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Author
Leff Yaffe, Daniel

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Essays on the Effects of Highway Spending

A dissertation submitted in partial satisfaction of the
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in

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by

Daniel Leff Yaffe

Committee in charge:

Professor Valerie A. Ramey, Chair
Professor Jeffrey Clemens
Professor David Lagakos
Professor Munseob Lee
Professor Craig McIntosh

2020

The dissertation of Daniel Leff Yaffe is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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Chair

University of California San Diego

2020

DEDICATION

To my son David. I want you to know that you are capable of achieving anything you put your mind to. You can never lose, you either win or learn. May all your dreams always come true.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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VITA

2008-2012	B.A. in Economics, Universidad Anáhuac México Norte, Mexico City, Mexico.
2011-2013	Analyst, Bank of Mexico, Mexico City, Mexico
2013-2014	M.A. in Economics and Finance, Barcelona GSE, Barcelona, Spain
2015	Professor of Statistics, Universidad Anáhuac México Norte, Mexico City, Mexico
2015-2020	Teaching Assistant, University of California San Diego, San Diego, U.S.A.
2015-2020	Ph.D. in Economics, University of California San Diego, San Diego, U.S.A.

ABSTRACT OF THE DISSERTATION

Essays on the Effects of Highway Spending

by

Daniel Leff Yaffe

Doctor of Philosophy in Economics

University of California San Diego, 2020

Professor Valerie A. Ramey, Chair

This dissertation is composed of three chapters, all related to the effects of highway spending. By considering the construction of the Interstate Highway System (IHS), Chapter 1 asks how big, if any, are returns to constructing new highways? I find that the biggest threats to identification are endogeneity and anticipation. To overcome endogeneity I note that a state's initial population and area shares played an important role in determining the assignment of interstate highway funds. To overcome the anticipation I use news to identify the timing of shocks. I combine my solutions in an IV local projection framework, as in Ramey and Zubairy (2018), and estimate a cumulative relative multiplier of 1.8 and a discounted relative multiplier of 2.3 at the 15 year horizon. I then extend my specification to allow for spillover

effects, and find evidence of zero spillovers across states.

Chapter 2 asks what is the relation between the relative and the aggregate multiplier from transportation spending? If we take as given a relative multiplier of 1.8 and no across-state spillovers from highway spending, what can we say about the aggregate multiplier? To answer this question, I build a multi-region model that captures two key mechanisms from building highways: (1) bilateral trade costs decrease, which leads to positive spillovers; and (2) TFP shifts up, which leads to a factor-stealing effect and negative spillovers. When only one region is shocked, positive and negative spillovers can cancel each other out. The calibrated model predicts an aggregate multiplier of 2.54.

Finally, Chapter 3 provides evidence of the popular belief that incumbent parties can attract votes by increasing government spending. A simple OLS analysis provides a downward biased estimate of this relationship as incumbents target spending on areas where they are less popular. To overcome this problem I employ an IV methodology that exploits the 1947 plan of the IHS. I find that receiving one extra highway mile causes the share of votes to the gubernatorial incumbent party to increase by 0.65 percentage points.

Chapter 1

The Interstate Multiplier

Depending on its category, government spending shocks can have very different effects on output. One important form of government spending is spending on highways, which accounts for 59% of all transportation spending, and 28% of gross government investment.[1] This chapter asks how big, if any, are returns to highway spending? To accomplish this I study the creation of the Interstate Highway System (IHS), which as of today accounts for 25% of all distance traveled by vehicles in the U.S.[2]

The federal government started appropriating funds toward the construction of the IHS in 1953. However, these funds only became significant after the Federal-Aid Highway Act of 1956 was passed. The 1956 Act envisioned a 41 thousand mile system connecting the principal routes, metropolitan areas, industrial centers and border points within the U.S. Back then, funding of the IHS was estimated to last until 1969. However, both the cost and the construction time of the IHS were greatly underestimated. The system continued receiving funding until 1996 and cost 2.2

[1]For 2014, the CBO estimates that highway spending was $165 billion & all transportation spending was $279 billion (Musick and Petz 2015). For that same year, ”Table 3.1. Government Current Receipts and Expenditures” from the BEA indicates that gross government spending was $594 billion.

[2]According to Table VM-1 of Highway Statistics this share was 24.83% in 2014 and 25.10% in 2015.

times its initial cost-estimate (inflation adjusted).[3]

There are two main challenges to overcome when studying the effects of government spending: endogeneity and anticipation. Until recently, applied research has mainly focused on the first issue and ignored the second one. This analysis is the first to study the impact of the IHS, while taking both of these challenges into consideration. To deal with endogeneity in government spending the traditional approach of the literature has been to use SVARs with contemporaneous restrictions. The basic assumption of this method is that spending does not respond within the period to shocks in output. The motivation for this restriction relies on lags in measuring output and delays from policy-makers in making decisions (Blanchard and Perotti 2002). Unfortunately, recent literature notes that for the case of anticipated spending this method will be inadequate (Ramey and Shapiro 1999; Ramey 2011b; Leeper et al. 2013).

Regarding anticipation, one should notice that government spending on several categories can usually be foreseen by agents in advance. This is especially true in the case of infrastructure spending, and it complicates any analysis wishing to claim causality. In the U.S., the federal government typically announces the total amounts to be appropriated for different types of federal-aid, as well as formulas to decide how these funds will be apportioned across states, a few fiscal years in advance. For example, to construct the IHS the Federal Highway Act of 1956 announced amounts to be appropriated for the following 13 fiscal years. Subsequent laws modified the amounts of 10 of these years and added 27 more years into the program.

Table 1.1 illustrates how IHS appropriations for fiscal years 1957 to 1969 changed as years went by. Spaces left blank in the table correspond to no changes taking place at the time. There are two main takeaways from this table. First,

[3] Own calculation using Table FA-3 of the Highway Statistics series from 1953 to 2006.

note that the amounts outlined in the 1956 Act provide reasonable estimates of the realized appropriation amounts for, at least, the 8 years that followed.[4] Second, notice that each Act is a news-shock; by 1962 nobody will be surprised to find an appropriation of $2,200 million USD because it was announced in 1956. While highway spending is only going to affect the structure of the economy until the highways are built, economic agents can clearly use information to react and re-optimize their behavior even before spending takes place. This suggests that in this setting it is more appropriate to study news-shocks.

To study the returns to highway spending I use panel data at the state-level with state and time fixed effects. My specification and level of aggregation imply that my baseline estimate is for the ”open economy relative output multiplier”. This multiplier differs conceptually from the ”closed economy aggregate output multiplier” (Ramey 2011a; Nakamura and Steinsson 2014) which, in this setting, can only be estimated if spillovers are taken into account. After estimating the relative multiplier, I go over how to quantify these spillovers and use them to create an estimate of the aggregate multiplier.

To see the conceptual difference between the relative and the aggregate multipliers, note that:

- The aggregate output multiplier measures the USD change in aggregate output from increasing spending by 1 USD in a union.
- The relative multiplier measures the USD change in local output from increasing spending by 1 USD in one state of the union, relative to another.

There are several important differences between these two objects. Some of the most important are: (1) Regions that receive spending may not need to pay for it. (2) By purchasing local output, government spending can cause the price of local output to

[4] Realized appropriations being ±20% around the amount in the 1956 Act.

rise. Chodorow-Reich (2019) refers to this as expenditure switching. (3) Monetary policy will not react to higher spending in a single region (Nakamura and Steinsson 2014). (4) Spending might make one region more productive (Leduc and Wilson 2013). (5) Spending might lower transportation costs across regions, affecting prices faced by consumers.

My empirical results suggest that, at a 15-year horizon, the relative output multiplier is 1.8 and the aggregate output multiplier is 5.2. I interpret this as steady-state multipliers where the effect of news has been washed away. The external validity of this estimate has important limitations, so I simply refer to it as ”the interstate multiplier”. There are not too many investment projects that can boost productivity as much as building an initial system of highways that connects a country. Today, with only 1% of the nation's road mileage, the IHS accounts for 25% of all distance traveled by vehicles in the U.S. A second interstate, or any other highway built today in the U.S., is likely to generate fewer productivity gains. Therefore, I expect my estimate of the multiplier to be more relevant for developing countries in the initial stages of building transportation infrastructure.

Across the leading estimation methods, most aggregate multiplier estimates in the literature lie in a range of 0.6 to 0.8 (Ramey 2019b). Therefore, it is imperative to ask why my estimate of the multiplier is bigger than most. I argue that the higher than average estimate is a consequence of the type of spending used in the identification. Most research exploits shocks to military spending since it is easier to claim exogeneity. While military spending can be thought of as having no effect in the structure of the economy, the same can not be assumed of highway spending. For example, the model by Baxter and King (1993) finds a benchmark long-run multiplier of 1.16 for unproductive spending, and a range of 1.45 to 13.02 for productive spending (Table 4 of Baxter and King 1993).

The rest of the chapter is divided as follows. Section 1.1 goes over relevant literature on highway spending, the anticipation of shocks and multipliers. Section 1.2 provides background information on the IHS. Section 1.3 creates an exogenous measure of news-shocks that takes into account changes in the present discounted value of interstate spending. Section 1.4 presents empirical results for the relative multiplier, along with robustness checks. Section 1.5 looks at spillovers from local infrastructure spending to other regions. Finally, Section 1.6 concludes.

Table 1.1: The Act of 1956 vs. Actual Appropriations
(in millions of USD)

Fiscal Year	Act of 1956 (6/29/1956)	Act of 1958 (4/16/1958)	Act of 1959 (9/21/1959)	Sec. of Com.[A] (10/8/1959)	Act of 1961 (6/29/1961)	Act of 1965 (8/28/1965)	Act of 1966 (9/13/1966)	Realized Appropriation
1957	1,175							1,175
1958	1,700							1,700
1959	2,000	2,200						2,200
1960	2,200	2,500						2,500
1961	2,200	2,500	2,000	1,800				1,800
1962	2,200							2,200
1963	2,200				2,400			2,400
1964	2,200				2,600			2,600
1965	2,200				2,700			2,700
1966	2,200				2,800			2,800
1967	2,200				2,900	3,000		3,000
1968	1,500				3,000		3,400	3,400
1969	1,025				3,000		3,800	3,800

A. Due to insufficient funds the Secretary of Commerce apportioned $1,800 million, instead of $2,000, across states on October 8, 1959.

1.1 Literature Review

This chapter is connected to research that touches on the topics of: (1) the anticipation of government spending; (2) the effect of government spending & infrastructure; and (3) the linkage between the relative and the aggregate multiplier. Across the leading estimation methods, most multiplier estimates in the literature lie in a range of 0.6 to 0.8 (Ramey 2019b). While these estimates usually exploit shocks to military spending, far less is known about the effects of infrastructure spending. However, a few studies suggest that for infrastructure spending the multiplier is likely to be above unity.

