THE ECONOMIC IMPACT AND FINANCING OF INFRASTRUCTURE SPENDING

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EXECUTIVE SUMMARY

The goal of this report is to understand the short- and long-term effects of public infrastructure spending on the U.S. economy, as well as to contribute new suggestions towards alternative financing of future road construction.

Estimated Short-Run Effects

- In the short-run, a dollar spent on infrastructure construction produces roughly double the initial spending in ultimate economic output.
- The biggest effects of infrastructure spending occur in the manufacturing and business services sectors.
- In better economic times, spending on infrastructure construction generates a larger return. Yet even in a recession, the overall effects of initial spending still double output as they ripple through the economy.

Estimated Long-Run Effects

- Over a twenty-year period, generalized 'public investment' generates an accumulated $3.21 of economic activity per $1.00 spent.
- Over twenty years, investing $1.00 in highways and streets returns approximately $0.35 in tax revenue to federal and state/local governments, of which $0.23 specifically accrues at the federal level.
- Over twenty years, investing $1.00 in sewer systems and water infrastructure returns a full $2.03 in tax revenue to federal and state/local governments, of which $1.35 specifically accrues at the federal level.

Spending on public infrastructure stimulates the U.S. economy in the short-run. Investing in infrastructure goes beyond mere improvements to the quality of roads, highways, sewers, and power plants. These investments also generate significant economic returns for other portions of the U.S. economy and substantially increase ultimate tax revenue for the government.

In order to adequately fund public infrastructure, the U.S. must seek innovative new funding mechanisms that do not burden rising deficits, and likely must stimulate the private sector. Programs like public-private partnerships, individual and corporate contributions to road financing and user fee lanes are potential mechanisms through which public spending on infrastructure can be supplemented beyond the gas tax.

The Economic Impact and Financing of Infrastructure Spending

Section 1.1. Introduction

Congress has not authorized new long-term spending on transportation infrastructure since the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), which expired in 2009. Although there are currently several proposals for new financing, it remains unclear if these will become law, and what levels of spending Congress will likely appropriate. Other categories of infrastructure have also found their funding streams to be insufficient. The current debate in Congress and state capitals frames money spent on infrastructure as one-shot spending. However, money is not truly *spent* on infrastructure so much as *invested* in it, an investment that helps the economy to grow and directly returns tax revenue to the government. The aim of this research project is to understand these effects. Specifically, our goal is to determine the impact of infrastructure investment on economic activity, including the tax revenues generated by this investment, and to propose alternative funding ideas for highway investment.

Section 1.2. Transportation Infrastructure Spending Over Time

During the 20th century, spending on public infrastructure in the United States has consistently grown in magnitude. Over the last thirteen years, Congress has invested in infrastructure at rates higher than inflation. Figure One illustrates this trend. These numbers are measured in constant 2005 dollars, to control for inflation and to make comparisons from year to year more meaningful. The red line shows trends for all types of infrastructure spending, whereas the blue line excludes military spending. Both lines trend upward, but dipped briefly downwards after the start of the current recession in 2008.

Figure One: Total Investment Spending, 1929-2010

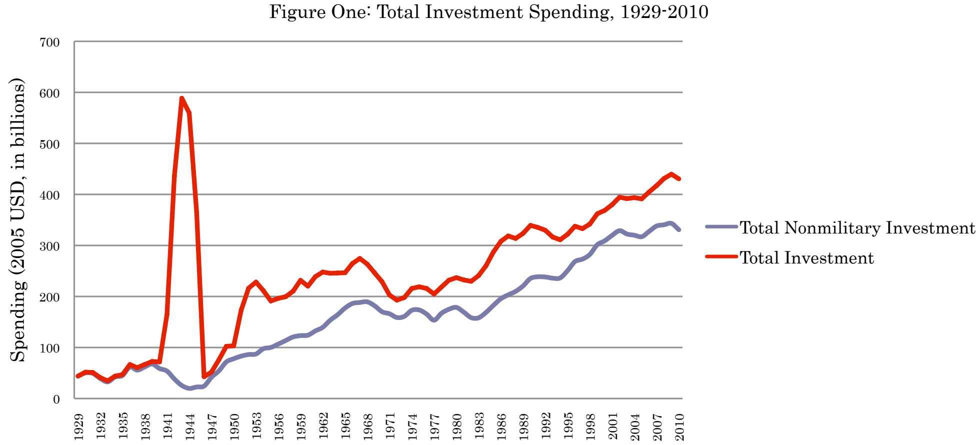

Figure Two: Types of Non-Military Investment Spending, 1997-2010

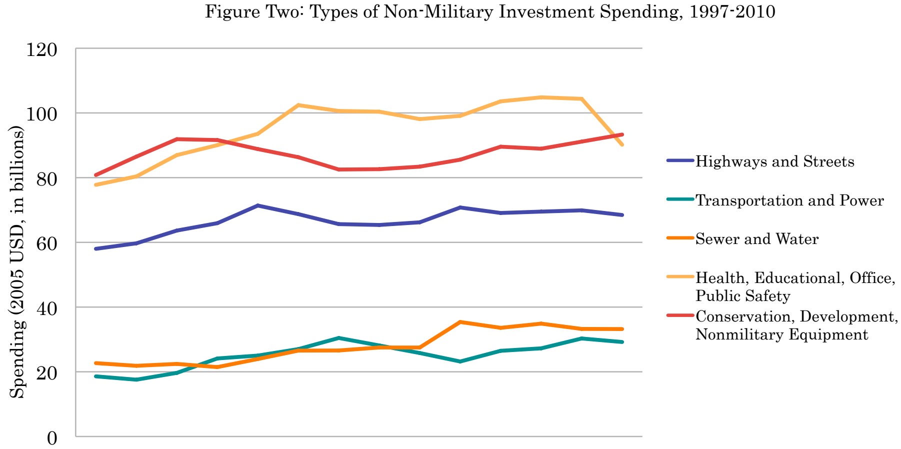

Figure Two highlights the state of public non-defense infrastructure spending since 1997. In this figure, the purple line indicates the level of spending on highways and streets. This line displays roughly the smallest increase in total real spending relative to other types of infrastructure during this time period. This suggets that highway spending has barely kept pace with inflation, even without accounting for recent depreciation of the highway network. The types of infrastructure with the highest funding levels are conservation, development and nonmilitary equipment, as well as health, educational, office, public safety and conservation structures. These categories show much more variation and growth than highways and streets.

Section 1.3. Short-Run Effects

To effectively gauge the short-run economic impact of different types of public infrastructure investment, we rely upon an input-output model using national data from the Bureau of Economic Analysis. The basic premise of an input-output model is to gauge the short-run impact of some initial amount of direct spending in one sector of the economy, and diagram how that money then ripples through other sectors as businesses purchase inputs and sell outputs.

For instance, one dollar spent on road construction is distributed to asphalt producers, laborers, and providers of heavy construction equipment among other places. These respective recipients then spend money on purchasing inputs, which stimulates further indirect effects on the manufacturing sector, the retail sector, and various other businesses.[1] In the end, one dollar spent in most sectors spreads through the whole economy, indirectly affecting other sectors, and generates greater than one dollar of ultimate economic impact.

Section 1.3.1. Benchmark BEA IO Multipliers

We use data from the Bureau of Economic Analysis's Input Output Accounts, publicly available through their website, for the years 1998 through 2009. The BEA annually publishes tables which diagram the indirect effect of spending through different sectors of the economy, including manufacturing and construction among others. Every five years, but most recently for 2002 data, the BEA also publishes "benchmark" estimates which break down aggregated sectors into hundreds of further sub-sectors.

We begin our analysis by aggregating these 2002 benchmark estimates to identify the appropriate multiplicative short-run effects of public infrastructure spending. To do so, we compile reported multipliers to isolate the effect of spending solely on new nonresidential construction, which most closely approximates the types of major public infrastructure spending generally undertaken by governmental entities in the United States.

Aggregated estimates are reported below in Table One. Overall, the multiplicative effect of new nonresidential construction totals $1.92 from every $1.00 initially spent. It is important to understand that the economic impact of every dollar of spending in the construction sector is nearly doubled by the indirect economic impact in other sectors of the economy. Thus public

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[1] To this end, our estimates are conservative in that we only include direct and indirect effects of initial spending. For methodological reasons discussed in the technical appendix, we do not include induced effects (the resulting money spent by laborers who work on a construction project, e.g.) in our analysis. As such, our estimates likely understate the total multiplicative effect of infrastructure spending.

infrastructure spending does not simply increase economic activity solely in construction; it leads to increased economic activity in the whole economy.

This includes roughly $0.35 on every $1.00 spent in indirect effects generated in the manufacturing sector. This is likely a product of the many manufactured goods that are required to both produce and properly equip major public infrastructure projects like roads and sewers. Indirect effects of new nonresidential construction are highest in manufacturing, but are also high in the professional and business services sector, and finance and real estate.[2]

Table One: Input-Output Effects of Non-Residential Structures, 2002 Benchmark Detail

Sector	Direct Effect	Indirect Effect	Total Effect
Agriculture, forestry, fishing, and hunting	0	0.0147	0.0147
Mining	0	0.0375	0.0375
Utilities	0	0.0159	0.0159
Construction	1	0.0064	1.0064
Manufacturing	0	0.3548	0.3548
Wholesale trade	0	0.0482	0.0482
Retail trade	0	0.0164	0.0164
Transportation and warehousing	0	0.0384	0.0384
Information	0	0.0321	0.0321
Finance, insurance, real estate, rental, and leasing	0	0.0994	0.0994
Professional and business services	0	0.2031	0.2031
Educational services, health care, and social assistance	0	0.0002	0.0002
Arts, entertainment, recreation, accommodation, and food services	0	0.0135	0.0135
Other services, except government	0	0.0299	0.0299
Government	0	0.0091	0.0091
Total Short-Run Multiplier	1	0.9196	1.9196

Source: Bureau of Economic Analysis, Benchmark Input-Output Accouts, 2002, and Author Calculations.
Note: All values are in 2002 US dollars.

At $1.92 of estimated impact, new non-residential structures amount to the largest overall short-run multiplicative effect on the economy among the non-residential construction subsectors. Residential construction, maintenance and repair all have slightly higher overall multiplicative effects, but new non-residential structures outpace nonresidential maintenance, and manufacturing and commercial and health care structures in terms of total short-run impacts.[3]

Section 1.3.2. Annual BEA IO Multipliers

The BEA also reports annual input-output estimates across fifteen main sectors without the explicit detail contained in the benchmark data. In Figure Three, we report the total effect of one dollar of construction spending on the economy in the short-run annually from 1998-2009.

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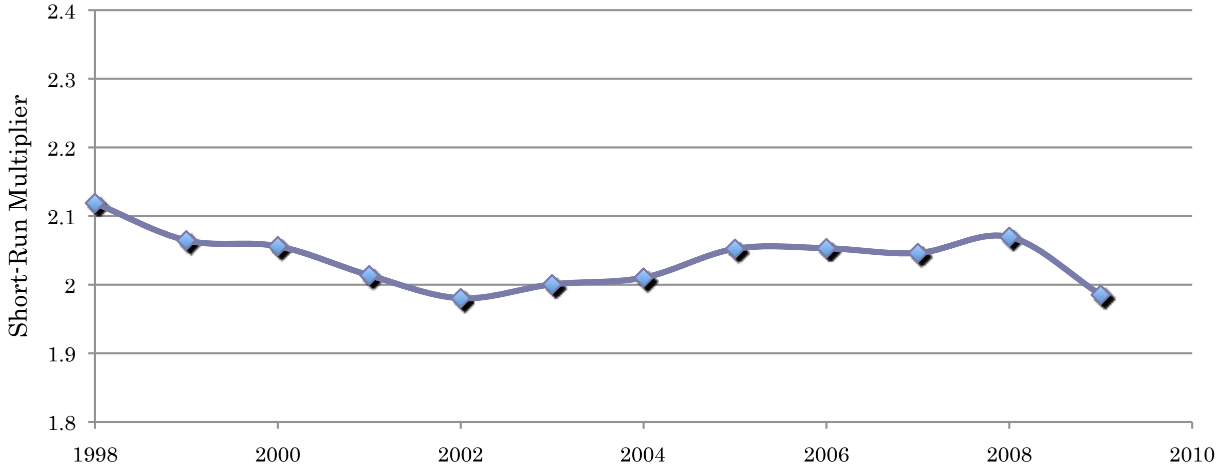
[2] See the technical appendix for discussion of the applicability of these 2002 data to modern studies of the economic impact of public infrastructure spending. Generally, an examination of more recent (but less detailed) annual data finds comparable total effects and sectoral breakdowns of indirect effects.

