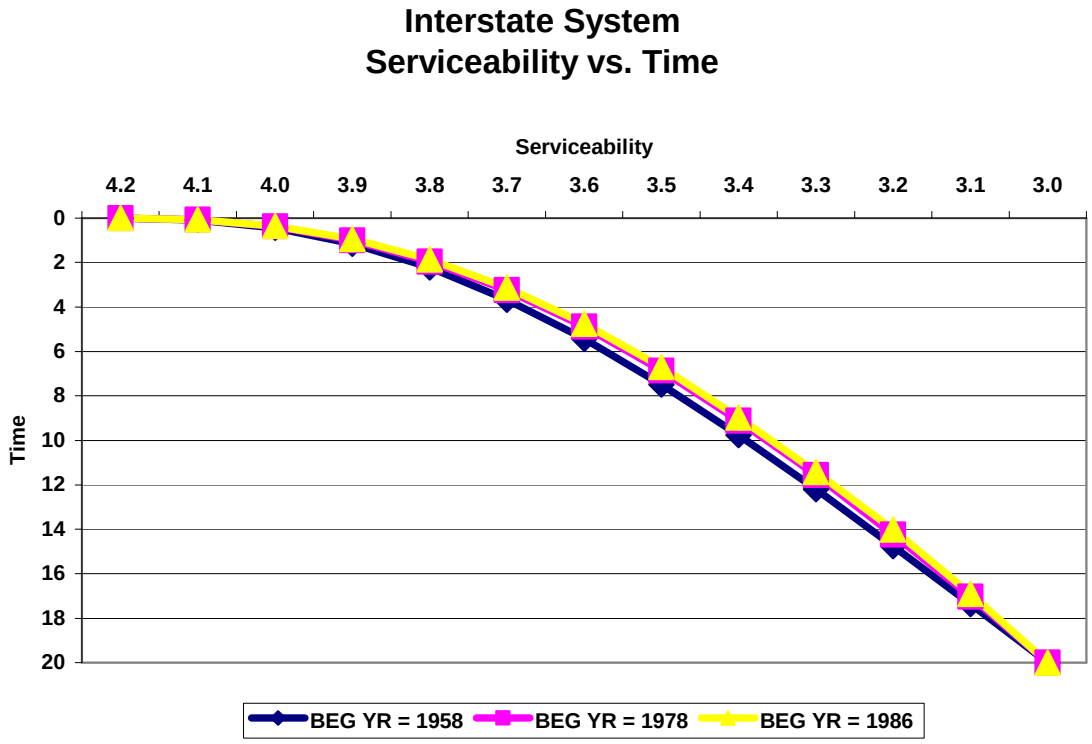
unusual movements in the implicit deflator. The graph below shows the implicit deflators. Previously all three implicit deflators were very similar as the all government and State and Local implicit deflator still are. Accordingly, the decision was made to use the all government deflator for Interstates.

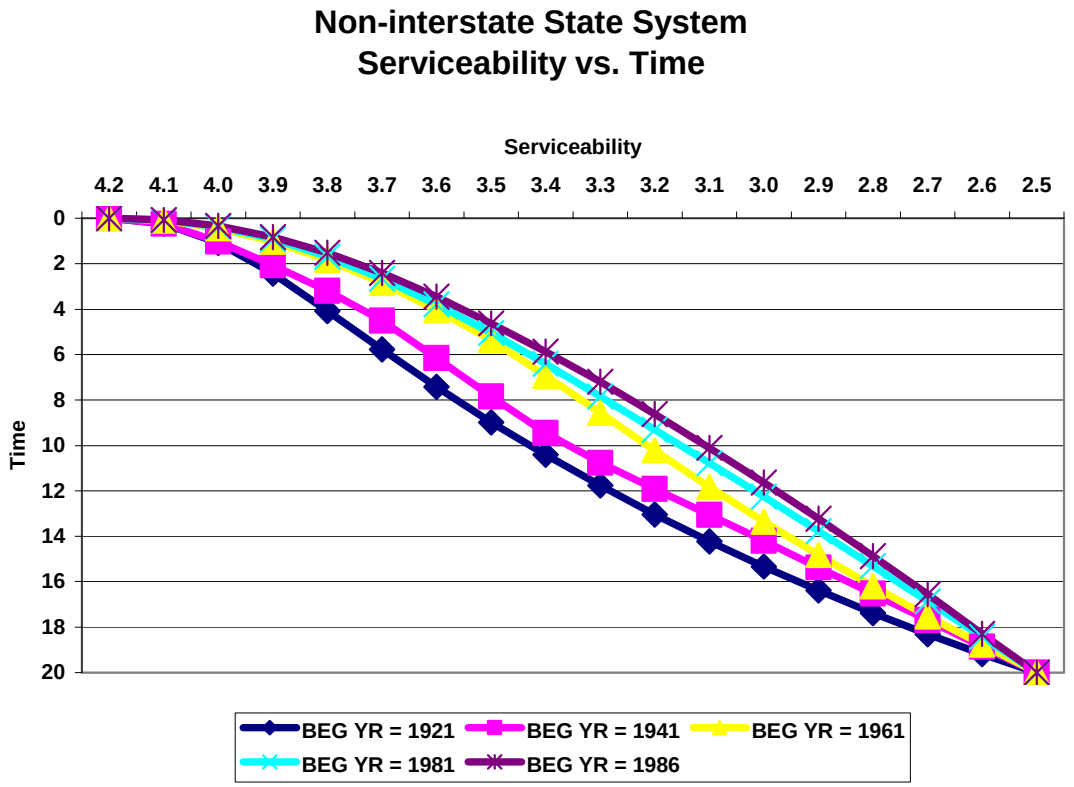


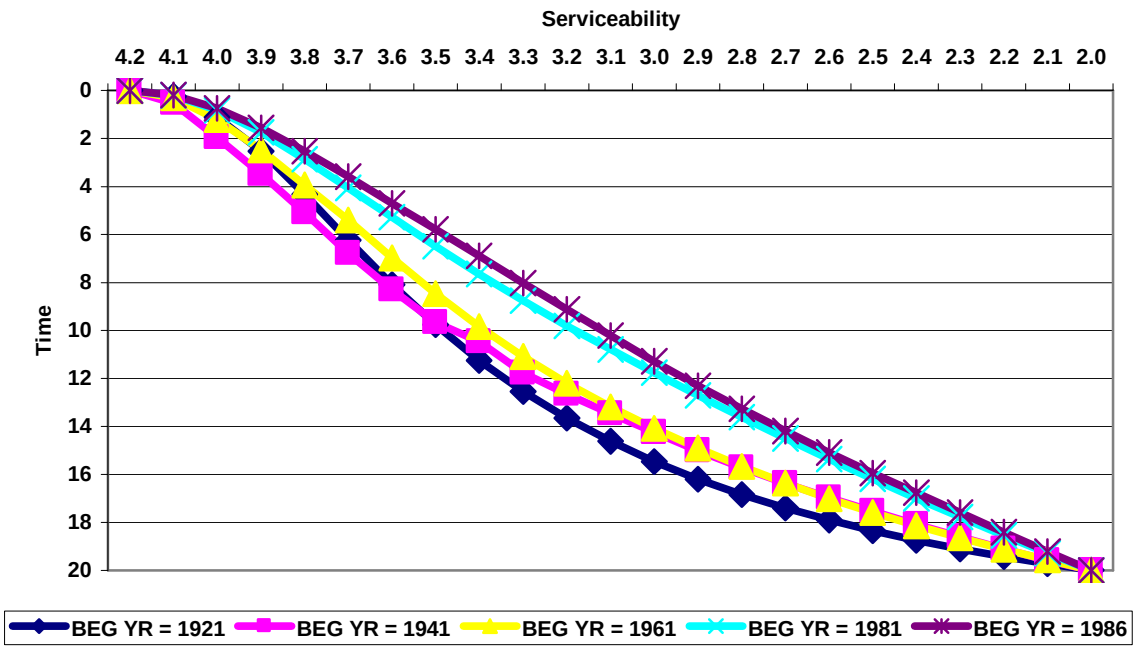
Net efficiency pavement curves, constructed from pavement curves, measure how productive pavements could be.[11] The estimation of net efficiency curves begins with the construction of a pavement serviceability – time relationship based on the intensity and type of traffic, and the road system: Interstate, Non-Interstate State, or Local System. Pavement serviceability determines the pavement condition. All systems pavement begins at the same serviceability level (4.2), but is allowed to deteriorate to a lower level depending on the system.[12] At the end of the 20-year design life, the Present Serviceability Index (PSI) is assumed to be 3.0 for the Interstate System, 2.5 for the Non-Interstate System, and 2.0 for the Local System. Serviceability curves for the Interstate System are constructed for years beginning in 1958, 1978, and 1986; for the Non-interstate and Local Systems for 1921, 1941, 1961, 1981, and 1986. The curvature of the Interstate System curves are convex throughout; the curvature switches from convex to concave in the early years in two of the Non-interstate State System curves, and in all of the Local System curves. For all systems, there is very little difference between the

[11] Gedeon Picher, a civil engineer, constructed the pavement curves.
[12] A PSI of 4.2 is the starting point for all curves as 4.2 is the average quality of a new asphalt road.

curves beginning in 1978 or 1981 and those beginning in 1986. The following graphs show the serviceability vs. time curves for each of the three systems.