1.1.1 Anticipation of Government Spending

Until recently the anticipation of government spending was not always considered when studying its effects on output. However, recent literature has pointed out how omitting the agents' foresight can lead to incorrect inference. In the empirical side, Ramey (2011b) shows that anticipation of future military spending can lead to an incorrect identification of spending shocks and argues that timing is not only an issue for defense spending. Interestingly, Ramey uses the IHS as a good example of when a VAR would fail. In a more theoretical framework Leeper et al. (2013) show how agents' foresight can generate challenges in recovering structural shocks.

The realization of how important anticipation of government spending actually is has lead new applied research to employ methods that take this issue into consideration (see e.g. Leduc and Wilson 2013; Arezki et al. 2017; Ramey and Zubairy 2018). Leeper et al. (2010) discuss implementation delays in constructing highways, and show how adding a time-to-build framework has dramatic effects on dynamics and short-run multipliers. They explain that, compared to a case without delay, implementation delays for productive government investment can lead private investment to fall more and labor and output to rise less (or even decline) in the short run. The expectation of a higher productive public capital stock generates a positive wealth effect, which discourages current work effort.

1.1.2 Effects of Government Spending & Infrastructure

Most research focusing on the effects of government spending has used military spending fluctuations (Barro 1981; Hall 1986; Rotemberg and Woodford 1992; Ramey and Shapiro 1999; Hall 2009; Ramey 2011b; Barro and Redlick 2011; Nakamura and Steinsson 2014). This type of spending has the advantage of being driven by major political events that are unrelated to the state of the economy. However, as Ramey (2011a) notes, there is a possibility that the events leading to military buildups may have influences on the economy apart from the effects on government spending (e.g. increased patriotism could raise labor supply). Moreover, it is very likely for different types of spending to have different effects on output, suggesting the importance of studying fluctuations in non-military spending as well. In this regard, Boehm (2019) uses a panel of OECD countries and finds a multiplier for temporary government investment shocks close to zero and a multiplier for government consumption of about 0.8. An important feature in Boehm's analysis is the temporal duration of the investment shock, which affects the shadow value of capital very little. Also, the investment category used by Boehm is very broad, and suggests that not all government investment may be effective at stimulating aggregate demand.

Blanchard and Perotti (2002) & Pereira (2000) are examples of papers that use a SVAR with contemporaneous restrictions to study the effects of non-defense spending on output. Their identification relies on the assumption that spending does not respond within the period to shocks in output. Blanchard and Perotti (2002), who use ”Purchases of Goods and Services, both current and capital” as their measure of government spending, find an aggregate output multiplier between 0.9 and 1.3. Meanwhile, Pereira (2000) studies the impact of different types of public investment on output. For the category of ”investment on all highways and streets” Pereira finds an aggregate multiplier of 1.97. The identification method used by these papers has two major drawbacks. First, not taking into account anticipation means that the VAR structural shock can probably be predicted a few quarters in advance which renders any inference invalid. Second, by using time-series data this method can't take into account time fixed effects which can result in a bias.[5]

The analysis performed in this chapter is close in spirit to Leduc and Wilson (2013), who ask a similar question but use the total appropriation amounts from Federal-Aid Highway funds from 1993 to 2010 instead. The authors construct a measure of highway spending news-shocks that captures revisions in expectations about future government spending and study how these shocks affect output using Jordà's local projection method (Jordà 2005). Their results suggest that news-shocks positively affect output on impact and after six to eight years.

Unfortunately, the estimate of the multiplier is not one of the most important contributions in Leduc and Wilson (2013), so their estimates have a few shortcomings: (1) their method follows a 2-step approach so they don't provide standard errors for their estimates of the multiplier; (2) further analysis of their data reveals a problem of weak instruments; (3) they use a log-log specification which is known to bias the estimate of the multiplier upward (see Ramey and Zubairy 2018); and (4) they use an unconventional formula of the multiplier which considers all the spending to occur in the 10 years following the shock but only 1 year output gains.

[5]As pointed out by Leduc and Wilson (2013): ”time fixed effects are potentially important when estimating the impact of government spending as it allows one to control for other national macroeconomic factors, particularly monetary policy and federal tax policy, that are likely to be correlated over time (but not over states) with government spending”.

Applying the conventional multiplier formula[6] to their results gives estimates of the relative output multiplier that lie between 6.6 and 18.1 (depending on the measure of spending they use).[7]

It is likely that Leduc & Wilson's selected initial year of 1993 was the result of data availability; state-level data before this year had not yet been captured electronically even though it was available in the Highway Statistics Series, a set of annual reports published by the Federal Highway Administration since 1945. For this chapter I capture and use such data. In contrast to Leduc & Wilson, by using historical data I can analyze the construction of the IHS. Being the most important highway system in the U.S., studying the IHS is important in its own right. Moreover, the likely existence of decreasing returns to scale in infrastructure spending makes this analysis even more interesting. Back when the construction of the IHS started, both the quantity and quality of roads in the U.S. were not what they are today. Therefore, it seems logical to expect a much stronger effect from building the first set of high-quality highways that connects a country compared to constructing substitute highways with the purpose of alleviating traffic congestion (Fernald 1999). The time period considered in this chapter renders more interesting results for developing countries lacking good infrastructure.

Suárez Serrato and Wingender (2016) exploit the fact that discontinuous changes in population estimates affect the allocation of billions of dollars in federal spending. They find a relative multiplier of between 1.7 and 2. Also studying local multipliers, Shoag (2010) uses excess returns to state pension fund returns as an instrument for state spending, and finds a relative multiplier of about 2.1.

[6]Such a formula considers all the output gains and spending that occur in the 10 years following the shock

[7]Leduc and Wilson (2013) use 3 measures of highway spending: ”FHWA Grants”, ”State Government Outlays on Highway Construction”, & ”Government Spending for all road related activities”. For each measure they provide a multiplier which they refer to as the ”Mean Multiplier”. The conventional 10-year cumulative multiplier can be obtained by multiplying such multiplier by 11 (the number of time periods they consider)

In a recent paper, Allen and Arkolakis (2019) study the welfare effects of transportation infrastructure improvements in the U.S. Using graph theory and spatial analysis, they find that even in rural mountainous areas the economic benefits from an additional lane-mile exceed the construction and maintenance costs. Henry and Gardner (2019) study whether poor countries have widespread opportunities for productive spending on infrastructure. They find that only in 7 out of 53 developing countries the rate of return to infrastructure investment is higher than that of private capital, and also financeable via rich country capital.

Based on a cost-benefit analysis, a study by Cox and Love (1998) claim that the interstate has returned between \$6.4 and \$7.7 in economic productivity for each \$1 it cost. While their estimate is not directly comparable to the concept of the multiplier, it does suggest very high returns to highway spending. Another study that considers the IHS is by Chandra and Thompson (2000), who focus solely on non-metropolitan counties. They argue that non-metropolitan counties generally receive an interstate just because they fall between cities, so they are less prone to endogeneity bias. Their analysis, which neglects any effects that may arise from agents' foresight, suggests that construction of highways affects the spatial allocation of economic activity: it raises the economic activity in the counties that they pass directly through, but draws activity away from adjacent counties. Moreover, they find that certain industries grow as a result of reduced transportation costs. Another study by Michaels (2008) also exploits the fact that highway assignment to many rural counties was exogenous, and finds that by increasing trade, the IHS raised the relative demand for skilled manufacturing workers in skill-abundant counties and reduced it elsewhere.

This study is also related to Donaldson (2018), who estimates the impact of railroads using data from colonial India. Donaldson obtains 3 empirical findings: (1) railroads decreased trade costs and interregional price gaps, (2) railroads increased interregional and international trade; and (3) when a district is connected to the railroad network, its real income rises by 16%. Donaldson and Hornbeck (2016) study the impact of railroads in the U.S. They find that, at the county level, the total impact of the railroad expansion can be measured by an expression called the ”market access”. They find that removing all railroads in 1890 is estimated to decrease the total value of U.S. agricultural land by 60%.

1.1.3 Relative vs. Aggregate Multipliers

As discussed above, the ”relative output multiplier” differs conceptually from the ”aggregate output multiplier” for several reasons. Even though the relative multiplier is not the usual object we are used to thinking about it is interesting in itself as it informs about the effect on a state’s output we would observe if we were to increase spending in that state alone. Recent research by Dupor and Guerrero (2017) suggests that, by measuring the relative multiplier along with spillovers, one may approximate the aggregate multiplier. However, this conclusion relies on: (1) one must specify correctly which states receive spillovers, and (2) there can’t be any additional impact from increasing spending in two states simultaneously.

Nakamura and Steinsson (2014) study how monetary policy affects the relationship between the the relative and aggregate multiplier. They argue that monetary policy will not respond to government spending in one region of the union, while it will respond to spending increasing in the whole union. Using this reasoning and a counter-cyclical monetary policy, they conclude that the relative multiplier is an upper bound of the aggregate multiplier.

Recently, Chodorow-Reich (2019, 2020) has worked models to translate the relative multiplier to an aggregate multiplier. He finds that when factors of production are immobile, a demand shock in one region causes positive spillovers to production in other regions. Therefore, he concludes that in such cases regional analysis of output effects provides a lower bound for the aggregate effect of the demand shock.

Clearly, the link between the relative and aggregate multiplier will be affected by many factors, and each case should be studied individually to reach the right conclusions.

1.2 The IHS

Each of the annual issues of the Highway Statistics Series from 1956 to 1996 provide excellent summaries of the IHS. Supplementing this series with the Federal-Aid Highway Acts, as well as with the cost-estimate reports of finishing the IHS, one can obtain detailed information on the funding and year-to-year changes in the IHS plans. In this section I present a summary on the evolution of the IHS.

The Federal-Aid Highway Act of 1944 gave birth to the IHS, back then called the National System of Interstate Highways. The Act called for the designation of a highway system of 40,000 miles to connect metropolitan areas, cities and industrial centers, as well as to connect the U.S. with Canada and Mexico at key border points. In 1947 the selection of the first 37,700 miles was announced; the remaining miles were reserved for additional urban routes. However, at the time there was no plan on how to fund the system, nor an estimate of how much it would cost, so its construction was uncertain.

In 1952, legislation approved some small funding towards what can be called a pilot stage in the program. The Act of 1952 devoted $25 million of federal funds for the fiscal year 1954 and a similar amount for the fiscal year 1955. States were required to match the federal funds with a 50% Federal - 50% State rule. Moreover, the funds were apportioned across states with a formula[8] that that assigned a weight

[8] Formula set forth by Section 21 of the Federal Highway Act of 1921.

of one-third to each of the following factors:

(1) Relative Population: the ratio which the population of each state bears to the total population of all the states (as shown by the latest available Federal census).

(2) Relative Area: The ratio which the area of each state bears to the total area of all the states.