[3] Further discussion of these comparisons, including presentation of specific data, is found in the technical appendix.

Figure Three: Total Impact of $1 Construction Spending in Short-Run, 1998-2009



Source: Bureau of Economic Analysis, Annual Input-Output Accounts
Note: Values are in nominal dollars based upon one dollar of generic construction spending also in nominal dollars.

As can be seen in this figure, the total short-run effect of one dollar in generic construction spending is slightly higher than the aggregated 2002 benchmark estimates solely for new nonresidential construction, because the annual estimates reported above include residential construction spending.

However, these values are still illustrative of the overall time trends of the short-run impact of public infrastructure spending. In lieu of more recent 2007 benchmark data, these values show that the estimated impact of one dollar of spending in the construction sector on the economy remains relatively constant above and around $2.00. It is important to note that fluctuations in the size of the short-run impact of public infrastructure spending are dependent upon the business cycle. The BEA's short-run multiplier for construction spending is highest in periods of economic growth, notably in the late 1990s and the mid 2000s, and lowest during recessions as seen in the early 2000s and in the 2009 estimate.[4]

Section 1.3.3. Calculated Short-Run Impact of Previous Government Investment

Using historical data on both federal and state/local investment in five types of public infrastructure, we can calculate the total economic impact of previous public investment by applying the annual input-output estimates for short-run construction spending discussed in the previous section. Table Two reports the total effect of spending on transportation, power, highways and streets, sewers, and water infrastructure for the period 1998-2009 in billions of 2005 dollars. Total effects equal the direct spending levels (reported in the technical appendix) plus the indirect effect of that spending based upon the generic construction input-output multiplier discussed previously for each year.

Business cycle differences from year-to-year are evident across each of these five types of spending. It is important to note that highways and streets investment occurs at roughly the highest levels, of the sectors reported in this table, and thus leads to the highest ultimate economic impact on the economy. The magnitude of these impacts should also be considered relative to the size of the economy – highways and streets spending accounts for roughly 1% of GDP per year.

[4] Complete tables presenting the sectoral breakdown of these effects per year are given in the technical appendix.

Table Two: Historical Input-Output Total Impact of Public Infrastructure Spending

	Transportation	Power	Highways and Streets	Sewers	Water
1998	30.22	7.21	128.77	24.43	22.21
1999	32.10	8.61	132.93	23.51	22.99
2000	39.62	9.97	137.08	22.19	21.94
2001	40.26	9.94	144.47	24.40	23.69
2002	43.09	10.48	137.75	26.69	26.01
2003	43.79	17.22	132.72	27.65	25.66
2004	42.51	14.28	133.53	29.28	26.29
2005	38.17	14.78	137.09	29.96	26.47
2006	30.24	17.19	145.70	39.39	32.96
2007	32.25	21.39	141.12	37.20	30.75
2008	35.39	20.16	142.02	39.05	31.66
2009	38.14	20.76	137.09	35.91	28.79

Source: Bureau of Economic Analysis, 1998-2009 Annual Input Output Accounts. Spending levels downloaded from the BEA are reported in the technical appendix, as well as indirect effects.
Note: Values are in billions of 2005 dollars.

Section 1.4. Long-Run Effects

In the long-run, our estimates suggest that investment in infrastructure continues to generate beneficial returns to the economy as a whole.

To calculate the long-run effects of government investment in public infrastructure, we begin by taking into account the long-term relationship between types of infrastructure spending and overall economic output (GDP), as well as fluctuations in the value and depreciation of the current stock of infrastructure. This long-term relationship is based on the sensitivity of GDP to different types of public investment.

After an exhaustive review of the relevant academic and professional literature which has previously sought to estimate this structural relationship between economic activity and public infrastructure investment, we use the vector autoregression (VAR) method explicated in Alfredo Pereira's (2000) paper, *Is All Public Capital Created Equal?*, published in the Review of Economics and Statistics.

This method produces an econometric determination of the long-run sensitivity of GDP to investment, a numerical value which captures the dynamic effects that GDP and investment spending each have on the other. We then adjust this natural sensitivity (or "elasticity") for recent changes in the stock of different types of infrastructure. These processes allow us to calculate the long-run permanent effect of investment on GDP.

Primarily, the econometric approach used by Pereira (2000) offers the most sophisticated and consistent means through which these long-run effects can be calculated. This method also allows for analysis of five different types of public infrastructure which are of interest to this study – highways and streets; transportation and power; sewer and water; health, educational, office, and public safety buildings; and conservation, development and nonmilitary equipment.[5]

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[5] The buildings category consists primarily of general office buildings, police and fire stations, courthouses, auditoriums, garages, and passenger terminals. Transportation and power includes electric and gas facilities, transit systems and airfields. Conservation, development, and nonmilitary equipment includes non-power dams and levees, irrigation facilities and the purchase of computers and software. See the technical appendix for more detail.

The VAR method allows us to isolate the effect of changes in investment on GDP from the effects that GPD growth has on investment.

This method of calculating long-run effects relies upon a relatively simple story: if there are already one hundred quality roads in an area, the hundred and first road will likely provide only a small additional economic benefit to that area economy. However, if there are only two roads in an area, or the roads are of poor quality, a third road will result in substantial economic benefit.

Section 1.4.1. Marginal Product Calculation

As such, we calculate the relative intensity of these five different types of infrastructure using 1997-2010 Bureau of Economic Analysis data which takes into account depreciation, the loss in quality of roads and other infrastructure over time, as well as current levels of spending by federal and state/local governments. These ratios are then adjusted by the raw sensitivity of GDP to each specific type of investment, as calculated by Pereira (2000).[6]

Equation One depicts the marginal product calculation for each type of public investment, *z*.

Equation One: Marginal Product Calculation

$$MP_z = \varepsilon^{GDP}_{Investment_z} x \frac{\sum_{i=1998}^{2010} GDP_i}{\sum_{i=1998}^{2010} \Delta Net\ Capital\ Stock_{iz-(i-1)z}}$$

This method produces estimates of the marginal product of each different type of infrastructure spending.[7] These marginal products describe the overall economic output (GDP) that results from one initial dollar of spending in each area, and over a twenty-year period.

As seen in Table Three, aggregate public investment in these five types of infrastructure is estimated to result in a marginal product of $3.21. This indicates that $1.00 in aggregate public infrastructure spending leads to $3.21 in economic output (GDP) over a twenty-year period. Transportation and power provides the largest economic gain, where spending $1.00 results in over $14.00 of output for a twenty-year period. Highways and streets investment is calculated to produce $1.15 of economic output in the long-run. Each of the other types of public infrastructure produces economic returns of size between these magnitudes.

These marginal products represent a significant update of previous findings in this field. Relative to Pereira (2000)'s calculated marginal products for these same infrastructure categories, we see that the overall economic benefit of spending in highways and streets, transportation and power, and public buildings has fallen by varying degrees. This is likely a product of declining relative scarcity of these types of infrastructure, meaning that increased spending relative to GDP has led to overall increases in the intensity net capital stock in our study compared to the 1988-1997 time period used in Pereira (2000)

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[6] See the technical appendix for a discussion of the applicability of Pereira (2000)'s elasticities to a newer analysis. Generally speaking, we have reason to believe that Pereira (2000)'s findings are robust and consistent over time based upon his model specifications.

[7] It is important to understand that marginal products and tax figures reported in this study constitute a dollar of general investment in each category of spending, and specific sub-categories within each category (e.g. highways and streets) will have marginal products which vary around each category's estimates.

However, marginal products for sewer and water infrastructure as well as conservation and development structures have increased, suggesting that relative scarcity of spending in these areas of late means that future spending will lead to increased economic benefit compared to what such spending would have accomplished in the late 1990s.

Table Three: Long-Run Effects and Tax Revenue from Government Investment Spending

	Percent	Relative Intensity	Elasticity (Pereira 2000)	Marginal Product (Pereira 2000)	Marginal Product	Estimated Tax Revenue (30%)	Federal (20%)	State & Local (10%)
Total Investment	1.33%	75.3843	0.0425	4.46	3.21	0.96	0.64	0.32
Highways and Streets	35.94%	209.7468	0.0055	1.97	1.15	0.35	0.23	0.12
Transportation and Power	11.20%	672.9762	0.0210	19.79	14.15	4.25	2.83	1.42
Sewer and Water	9.54%	790.5181	0.0086	6.35	6.77	2.03	1.35	0.68
Health, Educational, Office, Public Safety	39.83%	189.2740	0.0173	5.53	3.28	0.98	0.66	0.33
Conservation, Development, Nonmilitary Equipment	3.49%	2157.7874	0.0049	4.06	10.59	3.18	2.12	1.06

Source: Intensities calculated from BEA Net Capital Stock Data, 1997-2010, and BEA GDP data deflated using NIPA Implicit Price Deflators. Elasticities from Pereira (2000). Author's calculations.
Note: Values reported are in 1987 dollars, and marginal product indicates the total economic gain over a twenty-year period from one dollar of spending in each of the five areas of public infrastructure. Adjusting for 2011 dollar values would produce comparable results in magnitude.

For highways and streets construction spending, it is also important to understand why the long-run ensuing impact of spending is smaller than the estimated temporary (short-run) impact. It is possible that construction of a new road may drastically reduce traffic at first, but traffic congestion returns as businesses and communities develop along the new road. Alternatively, road spending may be conducted myopically, wherein short-run priorities are emphasized over what is best in the long-run.

More generally, these long-run findings can be seen as the fundamental and permanent change in GDP resulting from government investment. Short-run effects presented in the input-output model instead describe the temporary and stimulative impacts of spending. In either case, we see that the economic impact of highways and streets spending in the long-run remains positive and additive even beyond the initial one dollar spent.

Section 1.4.2. Tax Revenues from Public Infrastructure Investment

One key question, however, is the extent to which spending on infrastructure is truly an investment. In other words, the government spends taxpayer money to build roads, and there are quantifiable economic benefits of this construction. After calculating these ultimate economic impacts for the long-run, we can determine the tax revenue the government can expect to receive from these investments.

To calculate an appropriate tax rate for use in this study, we examine total tax receipts collected by the government (including personal taxes, sales taxes, corporate taxes, etc.) and divide this sum by total GDP.[8] Using recent data, we calculate that the overall rate of taxation at the federal and state/local level is roughly thirty percent, and we use this value to project estimates of the

[8] We utilize all available sources of tax revenue in calculating total receipts, rather than isolating revenues that may be relevant to each specific type of infrastructure. This is appropriate given the findings earlier in our study which describe how initial spending flows through all sectors of the economy. Thus, the resulting economic activity generated by construction spending will likely be subject to the whole complement of federal and state/local taxes.

ensuing tax revenue expected from these different types of infrastructure. Furthermore, we assume based upon historical data a constant ten percent rate of taxation at the state/local level, and thus a twenty percent rate of taxation solely at the federal level (Tax Foundation, 2009).

Over twenty years, $1.00 of spending on aggregate public investment results in about $0.96 in total tax revenue. For transportation and power investment, one single dollar returns over $4.24 in total, while spending on highways and streets results in $0.35 of total tax revenue. Sewer and water spending has significant returns as well, producing $2.03 in revenue per $1.00 spent over the same twenty-year period. These values are also reported in Table Three in the previous section, along with a breakdown of expected revenue accrued to the federal government and state and local governments.

For these types of infrastructure, Congress and state governments can expect to receive significant tax revenue returns to their initial spending. In many cases, particularly for transportation and power and sewers and water spending, public infrastructure investment will generate quadruple or double (respectively) the amount of tax revenue with which to finance future government spending.

It should be cautioned that based upon the methods used to calculate these marginal products and estimates of ensuing tax revenue, our findings dictate the expected economic impact of *present* spending. Drastic fluctuations in the quality of our nation's capital stock or in levels of government spending may dictate alternative estimates of these marginal products in the future.

Regardless, the most important take-away is that every type of public infrastructure spending in our study results in significantly positive returns to the government. These investments return some portion of the money initially outlaid by the government over a twenty-year time horizon, and, in several cases, more than pay for themselves.

Section 1.5. Alternative Financing of Highway Infrastructure

Currently there exists a gap between the capital needs of America's highway infrastructure and the level of revenue available to finance repair, maintenance and construction. The United States spends about $160 billion per year on highways, one quarter of which is paid for by the federal government (Kile, 2011). The Congressional Budget Office (CBO) projects that an additional fourteen billion dollars is needed per year to simply maintain the current performance of the highway system (Kile, 2011, 4). However, Congress is already spending more on highways than it receives annually in motor fuel excise taxes, and CBO suggests that the Highway Trust Fund will be unable to meet its ongoing obligations by late 2012 (Kile, 2011, 3).