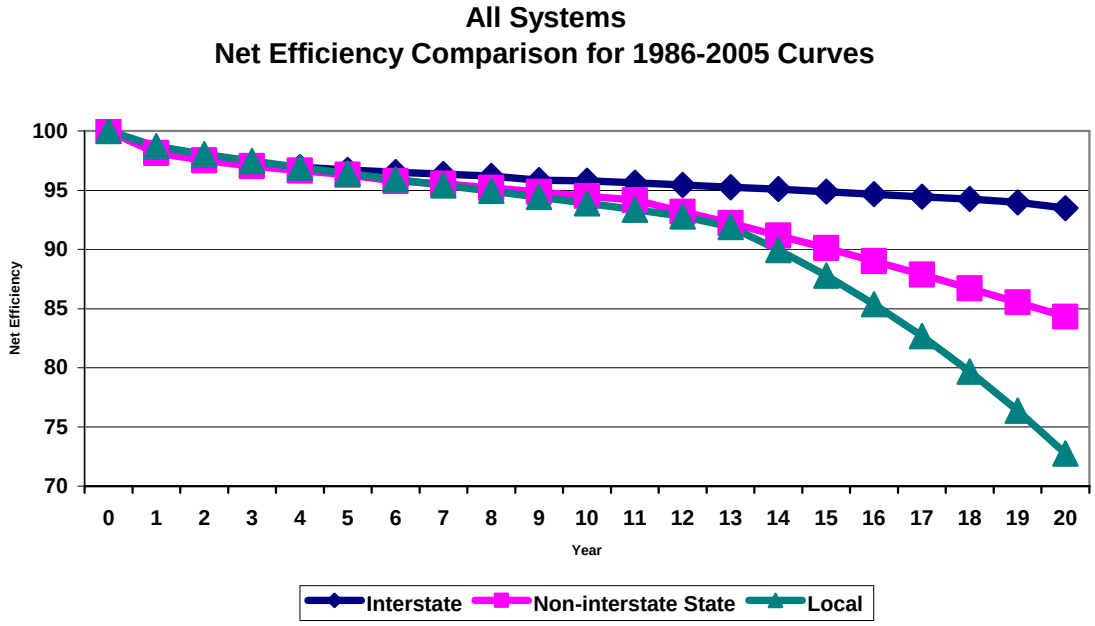






Net efficiency, which is the basis for productive capacity, is reduced if pavement conditions reduce speed or increase motor vehicle operating cost.[13] Pavement net efficiency on average never gets below 93% for the Interstate System curves; 84% for the Non-interstate System curves; and 72% for the Local System curves. The following graph shows the 1986-2005 net efficiency curves by system.

[13] Information on relative time costs, the maximum speed for given pavement conditions, and motor vehicle operating cost come from Jack Faucett Associates, 1991.



The research constructed productive highway capital stocks with a perpetual inventory method. State and Local Systems have a 1921 benchmark. Interstates have a 1958 benchmark from highways transferred from the State System. ROW has an infinite life; therefore zero depreciation. Pavement has a design life of 20 years and depreciation from the net efficiency curves. Grading has an 80-year life and one-hoss-shay depreciation. Structures have a life of 50 years and a geometric depreciation rate of 1.82 percent. (The structure assumptions are the BEA's assumptions for government non-defense, non-industrial buildings.)

Information on all rated bridges from the 1983, 1996, and 2006 National Bridge Inventory (NBI) is used to construct an experimental quality-adjusted bridge stock.[14] This stock is equal to the summation across all bridges of their length times the number of lanes times the inventory rating (IR).[15] The following table shows that from 1983 to 2006, the average size of an inventory rated bridge has increased, whether measured by average length or average number of lanes. In 1986 about 4 percent of bridges were not rated, by 1996 this percentage dropped to only 2 percent and remained constant in 2006.

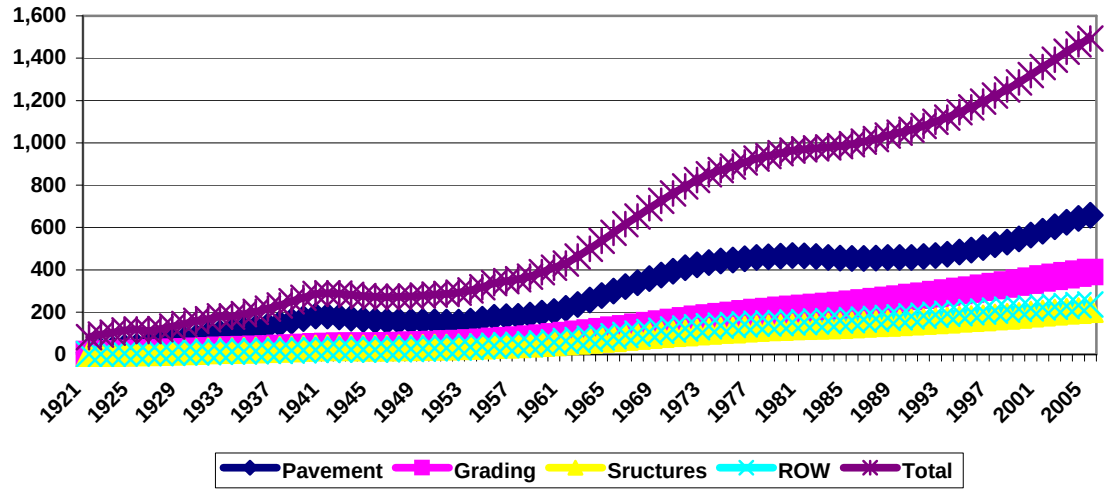
[14] Marc Hitchcock provided research assistance on this component of the research.
[15] There are between 464,000 and 472,000 rated bridges in each of the included years. The National Bridge Inventory coding text describes inventory rating as "The capacity rating, for which the vehicle type used in the rating, will result in a load level which can safely utilize an existing structure for an indefinite period of time." See U.S. Department of Transportation, FHWA (January 1979) p. 31.