(3) Relative Rural Delivery and Star Routes (RDSR) Mileage: the ratio which the mileage of rural delivery routes and star routes in each state bears to the total mileage of rural delivery and star routes in all the states at the close of the preceding fiscal year.

Two years later the Act of 1954, which expanded the pilot stage of the interstate program, was approved. It designated an appropriation of $175 million of federal funds for the fiscal year 1956 and a similar amount for the fiscal year 1957. For these years the apportionment formulas for the states were modified to give more weight to the state's population: (1) a weight of $2/3$ on relative population, (2) $1/6$ on relative area, and (3) $1/6$ on relative RDSR. Moreover, the matching funds rule changed to 60% Federal - 40% State.

Shortly after the Act of 1954 was passed, President Eisenhower started a campaign towards expanding the highway program with a speech given to the Governors' Conference.[9] After the speech, President Eisenhower asked General Clay to head a committee to propose a plan for constructing the interstate. At that time there was a consensus that there was a need for the IHS; however, there was no agreement on how to pay for it.[10] Using information on a report that was currently being developed by the Bureau of Public Roads, the Clay committee estimated the program would cost $27.2 billion (January 1955). They suggested for the Federal

[9] Since the President's mother was seriously ill the speech was delivered by Vice President Nixon, who read from the President's notes.

[10] See https://www.fhwa.dot.gov/infrastructure/originalintent.cfm

Government to cover $25 billion and to finance it with a 30-year bond. The financial plan set forth by the Clay committee had very little support and was rejected from Congress.

After legislation failed in 1955, it was predicted that in 1956 (a presidential election year) the Democratic Congress would not approve such an important plan sought by a Republican president. However, Eisenhower continued to urge approval and worked with Congress to reach compromises. New legislation in 1956 proposed to finance the interstate with the creation of a Highway Trust Fund (HTF), which would collect a tax of 3 cents per gallon tax on gasoline and diesel, along with other excise taxes on highway users.[11] The idea was for the HTF to be modeled after the Social Security Trust Fund; revenue would go into the general treasury, but credited directly to the Fund. The HTF was a successful compromise which lead to the approval of the Federal-Aid Highway Act of 1956.[12]

The Act of 1956 is sometimes referred to as the IHS Act as it set forth a plan for completing the IHS. First, it created the HTF to finance highway federal-aid; at the time this included the IHS and the ABC program.[13] Second, it envisioned that the IHS would be completed in the following 13 years. Third, it provided more substantial federal-aid funds than its predecessors, totaling $25 billion to be spent during the 13 year period considered. Fourth, it changed the matching funds rule to 90% Federal - 10% State, which provided more incentives for states to invest in the IHS.[14] This matching rule prevailed until the last federal-aid appropriations

[11]The HTF was also to be funded with taxes on tire rubber, tube rubber, new trucks, buses, and trailers. Today the HTF still exists, however it now collects a fuel tax of 18.4 cents per gallon on gasoline and 24.4 cents per gallon on diesel.

[12]The 1956 Act passed congress with 89 in favor and only 1 against, and was signed by President Eisenhower on June 29, 1956.

[13]The ABC program is a Federal-aid program that provides funds for Primary and Secondary Highway Systems, as well as for extensions of these systems within urban areas.

[14]The federal government actually covered 90.4% of the funds as section 108(e) of the Act of 1956 specified that the federal government would cover a percentage of the remaining 10% in any state where the ratio between the area of Federal lands and nontaxable Indian lands to the total area of the state exceeded 5%. The additional percentage was equal to 10% times such ratio and was capped at 5%. This rule affected only 12 states.

took place in 1996. The state matching funds rule together with the $25 billion appropriation meant total funds equaled 6.2% of GDP.

For 1957 to 1959 the apportionment formula was the same as the one provided by the Act of 1954. For the subsequent years, the 1956 Act provided a different formula, solely based on the relative costs of completing the IHS. That is, the formula was equal to the ratio of the estimated cost of completing the system in each state compared with the cost in all states.[15] To keep this formula up to date, the cost-estimate of completing the IHS was to be updated periodically by the Secretary of Commerce.[16] The logic behind this method was for all states to finish construction of the IHS around the same time.

Even though subsequent acts, amendments and resolutions shaped the future years of the IHS, its essence remained linked to the Act of 1956. The most important changes were triggered by the rising estimated cost of the system, which delayed the end of its construction until 1996 and required considerably more appropriations than what the original plan considered.

Figure 1.1 shows how appropriations and expenditures of federal funds evolved from the beginning of the program. While the final appropriation took place in fiscal year 1996, expenditure continued in the 2000's because funds had been obligated but not yet spent. The procedure by which spending took place was the following: (1) First, an estimate of the cost of completing the interstate was released. (2) Then, an authorization took place in a Federal Highway Act. These authorizations outline the amounts that would be available at the national level for the following couple of fiscal years. (3) Funds were then apportioned across states using formulas provided by legislation. The share each state receives is called the

[15]The Federal-Aid Highway Act of 1963 slightly changed the formula starting in fiscal year 1967. The new formula considered the ratio of the federal share of the estimated cost of completing the system in each state compared to the federal share of the estimated cost of completing the system in all states.

[16]This responsibility was later transferred to the Secretary of Transportation.

apportionment factor (AF). For each fiscal year apportionment factors were usually announced between 1 and 2 years in advance; however, they could be predicted with accuracy many years in advance using the formulas set forth by legislation. (4) Once the fiscal year of the appropriation was reached, states obligated funds in interstate highway projects. (5) Finally, as highways were built, spending took place. Payments to contractors for work completed were initially made from state funds[17] and the federal share was paid as reimbursements.

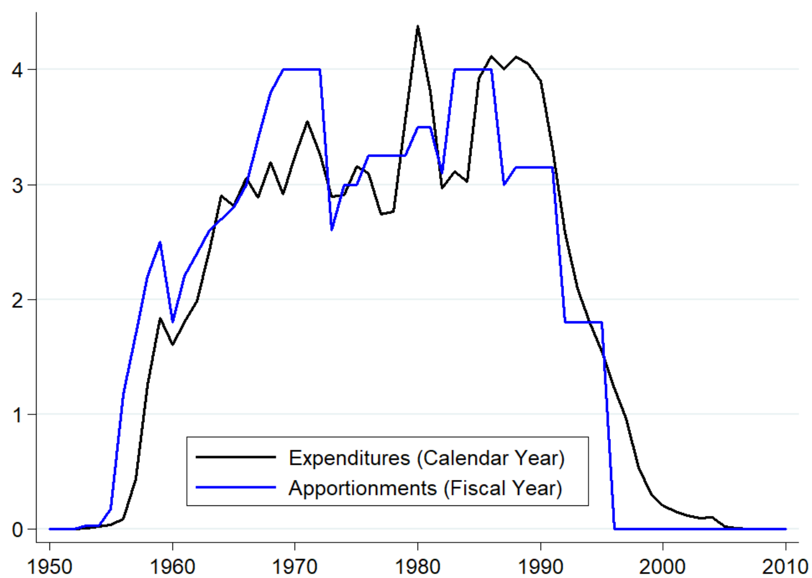


Figure 1.1: Federal Government Funds to Construct the IHS (Billions of Nominal USD)

1.3 Methodology

In this section I go over the estimation methodology for the relative multiplier. First, I go over the specification used and explain how to overcome the main identification challenges. Then, I construct a measure of exogenous interstate news-shocks that takes into account agents' knowledge of future IHS spending. I

[17] Sometimes from funds transferred to the state by cities, counties, or other local governments

explain how to use these news-shocks in a Local IV projection, as in Ramey and Zubairy (2018), to estimate the relative interstate multiplier. Finally, I present some extensions and robustness checks.

Throughout the chapter i indexes states and t indexes time periods. Let $y_{i,t+h} = \frac{Y_{i,t+h} - Y_{i,t-1}}{Y_{i,t-1}}$ and $g_{i,t+h} = \frac{G_{i,t+h} - G_{i,t-1}}{Y_{i,t-1}}$, where $Y_{i,t}$ is output and $G_{i,t}$ is IHS spending at the state level, both real and per capita. To estimate the relative multiplier, I use the following specification for every horizon $H \in \{0, \ldots, \bar{H}\}$:

$$\sum_{h=0}^{H} y_{i,t+h} = \mu_H \sum_{h=0}^{H} g_{i,t+h} + \alpha_{i,H} + \gamma_{t,H} + \boldsymbol{\psi_H} \boldsymbol{x}_{i,t} + \varepsilon_{i,t,H} \tag{1.1}$$

For each horizon the parameter of interest is μ_H, the cumulative relative interstate multiplier at horizon H. The variables α_i and γ_t are state and time fixed effects, respectively. $\boldsymbol{x}$ is a column vector of control variables discussed in subsection 1.3.4, and $\varepsilon_{i,t,H}$ is a residual. In this context the inclusion of time fixed effects is extremely important as it controls for aggregate shocks and policy that affect all states at a particular point in time.

The definitions of $y_{i,t+h}$ and $g_{i,t+h}$ used are now common in the literature (see Hall 2009; Barro and Redlick 2011; Owyang et al. 2013; and Nakamura and Steinsson 2014). As noted by Hall (2009), by using the same denominator this transformation preserves the normal definition of the multiplier as the dollar change in output per dollar of government purchases.[18]

There are two main challenges in the estimation of μ_H:

1. **Endogeneity**: G is not allocated randomly. In terms of the IHS, this translates

[18] Several papers studying fiscal policy have employed log-transformations instead. I depart from this convention because of three reasons. First, government spending in the IHS is zero in many entries of my data set, and by using logarithms I would be forced to drop these observations. Secondly, when using logarithms one needs to transform the estimated elasticities to dollar equivalents using the sample average of output to IHS spending (Y/G) to obtain an estimate of the multiplier. Ramey and Zubairy (2018) note that when Y/G is volatile across time this transformation biases the estimated multiplier upwards. In my sample Y/G fluctuates a lot because G happens to be zero, or close to zero, in many observations. Third, the transformation used in this chapter permits obtaining standard errors of the estimate of the multiplier directly, which is not possible when employing logarithms.

into the apportionment factors not being randomly assigned.

2. **Anticipation & implementation delays:** News about G might directly affect Y, and implementation delays may impact short run dynamics.

In what follows, I go over how to address both challenges individually, and then I suggest a natural method for combining these solutions.

1.3.1 Challenges

Endogeneity

The allocation of highways across regions takes a lot of planning and careful thinking. I classify the different components leading to highway assignment as either: (a) endogenous, or (b) exogenous. In principle, the government will want to assign more highways in regions with higher expected future growth. I refer to this as the endogenous portion of highway assignment.