As cars continue to become more fuel-efficient, gas tax revenues will continue to decline. Many have suggested closing the funding gap by increasing the tax rate itself, but this proposal faces significant political opposition. Others contend that gas tax hikes may over-burden diesel fuel users and benefit hybrid car users who purchase less fuel to drive the same roads. Although it is effective at reducing fuel consumption for environmental means, the gas tax is not a reliable way to raise ample money for road construction.

Limiting usage of the Highway Trust Fund to finance only highway infrastructure may be an effective solution to meet demand for funding in the short-run. For instance, one provision in SAFETEA-LU authorized a mass transit account within the HTF, among other non-highway related items.[9] Alternative non-gas tax revenues could support such accounts. Furthermore, given the positive and widespread economic benefits resulting from highway investment as discussed in this paper, such road construction and repair could be justifiably financed using general revenues.

Nonetheless, given the current political context surrounding tax revenues and the role of the HTF in financing portions of non-highway infrastructure, supplementary sources of financing for road construction are necessary to meet existing and future highway needs. Popular recent proposals and some original proposals are discussed below.

- **Public-Private Partnerships:** Public-private partnerships represent a creative way to harness private sector innovation and encourage cost-sharing in road construction. Generally, such partnerships are financed by both governmental revenues and private capital, with which a private company builds the road and collects tolls for a set period of time. Although public-private partnerships cannot replace public funding of infrastructure, they may be able to supplement what the government spends. Through calculations of likely operational expenses, bond structures, and toll requirements (reported in the technical appendix), we predict that public-private partnerships can bring significant economic gain to specific road construction projects, if done in a cost-effective manner via sufficient cost-benefit analysis.

- **Tax Deductible Infrastructure Investment:** Tax deductions for capital improvement are standard fare in many other industries, most notably agriculture. For instance, evidence suggests that tax-deductions paid to farmers for interest on new equipment has historically led to an overall increase in agricultural investment (Leblanc, 1986). Effects will naturally vary by sector and economic conditions, but these effects will likely hold true for infrastructure investment.[10] We estimate (in the technical appendix) that by incentivizing businesses to reinvest some portion of the increased economic output accrued by public infrastructure spending, the federal government and state/local governments can leverage significant additional resources towards infrastructure projects.

- **Fixmyroad.gov:** We recommend creation of a public-access web portal for identifying needed road repair projects and soliciting additional tax-deductible funding for road maintenance, which we have dubbed "fixmyroad.gov". The proposed system invites citizens to log into a web portal using a drivers' license number, nominate roads for repair or construction, donate to specific projects, check donation levels, and track the progress of road repairs. State legislatures could set funding benchmarks for each project and wait for a certain level of donations before conducting feasibility studies or approving projects. This site would not fully fund any projects but would likely help the

[9] This item's authorization was even extended beyond SAFETEA-LU. See these bills: Surface Transportation Extension Act of 2010 and Surface Transportation Extension Act of 2011.
[10] See the Technical Appendix for a specific analysis of the quantitative benefits.

government gauge public needs, supplement maintenance expenditures, and free Highway Trust Fund money for new infrastructure investments.[11]

- **Fee for Use Lanes:** High occupancy toll (HOT) lanes could also help generate revenue for highway investment. HOT lanes are toll lanes that run parallel to general use lanes. They capture the extent to which drivers value less congested roads and speedier travel. Small et al. (2006) identified two representative examples where this approach has succeeded: SR91 in Los Angeles and Queen Elizabeth Way (Highway 407) in Toronto. In both cases, anyone could pay to use the toll lane without special access based on type of vehicle or number of occupants.

Section 1.6. Conclusion

The United States faces an increasing shortfall of revenue for much-needed infrastructure investment. According to the CBO the US has already fallen behind the level of funding required to maintain our current network of highways and streets. However, money spent on infrastructure does much more than just maintain current stock. The effects of that spending multiply as they ripple throughout the economy, stimulating growth and output in other sectors, and ultimately return substantial tax revenue to the government per our findings.

In the short-run, spending on infrastructure produces twice as much economic activity as the level of initial spending. These effects are most heavily concentrated in the manufacturing and professional and business services sectors, but also accrue to smaller sectors like agriculture. In the long-run, spending on all types of infrastructure generates substantial permanent positive effects across the economy as a whole. Money spent now will produce significant tax revenue returns to the government's budget over twenty years.

Given the substantial economic benefit of infrastructure spending, current budget deficits, and concerns regarding the future economic growth of the economy, it is crucially important that the United States invest in infrastructure like road networks, power stations, sewer systems, public safety buildings, and airfields. We must find innovative new ways to fund infrastructure construction and maintenance, and we can be secure in the knowledge that our economy will grow and strengthen as a result.

[11] The basic economic idea behind this web portal is to capture unused willingness-to-pay among citizens for road repair, and minimize the deadweight loss of other taxation.

TECHNICAL APPENDIX

In lieu of reporting technical details of our methodology in the body of the main report we have described in detail below our analysis of the literature surrounding our report, the availability and selection of data for our study, appropriate interpretation of our results on the whole, further tables and figures which support our findings, and suggested areas for further research.

Section 2.1. Discussion of Input-Output Model

There are multiple sets of input-output multipliers available for use in analyses of the short-run impact of specific spending. The most popular measures provide local or county-level detail, at higher cost of usage, and allow for large multi-sector analyses of geographic and regional impacts. These multipliers include the popularly used IMPLAN, REMI, and RIMS-II.

These sets of multipliers are described at length in Lynch (2000) for further reference. Although minor differences exist between the methodology used to calculate short-run impacts in each set of multipliers, each process generates substantively similar results. These multipliers are used primarily in local-focused studies, as seen in Krop et al. (2008), Weinstein and Clower (2007), and Wubneh (2008).

Our decision to use aggregate input-output accounts data from the Bureau of Economic Analysis reflects a decision concerning the need to examine national-level effects. Given the major role that Congress plays in spending infrastructure funds via direct spending and block grants to states, nationalized aggregate short-run effects are needed to effectively gauge the overall impact of nationwide spending. National estimates from IMPLAN or RIMS-II are themselves based on aggregate BEA multipliers used in this study.

Further research should examine in greater detail the regional effects of state-by-state spending (rather than aggregated state spending as seen here), and the regional impact of federal spending.

Section 2.1.1. Brief Discussion of Literature on Input-Output Methodology

The academic literature on the use of input-output analysis to determine short-run impacts dictates a few stipulations for discerning the veracity and robustness of our findings presented in Section 1.3.

Zaman et al. (2010) discusses the time stability of input-output findings, and confirms that technical input-output coefficients are valid and consistent in both the short- and medium-run, but not to exceed roughly five years' time. Roland-Holst (1989) argues that when input-output transaction tables are distributed normally, they will generate unbiased multiplier estimates that are suitable for policy analysis. This finding also lends credibility to our results, as national-level aggregate transaction tables should follow a roughly normal distribution.

Grady and Muller (1988) discuss important considerations for the proper interpretation of input-output findings. Primarily the authors contend that these must be viewed not as economic benefits to society – they do not represent the benefit beyond the next-best alternative, as is the case for cost-benefit analyses – but rather simply as the economic impact of one dollar of spending. We have worked to keep this distinction in mind when discussing the findings of our short-run models.

Furthermore, the authors contend that because input-output models are calculated in a closed model with no feedback from price effects and the financial sector, their estimates are biased upward in terms of describing the ultimate economic *effect* of infrastructure spending. This is the major criticism of input output models, and partially the reason why such findings can describe only the temporary impact of spending rather than the long-run permanent effects. Without taking into account greater macroeconomic conditions and dynamic relationships between economic output and public investment (whereby changes in each variable are both caused by and the causing variation in the other), the consistency of input-output findings should be taken with significant caution.

Grady and Muller argue that for these reasons, induced effects (those accruing from household spending changes after initial spending has fed through the economy) are suspect given the time-gap between the initial spending and ultimate occurrence of induced effects.

We agree with these authors' assertion that input-output models are closed loops that do not fully account for economic feedback effects from spending and financing (e.g. deficit financing of a road may lead to further economic problems in the medium- and long-run). However, as the authors submit at the end of this paper, we do believe in the importance of input-output findings for showing the immediate short-term economic *impact* of spending.

Section 2.1.2. Relevance of Input-Output Findings Given Long-Run Analysis

In light of these criticisms, it is apparent that input-output models cannot determine the permanent long-run effects of public infrastructure investment. However, these models are indeed valuable to policymakers as a first step toward understanding these effects. Although there is no substitute for a proper cost-benefit analysis of each major construction initiative at the federal and state/local level to determine precisely how to invest in infrastructure, we do believe that examining the total short-run impact of spending is a valuable and necessary exercise for determining whether to invest in infrastructure at any given point in time.

The shortcomings of input-output models in describing lasting and robust effects are best overcome by the long-run vector autoregression approach conducted in Pereira (2000) and applied to updated data in this analysis. Only a VAR model can sufficiently account for the multiple feedback loops involved in public infrastructure spending, output, and GDP.[12]

Our long-run findings, taken jointly with the input-output estimates of the short-run economic impact of infrastructure spending, paint an overall positive picture of the economic impact and benefits of public investment in infrastructure. Especially taken as a pair, these estimates are robust and informative.

Section 2.1.3. Discussion of Benchmark Input-Output Multiplier Analysis

We use the Bureau of Economic Analysis's Industry-by-Industry Total Requirements after Redefinitions, 2002 benchmark data for discussion of our benchmark findings. These values

[12] See the technical appendix for further discussion of this methodology's ability to account for dynamic feedback.

measure the total requirements, direct and indirect, for every dollar of delivery to final demand at producers' prices.

To calculate aggregated effects across specific subsectors, we aggregate both horizontally and vertically for all non-construction subsectors from the table provided by the Bureau of Economic Analysis. In doing so, we calculate precisely the fifteen-sector breakdown produced by BEA's annual input-output reports.

We report the sectoral breakdown of the indirect and direct effects seen in the 2002 benchmark data for each of seven construction subsectors, as discussed in the main body of our report. These values are shown in Table Four.

It should be noted that these values are not the most up-to-date versions of the input-output multipliers. A similar presentation of the 2007 benchmark data should be conducted upon its release in 2014. Given the discussion of the sensitivity of total short-run multipliers to changes in the business cycle, it is likely that 2007 data (at the end of an expansion) will show higher input-output estimates for construction subsectors than these 2002 values, which occurred during an economic downturn. Again, we believe that our estimates are conservative.

Section 2.1.4. Discussion of Annual Input-Output Multiplier Analysis

Because of the nearly ten year gap between the 2002 benchmark data and the present, it is important to examine the rough sectoral breakdown between the economic impact of generic construction spending from the 2009 annual input-output estimates. These values are reported below in Table Five.

Generally, the breakdown of sectoral indirect effects roughly parallels that of the 2002 benchmark data, which bolsters the credibility of using aggregate construction measures on an annual basis in this analysis.

We report below in Table Six the summary breakdown of all annual input-output effects for one dollar of generic construction spending. Values reported under the total short-run multiplier column match those displayed in Figure Three in the main body of the report.

Sectoral breakdowns are relatively constant over time relative to other categories, although we see that sectors such as finance, insurance, and retail trade are more robust to fluctuations in the business cycle than manufacturing and professional/business services.