Bridge Statistics				
		1983	**1996**	**2006**
Number	ALL	488,486	474,300	474,272
Number	IR Rated	471,916	464,464	465,980
Average Length in feet	IR Rated	136	156	168
Average Number of Lanes	IR Rated	1.9	2.1	2.2

Under the simplifying assumption that all highway structures are bridges, implementation of the quality-adjusted experimental bridge would increase the annual rate of growth of the highway structure series by about four-tenths of a percentage point from 1983-1996 and by about two-tenths of a percentage point from 1996-2006.[16]

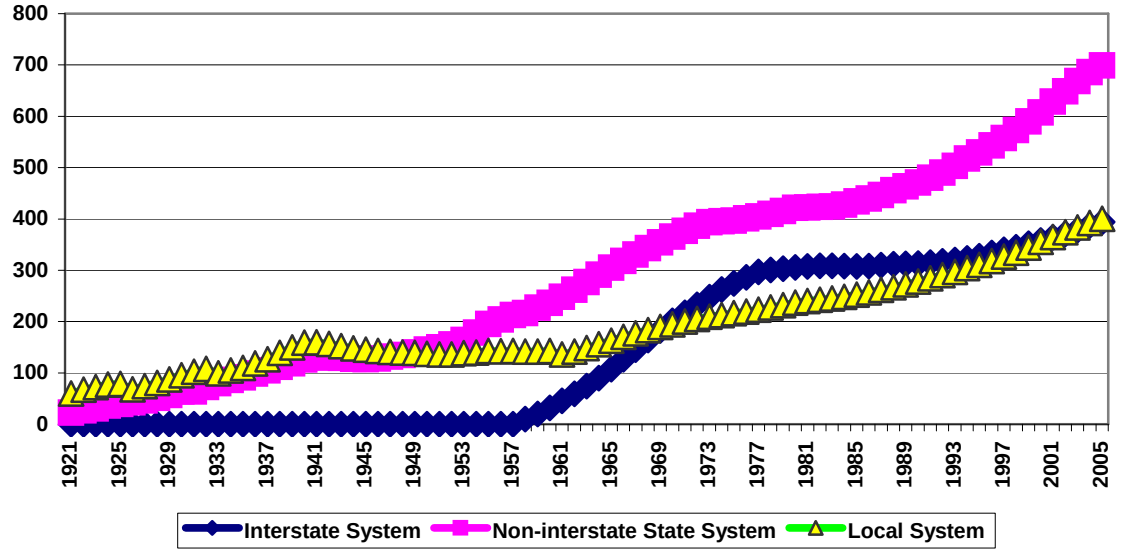
The graphs below show in 2000$s the total productive capital stock and the productive capital stock by two different subaggregates: The first by pavement, grading, structures, and ROW and the second by Interstate, Non-interstate State, and Local Systems.[17] The total capital stock is shown on the pavement, grading, structures, and ROW graph as it makes evident that most of the nonlinear variation in the total series comes from the pavement series. By 2005, in 2000 dollars the total stock is close to $1.5 trillion.
The path of the Interstate System line clearly shows the construction of the system in the fifties, sixties, and into the seventies. Note that the size of the Local System productive capital stock is now approximately equal to that for the Interstate System, in fact it is slightly larger.

Total Productive Capital Stock & Pavement, Grading, Structures, & ROW
Productive Capital Stock
Billions of 2000$s
1921-2005



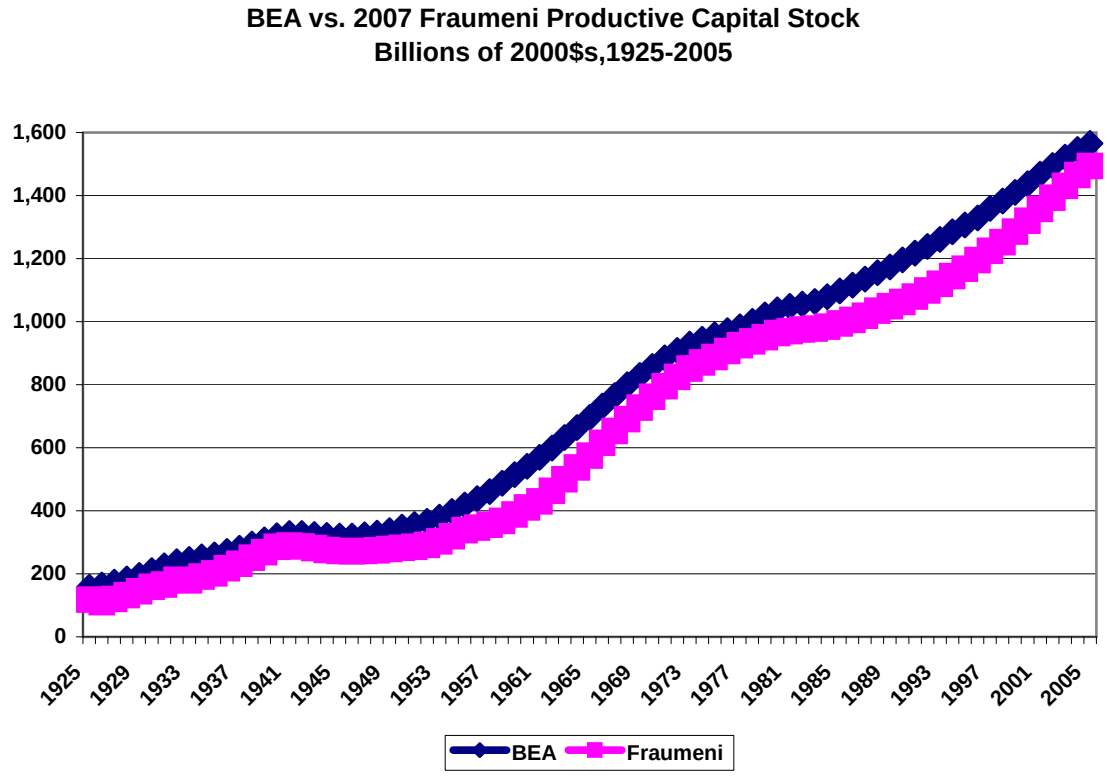
[16] The difference for the latter period is an approximation as the base case highway structure series ends in 2005.
[17] The final stock numbers did not incorporate the experimental bridge index.

Productive Capital Stocks
Interstate, Non-interstate State & Local Systems
Billions of 2000$s
1921-2005



There is a perceptible difference between the BEA and the 2007 Fraumeni estimates of productive capital stocks in the following graph. Although it is only somewhat apparent from the graph because of its scale, the differences relate to annual rates of growth as well as to the level of the stock. Although the average absolute value difference in the rates of growth diminish substantially after 1939 from over 3.5 percentage points to something in the about 1.0 to 1.5 percentage point range in the forties, fifties, and sixties, before trending downwards to about .5 of a percentage point, these average absolute value differences all are significant.[18] The implicit BEA and Fraumeni price deflators are also significantly different.

[18] The comparisons were done in absolute value terms because the raw annual differences frequently were different in sign.



To get a sense of what causes the differences, the BEA series is scaled in two different ways. First, the BEA series is scaled to the Fraumeni value in 2000 (nominal=2000$s in that year). This reduces the differences by about one-third. Second, the BEA series is scaled to the Fraumeni 2000$ value in 1925. This reduces the differences by much less, by about one-twelfth. The conclusion is that the differences are primarily not a function of differences in the 1925 benchmark/starting point, rather a function of differences in the component series underlying the Fraumeni estimates and use of the BEA all Government deflator, both directly and through differences in the share of capital outlay using a State and Local deflator versus a Federal or an all Government deflator.

Note that the Fraumeni stock is lower than the BEA stock even though Fraumeni capital outlay is higher than the BEA investment. BEA highway and street investment is deteriorated at a constant rate. Fraumeni capital outlay is deteriorated at a varying rate which depends upon the composition of the capital outlay. The rate depends upon the distribution of outlays among the Interstate, Non-interstate State, or Local Systems, which have varying percentages of ROW, pavement, grading and structures by new construction or reconstruction or Other than new construction or reconstruction for all but ROW.[19] Accordingly, it is not surprising that differences remain between the two series even though an attempt was made to bring the Fraumeni and the BEA series into closer alignment.[20]

[19] See the "Disaggregation of Total Capital Outlay Classified by System" table much earlier in this volume.
[20] The rate of deterioration of the BEA stock was reduced by 15 percentage points after the publication of the 1999 Fraumeni estimates. See Fraumeni and Bennet, 1999.

The value of the Fraumeni estimates is two-fold: They reflect changes in patterns of allocation of capital outlays and they allow analysts to use multiple component series which underlie the aggregate estimates.

Contributions

The research estimates three types of contributions:

- Contribution of highway capital outlays to GDP growth (1929-2005)
- Contribution of highway capital input to adjusted GDP growth (1929-2005), and
- Contribution of highway gross output to adjusted U.S. gross output growth (1958-2005).