Another important factor in highway assignment is determined by initial regions' characteristics. This is the exogenous component. In the case of the IHS, the initial plan was developed in 1947. As years progressed the plan was actually followed very closely.[19] This can be seen in Figure 1.2, which shows a digitized version of the 1947 plan together with a digital map of the IHS as of May 2014. The persistence of the original plan means that highway assignment was at least partially determined by characteristics of 1947. Figure 1.3 displays the correlation between observed apportionment factors, and both area and 1947 population shares. From 1954 to 1959 this relationship is trivial, as these variables were directly used in the apportionment formula. Starting in 1960 we see that the correlation exists simply because states with more initial population and area required more highways. In the

[19] The correlation between the number of miles received by each county according to the 1947 plan, and the observed IHS (as of May 2014) is equal to 86%.

last 10 years of the program we find the weakest correlations; however, in these years appropriations were also very small as not that much money was needed to finish the interstate at the time. The average of these correlations weighted by appropriation amounts is given in Table 1.2. For area it's 0.79 and for the 1947 population share 0.22. It is also interesting to note that the correlation between population and area is low (just 0.11).

Table 1.2: Average Cross Sectional Correlations

	App. Factor	**Area Share**	**Pop. Share 1947**
App. Factor	1.00		
Area Share	0.79	1.00	
Pop. Share 1947	0.22	0.11	1.00

Notes: The correlations with the observed apportionment factors are a weighted average of cross sectional correlations between fiscal years 1954 and 1996, where real appropriations amounts are used as the weights.

The discussion above is indicative that area and 1947 population shares may be used as valid and relevant instruments for highway assignment. To see how this would work, consider the following data generating process, with no anticipation and no implementation delay:

$$y_{i,t} = \mu g_{i,t} + \alpha_i + \underbrace{u_{i,t} + \eta^{(y)}_{i,t}}_{\varepsilon^{(y)}_{i,t}} \tag{1.2}$$

$$G_{i,t} = \pi s_i \sum_j G_{j,t} + (1-\pi)\,\theta\,\mathbb{E}_{t-1}\left[Y_{i,t}\right] + \varepsilon^{(G)}_{i,t} \tag{1.3}$$

Where $\varepsilon^{(y)}_{i,t} = u_{i,t} + \eta^{(y)}_{i,t}$. Equation 1.2 is a simpler version of equation 1.1 for illustration purposes. The variable $u_{i,t}$, which affects $y_{i,t}$, can be seen by the policy maker but not by the econometrician. So from the econometrician's stance, both $u_{i,t}$ and $\eta^{(y)}_{i,t}$ are error terms. One can think of $u_{i,t}$ as capturing time varying fixed effects that are likely to be present during long time spans; for example, this term would

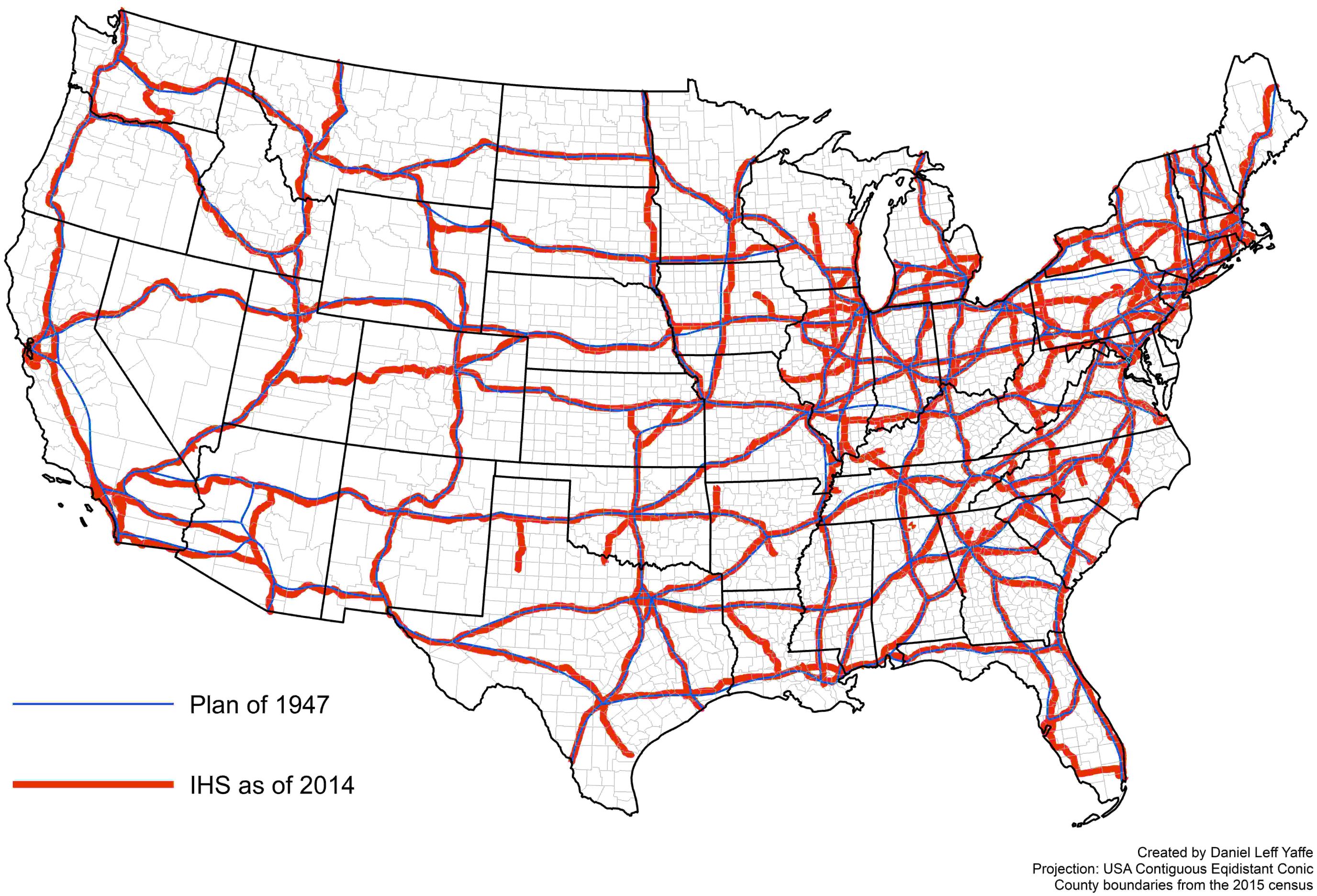
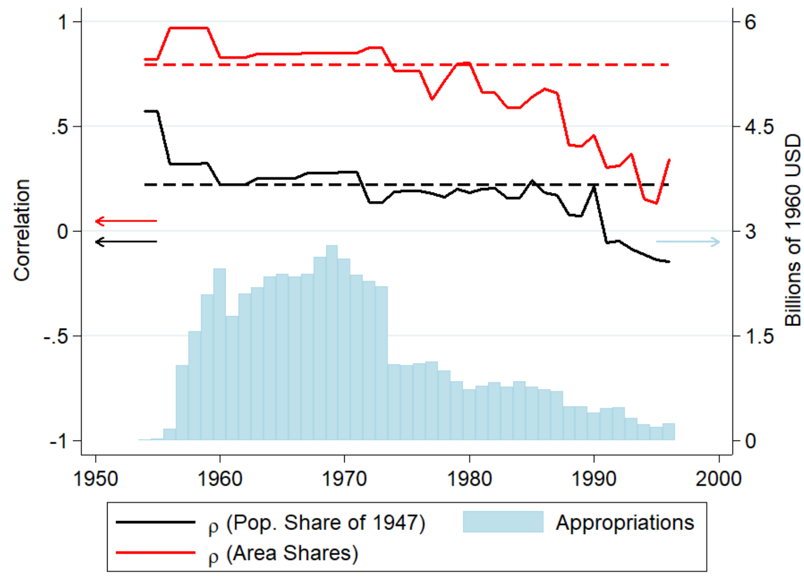


Figure 1.2: The 1947 Plan vs. the 2014 IHS



Notes: Dashed lines represent average correlations weighted by real appropriation amounts.

Figure 1.3: Apportionment Factor Correlations & IHS Appropriations

help capture the growth of the Silicon Valley Area, or the collapse of the economy in Detroit.

Equation 1.3 is the highway assignment rule, which depends on an exogenous rule ($s_i \sum_j G_{j,t}$)), an endogenous mechanism ($\theta \mathbb{E}_{t-1}[Y_{i,t}]$), and an error term ($\varepsilon_{i,t}^{(G)}$). The parameter $\pi \in (0,1)$ is the weight given to the exogenous rule, and $(1-\pi)$ is the weight assigned to the endogenous mechanism. The s_i terms are state specific pre-determined shares satisfying $s_i \in [0,1]$ and $\sum_i s_i = 1$. Moreover, the expectation of current output $\mathbb{E}_{t-1}[Y_{i,t}]$ is formed using the policy-makers information set and is responsible for system feedback, which generates endogeneity in the apportionment factors $a_{i,t} = G_{i,t}/\sum_j G_{j,t}$.

While highway assignment at the state-level, G_{it}, is determined endogenously, from each state's perspective spending at the national level, $\sum_j G_{jt}$, is given. Therefore the endogeneity is completely captured by the apportionment factors a_{it}. We refer to s_i as the exogenous apportionment factors, which can be thought of as: the relative area of state i, the initial population share of state i, or a combination of both:

$$s_i = p \underbrace{\left(\frac{Pop_{i,1947}}{\sum_i Pop_{i,1947}}\right)}_{s_i^{(P)}} + (1-p) \underbrace{\left(\frac{Area_i}{\sum_i Area_i}\right)}_{s_i^{(A)}} \text{ where } p \in [0,1] \tag{1.4}$$

Note that after some manipulation of equation 1.3 we obtain:

$$g_{i,t} = \pi \underbrace{\left(s_i \frac{\sum_j [G_{j,t} - G_{j,t-1}]}{Y_{i,t-1}}\right)}_{z_{i,t}} + (1-\pi)\theta \mathbb{E}_{t-1}[y_{i,t}] + \varepsilon_{i,t}^{(g)} \tag{1.5}$$

where $\varepsilon_{i,t}^{(g)} = (\varepsilon_{i,t}^{(G)} - \varepsilon_{i,t-1}^{(G)})/Y_{i,t-1}$ and $z_{i,t} = s_i \sum_j [G_{j,t} - G_{j,t-1}]/Y_{i,t-1}$. Moreover, note that $\mathbb{E}_{t-1}[y_{i,t}] = \mu g_{i,t} + \alpha_i + u_{i,t}$.

First, consider the case where $u_{i,t} = 0$. An OLS regression of $y_{i,t}$ on $g_{i,t}$ will deliver a biased estimate of μ because $g_{i,t}$ is influenced by the fixed effects α_i. In other words, the system feedback generates $cov(g_{i,t}, \alpha_i) \neq 0$. However, note that in this case the FE estimator will be consistent.