Table Four: Input-Output Effects of Construction Sub-Sectors, 2002 Benchmark Detail

	Nonresidential commercial and health care structures	Nonresidential manufacturing structures	Other nonresidential structures	Residential permanent site single- and multi-family structures	Other residential structures	Nonresidential maintenance and repair	Residential maintenance and repair
Agriculture, forestry, fishing, and hunting	0.0169	0.0039	0.0147	0.0335	0.0228	0.0205	0.0439
Mining	0.0214	0.0182	0.0375	0.0442	0.0370	0.0422	0.0389
Utilities	0.0157	0.0131	0.0159	0.0201	0.0188	0.0151	0.0186
Construction	1.0058	1.0047	1.0064	1.0071	1.0066	1.0059	1.0068
Manufacturing	0.4084	0.3863	0.3548	0.4690	0.4443	0.3137	0.5010
Wholesale trade	0.0547	0.0608	0.0482	0.0639	0.0585	0.0453	0.0683
Retail trade	0.0064	0.0015	0.0164	0.0912	0.0888	0.0354	0.0864
Transportation and warehousing	0.0336	0.0236	0.0384	0.0583	0.0467	0.0405	0.0575
Information	0.0323	0.0297	0.0321	0.0367	0.0357	0.0290	0.0336
Finance, insurance, real estate, rental, and leasing	0.0871	0.0745	0.0994	0.1038	0.0959	0.0906	0.0992
Professional and business services	0.1718	0.1485	0.2031	0.1727	0.1626	0.1575	0.1624
Educational services, health care, and social assistance	0.0002	0.0002	0.0002	0.0004	0.0004	0.0002	0.0004
Arts, entertainment, recreation, accommodation, and food services	0.0150	0.0106	0.0135	0.0146	0.0134	0.0124	0.0130
Other services, except government	0.0184	0.0169	0.0299	0.0221	0.0206	0.0262	0.0229
Government	0.0086	0.0074	0.0091	0.0118	0.0106	0.0088	0.0120
Total Short-Run Multiplier	1.8963	1.7999	1.9196	2.1495	2.0626	1.8432	2.1649

Source: Bureau of Economic Analysis, Benchmark Input-Output Accounts, 2002, and Author's Calculations.
Note: All values are in 2002 dollars.

Table Five: Short-Run Input-Output Effects, 2009 Detail

Sector	Direct Effect	Indirect Effect	Total Effect
Agriculture, forestry, fishing, and hunting	0	0.0232	0.0232
Mining	0	0.0469	0.0469
Utilities	0	0.0131	0.0131
Construction	1	0.0066	1.0066
Manufacturing	0	0.4284	0.4284
Wholesale trade	0	0.0513	0.0513
Retail trade	0	0.0377	0.0377
Transportation and warehousing	0	0.0337	0.0337
Information	0	0.0312	0.0312
Finance, insurance, real estate, rental, and leasing	0	0.0997	0.0997
Professional and business services	0	0.1680	0.1680
Educational services, health care, and social assistance	0	0.0007	0.0007
Arts, entertainment, recreation, accommodation, and food services	0	0.0098	0.0098
Other services, except government	0	0.0205	0.0205
Government	0	0.0144	0.0144
Total Short-Run Multiplier	1	0.9853	1.9853

Source: Bureau of Economic Analysis, Annual Input-Output Accounts.
Note: Values are in nominal dollars.

Table Six: Effect of $1 Construction Spending in Short-Run, 1998-2009

Year	Total Short-Run Multiplier	Agriculture, forestry, fishing, and hunting	Mining	Utilities	Construction	Manufacturing	Wholesale trade	Retail trade	Transportation and warehousing
1998	2.1189	0.0272	0.0255	0.0146	1.0072	0.5092	0.0586	0.0602	0.0438
1999	2.0646	0.0240	0.0269	0.0171	1.0065	0.4811	0.0579	0.0581	0.0417
2000	2.0561	0.0218	0.0345	0.0198	1.0064	0.4613	0.0572	0.0561	0.0402
2001	2.0137	0.0221	0.0320	0.0244	1.0064	0.4277	0.0539	0.0542	0.0396
2002	1.9803	0.0210	0.0313	0.0144	1.0065	0.4220	0.0557	0.0598	0.0383
2003	2.0005	0.0226	0.0366	0.0141	1.0064	0.4238	0.0564	0.0660	0.0396
2004	2.0102	0.0242	0.0430	0.0127	1.0053	0.4398	0.0593	0.0684	0.0404
2005	2.0523	0.0237	0.0516	0.0150	1.0061	0.4596	0.0579	0.0644	0.0408
2006	2.0531	0.0226	0.0537	0.0132	1.0063	0.4644	0.0583	0.0647	0.0408
2007	2.0462	0.0239	0.0558	0.0139	1.0064	0.4669	0.0582	0.0534	0.0388
2008	2.0696	0.0259	0.0728	0.0165	1.0068	0.4770	0.0599	0.0435	0.0393
2009	1.9853	0.0232	0.0469	0.0131	1.0066	0.4284	0.0513	0.0377	0.0337

Year		Information	Finance, insurance, real estate, rental, and leasing	Professional and business services	Educational services, health care, and social assistance	Arts, entertainment, recreation, accommodation, and food services	Other services, except government	Government
1998		0.0427	0.0981	0.1725	0.0014	0.0127	0.0291	0.0160
1999		0.0405	0.0952	0.1607	0.0012	0.0117	0.0262	0.0157
2000		0.0409	0.1019	0.1629	0.0011	0.0116	0.0245	0.0157
2001		0.0402	0.1010	0.1594	0.0009	0.0113	0.0250	0.0156
2002		0.0366	0.0961	0.1496	0.0004	0.0114	0.0225	0.0148
2003		0.0356	0.0994	0.1512	0.0004	0.0117	0.0221	0.0147
2004		0.0326	0.0954	0.1433	0.0004	0.0111	0.0195	0.0146
2005		0.0332	0.1014	0.1511	0.0005	0.0113	0.0206	0.0149
2006		0.0312	0.1022	0.1486	0.0006	0.0111	0.0206	0.0147
2007		0.0306	0.0983	0.1559	0.0004	0.0104	0.0192	0.0139
2008		0.0306	0.0899	0.1630	0.0006	0.0099	0.0190	0.0149
2009		0.0312	0.0997	0.1680	0.0007	0.0098	0.0205	0.0144

Source: Bureau of Economic Analysis, Annual Input-Output Accounts
Note: Values are in nominal dollars.

Table Seven: Historical Input-Output Estimates for Specific Infrastructure Construction Spending

	Transportation			Power Structures			Highways and Streets			Sewer Structures			Water Structures		
	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total	Direct	Indirect	Total
1998	14.26	15.96	30.22	3.40	3.81	7.21	60.77	68.00	128.77	11.53	12.90	24.43	10.48	11.73	22.21
1999	15.55	16.55	32.10	4.17	4.44	8.61	64.39	68.54	132.93	11.39	12.12	23.51	11.13	11.85	22.99
2000	19.27	20.35	39.62	4.85	5.12	9.97	66.67	70.41	137.08	10.79	11.40	22.19	10.67	11.27	21.94
2001	19.99	20.27	40.26	4.94	5.01	9.94	71.74	72.73	144.47	12.11	12.28	24.40	11.76	11.92	23.69
2002	21.76	21.33	43.09	5.29	5.19	10.48	69.56	68.19	137.75	13.48	13.21	26.69	13.13	12.87	26.01
2003	21.89	21.90	43.79	8.61	8.61	17.22	66.35	66.38	132.72	13.82	13.83	27.65	12.83	12.83	25.66
2004	21.15	21.36	42.51	7.10	7.17	14.28	66.43	67.11	133.53	14.56	14.71	29.28	13.08	13.21	26.29
2005	18.60	19.57	38.17	7.20	7.58	14.78	66.80	70.29	137.09	14.60	15.36	29.96	12.90	13.57	26.47
2006	14.73	15.51	30.24	8.37	8.82	17.19	70.96	74.73	145.70	19.19	20.21	39.39	16.05	16.91	32.96
2007	15.76	16.49	32.25	10.45	10.94	21.39	68.97	72.15	141.12	18.18	19.02	37.20	15.03	15.72	30.75
2008	17.10	18.29	35.39	9.74	10.42	20.16	68.62	73.40	142.02	18.87	20.18	39.05	15.30	16.36	31.66
2009	19.21	18.93	38.14	10.46	10.30	20.76	69.05	68.04	137.09	18.09	17.82	35.91	14.50	14.29	28.79

Note: Values are in billions of 2005 US dollars.

Source: Bureau of Economic Analysis, 1998-2009 Annual Inpuut Output Accounts, and BEA, Investment in Government Fixed Assets (Table 7.5), Release 2011

Author's calculations have deflated values to 2005 dollars using the appropriate federal non-defense and state/local deflators, and input-output effects are calculated by the author.

Section 2.1.5. Discussion of the Short-Run Impact of Historical Investment Analysis

We reported in the main body the total effects of previous spending on five types of public infrastructure at the federal and state/local level, presented in Table Two. Table Seven above provides a more detailed version of these estimates, including both direct and indirect effects which total to the estimates reported in the main body.

All values are reported in billions of 2005 dollars, deflated using the appropriate federal non-defense or state/local deflator from the Bureau of Economic Analysis. Direct spending levels are the reported investment spending values at the state/local and federal level in each of the five areas of public infrastructure reported in the table. These values come from the BEA's Table 7.5, Investment in Government Fixed Assets. Annual construction multipliers are then applied to these direct values to produce indirect effects, and both are summed to calculate the total economic impact of each type of infrastructure investment in the short-run.

Section 2.2. Marginal Product Calculation

Data for the long-run analysis came from BEA National Economic Accounts, and we specifically use Gross Domestic Product (Table 1.1.5), NIPA Implicit Price Deflators (Table 1.1.9), and the Current-Cost Net Stock of Government Fixed Assets (Table 7.1B), most recently updated in Fall 2011. All numbers were deflated to 1987 US dollars using the government consumption and investment deflator series to match the 1987 values used in Pereira (2000)'s VAR elasticity calculations.

Section 2.2.1. Selection of Elasticities

The basic calculation of the marginal product of infrastructure investment involves multiplying the elasticity of public investment to GDP by the relative intensity of public investment over the last thirteen years.

Our first task was to select appropriate elasticities. We read over one hundred articles to understand how the relationship between public investment and economic output has been studied. Most studies have found slightly positive or neutral long-run and short-run effects of infrastructure spending. Results from seventy-nine articles that directly calculated either a marginal product, elasticity, or both, are presented at the end of this appendix. These articles were found by examining three major, recent literature reviews – Pfahler (1996), Pereira (2010) and Ramey (2011). The articles included were either cited in those reviews, updated versions of cited articles, or other articles found in a review of the elasticity of public investment literature.

The team identified trends in the literature that supported the theoretical underpinnings of our research. Most of the articles reported positive relationships between investment and GDP; some did report a negative relationship and or statistically insignificant results. An initial review of the literature suggested that the some differences in findings are explained by differential methods used between papers. Ultimately, after careful consideration, we elected to use the results from the VAR conducted by Pereira (2000) based both on their technical sophistication and theoretical compatibility.

One of the biggest causes of different findings was the type of model used to estimate the effect of public investment. The most common model utilized in our survey was the production function approach, deployed in more than half of the papers surveyed, as can be seen in Table Eight below. However, in recent years, use of the vector autoregression approach (VAR) has grown in popularity.

Table Eight: Long-Run Literature, Models Used

Model	Uses
Production Function	39
VAR	16
Total Factor Productivity	7
Profit Function	3
Cost Function	3
VECM	3
Rate of Return to Capital	2
2SLS	2
Wharton, Klein-Goldberger, and Brookings Models	1
OLS (Personal Income)	1
Differencing	1
GMM	1
SW DSGE Model	1
First Differences	1

Source: Literature review of relevant academic and professional long-run studies. Author's Calculations.
Note: Some papers studied utilize multiple models.

The production function approach implicitly considers public capital "an exogenous variable not affected by private sector variables" (Pereira and Flores, 1999, 302). This restriction thus fails to consider the possibility that levels of public capital investment may also be driven by private economic activity. VAR's true advantage over other approaches used in this literature is that the time-series method allows for the possibility of dynamic feedback effects (in other words, back-and-forth effects between public capital and private output). The VAR framework does not impose an a priori restriction on the dynamic relationship, meaning it accounts for observed feedback in its estimates of the elasticity of GDP to public capital. Therefore, VAR's main strength over other approaches is its systematic handling of the possibility of the endogenous determination of private capital and employment (Pereira and Flores, 1999, 303).

There are also criticisms of the VAR model. Edelberg (1999) criticizes the VAR approach on the basis that if the estimation time period does not include the occurrence of one particular type of shock, VAR findings will fail to accurately predict the impact of such a shock if and when it does occur (168). Other criticisms of VARs focus around their robustness, suggesting they are sensitive to outliers in the sample period or small changes in the list of variables used (Edelberg, 1999, 168). Another critique points out that although the VAR does not impose causality restrictions, it does impose restrictions on proper ordering of variables, the theoretical basis of which can be open to scrutiny (Duggal, 1999, 50).

Ultimately, however, the ordering of variables can be theoretically justified, and tested for robustness during model estimation. Production function models simply do not account for dynamic feedback effects. Especially given recent political decisions on infrastructure funding contingent upon economic conditions, this omission produces results that are too simplistic. Even if this bias is corrected, OLS estimates do not allow for conclusions about causality to be drawn (Pereira, 2000, 513). On this basis, we selected elasticities derived using the VAR method over the production function approach.