Each of these contributions is an approximate contribution. The first looks at contribution from a product perspective. For the typical type of investment, it is the economic activity of making a capital good.[21] Only recently have intangibles such as software, and soon R&D, been recognized. For a market good, the typical case is that a piece of machinery is manufactured or a building is constructed, which is in turn bought by someone who intends to use it, say a business. The maker most often is not the buyer.[22] That capital asset is then most often used by a business to produce something else, e.g., an oil well is used to drill for oil. When the buyer uses it, the attention shifts to the asset as an input and to the income side of the GDP accounts. On the income side of the GDP accounts it is capital and labor input that underlie capital and labor income. In producing a good or service, a business, for example, also uses materials, energy, and services that are collectively labeled intermediate inputs. Accordingly, there are two foci of contribution analysis on the income side: That which encompasses GDP (only capital and labor inputs) and that which encompasses gross output (capital, labor, and intermediate inputs). Each of these contribution perspectives is valuable, but they are different and look at a different aspect of economic growth.

Approximate contributions in this research are estimated as a weighted rate of growth. [23] The weights are nominal shares of:

- Highway capital outlays in GDP
- Highway capital input in adjusted GDP or
- Highway gross output in adjusted U.S. gross output.

The rates of growth are rates of growth of 2000 dollars for:

- Highway capital outlays
- Highway capital stock or
- Highway gross output.

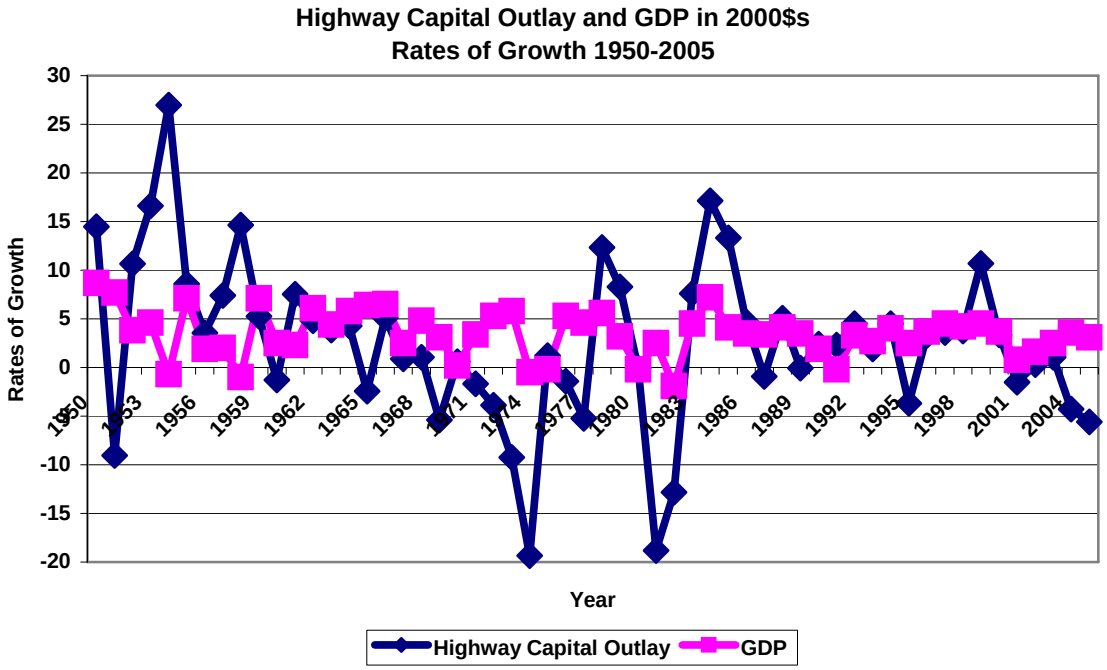
The first listed weight is multiplied times the first listed rate of growth to produce the first listed contribution; the second listed for the second, and so forth. In the majority of years, the weights and the rates of growth are small; accordingly the contributions are small.

[21] Major durable additions or changes to an existing capital asset are also counted as investment; accordingly both new construction or reconstruction and Other than new construction or reconstruction are part of capital outlays.

[22] R&D is a notable exception the majority of R&D is performed by the funder of the R&D. There is no "buyer" in the normal sense.

[23] Differences between the highway approximate contributions and the official BEA contributions estimates derived from a Fisher index are probably small. Differences would be significant for certain products such as computers whose price trends depart from that of other GDP components.

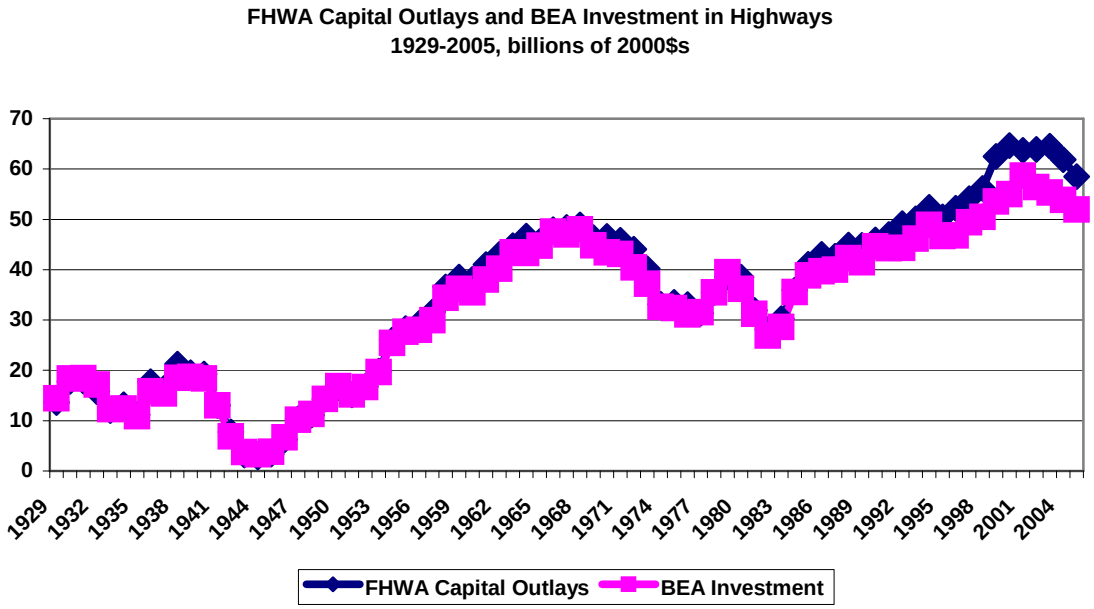
Highway capital outlays in 2000 dollars are highly variable and their rate of growth is less than the rate of growth of GDP. The following graph begins in 1950 as in some earlier years the rate of growth of highways capital outlays are almost 70 percent and –90 percent, swings that hide more normal variations.



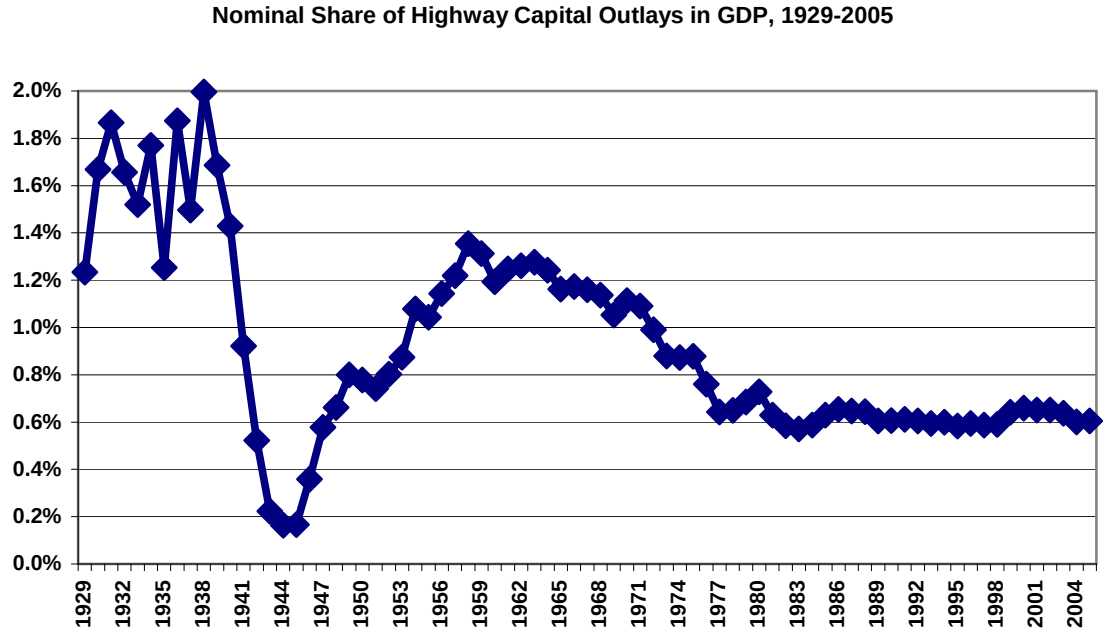
Over the period shown the average annual rate of growth of highways capital (2000 dollars) outlays is 2.5 percent and the annual rate of growth of GDP is 3.5 percent.