Second, consider the case where $u_{i,t} \neq 0$. This variable takes into account that apportionment factors were likely to have been adjusted due to changes in local economic conditions. In this case both OLS and FE will be inconsistent. The additional bias arises because $u_{i,t}$ is omitted from the regression, and also correlated with $g_{i,t}$ due to the system feedback. So how can one obtain a consistent estimate for μ when $u_{i,t} \neq 0$? The idea is to just use the exogenous variation in $g_{i,t}$. To do this we simply need to use $z_{i,t}$ as an instrument for $g_{i,t}$, plus FE.

An additional challenge arises when s_i is not observed directly, and the parameter p from equation 1.4 is not known. In such a case, we may use 2 instruments to consistently estimate μ: $z_{i,t}^{(P)} = s_i^{(P)} \sum_j [G_{j,t} - G_{j,t-1}]/Y_{i,t-1}$ and $z_{i,t}^{(A)} = s_i^{(A)} \sum_j [G_{j,t} - G_{j,t-1}]/Y_{i,t-1}$. A benefit of this scenario is that with 2 instruments we can perform a test of over-identifying restrictions to test the joint validity of the instruments.

Anticipation and implementation delays

Work from Leeper et al. (2010) outlines the importance of implementation delays in studying multipliers for highway spending. Moreover, Ramey (2011b), Ramey and Zubairy (2018), and many others, have shown the importance of anticipation when studying government spending in general. In what follows, I show how to use Local IV Projection, as outlined by Ramey and Zubairy (2018), to consider both anticipation and implementation delays. For this, consider a scenario where highway assignment is exogenous, but anticipated.

To use Local IV projection, first we need to define the concept of news-shocks. Let $\phi_{i,t}$ be the news-shock of state i at time t, in real and per capita terms. A news-shock stems from agents having more information available at date t than at date $t-1$. In this setting, it is defined as the unexpected change in the present discounted value (PDV) of IHS spending as a fraction of lagged output (for consistency with equation 1.1):

$$\phi_{it} = \frac{\mathbb{E}_t[PDV_{it}] - \mathbb{E}_{t-1}[PDV_{it}]}{Y_{i,t-1}} \tag{1.6}$$

where

$$PDV_{it} = \sum_{\tau=0}^{\infty} \left[\beta_t^{\tau} \underbrace{a_{i,t+\tau} \sum_j [G_{j,t+\tau}]}_{G_{i,t+\tau}} \right] \tag{1.7}$$

The parameter β_t is the discount factor at time t, $a_{i,t}$ are the apportionment factors, and $\sum_j [G_{j,t+\tau}]$ is national-level spending at time $t+\tau$ (in real and per capita terms). Note that $G_{i,t} = a_{i,t} \sum_j [G_{j,t}]$.

Since $\phi_{i,t}$ is not observed, it needs to be estimated using narrative evidence. I discuss this in detail below. For now, assume $\hat{\phi}_{i,t}$ is a reliable estimate of $\phi_{i,t}$. Then to estimate μ_H one simply needs to use $\hat{\phi}_{i,t}$ as an instrument for $\sum_{h=0}^{H} g_{i,t+h}$ in equation 1.1 for every horizon $H \in \{0, \ldots, \bar{H}\}$. That is, a total of $H+1$ regressions are estimated, one for each H.

We have described how to use an estimate of $\phi_{i,t}$ as an IV to estimate μ_H. However, an additional problem is likely to occur as our instrument may be violating the exclusion restriction. The exclusion restriction may be violated in two ways: (a) if the news-shock has a direct impact on output, or (b) if the news-shock has an effect on output through omitted spending categories, which I refer to as spending crowd-in.

The first type of violation is likely to occur in the short-run, as agents may respond to news even if spending has not yet taken place. In the long-run the effects of news should fade, and we should see μ_H becoming stable. Therefore, a practical solution to the direct effect of news is to just focus on high H.

Spending crowd-in can occur if news about highways leads to higher government spending in other categories, or if the timing of news about other types of spending coincides with that of highways. Under the presence of spending crowd-in, using a narrow definition of spending, such as IHS spending, can bias the multiplier upwards because the spillover would be captured by the change in output, but not by the change in spending. To deal with this issue the basic idea is to be flexible with the definition of the spending measure $G_{i,t}$ that goes into creating the endogenous variable $g_{i,t}$.

So far we have been thinking of $G_{i,t}$ as IHS spending, this is fine in terms of creating the news-shock, but not in terms of the spending that reacts to the news-shock. We can broaden this definition to consider all state spending, or all local and state spending (both measures include IHS spending). Note that by recognizing the presence of spillovers in other spending categories, the estimated multiplier reflects the returns from spending in a basket of categories, and not only in the interstate. After estimating the multiplier, I will estimate the components of the underlying basket. Figure 1.4 plots the fraction that IHS spending represents of all state spending (black line), and all local plus state spending (blue line) at the national level. The fractions started at zero, since the first appropriation toward constructing the IHS was done in fiscal year 1954. Both fractions increased rapidly and reached their peaks in the 1960s. Then, the fractions slowly went back to zero.

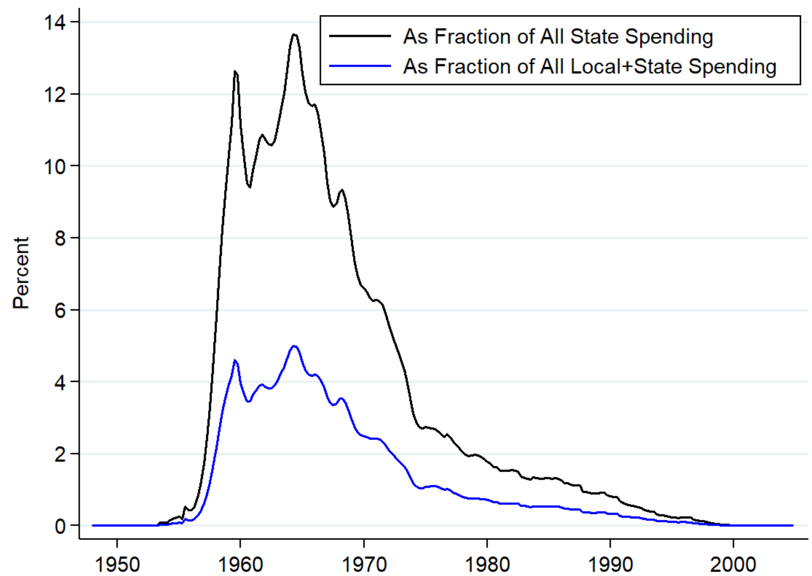


Figure 1.4: IHS Spending

1.3.2 Solution to all Challenges

We have discussed how to address endogeneity, as well as anticipation and implementation delays individually. In what follows I suggest a natural way to combine the solutions for both of these challenges.

As mentioned above, the endogeneity is fully captured by the apportionment factors $a_{i,t}$. To address endogeneity in the case of no anticipation, we suggested using $s_i z_{i,t}$ as an instrument for $g_{i,t}$ (this is equivalent to using $s_i \sum_j G_{j,t}$ as an instrument for $G_{i,t} = a_{i,t} \sum_j G_{j,t}$). The problem is addressed by noticing that, conditional on the FE, s_i is exogenous while $a_{i,t}$ is endogenous.

In a similar fashion, in the case of anticipation and implementation delays, we simply need to substitute $a_{i,t}$ by s_i in equation 1.7:

$$PDV_{i,t} = \sum_{\tau=0}^{\infty}\left[\beta_t^{\tau} s_i \sum_j [G_{j,t+\tau}]\right] = s_i PDV_t \tag{1.8}$$

where $PDV_t = \sum_{\tau=0}^{\infty}\left[\beta_t^{\tau}\sum_j [G_{j,t+\tau}]\right]$ is the national-level PDV of IHS spending. This leads to the following simplified expression of news-shocks:

$$\phi_{it} = \frac{s_i\left(\mathbb{E}_t[PDV_t] - \mathbb{E}_{t-1}[PDV_t]\right)}{Y_{i,t-1}} = \frac{s_i \Phi_t}{Y_{i,t-1}} \tag{1.9}$$

where $\Phi_t = \mathbb{E}_t[PDV_t] - \mathbb{E}_{t-1}[PDV_t]$ is the national level news-shock. Here, $\phi_{i,t}$ can be interpreted as the unexpected change in the PDV of IHS funds, that is unrelated to future growth prospects. Since s_i is not directly observed, we create two instruments instead. One based on area, and another based on population:

$$\phi_{it}^{(j)} = \frac{s_i^{(j)}\Phi_t}{Y_{i,t-1}} \text{ for } j \in \{A, P\} \tag{1.10}$$

Ramey and Zubairy (2018) explain how, in the case of one instrument, the Local IV Projection method is equivalent to a a three-step method in which the integral of the impulse response function (IIRF) of output is divided over that of spending. In the case of M instruments ($\phi_{it}^{(1)}, \ldots, \phi_{it}^{(M)}$), the 2-stage least squares (2SLS) estimator is equivalent to the following 3-step method:

1. **First-stage regression:** For every H regress $\sum_{h=0}^{H} g_{i,t+h}$ on $\phi_{it}^{(1)}, \ldots, \phi_{it}^{(M)}$ and all exogenous covariates. Let $\beta_{g,H}^{(m)}$ denote the coefficient on $\phi_{it}^{(m)}$ for $m = 1, \ldots, M$. Define $\beta_{g,H}^{(*)} \equiv \beta_{g,H}^{(1)} + \ldots \beta_{g,H}^{(M)}$. Then $\{\beta_{g,H}^{(*)}\}_{H=0}^{\bar{H}}$ is the IIRF of a news-shock on spending.

Also, define the normalized news-shock as:

$$\phi_{itH}^{(*)} \equiv \frac{\beta_{g,H}^{(1)}\phi_{it}^{(1)} + \dots \beta_{g,H}^{(M)}\phi_{it}^{(M)}}{\beta_{g,H}^{(1)} + \dots \beta_{g,H}^{(M)}}$$

2. **Reduced form regression:** For every H regress $\sum_{h=0}^{H} y_{i,t+h}$ on $\phi_{itH}^{(*)}$ and all exogenous covariates. Let $\beta_{y,H}^{(*)}$ denote the coefficient on $\phi_{itH}^{(*)}$. Then $\{\beta_{y,H}^{(*)}\}_{H=0}^{\bar{H}}$ is the IIRF of a news-shock on output.

3. **Multiplier computation:** the 2SLS estimate of the multiplier at horizon H is defined as $\hat{\mu}_H^{2SLS} = \hat{\beta}_{y,H}^{(*)}/\hat{\beta}_{g,H}^{(*)}$.