Other trends in the literature had to do with the types of investments analyzed, which varied widely. Most of the literature analyzed aggregate spending, and forty-eight of the articles studied aggregate spending at the national and state level. However, even within these articles, the definition of "aggregate" spending varied widely. For example, Auerbach and Gorodnichenko (2010) defined aggregate as all government spending, whereas Abdih and Joutz (2008) define aggregate public capital as the non-residential non-military stock of federal, state, and local structures, equipment and software. Pereira (2000), the origin of our elasticities, defined aggregate spending as the sum of five sectors studied rather than all public investment.

Many of the articles studied some form of highway spending, and generally agreed that the appropriate elasticity for highway investment spending was positive. However, the elasticities and marginal products presented ranged widely. The marginal products varied from as low as .07 in Eberts (1986) with a production function approach, to as high as 1.97 in Pereira (2000) with a VAR approach.

Pereira (2000) looked at a number of public infrastructure sectors that included highways and streets; electric power generation or gas fired power generation and mass transit systems; sewage and water treatment facilities; public buildings; and conservation and development structures. These five broad categories allow for a more detailed approach, and are consistent with the categories presented by the BEA. Selecting a paper which produces relevant elasticities over broad and varied sectors and types of infrastructure enabled this study to present findings relevant to transportation infrastructure as well as across a broad spectrum of categories of public infrastructure spending.

We are confident that the elasticities calculated in Pereira (2000) pass thorough scrutiny. The paper described extensive testing for unit roots, the optimal number of lagged differences and deterministic components, and cointegration (Pereira 2000, 514). The final elasticities represent the total percentage-point changes in GDP for each long-term accumulated percentage-point change in public investment accounting for dynamic feedback. In other words, they estimate the true sensitivity of GDP to public investment.

It should be noted that the term marginal product in this context refers to a measurement of both the direct effects of public investment on output "and the indirect effects of public investment on output through changes in the evolution of private inputs" (Pereira 2000, 516). This differs from the typical definition of a marginal product, which only includes direct effects, in that it is more complete and relevant to policy application.

The relative intensity of recent spending on infrastructure was calculated by dividing the summation of all GDP produced during our sample by the sum of all annual changes in the value of net capital stock of public infrastructure for each type of investment. The basic premise of calculating this intensity over the last thirteen years is that the current stock of infrastructure has a large impact on the usefulness of additional spending. Specifically, the data used was the same type of series as used in Pereira (2000), the differences in the levels of net stock. This takes into account both new investment in infrastructure from year-end to year-end, as well as any depreciation of capital stock that took place contemporaneously.

Equation One: Marginal Product Calculation

$$MP_z = \varepsilon^{GDP}_{Investment_z} x \frac{\sum_{i=1998}^{2010} GDP_i}{\sum_{i=1998}^{2010} \Delta Net\ Capital\ Stock_{iz-(i-1)z}}$$

For ease of reference, we present below a slightly modified Table Three from the main body of the report to show the relative intensity calculation in depth. Table Three (Redux) (below) reports the raw change in the value of capital stock from 1997 to 2010 (and percentage change), as well as the GDP summation from this period. The latter divided by the former produces the calculated relative intensity, and when multiplied by the appropriate elasticity from Pereira (2000), this method calculates marginal products.

Table Three (Redux): Derivation of Marginal Products

	Value of Capital Stock Raw Change 1997-2010	Value of Capital Stock Per. Change 1997-2010	GDP Sum 1997-2010	Relative Intensity (GDP Change / Capital Stock Change)	Elasticity (Pereira (2000))	Marginal Product
Total Investment	1349.6735	47.42%	101744.14	75.38	0.0425	3.2061
Highways and Streets	485.0808	53.15%	101744.14	209.75	0.0055	1.1536
Transportation and Power	151.1854	56.76%	101744.14	672.98	0.0210	14.1527
Sewer and Water	128.7056	34.31%	101744.14	790.52	0.0086	6.7668
Health, Educational, Office, Public Safety	537.5496	54.93%	101744.14	189.27	0.0173	3.2782
Conservation, Development, Nonmilitary Equipment	47.1521	15.03%	101744.14	2157.79	0.0049	10.5947

Source: Intensities calculated from BEA Net Capital Stock Data, 1997-2010, and BEA GDP data deflated using NIPA Implicit Price Deflators. Elasticities from Pereira (2000). Author's calculations.

Note: Values reported are in 1987 dollars, and marginal product indicates the total economic gain over a twenty-year period from one dollar of spending in each of the five areas of public infrastructure. Adjusting for 2011 dollar values would produce identical results.

Section 2.2.2. Sensitivity Analyses

Pereira (2000) remained the most current application of the VAR methodology that effectively gauged the added economic benefit of the specific types of infrastructure studied in this project. Applying elasticities calculated using dated BEA data did require the authors of this study to work closely with Alfredo Pereira, as well as very helpful individuals at both the Census Bureau and the BEA to accurately reclassify data to accommodate 1997 changes in the classification of specific types of federal and state/local investment used in this study.

Before 1997, BEA used an "asset-based classification system", but has since utilized a functional classification system (Bennett, 2011, 29). This entailed a reorganization of many relevant categories to this project; for example, some items shifted from a category known as 'other structures' into highways and streets. The second set of changes had to do with the rate of depreciation, which has been revised several times since Pereira first conducted his analysis (Bennett 2011).

In an effort to ensure the applicability of Pereira (2000)'s elasticities to newer data on the relative intensity of net capital stock, this study sought first to reclassify new BEA gross fixed capital categories given in Table 7.1B along Pereira (2000)'s classification schemes. To do so, we utilized Pereira (2000)'s dataset, the Fixed Reproducible Tangible Wealth (1925-1997) tables available via compact disc, and were successful at replicating Pereira's 1988-1997 findings within a reasonable degree of certainty. Using the categories obtained through this replication, we then closely applied these categories to the new classification schemes present in post-1997 BEA data. Our categorizations relative to Pereira (2000) can be found below in Table Nine.

It is valuable to briefly define the types of public investment which are included in each of these categories. These definitions given below were drawn from the Census Bureau's Construction Spending Methodology, and they represent a close approximation of the categories used by the Bureau of Economic Analysis for our data. The following list should be taken as illustrative of the types of programs and spending areas included in our analysis, however it should not be taken as an exact listing of the specific types of spending either conducted by the government each year or included in our study. It is therefore meant solely for reference and ease of future research.

Table Nine: Breakdown of BEA Investment Categories, Post-1997

Category (Pereira 2000)	Investment Type (BEA)	Federal or State (BEA)
Highways and Streets	Highways and Streets	Federal
	Highways and Streets	State
Transportation and Power	Transportation	Federal
	Power	Federal
	Transportation	State
	Power	State
Sewers and Water	Sewer Systems	State
	Water Systems	State
Health, Educational, Office and Public Safety	Office	Federal
	Commercial	Federal
	Health Care	Federal
	Educational	Federal
	Public Safety	Federal
	Other Structures	Federal
	Office	State
	Commercial	State
	Health Care	State
	Educational	State
	Public Safety	State
	Other structures	State
Conservation and Development	Conservation and Development	Federal
	Equipment and Software	State
	Conservation and Development	State

Source: Author's efforts to replicate Pereira (2000)'s findings using Fixed Reproducible Tangible Wealth, 1925-1997 data, and BEA 1997-2010 Current Cost Net Stock of Government Fixed Assets, Table 7.1B.

Generally, highways and streets spending includes pavement, lighting, retaining walls, tunnels, bridges, toll facilities, border crossing stations, maintenance buildings and rest facilities. Transportation includes air transportation (e.g. airport terminals and runway construction), land transportation (e.g. bus terminals, light rail, subways and railroad track), and water transportation (e.g. docks and marinas). Power includes all types of power generation facilities, electric distribution systems, as well as buildings and structures for the distribution, transmission, gathering and storage of natural gas and crude oil. Sewer systems include sewage and waste disposal infrastructure, specifically solid waste and wastewater disposal plants, sanitary sewers, sewage pipelines, sewer stations, and water collection systems. Water systems include plants, wells, water transmission pipes, pump stations, reservoirs, and water storage systems.

Buildings include general administration buildings, computer centers, and financial or bank institutions. Commercial buildings include automotive buildings, food and beverage facilities, warehouses, and some farm construction. Health buildings include hospitals and other medical buildings. Educational buildings include all levels of schooling, as well as libraries, archives and museums. Public safety buildings include correctional facilities, police stations and fire stations. Conservation and development structures include non-power dams, dikes, levees, locks and lock gates, breakwater and jetty systems, irrigation projects, fish hatcheries, wetlands and non-irrigation related dredging.

Generally speaking, construction in these categories is defined as new buildings and structures, as well as site preparation and outside construction, plus additions, alterations, conversions, expansions, reconstructions, renovations, rehabilitations and major replacements.

Beyond attempting to reclassify data according to the classifications used in Pereira (2000), we also took steps to ensure that our findings were robust to BEA's 1997 alterations in the depreciation rate used to calculate net capital stock.We conducted two sensitivity analyses, whereby we modified the post-1997 data using information gleaned from the pre-1997 classifications available in the Fixed Reproducible Tangible Wealth (FRTW) dataset. We worked to determine if changing the underlying data for new depreciation rates would seriously or critically alter any of our findings such that we question the applicability of Pereira (2000)'s elasticities.

Fortunately for our efforts, the FRTW dataset used by Pereira (2000) contained 1997 data pre-classification change. Our current dataset (updated for new classifications and depreciation rates) also included 1997 values. Thus, our first sensitivity analysis involved taking the percent difference between the levels of each type of net capital stock in our new data and the FRTW dataset in year 1997, and adjusting the new data based upon this percent difference. Specific adjustment factors for each of the five categories are found in Table Ten below.

As reported below in Table Eleven, adjusting all data values by these factors produces marginal product and total tax revenue estimates (including federal and state/local) which were roughly similar to the values produced in our unadjusted estimates reported in the main body of this text. Findings for all categories mirror in magnitude and order our initial results. [13]

[13] The largest differences are seen in the conservation, development, and nonmilitary equipment section. It is likely that determination of net capital stock in this category is highly subject to depreciation formulas.

Table Ten: Sensitivity Analysis One, 1997 Adjustment Factors

Category	FRTW 1997 Net Capital Stock	BEA 7.1B 1997 Net Capital Stock	Percent Difference
Aggregate	4,073,398	3,782,000	7.70%
Highways and Streets	1,359,089	1,208,800	12.43%
Transportation and Power	335,946	352,700	-4.75%
Sewers and Water	495,556	496,300	-0.15%
Buildings	1,361,283	1,301,900	4.56%
Conservation & Development	521,524	422,300	23.50%

Source: Fixed Reproducible Tangible Wealth, 1925-1997 (FRTW), as used in Pereira (2000). BEA 1997-2010 Current Cost Net Stock of Government Fixed Assets, Table 7.1B. Author's Calculations.
Note: Values reported are net capital stocks in tens of thousands of 1997 US dollars.

Table Eleven: Long-Run Effects and Tax Revenue from Government Investment, Sensitivity Analysis One

	Pereira (2000) MP	Unadjusted MP	Adjusted I MP	Unadjusted Tax Revenue	Adjusted I Tax Revenue
Total Investment	4.46	3.21	3.01	0.96	0.90
Highways and Streets	1.97	1.15	1.03	0.35	0.31
Transportation and Power	19.79	14.15	14.86	4.25	4.46
Sewer and Water	6.35	6.77	6.78	2.03	2.03
Health, Educational, Office, Public Safety	5.53	3.28	3.14	0.98	0.94
Conservation, Development, Nonmilitary Equipment	4.06	10.59	8.58	3.18	2.57

Source: Pereira (2000). Fixed Reproducible Tangible Wealth, 1925-1997 (FRTW), as used in Pereira (2000). BEA 1997-2010 Current Cost Net Stock of Government Fixed Assets, Table 7.1B. Author's Calculations.

The second sensitivity analysis involved calculating the annual growth rates for each series of net capital stock for years 1998-2010, and applying these growth rates to the old FRTW data starting from 1997. This adjustment preserved the growth rates present in new data, while utilizing the pre-classification levels of net capital stock. Table Twelve shows the results of applying the second adjustment to our marginal product and tax revenue calculation. Although the resulting marginal products changed in magnitude, they again remained in the same order of magnitude as the unadjusted values. Overall, this second sensitivity analysis produced results that are not significantly different from our main findings such that we believed the data are compatible.