The official BEA series for investment in highways does differ from the capital outlays series produced from FHWA data by Fraumeni as the following graph shows. However, the differences are small until the mid-eighties. The Fraumeni FHWA capital outlays are larger than the BEA investment series during the latter period. Accordingly, if anything the Fraumeni series will slightly overstate the contribution of highway capital outlays to GDP growth as the shares of GDP will be slightly larger. In all periods, both series follow very similar trends so that the rates of growth will be a negligible, if at all, source of any differences.[24]

[24] The Fraumeni capital outlays do not include outlays not classified by system as these could not be classified into expenditures for ROW, pavement, grading, or structures. Capital outlays not classified by system are small compared to total capital outlays.



The following graph shows that the nominal share of highway capital outlays in GDP, the other component of the contribution calculation, has never exceeded 2%. It varies as a result of the wars, the Great Depression, and the building of the Interstate System before settling down into the .6% range beginning in 1981.



The conclusion is that from the perspective of the economic activity that it takes to produce highways (the "machine"), the contribution of highways to economic growth is very small. The contribution has varied significantly across the decades, never reached the level of a tenth of one-percent except during the building of the Interstate System, but almost made it during the thirties when public works projects were used to help being the

economy out of the Great Depression. Over the longer term, the average contribution has been a scant .03% (1930-2005) or .02% (1950-2005).

The focus of the contribution analysis now shifts from the "capital part" of the economic activity that occurs when a highway is built, reconstructed, improved, and so forth to the use of highways in production. Here the shift begins with a change in focus from the outlays to the total highway capital stock, which can be thought of as the entire system. The highway system (the stock) provides services to the economy, which are called capital input or capital services. The household sector is not conceived as a producer when GDP is constructed except in the case of owner-occupied housing.[25] Accordingly the focus of this chapter's analysis relates to business', nonprofit's or government's use of highways.

There are three major components to capital input: the stock, the net return to the stock, and depreciation of the stock.[26] Depreciation is estimated when highway capital stock is estimated; therefore the most important unmeasured component of capital input is the net return. The equation for nominal highway capital input is:

$\text{Capital input}_{year} = \text{Net return}_{year} + \text{Depreciation}_{year} = \text{Gross return to the capital stock.}$

In this research, the depreciation rate is variable as it depends upon the composition of highway capital outlay, e.g., new construction vs. reconstruction or Other than new construction or reconstruction, which leads to estimates for ROW, pavement, grading, and structures. Accordingly, depreciation is estimated as a total nominal dollar value as opposed to a (geometric) rate of deprecation. However, the nominal net return is estimated by multiplying a net own rate of return by the nominal capital stock:

$\text{Capital input}_{year} = \text{Net return}_{year} + \text{Depreciation}_{year} = \text{Gross return to the capital stock.}$

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$\text{Net return}_{year} = \text{Net own rate of return}_{year} * \text{Capital stock}_{year-1},$

[25] In the case of owner-occupied residential housing, housing services are treated as coming from a fictitious owner-occupied residential housing sector. However, this does not occur for other types of household activity. Accordingly if an individual's labor (time) is substituted for a banking employees labor when ATM's are installed, economic activity can in fact decrease. Individuals' convenience or time saved or lost does not enter into GDP except in that these factors may impact on price or the total quantity of goods sold.

[26] Depreciation is the term used in reference to capital input; deterioration is the term used in reference to capital stock. Under certain circumstances, depreciation is equal to deterioration. In this research, it is assumed that this equivalence can be made.

where the term "own" refers to the fact that the rate of asset capital gain has already been subtracted from the net rate of return.[27] The important question becomes: What is the appropriate net own rate of return to apply to highway capital stocks?

It makes sense to look to BEA for the answer to this question to maintain consistency with a national income accounting approach, with one important qualification. BEA currently assumes when estimating GDP that government assets earn a zero net rate of return. The return to government assets is set equal to depreciation. Although it was proposed in the currently ongoing international revision of the System of National Accounts (SNA) that this be changed, this proposal failed.[28] However, in the official BEA/National Science Foundation (NSF) R&D Satellite Account which was released in 2006, government funded R&D is assumed to earn a positive net return; in the previous experimental performer-based version, government performed R&D is assumed to earn a positive net return as well.[29] The position that all government assets earn a zero rate of return seems unrealistic; this is certainly true in the case of highways, which are predominantly government assets.

When it is assumed that a government asset, e.g., highways, earn a positive net return, GDP (and U.S. gross output) must be increased by the amount of the net return. This is done in this research to ensure consistency between the components of GDP (sectoral gross output) and GDP (U.S. gross output) itself.

The official BEA/NSF R&D satellite account report directly or indirectly indicates the computed net own rate of return to private and the aggregate of nonprofit and government assets. The report states that the net rate of return on R&D assets is 15 percent, which is "approximately four percentage points higher than the average rate of return to all private assets."[30] The text goes on to say in a footnote that the net rate of return on government assets is assumed to be lower that the net rate of return on R&D financed by government or nonprofits by the ratio of the corresponding all private assets net return to the private R&D assets return. Tables 1.5 and 3.3 of the BEA/NSF report are used to determine the all private and all government plus nonprofits R&D asset net rate of return and to mimic the unpublished BEA calculations.[31] Accordingly the net return to private assets is set to 11 percent and the net return to government assets is set to 4.4 percent.[32]

The BEA methodology for estimating the net rate of return is summarized in a recent article by Lally et.al. (2007). The net return to domestic nonfinancial business assets, using an endogenous approach, is calculated as the ratio of net operating surplus to produced assets (capital stock). Net operating surplus, which is a SNA term approximating capital income, is the sum of corporate profits, net interest, and business transfer payments. It is reasonable to assume that the net return to all private assets

[27] Capital input is equal to the net return plus depreciation minus asset capital gain.
[28] See the 1993 SNA (Commission of the European Communities, et. al. 1993) for the current practice.
[29] See Okubo et. al., 2006 and Fraumeni and Okubo, 2005.
[30] Okubo, et. al., 2006, p. 33.
[31] See the appendix of Okubo et. al., 2006, p. 10 and 17. This appendix is available at http://www.bea.gov/newsreleases/general/rd/2006/pdf/rdreport_append.pdf .
[32] Fraumeni also discussed her calculations with Brian Sliker of BEA to confirm her general methodology.

referred to in the BEA/NSF R&D satellite article was calculated in a similar manner, with capital gains on assets subtracted to derive an own return.