The 3-step approach is quite informative of how the shock affects the economy, as it involves estimating IRFs that track the effect of the news-shock on both output and actual spending. Estimation for both the reduced form and first-stage regressions can be done by using Jordà's direct projections approach (Jordà 2005). There are two shortcomings of using the 3-step method to estimate the multiplier: (1) unlike Local IV Projection, this approach does not deliver standard errors for the estimate of the multiplier, and (2) the 3-step method gives back the 2SLS estimate of the multiplier, which is less efficient than two-step feasible GMM.

1.3.3 Constructing the News-Shock

To construct the news-shock, the first step is to estimate the national-level news-shock: $PDV_t - \mathbb{E}_{t-1}[PDV_t]$. For this, I use information from: (a) 20 public laws issued between 1952 and 1991, and (b) 29 Interstate Cost Estimates (ICEs) issued between 1958 and 1991. The public laws, usually Highway Acts, were responsible for national-level authorizations. They gave birth to the IHS, modified appropriations and extended its construction time. The ICEs provided updated estimates of the cost of completing the IHS, as well as updated AFs.

Using information from all these documents I construct nationwide news-shocks that affect all states simultaneously by affecting appropriation amounts (and required state-matching funds) for each fiscal year. From the public laws documents I obtain changes in expected spending at the national level. The ICEs are also very important as they describe the reason for the updated cost, which can be divided in either price related changes, or quantity/quality related changes. For creating the news-shocks, I only use updates that come from quantity/quantity related changes.

To estimate the national-level news-shocks a few choices must be made on: (1) the time frequency of the variables; (2) the timing of shocks; and (3) the estimation of β_t.

Quarterly frequency: Since shocks can potentially be dated at a daily frequency and output can be observed at a quarterly frequency, I use a quarterly frequency for all variables. This poses a few challenges: **(1)** Appropriations are for fiscal years. A simple way to deal with this is to divide each fiscal year's expected spending by four. This assumption is harmless as the PDV formula will aggregate these quantities back together with a discount factor that is close to 1. **(2)** Expenditure on the IHS is observed in calendar years until 1991, and in fiscal years starting in 1992. I use the proportional Denton method (see Bloem et al. 2001) to interpolate this variable at a quarterly frequency.

The Timing of Shocks: I set the timing of the news-shocks to the quarter that the Highway Acts passed Congress. I use the timing of the public-laws, instead of that of the ICEs as: (a) there was never certainty that changes in cost-estimates would affect authorization; (b) cost-estimates begin in 1958, while Highway Acts in 1952; and (c) starting in 1976 Highway Acts started considering future inflation while ICEs did not.

The Discount Factor: To estimate β_t I use an approach similar to Leduc and Wilson (2013). I let $\beta_t = \dfrac{1}{1+i_t}$, where i_t is the quarterly discount rate at quarter

t, which I estimate using a 5 year rolling average of the 3-month T-Bill rate. I assume that interest rates can be anticipated fully one quarter ahead, so $\mathbb{E}_{t-1}[i_t] = i_t$ (this avoids interest rates generating news-shocks).

Figure 1.5 plots summary statistics of the estimated news-shock where lagged per capita GDP has been annualized for ease of interpretation. Panel A uses area shares, and Panel B uses 1947 population shares. Letting $j \in \{A, P\}$, for each quarter the average state shock is given by $\sum_i \left[\phi_{i,t}^{(j)}/4\right]/N$, where $N = 48$ (Alaska, Hawaii, and the District of Columbia are not considered). As may be noted, the news-shock is different than zero in 18 occasions.[20] The plot makes clear that the most important news-shocks were triggered by the Highway Acts of 1956, 1961, and 1976. A closer look of the 1956 shock is shown in figure 1.6, which illustrates the distribution of the shock across states, for both population and area shares. Note how using either area or population shares greatly impacts the distribution, and the measured magnitude of the shock.

1.3.4 Control Variables

The controls $\boldsymbol{x}$ included in the baseline specification are:

- Short term lags of the endogenous variables: $\dfrac{Y_{i,t-p} - Y_{i,t-1-p}}{Y_{i,t-1-p}}$ and also $\dfrac{G_{i,t-p} - G_{i,t-1-p}}{Y_{i,t-1-p}}$ for $p = 1$ to 4. These terms are meant to capture business cycle movements and short term dynamics.

- Long term growth (5 years) of the endogenous variables: $\dfrac{Y_{i,t-1} - Y_{i,t-21}}{Y_{i,t-21}}$ and $\dfrac{G_{i,t-1} - G_{i,t-21}}{Y_{t-21}}$. The first term is of special importance as it can be used to proxy the future growth potential of states.

- Lagged variables: Y_{t-1}, G_{t-1} and P_{t-1}. These control for relations between

[20] There are 20 public laws in the sample, but 2 of them overlap in 1959 Q3 and the other two overlap in 1976 Q1.

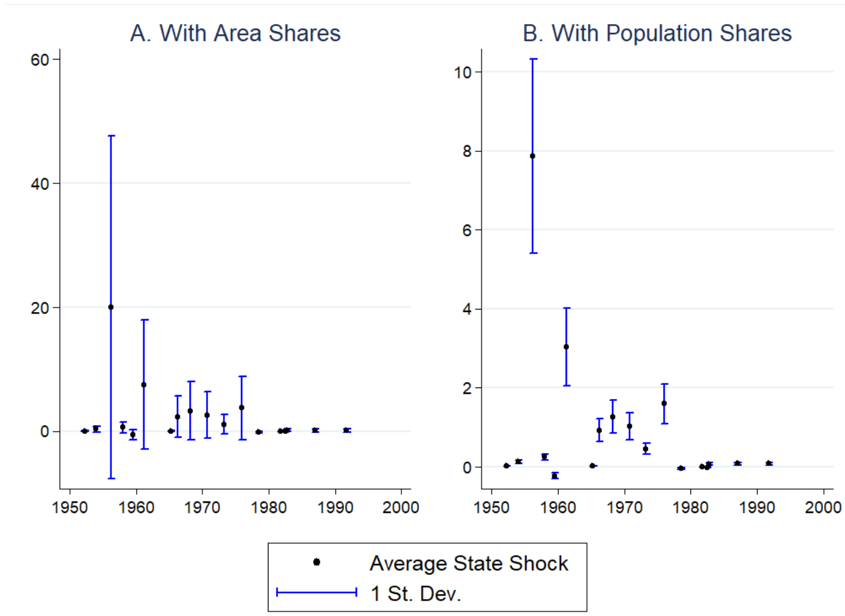
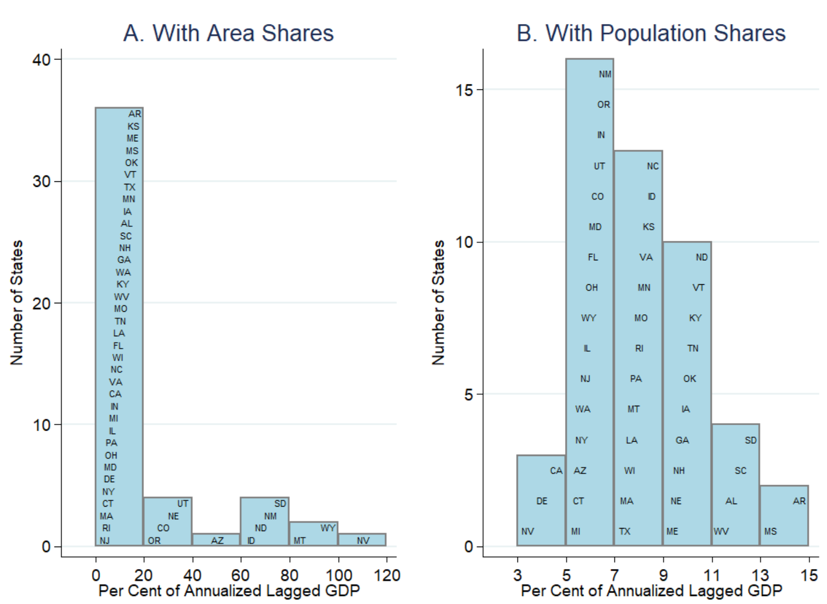


Figure 1.5: News-Shock as Fraction of Annualized Lagged GDP (%)



Notes: States whose codes are placed further to the right received a higher shock.

Figure 1.6: The Shock of 1956

growth rates and levels; the first term is especially important as it can capture economic convergence.

- Short term lags on population growth: $\frac{P_{i,t-p} - P_{i,t-1-p}}{P_{i,t-1-p}}$ for $p = 1$ to 4 (where $P_{i,t}$ denotes population).
- Long term growth (5 years) of population: $\frac{P_{i,t-1} - P_{i,t-21}}{P_{i,t-21}}$.

1.4 Empirical Results

This section presents the empirical results. First, I show the baseline results, and then I go over robustness checks.

I let $\bar{H} = 60$, meaning that I will estimate the multiplier up until a 15 year horizon following the news-shock. Data covers the 48 contiguous states from 1948:Q1 to 2008:Q3.[21] Heteroskedasticity, serial correlation, and cross-sectional correlation in the error term are taken into consideration by estimating Driscoll-Kraay standard errors. Additionally, to obtain a nationally representative relative multiplier, equation 1.1 is also estimated by weighting with each state's population share.

The preferred estimation method is IV-GMM, which is more efficient than 2SLS given that there are more instruments than endogenous variables. While the multiplier is estimated for different horizons, the preferred horizon is the one that uses all 15 years. Being the farthest away from the shock, the 15-year multiplier is less likely to be contaminated by anticipation effects. Moreover, it uses the most information on spending and output changes, and has one of the highest first-stage F-statistics.

[21] Due to the use of lags in the control variables and leads in the dependent variables, the regression sample is fixed for all horizons between 1953:Q2 and 1993:Q3. So each regression sample contains 7,776 observations.

1.4.1 Baseline Results

Table 1.3 provides estimates of the 15-year cumulative multiplier with and without population weights, for different spending measures. The results illustrate both the importance of weighting and of using a broad measure of spending. If one only uses IHS spending, and does not weight by population, the estimate is equal to 6.37. The estimate changes to 3.92 if all state spending is considered, and to 4.25 if all local and state spending is taken into account. Moreover, when population weights are employed the estimate changes considerably. For the IHS spending measure the multiplier is equal to 7.47, for state spending 1.94, and for local and state spending 1.81. Since the interest lies in a nationally representative multiplier the weighted version is preferred. Moreover, the fact that the multiplier estimate tends to decrease as broader spending measures are considered is a clear indication of the presence of spending crowd-in. Therefore the 1.81 multiplier estimate is the preferred one.