Table Twelve: Long-Run Effects and Tax Revenue from Government Investment, Sensitivity Analysis Two

	Pereira (2000) MP	Unadjusted MP	Adjusted II MP	Unadjusted Tax Revenue	Adjusted II Tax Revenue
Total Investment	4.46	3.21	2.94	0.96	0.88
Highways and Streets	1.97	1.15	1.02	0.35	0.31
Transportation and Power	19.79	14.15	13.80	4.25	4.14
Sewer and Water	6.35	6.77	6.78	2.03	2.04
Health, Educational, Office, Public Safety	5.53	3.28	3.01	0.98	0.90
Conservation, Development, Nonmilitary Equipment	4.06	10.59	8.94	3.18	2.68

Source: Pereira (2000). Fixed Reproducible Tangible Wealth, 1925-1997 (FRTW), as used in Pereira (2000). BEA 1997-2010 Current Cost Net Stock of Government Fixed Assets, Table 7.1B. Author's Calculations.

The comparison in Table Thirteen below shows that both sets of adjusted values tended to be very similar, suggesting the robustness of both checks, as well as the original calculations.

Table Thirteen: Comparison of Long-Run Effects and Tax Revenue, Sensitivity Analysis Findings

	Adjusted I MP	Adjusted II MP	Adjusted I Tax Revenue	Adjusted II Tax Revenue
Total Investment	3.01	2.94	0.90	0.88
Highways and Streets	1.03	1.02	0.31	0.31
Transportation and Power	14.86	13.80	4.46	4.14
Sewer and Water	6.78	6.78	2.03	2.04
Health, Educational, Office, Public Safety	3.14	3.01	0.94	0.90
Conservation, Development, Nonmilitary Equipment	8.58	8.94	2.57	2.68

Source: Pereira (2000). Fixed Reproducible Tangible Wealth, 1925-1997 (FRTW), as used in Pereira (2000). BEA 1997-2010 Current Cost Net Stock of Government Fixed Assets, Table 7.1B. Author's Calculations.

Based on the relative robustness of our results given our sensitivity analysis, we elected to present the original unadjusted series in the main report itself. Further research should work to calculate new elasticities using post-1997 BEA classifications and depreciation definitions. However, we are confident that the true marginal product of each category of public infrastructure lies between the maximum and minimums reported in our initial findings and both sensitivity analyses, spanning the range indicated in Table Fourteen below.

Table Fourteen: Upper and Lower Bounds of Marginal Products

	Pereira (2000)	Lower Bound	Upper Bound	Range
Total Investment	4.46	2.94	3.21	0.27
Highways and Streets	1.97	1.02	1.15	0.13
Transportation and Power	19.79	13.80	14.86	1.06
Sewer and Water	6.35	6.77	6.78	0.02
Health, Educational, Office, Public Safety	5.53	3.01	3.28	0.26
Conservation, Development, Nonmilitary Equipment	4.06	8.58	10.59	2.02

Source: Pereira (2000). Fixed Reproducible Tangible Wealth, 1925-1997 (FRTW), as used in Pereira (2000). BEA 1997-2010 Current Cost Net Stock of Government Fixed Assets, Table 7.1B. Author's Calculations.

Section 2.2.3. Tax Revenue Calculations

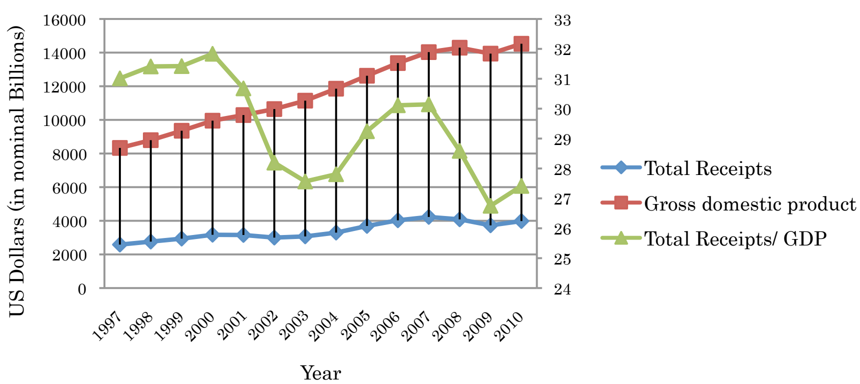
Our research suggests that initial infrastructure investment generates significant tax revenue for the government in the long-run.

To allow an accurate approximation of tax revenues likely generated by resulting economic output, our study first examined the history of tax receipts collected by the federal and state/local governments to make a good estimate of future tax receipts. To accomplish this task, our team used data collected by the Bureau of Economic Analysis (BEA). Specifically, the team used the BEA National Income and Product Accounts Table, Table 3.1 Government Current Receipts and

Expenditures. Total receipts thus include personal income taxes, corporate income taxes, production and import taxes, taxes from foreign income, contributions for government social insurance, income receipts from government owned assets such as interest and dividends, and transfer receipts from businesses and individuals and lastly, any surplus (i.e. profit) from government enterprises. This is a long list, but as seen in the input-output model of our main body, infrastructure investment can affect all of these revenue streams and therefore must be taken into account.

The relationship between current receipts and GDP is how the team derived the rate of future taxes to be expected. Figure Four illustrates this relationship. On the left axis of the figure is US GDP in billions of US Dollars. The right axis of the figure shows the ratio of total receipts to GDP as a percentage. The red line with the boxes shows an upward trend of GDP from 1997 to 2010. The blue line similarly shows an upward trend of total receipts but the increase is not as pronounced. The green line with the triangles describes the ratio of total receipts to GDP. The green line appears to fluctuate above and below the thirty percent rate with seven years above and seven years below. Furthermore, our study calculated average total receipts over the period covered in our study, which amounted to 29.442%. Thus, for simplicity's sake the team chose thirty percent as an estimate for future total tax revenues.

Figure Four: Expected Tax Revenue [14]



According to an analysis of state and local tax revenues completed by the Tax Foundation for the years 1977-2009 (Tax Foundation, 2009), the average annual state/local average tax rate across all fifty states varies between 10.4% and 9.2% during these years. From 1997 – 2009, which more closely matches the sample used in this analysis, the state/local tax rate varies between 9.4% and 9.8%. Based upon these data and for ease of discussion of findings, this study assumed a 10% rate at the state/local level, and thus a 20% rate for federal taxation.

Section 2.3. Scoring of Alternative Financing Proposals

This study has produced two simple scores of hypothetical financing proposals for public infrastructure projects which we feel are illustrative of the economic benefit of new and creative means to supplement the gas tax. These are necessarily rough estimates of costs, inputs, and

[14] Source: Bureau of Economic Analysis, US Department of Commerce, Table 3.1 Government Current Receipts and Expenditures, National Income and Product Accounts Table (NIPA), from year 1997 to 2010 annually. http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=86&ViewSeries=NO&Java=no&Request3Place=N&3Place=N&FromView=YES&Freq=Year&FirstYear=1997&LastYear=2011&3Place=N&Update=Update&JavaBox=no#Mid , accessed on November 22, 2011.

resulting economic profits; however, we believe that simple calculations as such can drive further more empirical research into new financing proposals.

Section 2.3.1. Public-Private Partnerships

Public-private partnerships work in part as matching grant from a government to a private enterprise. The private partner funds the project at fifty percent (or thereabouts) while the state lends the other fifty percent to the firm. The firm agrees to pay the state payments for a designated period of time that will repay the total amount of the project. Those funds can be in turn used for any purpose under the Federal Surface Transportation Legislation (Becker and Patterson, 2005).

To score this option our team made the following assumptions: first that there is a perfectly competitive process by which the private enterprise is selected for participation to ensure that the private enterprise is incentivized to remain cost effective; second, that a project cost of $100 million could be funded by a $50 million loan from the government paid back at a 4% interest rate over 30 years; and third, a $50 million upfront cost by the private enterprise would be bonded at 4% interest rate over 30 years to finance that company's upfront expenses (Kile, 2011, 2).[15] The team chose a 4% bond interest rate for simplicity of calculation and because rates fluctuate above and below periodically. Lastly, we assumed that discounting will follow the standard for required for subsidy costs and loan guarantees as outlined in the Federal Credit Reform Act of 1990 (FCRA).[16] The FCRA requires that the net present value be calculated using discount rates equal to the interest rates on Treasury securities of comparable maturity. Since the team assumed a 4% thirty-year bond rate, that same rate was used as the discount rate.

Figure Five: Scoring of Public-Private Partnership Proposal

Assumptions:
(1) Cost of road project is $100 million, shared between government and private enterprise.
(2) Government pays $50 million loan to private enterprise, paid back at 4% interest rate over 30 years.
(3) Private enterprise bonds remaining $50 million cost at 4% interest rate over 30 years.
(4) Road maintenance and operation costs amount to 5% of total cost each year.
(5) Perfectly competitive selection process to enter into PPP.

Private Sector Costs:	
(1) Operation and Maintenance:	$ 5 million per year
(2) Debt Service:	$10 million per year
(T) Total:	$15 million per year

Private Sector Revenues:
(1) Assume $1.00 toll charged in one toll plaza.
(2) To break even, 1804 cars per hour must pass through toll plaza.

Conclusion:
(1) Relative to known traffic estimates, 1804 cars per hour is low.
(2) If costs are kept to a minimum and road placement is efficient, this is likely cost effective.

Source: Author's calculations.

[15] Kile, page 21, 4.26 percent was the rate for a 30-year Treasury bond as of May 5, 2011. These rates are subject to daily market change. Our estimate is based on an initial offering and assuming compliance with the Transportation Infrastructure Finance and Innovation Act. The TIFIA is administered by the Department of Transportation and only approves projects that are relatively safe. Riskier projects are handled as subsidies at an average rate of 10%.

[16] Federal Credit Reform Act, Financial Management Service, US Department of Treasury, Publications, http://www.fms.treas.gov/ussgl/creditreform/fcra.html, accessed on 28NOV11, also accessed on westlaw.com and cited as 51 U.S.C.A. § 50302, Loan guarantees for production of commercial reusable in-space transportation

From the perspective of the private enterprise, these assumptions generated a total annual cost of the project of $15.8 million dollars over the life of the project (30 years), which sums to $474.3 million in non-discounted lifecycle cost. Assuming that one toll plaza is constructed charging one dollar tolls for every vehicle, we estimated that daily traffic through the projected road must amount to roughly 1,804 cars per hour to annually fund the project given the private enterprise's expenses.[17] This is a moderate level of volume given an analysis of daily traffic on prominent highways. Heavy volume highways can see anywhere from 200,000 to 220,000 vehicles per day and light volume from 20,000 to 30,000 vehicles per day. Our estimate is approximately 43,000 vehicles per day which rates at the lighter side for volume compared to available data.[18]

Funding mechanisms are already in place for public-private partnerships. For example, the Transportation Infrastructure Finance and Innovation Act (TIFIA) provides federal loans to qualifying state and local projects for up to thirty-five years at interest rates on Treasury securities (Kile, 2011, 21). TIFIA loans can be used for up to one-third of a projects cost. Riskier projects can still be funded by TIFIA but at a substantially higher interest rate of 10% (Kile, 2011, 21). The Department of Transportation administers the TIFIA program and makes the determination on which projects to fund. The TIFIA loans encourage private-sector participation by having lower priority for repayment than private debt in the event of default because private managers can defer repayment for up to five years after the project's completion. This is valuable if there is uncertainty over how much toll revenue a highway will generate (Kile, 2011, 22).

Section 2.3.2. Tax Deductible Infrastructure Investment

Tax deductions for infrastructure investment will likely lead to an overall increase in the level of funding available to finance future investment, per our study's calculations below.

The team scored this option by using a simple calculation of the effect of a one-for-one deduction for corporate re-investment in highways and roads spending. Assuming that the state spends one dollar on highways and streets that generates $0.98 in additional economic activity per our input-output findings presented earlier, businesses under this scheme would be encouraged to reinvest their profits into building further roads. If private enterprises reinvest only 5% of this additional economic output into highway construction, the state receives an additional $0.049 for use in highway spending. We assume a 30% aggregate tax level.

This new investment leads to a decrease of $0.0147 in total tax receipts collected, but an increase in $0.049 in "revenues" that can be put toward highway spending. The net increase is then $0.0343 in total government receipts. These additional 3.4 cents of investment become a much larger number when investment occurs in the tens of thousands of dollars. This simple scoring illustrates how tax deductions lead to increased total investment.

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[17] We divided annual cost of the project by 365 days, then divided that number by 24 hours to get 1804.9 drivers per hour needed to pay a one dollar toll to break even.