Arguably, either the net own return to government assets or to private assets can be applied to highway capital stocks, or some combination of the two rates. If government like an industry is viewed as producing transportation services, then the government net own return applies. Alternatively, if the primarily highways are viewed as inputs to private production processes, then the all private net own rate of return applies. Another approach is to apply the all private assets net own rate of return to the Interstates System assets as they are near-market assets. Although certainly even the Interstate System has some public goods features, Interstates are excludable and are the highways that are most amenable to private ownership as a result. Therefore, the study estimates three rate of return scenarios:

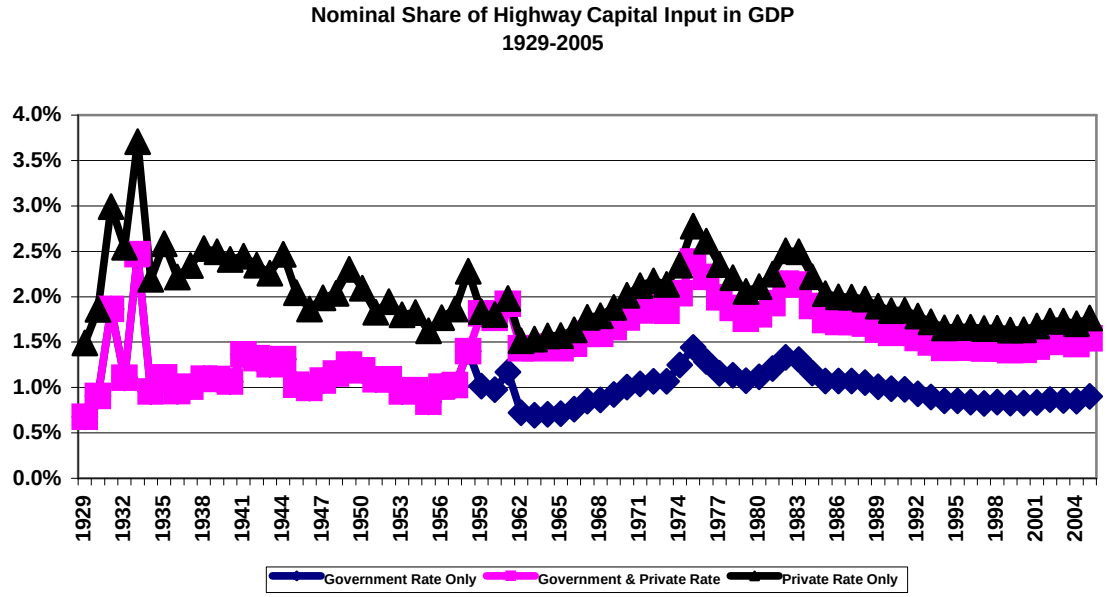
- The government net own rate of return is used for all highway systems
- The private net own rate of return is used for the Interstate System; the government net own rate of return is used for all other systems and
- The private net own rate of return is used for all systems.

Rates of growth are identical between the three scenarios in the contribution of highway capital input to GDP calculation. This is because when there is one asset type (highways): 2000$ capital input is the 2000$ productive highway capital stock normalized to the nominal capital input in the base year: 2000.[33] Therefore the only difference between the three alternative net own rate of return scenarios comes from differences in the nominal share of capital input in GDP, which is the other component of the contribution calculation.

The nominal share of capital input in adjusted GDP is on average higher than the nominal share of capital outlays in GDP for all rate of return scenarios. The shares become relatively constant beginning in the mid-eighties, with (except for one year) a low of .8 percent for the government net rate of return version to a high of something between 1.5 and 2.0 percent for the private net rate of return scenario. The nominal share for the government net rate of return version although still quite small is approximately 33 percent higher than the nominal share for capital outlay.[34]

[33] The extent of the difference between the Interstate and the Non-interstate State and Local deflator do not justify maintaining that these stocks are different once they have been quality-adjusted. Deflators can be said to summarize characteristic differences between assets.

[34] In the tables and graphs that follow, the word "net" is frequently omitted from rate of return labels due to space constraints. Also, the abbreviation "ROR" is frequently used in place of "rate of return."



The contribution rankings shown in the table below reflect the fact that the nominal share is the highest for the private rate only variation and the lowest for the government rate only variation. However, the rate of growth of the total productive highway capital stock does differ significantly from the rate of growth of capital outlays. Recall that the rate of growth for capital outlays from 1950-2005 is 2.5%, a full half of a percentage point lower than the rate of growth for productive highway capital stock shown in the table below. However as previously noted, the post-World War II rate of growth of productive highway capital stock is itself half of a percentage point below the rate of growth of GDP over the same period. In addition, note that the annual rate of growth for productive highway capital stocks is negative only during one Great Depression year and during five years during or immediately following World War II. As an earlier graph showed, the rates of growth for highway capital outlay are negative much more often. Accordingly as expected there is far less variation in the contribution of capital input to GDP growth than in the contribution of capital outlays to GDP growth and the average contribution of capital input for 1930-2005 and 1950-2005, even for the most conservative option, exceeds that for capital outlay. In addition, the contribution for the private net rate of return version on average is about twice that for the government net rate of return version.

Year	% Rate of Growth of Productive Highway Capital Stock	Contribution of Capital Input to GDP Growth (%)		
		Government Rate Only	Government & Private Rate	Private Rate Only
1930-1939	6.43	.09	.09	.17
1940-1949	.89	.01	.01	.02
1950-1959	2.93	.03	.03	.05
1960-1969	6.30	.05	.10	.11
1970-1979	3.06	.03	.06	.07
1980-1989	.98	.01	.02	.02
1990-1999	1.91	.02	.03	.03
2000-2005	2.62	.02	.04	.04
1930-2005	3.17	.034	.047	.066
1950-2005	2.99	.028	.046	.055

The third and last contribution estimate is for the contribution of highways gross output to growth in U.S. gross output. There is more than one possible way to conceptualize highway gross output, but both ways result in the same contribution estimate. Government can be thought of as an industry that produces highway services for use by other sectors as well as by itself. Alternatively, a highway transportation industry does the same. In either case, capital, labor, and intermediate inputs are included in the production process and highways themselves (including the associated structures) are capital inputs as a machine is in a business production process.[35] For the same reason that GDP is adjusted upwards by the amount of the net return to highway assets, U.S. gross output is adjusted upwards by the same amount. The scope of what is included as an input is increased with the addition of non-capital inputs as highway gross output is equal to the sum of highway capital input and other than capital outlays on highways.

For the other types of outlays on highways, total nominal outlays can be obtained by simply deducting highway capital outlays from total highway capital outlays. Ideally, these other than capital outlays could be separated into nominal outlays for different types of labor, materials, energy and service inputs, which could be deflated by type-specific deflators. Realistically, this is not going to happen. So what is the next best alternative? BEA produces a chain-type price index for government value-added from 1947 forward. BLS produces a nominal and a real series for gross output for a number of government industries from 1958-2006 from which an implicit price can be derived. Because intermediate inputs normally are substantially larger than labor inputs and because a subset of all government sectors can be picked, the gross output implicit deflator for an aggregate of selected government industries is used in preference to the

[35] It takes capital, labor, and intermediate inputs to produce highways as it does a machine, but the analysis is from the point of view of the constructed highways as capital inputs into another production process, as a machine is used to produce another product.

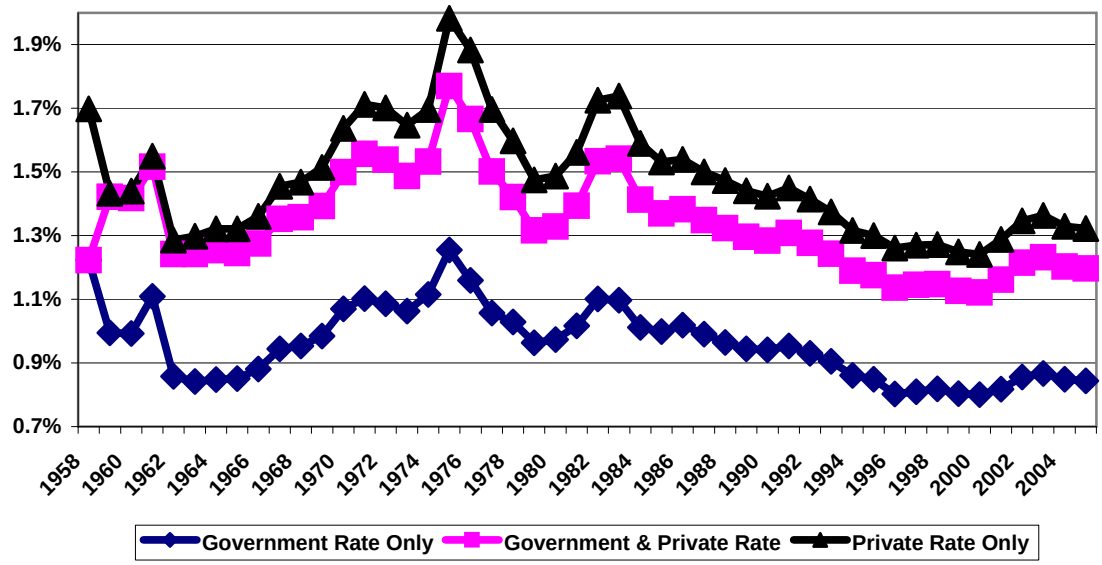
chain-type price government value-added index. The selected BLS government sectors include: 1) Federal non-defense government except enterprises, 2) Local government passenger transit, 3) Local government excluding enterprises, educational services, and hospitals, and 4) State government excluding enterprises, educational services, and hospitals. Capital services are not included in the selected sectors as the Fraumeni measure of capital input is used. The BLS implicit price for selected government sectors is applied to other than capital highway outlay.