Table 1.3: Cumulative IV-GMM Estimates
(15-year horizon)

Spending Measure		Without Weights	With Weights
IHS	$\hat{\mu}$	6.37	7.47*
	$\hat{se}(\hat{\mu})$	(4.87)	(3.63)
	Hansen's J	{0.39}	{0.83}
	R^2	[0.41]	[0.46]
State	$\hat{\mu}$	3.92***	1.94***
	$\hat{se}(\hat{\mu})$	(0.45)	(0.48)
	Hansen's J	{0.20}	{0.91}
	R^2	[0.47]	[0.54]
Local + State	$\hat{\mu}$	4.25***	1.81***
	$\hat{se}(\hat{\mu})$	(0.27)	(0.30)
	Hansen's J	{0.80}	{0.97}
	R^2	[0.48]	[0.55]

Notes: Driscoll and Kraay SEs in parentheses, Hansen's J overidentification test P-Value in braces, R^2 in brackets. Regression sample of 7,776 observations.

In some contexts, we might be interested in estimating the discounted relative multiplier. To do so, we modify equation 1.1 and use the following specification instead:

$$\sum_{h=0}^{H} \frac{y_{i,t+h}}{(1+r)^{h/4}} = \mu_H \sum_{h=0}^{H} \frac{g_{i,t+h}}{(1+r)^{h/4}} + \alpha_{i,H} + \gamma_{t,H} + \boldsymbol{\psi_H} \boldsymbol{x}_{i,t} + \varepsilon_{i,t,H} \tag{1.11}$$

where r is the average interest rate. Note that the only difference between equations 1.1 and 1.11 is that future flows of output and government spending are discounted with rate r. Table 1.4 repeats the results from Table 1.3 when we use $r = 5.55\%$ (the average 3-month T-Bill during the sample period). It's straightforward to see that all estimates of the multiplier increase, implying that following a shock output increases before spending. For example, the preferred estimate of the multiplier goes up from

1.81 to 2.30.

Table 1.4: Discounted IV-GMM Estimates
(15-year horizon)

Spending Measure		Without Weights	With Weights
IHS	$\hat{\mu}$	7.47	8.62*
	$\hat{se}(\hat{\mu})$	(4.60)	(3.48)
	Hansen's J	{0.45}	{0.97}
	R^2	[0.39]	[0.45]
State	$\hat{\mu}$	4.39***	2.59***
	$\hat{se}(\hat{\mu})$	(0.47)	(0.47)
	Hansen's J	{0.23}	{0.97}
	R^2	[0.43]	[0.52]
Local + State	$\hat{\mu}$	4.64***	2.30***
	$\hat{se}(\hat{\mu})$	(0.28)	(0.31)
	Hansen's J	{0.93}	{0.84}
	R^2	[0.43]	[0.53]

Notes: Driscoll and Kraay SEs in parentheses, Hansen's J overidentification test P-Value in braces, R^2 in brackets. Regression sample of 7,776 observations.

Table 1.5 shows how the preferred estimate of the cumulative multiplier (15-year horizon, weighted, and with local and state spending) changes if only one of the two IVs is used. If only the area IV is used the estimate is 1.79; if only the population IV is used the estimate is 1.69. The fact that these two numbers are so close together, even when the correlation between area and 1947 population shares is just 0.11, boosts confidence in the joint estimate of 1.81. Notably, when both instruments are employed, the P-value from Hansen's J test statistic is 0.97, implying that the null of all the instruments being valid can't be rejected. Table 1.6 repeats the analysis for the case of the discounted relative multiplier.

Table 1.5: Cumulative IV-GMM Estimates
(15-year horizon, all local and state spending, weighted)

	Just Area	**Just Population**	**Both**
$\hat{\mu}$	1.79***	1.68***	1.81***
$\hat{se}(\hat{\mu})$	(0.31)	(0.31)	(0.30)
Hansen's J	-	-	{0.97}
R^2	[0.55]	[0.55]	[0.55]

Notes: Driscoll and Kraay SEs in parentheses, Hansen's J overidentification test P-Value in braces, R^2 in brackets. Regression sample of 7,776 observations.

Table 1.6: Discounted IV-GMM Estimates
(15-year horizon, all local and state spending, weighted)

	Just Area	**Just Population**	**Both**
$\hat{\mu}$	2.19***	1.53***	2.30***
$\hat{se}(\hat{\mu})$	(0.31)	(0.31)	(0.31)
Hansen's J	-	-	{0.84}
R^2	[0.53]	[0.53]	[0.53]

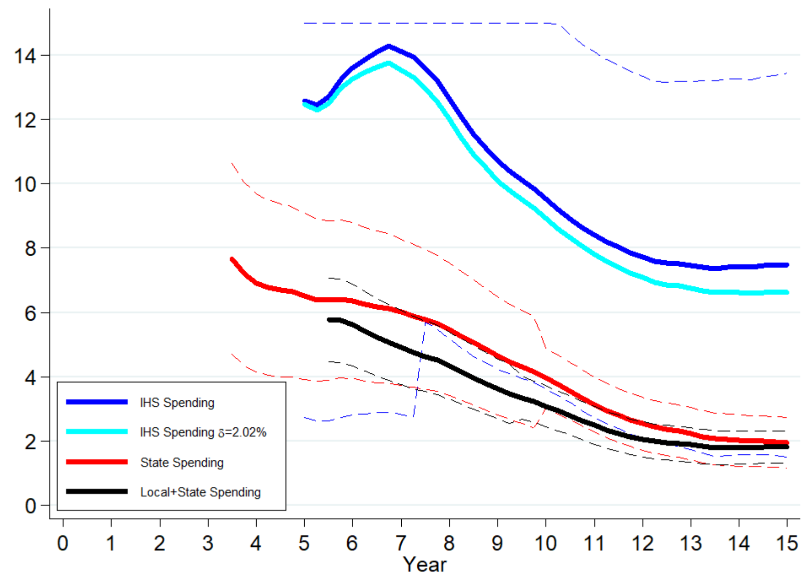
Notes: Driscoll and Kraay SEs in parentheses, Hansen's J overidentification test P-Value in braces, R^2 in brackets. Regression sample of 7,776 observations.

Figure 1.7 shows the cumulative relative multiplier at different horizons for the 3 different spending measures. The multiplier is only shown starting at the quarter when the 10% level threshold for weak instruments is reached (see figure 1.8 which is explained below). For the IHS spending measure, an additional estimate that takes into account a 2.02% depreciation rate of highways is estimated (Herman et al. 2003).[22] The figure also illustrates how broader spending measures lead to smaller multiplier estimates, suggesting important spending crowd-in effects.

Figure 1.7 shows a downward sloping behavior of the multiplier until year 12. This may be a consequence of agents anticipating future spending. In the long run, however, the 3 different estimates stabilize, suggesting that the effects of news

[22] An advantage of the other spending measures is that depreciation is already taken into account by the estimate.

and implementation lags has faded away. For the preferred version, the estimate lies between 1.8 and 2.0 for years 12 to 15.

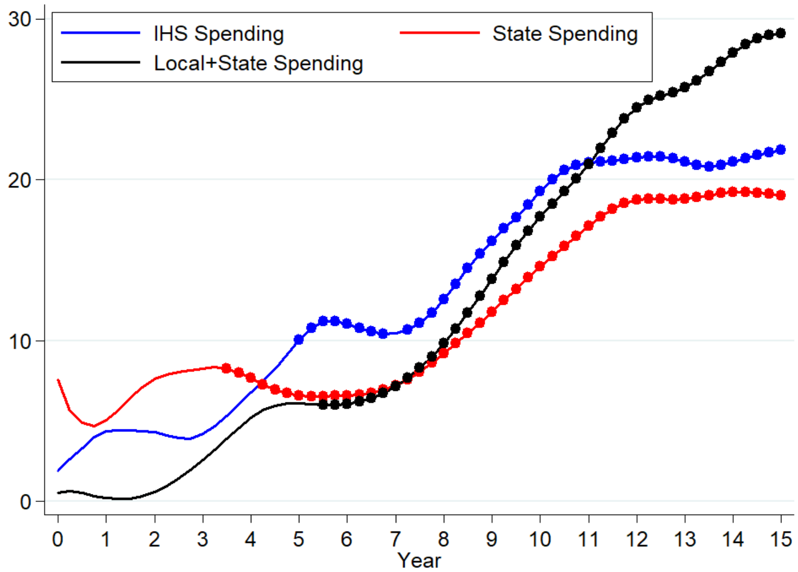


Notes: Dashed lines correspond to 90% confidence intervals. Each estimate is based on a regression with a sample size of 7,776.

Figure 1.7: Cumulative Multiplier with Different Spending Measures

By definition, the news-shock only informs about future funding taking place, and does not assign any funds immediately. Even after time passes, and funds are assigned, it still takes time between when a state obligates funds and the highway is constructed. This situation means that the multiplier can't be accurately estimated during the first few quarters that follow the shock due to the instrument irrelevance. However, as the horizon increases the instrument goes from irrelevant to weak, and then from weak to strong. This dynamic can be seen in figure 1.8, which plots the Kleibergen-Paap Wald F-statistic for the 3 spending measures. Given the serial correlation of the error term, the statistic is compared to thresholds derived by work from Montiel Olea and Pflueger (2013). As can be noted from the figure, at the 10% level the instrument stops being weak around year 5 (for local and state spending).

Figure 1.9 shows the IIRFs of a news-shock on output and the 3 measures

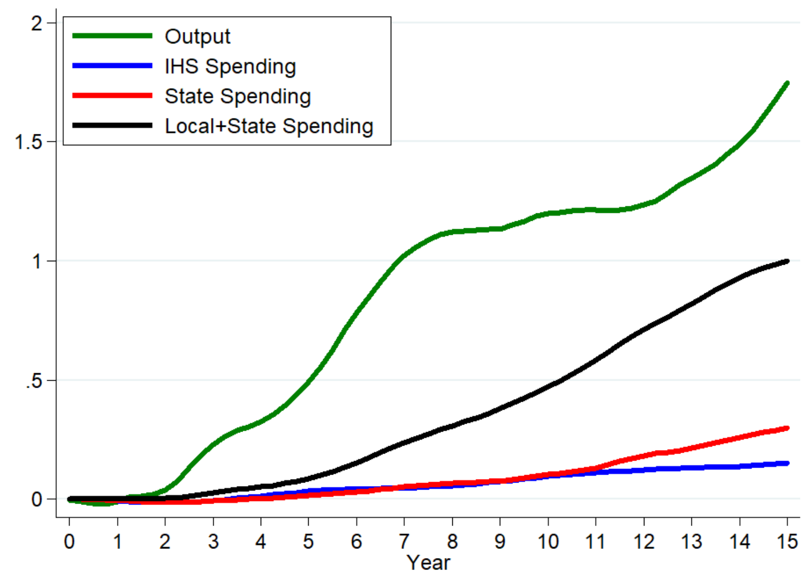


Notes: First stage F-statistic computed using Newey-West standard errors. Round dots denote horizons where weak instruments are rejected at the 10% level using the Montiel Olea and Pflueger (2013) test.