[18] The team used traffic counts from I-95 corridor to estimate a moderate volume of traffic around toll booths. We used the toll booth located in Elkton Maryland as a baseline estimate. http://www.interstate-guide.com/i-095.html accessed 15NOV11.

Figure Six: Scoring of Tax-Deductible Private Investment Proposal

(1) Government spends $1.00 on highways and roads.
(2) That creates $0.98 in additional revenue given the BEA IO short-run construction multiplier.
(3) Assume that businesses reinvest 5% of that $0.98 in this program, or $0.049.
(4) Assuming an average tax rate of 30%.

Pre-Inv Tax Liability	$0.980
Post-Inv Tax Liability	$0.931
Difference	$0.049
Pre-Inv Tax Receipts	$0.294
Post-Inv Tax Receipts	$0.279
Difference	$0.0147

(5) This leads to a decrease in $0.0147 in tax receipts, but an increase in $0.05 towards road spending.
(6) That is a net increase of $0.0343 towards road construction.

Source: Author's calculations.

Section 2.4. Suggested Areas for Further Research

This study has identified several areas of further research which would aid in updating the academic and professional literature regarding the economic impacts of infrastructure spending. Although outside of the purview of this project, future research should look to run a new VAR model simulating the dynamic feedback between output and investment spending using BEA data following their 1997 reclassification and rate of depreciation changes. New elasticities calculated from this VAR could then be applied to comparable data used in this study. Although we expect such a process to produce results which closely mirror our own findings and sensitivity analyses, newer elasticities would be a boost to future research in this field.

Future recalculations of elasticities should look to include tax revenue and rate variables directly within the model estimation to incorporate governmental taxation into the dynamic feedback loops estimated by the VAR. As dynamic interaction occurs between economic output and public investment, so it is likely to occur between economic output and taxation. An estimation of these effects with taxation included as a controlled-for variable would result in a more precise and sophisticated calculation of ensuing tax revenue.

Another valuable area of extension would be to conduct similar analyses using region- or state-level data. A similar project with disaggregated marginal products and tax revenue calculations by region or state would substantially improve policymakers' ability to target infrastructure spending towards areas with highest expected returns. Such a study would also need to carefully account for the effects of regional and state spillovers, as in Pereira and Andraz (2004, 2010).

It would be similarly valuable to produce a VAR that diagrams marginal products of infrastructure investment across industries. Just as there are spillovers between regions, there are also spillovers between industries. The results of the input-output model in this study describe the effects of sector-specific investment that spills over into other sectors, which calls for further research into the long-run permanent spillover effects calculated through the more robust VAR methodology. If possible, it would produce a more informed and informative discussion of how, for example, public investment in highways and streets infrastructure affects the manufacturing sector and the agricultural sector.

SUMMARY TABLE OF LONG-RUN LITERATURE STUDIED

Section 3.0. Summary Table of Long-Run Literature Studied

Author(s)	Title	Journal	Year	Data	Model	Type of Public Investment	Multiplier /MP	Elasticity	Source
Evans, Michael K.	Reconstruction and Estimation of the Balanced Budget Multiplier	Review of Economics and Statistics	1969	Q, 1948-1962	Wharton, Klein-Goldberger, and Brookings Models	Aggregate	Slightly Above 2		Ramey (2011)
Barro, Robert J.	Output Effects of Government Purchases	Journal of Political Economy	1981	TS, 1889-1978	Production Function	Defense Spending Non-Defense Spending	Temporary defense shifts correspond to double the impact. Permanent defense spending shifts correspond with little long-term effects. Non-defense estimated imprecisely.		Article
Ratner, J.	Government capital and the production function for the US private output	Economic Letters, Vol 13, pp. 213-217	1983	TS, 1949-1973	Production Function	Aggregate	Insignificant effects.	0.06	Pereira (2010)
Eberts, R.	Estimating the contribution of urban public infrastructure to regional growth	Federal Reserve Bank of Cleveland, Working Paper 8610	1986	PD, 1958-1978, SMSAs	Production Function	Aggregate Highways & Water	.03 .07	0.04 0.03	
Hall, Robert E.	The Role of Consumption in Economic Fluctuations	in Gordon, Robert J.. The American Business Cycle: Continuity and Change, National Bureau of Economic Research Conference on Business Cycles (Chicago: University of Chicago Press, 1986), pp. 237-255.	1986	TS, 1920-1942, 1947-1982	Production Function	Military Spending	0.62		Article
Costa, J., R. Ellson and R. Martin	Public capital, regional output, and development: some empirical evidence	Journal of Regional Science, Vol. 27, No. 3, pp. 419-437	1987	CS, 1972, 48 States	Production Function	Aggregate Manufacturing Non-Agriculture Spending		0.20 0.19 0.26	Article
Aschauer, D.	Government Spending and the "Falling Rate of Profit"	Economic Perspectives, XII, pp. 11-17	1988	TS, 1953-1985	Rate of Return to Capital	Aggregate		0.18-0.23	Article
Deno, K.	The effect of public capital on U.S. manufacturing activity: 1970 to 1978	Journal was Southern Economic Journal, Vol. 55, pp. 400-411	1988	PD, 1970-1978, 36 SMSAs	Profit Function	Aggregate Highways Water Sewers		0.69 0.31 0.08 0.30	Article
Holtz-Eakin, D.	Private output, government capital and the infrastructure 'crisis'	Department of Economics Discussion Paper Series No. 394, Columbia University	1988	TS, 1950-1985	Production Function	Federal Aggregate State Aggregate		0.39 0.23	Pfahler (1996/1997)

Aschauer, D.	Is public expenditure productive?	Journal of Monetary Economics, Vol. 23, pp. 177-200	1989	TS, 1949-1985	Production Function	Aggregate Core (Highways, Transit, Power, Water, Sewers) Other Buildings Hospitals Conservation and Development Structures Education Buildings		0.38-0.56 0.24 0.04 0.06 0.02 (~0) -0.01 (~0)	Article
Aschauer, D.	Does public capital crowd out private capital?	Journal of Monetary Economics, Vol. 24, pp. 171-188	1989	TS, 1953-1986	Rate of Return to Capital	Nonmilitary Public Capital Stock		0.24	Pfahler (1996/1997)
Ram, R. and D. Ramsey	Government capital and private output in the United States --additional evidence	Economic Letters, Vol 30, pp. 223-226	1989	TS, 1949-1985	Production Function	Aggregate Federal State		0.24 0.05 0.19	Pereira (2010)
Aschauer, D.	Why is infrastructure important	in Munnell, A. (Ed.) Is There a Shortfall in Public Investment?, Federal Reserve Bank of Boston, pp. 21-50	1990	PD, 1965-1983, 50 States	Production Function	Core Infrastructure (Base Model) Core Infrastructure (Assuming increasing returns to scale)	2.226-2.230 4.5	0.055 0.11	Article
Eberts, R.	Cross sectional analysis of public infrastructure and regional productivity growth	Working Paper 9004, Federal Reserve Bank of Cleveland	1990	PD, 1965-1977, 36 SMSAs	Total Factor Productivity	Aggregate		0.49	Article
Merriman, D.	Public capital and regional output: another look at some Japanese and American data	Regional Science and Urban Economics, Vol. 20, pp. 437-458	1990	CS, 1972, 48 States	Production Function	Aggregate		0.2	Pereira (2010)
Munnell, A.	Why has productivity growth declined? Productivity and public investment	New England Economic Review, January/February, Federal Reserve Bank of Boston, pp. 3-22	1990	TS, 1948-1987	Production Function	Core Infrastructure		0.31-0.39	Article
Munnell, A. and L. Cook	How does public infrastructure affect regional economic performance	New England Economic Review, Sept/Oct, Federal Reserve Bank of Boston, pp. 11-33	1990	PCS, 1970-1986, 48 states and 4 regions	Production Function	Aggregate Highways Water and Sewers Other		0.15 0.06 0.12 0.01	Article
Rubin, L.S.	Productivity and the Public Capital Stock: Another Look	Board of Governors of the Federal Reserve System, Working Paper 118	1990	PD, 1956-1986, 11 Sectors	Total Factor Productivity	Core Infrastructure		~0	Pfahler (1996/1997)
Duffy-Deno, K.T.	Public Capital and the Factor Intensity of the Manufacturing Sector	Urban Studies, 28, pp. 3-14	1991	PD, 1970-1978, 36 SMSAs	Profit Function	Aggregate		0.24-0.27	Pfahler (1996/1997)

Duffy-Deno, K. and R. Eberts	Public infrastructure and regional economic development: a simultaneous equations approach	Journal of Urban Economics, Vol. 30, pp. 329-343	1991	PD, 1980-1984, 28 SMSAs	OLS (Personal Income) 2SLS (Personal Income)	Aggregate		0.037 0.113	Article
Eisner, R.	Infrastructure and regional economic performance: comment	New England Economic Review, September, Federal Reserve Bank of Boston, pp. 47-58	1991	PCS + PTS, 1970-1986, 48 states	Production Function	Aggregate		0.155-0.165	Article
Hulten, C. and R. Schwab	Public capital formation and the growth of regional manufacturing industries	National Tax Journal, Vol. 64, No. 4, pp. 121-134	1991	PD, 1949-1985, 9 Regions	Total Factor Productivity	Aggregate		~0	Pereira (2010)
Hulten, C. and R. Schwab	Is there too little capital? Infrastructure and economic growth	The University of Maryland and the American Enterprise Institute	1991	TS, 1949-1985	Production Function	Aggregate		~0	Pereira (2010)
Moomaw, R. and M. Williams	Total Factor Productivity growth in manufacturing: further evidence from the states	Journal of Regional Science, Vol. 31, No. 1, pp. 17-34	1991	PD, 1954-1976, 48 states	Total Factor Productivity	Federal Highway Density		0.17	Article
Tatom, J.	Public capital and private-sector performance	Review of the Federal Reserve Bank of St. Louis, Vol. 78, No. 3, pp. 3-15	1991	TS, 1949-1989	Production Function	Aggregate		0.135-0.343, varies with estimation parameters	Article
Carlino, G. and R. Voith	Accounting for differences in aggregate state productivity	Regional Science and Urban Economics, Vol. 22, pp. 597-617	1992	PD, 1963-1991, 48 states	Total Factor Productivity	Highway Density		0.22-1.00	Pereira (2010)
Dalenberg, D.R. and R.W. Eberts	Estimates of the Manufacturing Sector's Desired Level of Public Capital: A Cost Function Approach	Paper presented at the Annual meeting of the Western Economic Association, San Francisco, mimeo	1992	PD, 1979-1992, 31 SMSAs	Production Function	Highway Capital Stock		0.104-0.149	Article
Garcia-Mila, T. and T. McGuire	The contribution of publicly provided inputs to states' economies	Regional Science and Urban Economics, Vol. 22, pp. 229-241	1992	PD, 1969-1983, 48 states	Production Function	State Highway Capital Stock		0.04	Pfahler (1996/1997)
Lynde, C.	Private profit and public capital	Journal of Macroeconomics, Vol. 14, No. 1, pp. 125-142	1992	TS, 1958-1988	Profit Function	Aggregate		0.332-0.59	Pfahler (1996/1997)
Rotemberg, J. and M. Woodford	Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity	Journal of Political Economy, Vol. 100, pp. 1153-1297	1992	Q, 1947-1989	Differencing	Military Spending	1.25		Ramey (2011)
Finn, M.	Is all government capital productive?	Federal Reserve Bank of Richmond, Economic Quarterly, Vol. 79, No. 4, Fall, pp. 53-80	1993	TS, 1950-1989	GMM	Highway Capital		0.16	Article
Hulten, C. and R. Schwab	Infrastructure spending: where do we go from here?	National Tax Journal, Vol. 46, No. 3, September, pp. 261-273	1993	PD, 1970-1986, 9 regions	Total Factor Productivity	Aggregate		0.15	Article
Evans, P. and G. Karras	Are government activities productive? Evidence from a panel of U.S. states	The Review of Economics and Statistics, Vol. 76, No. 1, pp. 1-11	1994	PD, 1970-1986, 48 states	Production Function	Aggregate Highways Sewers and Water Other Infrastructure		-0.223 - 0.102 -0.062 0.011 -0.061	Article
Holtz-Eakin, D.	Public sector capital and the productivity puzzle	The Review of Economics and Statistics, Vol. 76, pp. 12-21	1994	PD, 1969-1986, 48 states, 8 regions	Production Function	Aggregate		-0.22 - 0.18 (~0)	Article