Nominal adjusted U.S. gross output is needed to determine the share of highway gross output in adjusted U.S. gross output. A BEA time series is available only from 1987-on; a BLS time series is available from 1958-on. In order to have a longer time series and to avoid unintended inconsistencies by using data from two different sources, the BLS U.S. gross output series is chosen. However, the BLS time series is normalized to the BEA time series nominal value plus the return to highway assets in 2000. Note that the BLS and BEA U.S. nominal gross output time series are very similar (before the net return is added in) even before normalization.[36]

The nominal share of highway gross output in adjusted U.S. gross output shown in the graph below depends on highway capital input, other than capital highway outlay, and adjusted U.S. gross output. How important the first two components are in the three scenarios depends upon the nominal share of highway capital input in highway gross output.

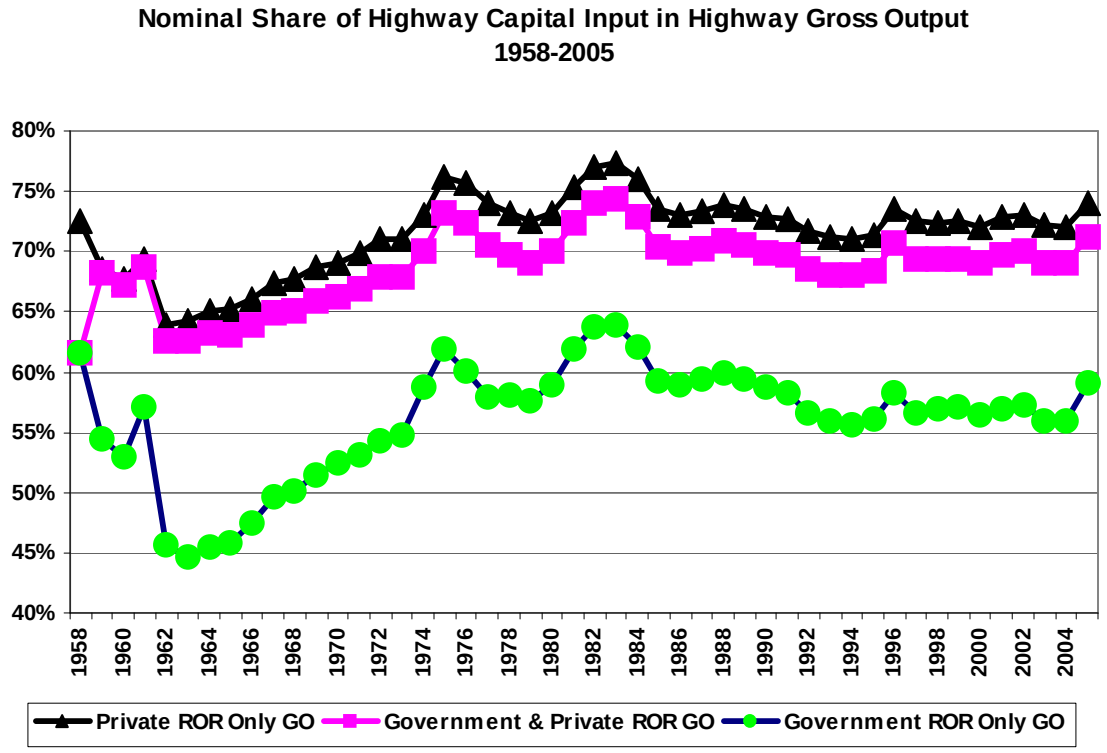
[36] In absolute value terms, the average percentage difference between the two series is less than .4 percentage point and the largest difference for any one year is 1.09 percentage point.

Nominal Share of Highway Gross Output in Adjusted U.S. Gross Output
1958-2005



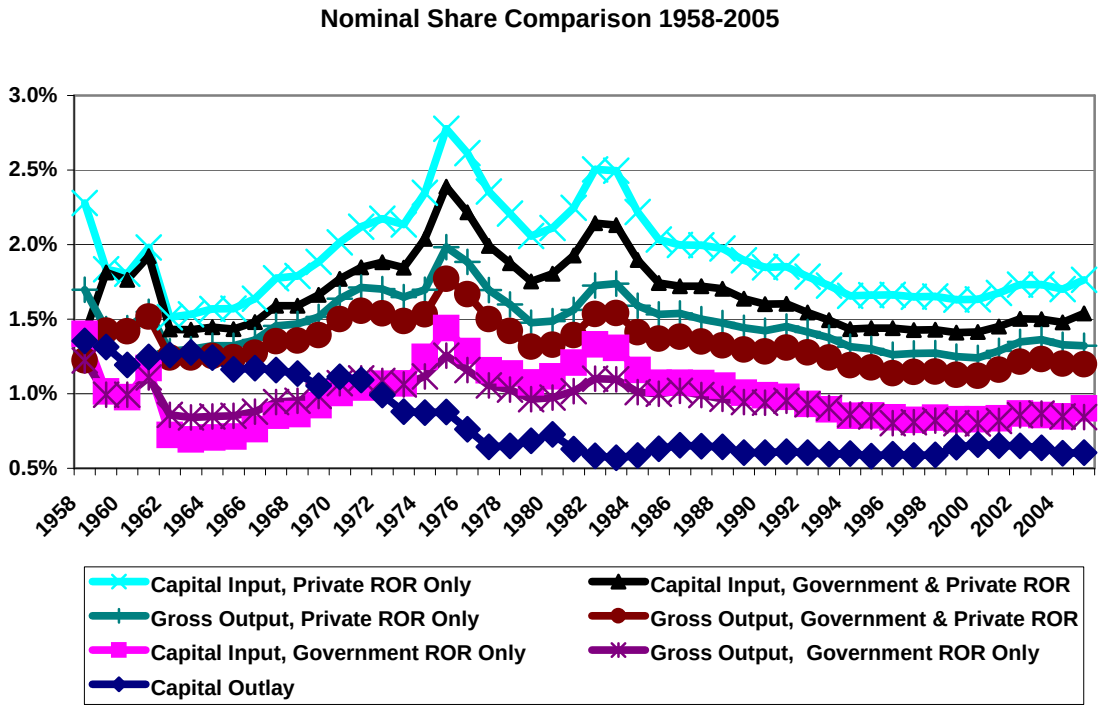
The next graph shows that in all but a few years the share of highway capital input in highway gross output exceeds 50 percent. This is atypical for a production process. As a general rule of thumb, the nominal share of labor input in GDP (value-added) tends to be about 60 percent and the nominal share of capital input in GDP (value-added) about 40 percent.[37] Looking at a BEA sample of information on gross output and value-added for 1987-1997 reveals that the nominal share of value-added in gross output for all private industries is about 55 percent and that the corresponding figure for all of government is about 10 percentage points higher. That figure for State and Local government enterprises is about 50 percent and the highest government figure is for Federal government enterprises at approximately 75 to 80 percent. This all works out to capital input being about 20 to 30 percent of gross output depending upon which sector aggregate is the reference point, far lower than the figure of more than 50 percent for highways. However, this is not surprising as highways are the essential and clearly by far the largest input to the production of highway transportation services.

[37] For this approximation, taxes not allocated to labor or capital are being ignored. In the BEA data file, the sum of nominal value-added and intermediate inputs equals gross output.



What is perhaps most interesting is a comparison across all contribution extimates.

The final nominal share graph shows the nominal shares for all seven contribution estimates. The order of the legend titles (reading across the rows) is the same as the size order of the estimates for most years from the largest share to the smallest share. The capital outlay share noticeably decreases over time. In the first few years it is difficult to make sense of the pattern shown. The two share series that are often very close in value are the two variations that use a government net rate of return to estimate capital input. It is no surprise that the highest share is for the contribution of capital input that uses a private net rate of return and that for most years the lowest share is for the contribution of capital outlay. For all contribution estimates, as has been noted previously, all shares are relatively small.



There is no question that among the contribution estimates, the rate of growth for capital outlay exhibits the greatest variation and has the lowest average for the longer period (1930-2005) and for the shorter period (1958-2005) covered by all contribution estimates. Remember that there is only one rate of growth for all capital input variations as the rate of growth in all variations by construction is the rate of growth of the productive capital stock. The rates of growth for the three gross output variations on the other hand are different as the highway gross output rate of growth is equal to a weighted rated of growth of capital input and other than capital outlay components. The weight for capital input is equal to the nominal share of capital input in highway gross output. As was recently shown, these weights vary depending upon the net rate of return scenario. The average rate of growth for capital input, which is the capital stock rate of growth, is the highest. All average rates of growth are below the average annual 1958-2005 GDP rate of growth.

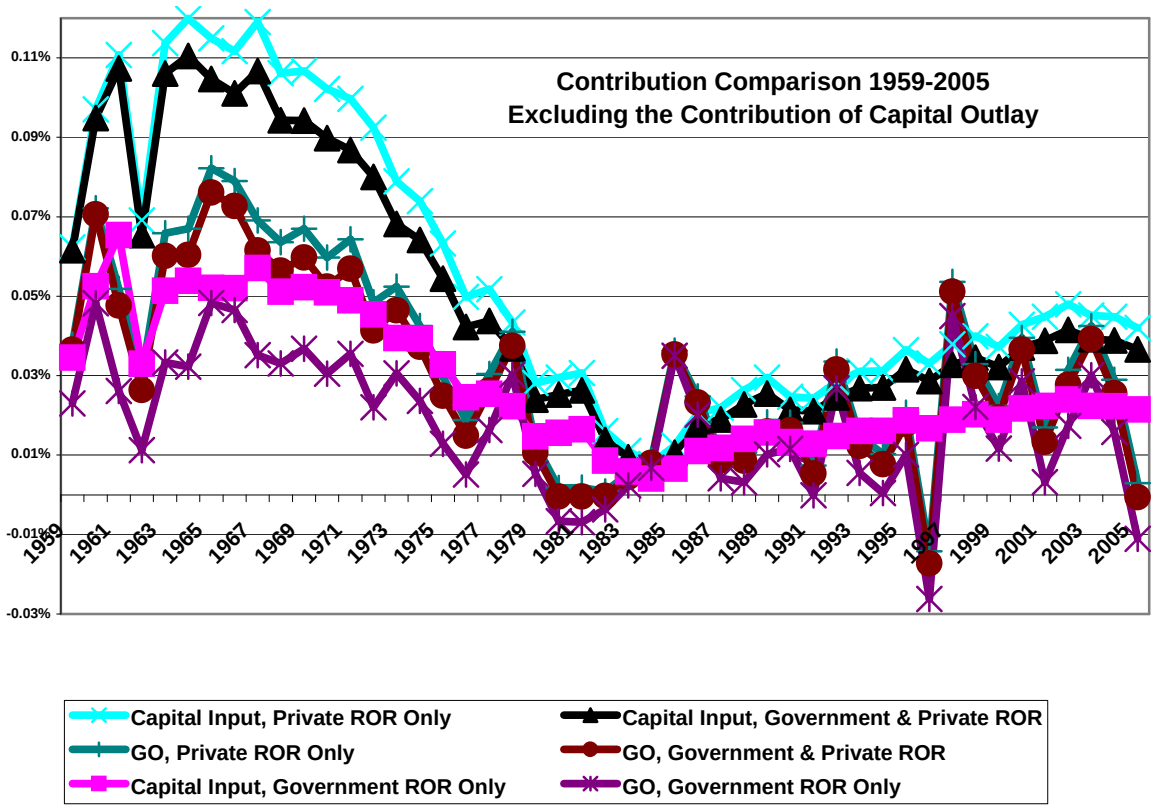
The table below shows that the rate of growth of GDP is higher than any measure of the growth in highways (all in 2000 dollars). (The table and graph below begin in 1959 as all measures are available for these years.)

Percentage Average Rates of Growth 1959-2005		
Capital Outlay		1.28
Capital Input (Capital Stock)		3.00
Gross Output	Government Net Own ROR only	1.85
	Government & Private Net Own ROR	2.17
	Private Net Own ROR Only	2.25
GDP		3.34

For subperiods starting in 1960 or later, the average rate of growth of productive highway capital stock is always higher than that for highway gross output.

	% Rate of Growth of Highway Gross Output			Contribution of Highway Gross Output to U.S. Gross Output (%)		
Year	**Government Rate Only**	**Government & Private Rate**	**Private Rate Only**	**Government Rate Only**	**Government & Private Rate**	**Private Rate Only**
1958-1959	1.16	1.29	1.32	.01	.02	.02
1960-1969	3.82	4.47	4.64	.04	.06	.06
1970-1979	1.96	2.29	2.37	.02	.03	.04
1980-1989	.65	.76	.78	.01	.01	.01
1990-1999	1.24	1.46	1.51	.01	.02	.02
2000-2005	1.67	1.99	2.06	.01	.02	.03

The final chart graphs the highway contribution estimates. The analysis excludes the contribution of capital outlay to GDP growth from the graph because its' high degree of variability makes the graph difficult to read.



The contribution of highway capital input to adjusted GDP using a private net own rate of return for all assets is largest in most years. The contribution of highway gross output to adjusted U.S. gross output using a government net own rate of return for all years is smallest in most years. In all years the contributions are small except in the few years when the rate of growth of capital outlays is high. (These years are not shown.) The contribution estimates are small because the shares and 2000$ rates of growth are small.

Conclusion

This research estimates the contribution of highways to GDP growth in a manner that is directly comparable to BEA GDP contribution estimates. The resulting estimates of the contribution of highways to economic growth is small as distinct from measures which incorporate multiplier or spillover effects and the use of highways by households. This research perhaps most importantly provides productive highway capital stocks as inputs to other research. A major theme in this report is that highway-related rates of growth are all on average substantially below the post-World War II (or 1958-2005) GDP average rate of growth.

Particular attention is paid to breaking out capital outlays by type and constructing pavement curves in the Fraumeni research. Differences between the BEA capital stocks and the Fraumeni capital stocks are largely a function of the fact that the distribution of capital outlays by type are allowed to vary over time. The shapes of the pavement curves are very similar between the last January 1999 set of curves, which started in 1978 or 1981, and the new pavement curves constructed in this research, which start in 1986. Pavement does deteriorate more rapidly in the curves with more recent starting years. However, the evidence seems to indicate that frequent updating of the pavement curves or the net efficiency curves is not necessary and that either type of curve beginning in 1986 could be used as proxies for curves beginning in even more recent years. On the other hand, highway capital outlay needs to be updated regularly as these outlays vary significantly across time.

The pilot, experimental, 1983-2005 series for structures, which incorporates growth rates from a quality-adjusted bridge stock, is significantly different than the featured productive highway structure stock during the 1983-1996 subperiod. Further research needs to be done to determine if a quality-adjusted measure warrants the additional effort to construct it.

The contribution estimates typically differ significantly; the question is what contribution estimate is preferred on conceptual grounds? The capital outlay contribution estimates focus on the building (and substantial repair or improvement) of highways; the capital input and gross output contribution estimates focus on the use of highways, particularly the capital input contribution estimates. In the short run building, repairing, and improving highways can give the most immediate stimulus to economic growth, however in the long run it is the use of highways that is most important in stimulating economic growth. Looking at the capital outlay contribution estimates is worthwhile as doing so highlights the substantial variation in highway capital outlays over time and gives a sense of what possibilities there are to impact on the economy in the short-run. Of course, highway capital outlay adds to the capital stock, which underlies the capital input and gross output contribution estimates. The three capital input scenarios use conservative estimates of the net rate of return as is appropriate for a national income accounting analysis, accordingly it is easy to contend that the actual contribution of capital input to GDP growth might be higher than any of the estimates presented in this report.

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