McMillin, W. and D. Smyth	A multivariate time series analysis of the United States aggregate production function	Empirical Economics, Vol. 19, pp. 659-674	1994	TS, 1952-1990	VAR	Aggregate		~0	Pereira (2010)
Nadiri, M. and T. Mamuneas	The effects of public infrastructure and R&D capital on the cost structure and performance of U.S. manufacturing industries	The Review of Economics and Statistics, Vol. 76, No. 1, pp. 22-37	1994	TSCS, 1956-1986, 12 manufacturing sectors	Cost Function	Aggregate		-0.11 - -0.21	Article
Pinnoi, N.	Public infrastructure and private production: measuring relative contributions	Journal of Economic Behavior and Organization, Vol. 23, No. 2, pp. 127-148	1994	PD, 1970-1986, 48 states, 4 industries	Production Function	Aggregate		`-0.11 - 0.08	Pereira (2010)
Ai, C. and S.P. Cassou	A normative analysis of public capital	Applied Economics, No. 27, pp. 1201-1209	1995	TS, 1947-1989	VAR	Aggregate		0.15 - 0.20	Pereira (2010)
Andrews, K. and J. Swanson	Does public infrastructure affect regional performance?	Growth and Change, Vol. 25, No. 2, pp. 204-216	1995	PD, 1970-1986, 48 states	Production Function	Aggregate	0.25	0.011	Article
Baltagi, B. H. and N. Pinnoi	Public capital stock and state productivity growth: further evidence from an error components model	Empirical Economics, Vol. 20, pp. 351-359	1995	PD, 1970-1986, 48 states	Production Function	Aggregate		0.16-0.39	Article
Holtz-Eakin, D. and A. Schwartz	Spatial productivity spillovers from public infrastructure: evidence from state highways	International Tax and Public Finance, Vol. 2, No. 3, pp. 459-468	1995	PD, 1971-1986, 48 states	Production Function	Aggregate		~0	Pereira (2010)
Moomaw, R., J. Mullen, and M. Williams	The interregional impact of infrastructure capital	Southern Economic Journal, Vol. 61, No. 3, pp. 830-845	1995	TSCS, 1970/80/86, 48 states	Production Function	Aggregate Highways Water and Sewers Other		0.07 - 0.26 0.001 - 0.027 0.003 - 0.3045 ~0	Article
Sturm, J. and J. De Haan	Is public expenditure really productive? New evidence for the U.S.A. and the Netherlands	Economic Modelling, Vol. 12, No. 1, pp. 60-72	1995	TS, 1949-1985	Production Function	Aggregate		0.03 - 0.70	Article
Garcia-Mila, T., T. McGuire, and R. Porter	The effect of public capital in state-level production functions reconsidered	The Review of Economics and Statistics, Vol. 78, 177-180	1996	PD, 1970-1983, 48 states	Production Function	Highways Water & Sewers Other		0.120-0.370 0.043-0.069 -0.048 - -0.010	Article
Harmatuck, D.	The influence of transportation infrastructure on economic development	Logistics and Transportation Review, Vol. 32, No. 1, pp. 76-92	1996	TS, 1949-1985	Production Function	Net Nonmilitary Public Investment		0.03	Article, Pereira (2010)
Morrison, C. and A. Schwartz	State infrastructure and productive performance	American Economic Review, Vol. 86, No. 5, pp. 1095-1111	1996	PD, 1970-1987, 48 states	Cost Function	Aggregate		0.056 - 0.349	Article

Nadiri, M. and T. Mamuneas	Contribution of highway capital to industry and national productivity growth	Report prepared for Apogee Research, Inc. for the Federal Highway Administration Office of Police Development	1996	PD, 1950-1989, 35 manufacturing sectors	Cost Function	Total Highway Stock Total Federal Highway Stock		-0.146 - -0.220 (manufacturing) 0.02-0.06 (non-manufacturing) Similar in range, 50-60% smaller in magnitude solely for federal stock.	Article
Crowder, W. and D. Himarios	Balanced growth and public capital: an empirical analysis	Applied Economics, Vol. 29, No. 8, pp. 1045-1053	1997	TS, 1947-1989	VECM	Aggregate		0.0652 - 0.382	Article
Kelejian, H. and D. Robinson	Infrastructure productivity estimation and its underlying econometric specifications: a sensitivity analysis	Papers in Regional Science, Vol. 76, pp. 115-131	1997	PD, 1972-1985, 48 states	Production Function	Aggregate Roads Water Other		-0.102 - .146 -.193 - 0.101 -0.031 - 0.147 -0.076 - 0.004	Article
Lau, S. and C. Sin	Public infrastructure and economic growth: time series properties and evidence	The Economic Record, Vol. 73, No. 221, pp. 125-135	1997	TS, 1925-1989	VECM	Aggregate		0.11	Article
Attaray, E.	Transportation and economic prosperity	Issue Paper, Economic and Financial Analysis Branch, Office of Strategic Management & Policy Analysis, Division of Transportation Planning, California Department of Transportation	1998	TS, 1950-1985	Production Function	Highways		0.25	Pereira (2010)
Batina, R. G.	On the long-run effects of public capital and disaggregated public capital on aggregate output	International Tax and Public Finance, Vol. 5, pp. 263-281	1998	TS, 1948-1993	VAR VECM	Aggregate Highways and Streets Water and Sewers		-.11 (VAR) - 0.022 (VECM) 0.024 ~0	Article
Boarnet, M. G.	Spillovers and the locational effects of public infrastructure	Journal of Regional Science, Vol. 38, pp. 381-400	1998	PD, 1969-1988, California counties	Production Function	Aggregate		0.236 - 0.300	Article
Batina, R. G.	On the long run effect of public capital on aggregate output: estimation and sensitivity analysis	Empirical Economics, Vol. 24, No. 4, pp. 711-717	1999	TS, 1948-1993	Production Function	State Public Capital		0.14 - 0.40 (on industrial production)	Article
Duggal, V., C. Saltzman, and L. Klein	Infrastructure and productivity: a nonlinear approach	Journal of Econometrics, Vol. 92, pp. 47-74	1999	TS, 1960-1989	Production Function	Aggregate	0.331 - 0.469	0.27	Article
Fernald, J.	How productive is infrastructure? Distinguishing reality and illusion with a panel of U.S. industries	Board of Governors of the Federal Reserve System	1999	TS, 1953-1989	Total Factor Productivity	Roads and Highways	0.4 - 1.4% of GDP		Pereira (2010)

Pereira and Flores, R.	Public capital accumulation and private-sector performance in the U.S.	Journal of Urban Economics, Vol. 46, pp. 300-322	1999	TS, 1956-1989	VAR	Aggregate	0.65	0.63	Article
Bougheas, Spiros, Panicos O. Demetriades, Theofanis P. Mamuneas	Infrastructure, Specialization, and Economic Growth	Canadian Journal of Economics	2000	Pooled 1975-1980, 1980-85	Production Function	Paved Roads Telecommunications		0.129 0.017	Article
Pereira, A.	Is all public capital created equal?	The Review of Economics and Statistics, Vol. 82, No. 3, pp. 513-518	2000	TS, 1956-1997	VAR	Aggregate Highways and Roads Electric/Gas,Mass Transit Sewage and Water Public Buildings Conservation/Development	4.46 1.97 19.79 6.35 5.53 4.06	0.043 0.006 0.021 0.009 0.017 0.005	Article
Shioji, E.	Public capital and economic growth: a convergence approach	Journal of Economic Growth, Vol. 6, No.3, pp. 205-227	2001	PS, 1963-1993, 50 states	Production Function	Aggregate	0.174-0.466	0.082-0.143	Article
Blanchard, Olivier and Roberto Perotti	An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output	Quarterly Journal of Economics	2002	Q, 1960-1997	SVARS	Aggregate	0.9-1.29		Article
Pereira, A. and J. Andraz	On the impact of public investment on the performance of US industries	Public Finance Review, Vol. 31, No. 1, pp. 66-90	2003	PD, 1977-1999 across 48 states, 1956-1997 across 12 sectors	VAR	Highways	80% of effects are spillovers across states, and effects differ across industries		Article
Pereira, A. and J. Andraz	Public highway spending and state spillovers in the USA	Applied Economics Letters, Vol. 11, No. 12, pp. 785-788	2004	TS, 1956-1997	VAR	Highways	80% of effects are spillovers across states		Article
Cavallo, Michele	Government Employment Expenditure and the Effects of Fiscal Policy Shocks	Federal Reserve Bank of San Francisco Working Paper 2005-16	2005	Q, 1948-2000	Production Function	Military Buildup	0.25 (Peak)	0.0132 (Peak)	Article
Eichenbaum, Martin and Jones D. M. Fisher	Fiscal Policy in the Aftermath of 9/11	Journal of Money, Credit and Banking	2005	TS, 1947-2002	VAR	Post-9/11 Government Consumption	0.19-0.61		Article
Pina, A. and M. St. Aubyn	How should we measure the return on public investment in a VAR?	Economics Bulletin, Vol. 8, No. 5, pp. 1-4	2006	TS, 1956-2001	VAR	Aggregate	2.058 - 4.117	0.0769-0.1220 (Private Output)	Article
Abdih, Y. and F. Joutz	The impact of public capital, human capital and knowledge on aggregate output	Working Paper 218, International Monetary Fund	2008	TS, 1984-2004	Production Function	Aggregate		0.39	Article

Iall, Robert E.	By How Much Does GDP Rise if the Government Buys More Output?	Brookings Papers on Economic Activity	2009	TS, 1930-2008	Production Function	Military Spending	0.55 (1930-2008), 0.47 (1948-2008), 0.13 (insig) (1960-2008), 0.53 (1939-1948), 0.48 (insig) (1949-1955), 0.36 (1939-1944), 0.39 (1945-1949)		Article
Iountford, Andrew and Iarald Uhlig	What are the Effects of Fiscal Policy Shocks?	Journal of Applied Econometrics 24:960-992 (2009)	2009	Q, 1955-2000	VAR	Deficit-Financed Spending	0.65 (Peak)		Article
Cogan, John F., Tobias Cwik, John B. Taylor, and Volker Wieland	New Keynesian versus Old Keynesian Government Spending Multipliers	Journal of Economic Dynamics and Control	2010	Q, 1966-2004	SW DSGE Model	Aggregate	0.04 - 0.0103		Article
Fishback, Price V. and Valentina Kachanovskaya	In search of the multiplier for federal spending in the states during the Great Depression	NBER Working Paper 16561	2010	PD, 1930-1940, states	First Differences	Great Depression Grants to States	-0.57 - 1.67		Ramey (2011)
Fisher, Jonas D. M. and Ryan Peters	Using Stock Returns to Identify Government Spending Shocks	The Economic Journal	2010	Q, 1960-2007	VAR	Military Contractor Spending	1.5		Article
Gordon, Robert J. and Robert Krenn	The End of the Great Depression: VAR Insight on the Roles of Monetary and Fiscal Policy	NBER Working Paper 16380	2010	Quarterly, 1919-1941	VAR	Fiscal Spending	1.8		Article
Nakamura, Emi and Jon Steinsson	Fiscal Stimulus in a Monetary Union: Evidence from US Regions	Columbia University Working paper	2010	PD, 1966-2006, states	Production Function	Military Spending in a Monetary Union	1.5		Article
Pereira, Alfredo and Jorge Andraz	On the regional incidence of highway investments in the USA	Annals of Regional Science, forthcoming	2010	TS, 1977-1999, 48 states and USA average	VAR	Highways	16.08	0.139	Article
Auerbach, Alan and Yuriy Gorodnichenko	Measuring the Output Responses to Fiscal Policy	Berkeley Working Paper	2011	Q, 1947-2008	VAR	Aggregate	0.5-1 (Peak), 0-0.5 (Expansion), 1-1.5 (Recession)		Article
Barro, Robert J. and Charles J. Redlick	Macroeconomic Effects from Government Purchases and Taxes	Quarterly Journal of Economics	2011	TS, 1914-2006	2SLS	Military Spending	0.6-0.7		Article
Ramey, Valerie	Identifying Government Spending Shocks: It's All in the Timing	Quarterly Journal of Economics	2011	TS, 1939-2008	VAR	All Government Spending	1.1-1.2 (incl. WWII), 0.6-0.78 (excl. WWII)	.23 (incl. WWII), .16 (excluding WWII)	Article
Serrato, Juan Carlos Suarez and Philippe Wingender	Estimating Fiscal Local Multipliers	Berkeley Working Paper	2011	PD, 1970-2009, counties	Production Function	Spending on Localities	1.88	0.25 - 1.56	Article

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