Figure 1.8: Instrument Relevance: Kleibergen-Paap Wald F-statistic

of spending. Note that control variables change for each spending measure, so the estimated IIRF on output marginally changes as well. I only plot the IIRF that uses all local and state spending controls. Additionally, for ease of comparison, for the IIRFs on IHS spending and all state spending I added control variables based on the "all local and state" spending measure. Finally, the figure is normalized such that local and state spending increases by 1 USD 15 years after the shock.

The 2SLS estimate of the multiplier for the all local and state spending measure at horizon H may be calculated by dividing the point estimate of the IIRF of output over that of spending. For example, at the 15 year horizon the estimate of the multiplier is 1.75 (close to the feasible GMM estimate of 1.81). Moreover, the plot suggests that for each USD spent in the IHS: (1) state expenditures increased $1.0 more, and (2) local expenditures increased $4.7 more. These results are evidence of high spending crowd-in originating from highway construction, and illustrate how by not considering other spending one may overestimate the returns to highway spending.



Notes: Each estimate is based on a regression with a sample size of 7,776. All IIRFs are estimated with controls based on all local and state spending.

Figure 1.9: Integrals of IRFs

The results presented thus far control for movements in population associated with government spending by using per capita variables. I follow Nakamura and Steinsson (2014) to test if government spending shocks could be affecting population. For this I estimate a specification analogous to equation 1.1, where the left hand side variable is $\sum_{h=0}^{60} \frac{P_{i,t+h} - P_{i,t-1}}{P_{i,t-1}}$ ($P_{i,t}$ stands for population in levels) and the right-hand-side government spending variable is constructed from the level of government spending and output (rather than per capita). I find that the population responses to government spending shocks are not significantly different than zero. I obtain a point estimate of -.22, along with a standard error of .22. This is a similar result to the one obtained by Nakamura and Steinsson, who study military spending shocks.

1.4.2 The Spending Basket and how it is Financed

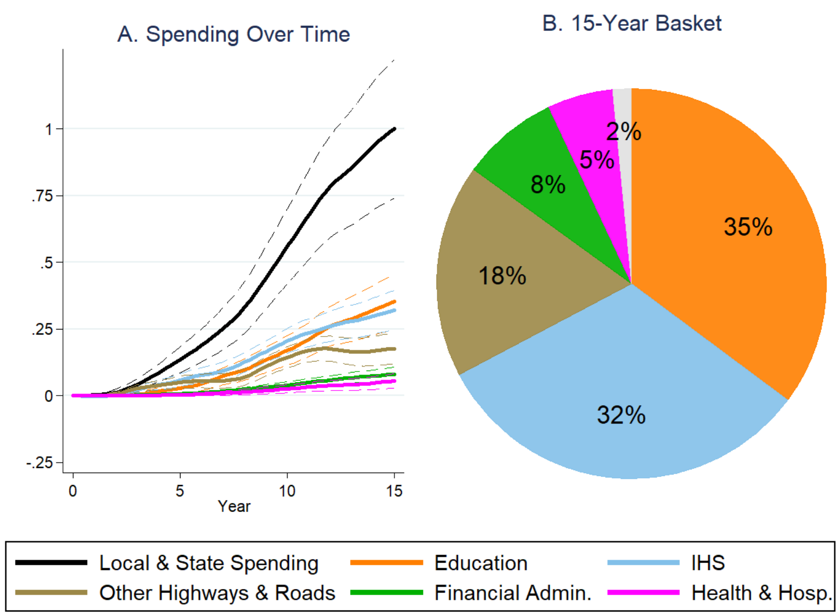
So far the results suggest large crowd-in effects from the IHS on other spending categories. This raises the question of what other types of spending are increasing? Let $w_{i,t}$ denote the spending category of interest. To study the effect of the news-shock on $w_{i,t}$ I include it as an endogenous variable in my baseline specification (one category at a time).[23] Then, I look into the sum of the coefficients on $\phi_{i,t}^{(A)}$ and $\phi_{i,t}^{(P)}$ when $\sum_{h=0}^{H} w_{i,t+h}$ is the dependent variable (this is a new first-stage regression). The results, which are normalized by having spending increase 1 USD 15 years after the shock, are plotted in figures 1.10, and 1.11.

Figure 1.10 shows the spending categories that are more impacted by the news-shock. Panel A shows their evolution over the following 15 years, and panel B shows the cumulative effect over a 15 year period. After 15 years, I find that a 1 USD increase in local and state spending is explained: (1) 35% by spending in education; (2) 32% by spending in the IHS; (3) 18% by spending in other highways and roads; (4) 8% by spending in financial administration; (5) 5% by spending in health and hospitals; and (6) 2% by spending in other categories. In contrast, figure 1.11 shows a few spending categories that do not seem to be affected by the news-shock: police, sewerage, fire protection, libraries, and parks and recreation.

To finance the 1 USD increase in spending, state and local revenue also must have increased by 1 USD following the news-shock. The effect of the news-shock on income categories is explored in figures 1.12, and 1.13.

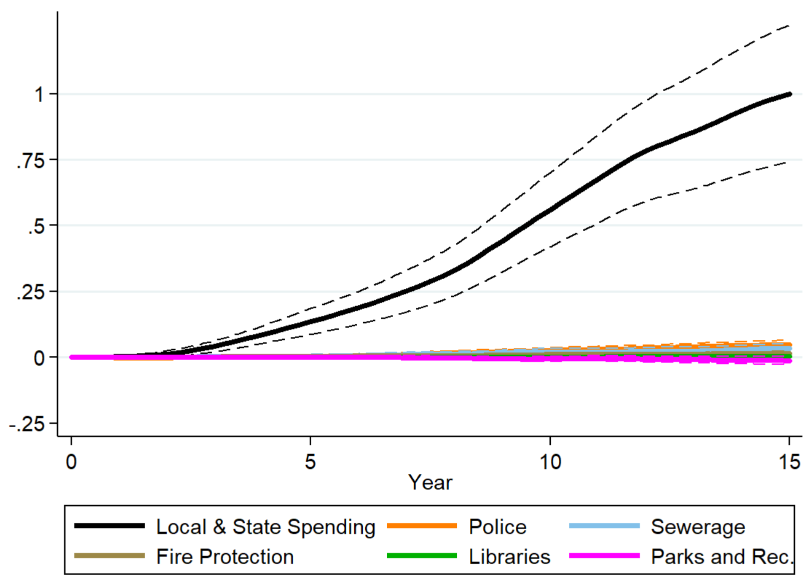
Figure 1.12 shows the revenue categories that are more impacted by the news-shock. Panel A shows their evolution over the 15 year period, and panel B shows the cumulative effect over a 15 year period. After 15 years, I find that a 1 USD increase in local and state spending is explained: (1) 28% by intergovernmental revenue from the federal government for IHS construction; (2) 14% by other types

[23] I also include any relevant control variables based on lags of $w_{i,t}$ in the specification.



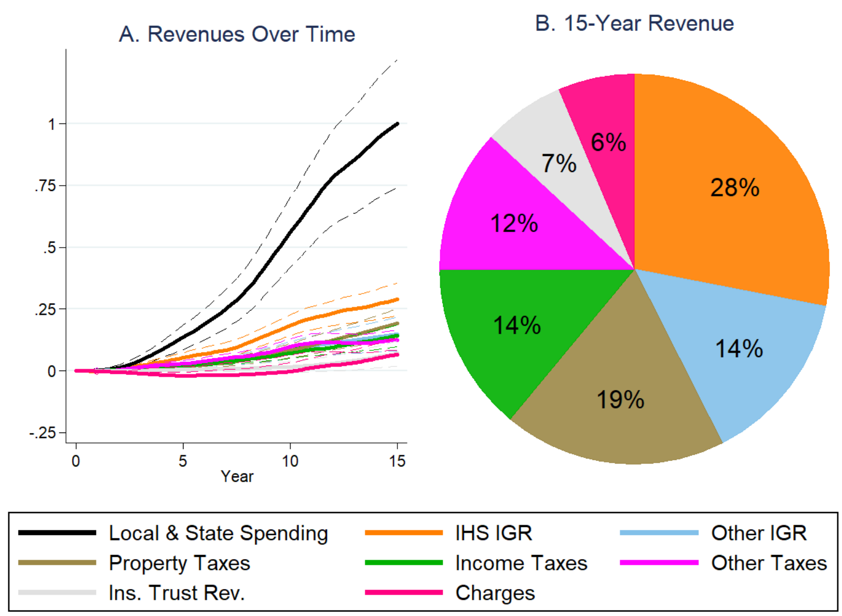
Notes: Dashed lines correspond to 90% confidence intervals. Each estimate is based on a regression with a sample size of 7,776.

Figure 1.10: The Spending Basket for Relevant Categories



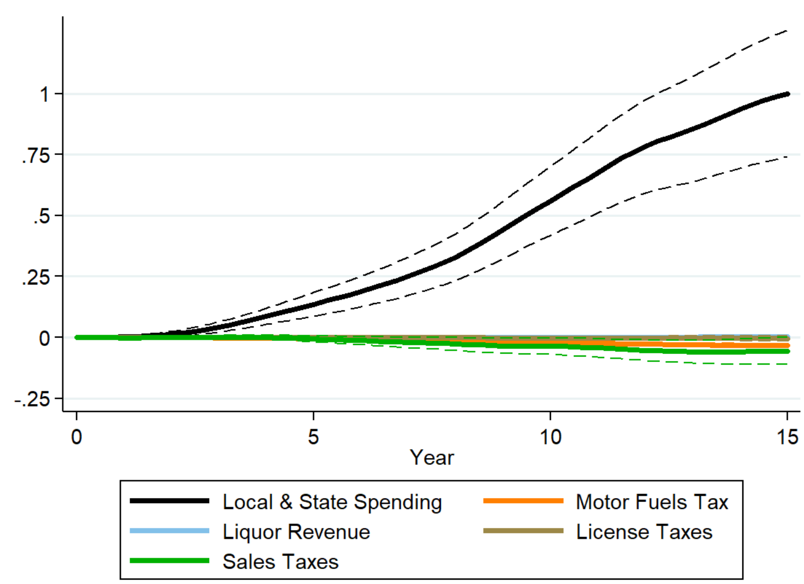
Notes: Dashed lines correspond to 90% confidence intervals. Each estimate is based on a regression with a sample size of 7,776.

Figure 1.11: The Spending Basket for Irrelevant Categories



Notes: Dashed lines correspond to 90% confidence intervals. Each estimate is based on a regression with a sample size of 7,776.

Figure 1.12: The Income Effects for Relevant Categories



Notes: Dashed lines correspond to 90% confidence intervals. Each estimate is based on a regression with a sample size of 7,776.

Figure 1.13: The Income Effects for Irrelevant Categories

of intergovernmental revenue; (3) 19% by an increase in property taxes; (4) 14% by income taxes; (5) 12% by other types of taxes; and (6) 13% by other sources. In contrast, figure 1.13 shows a couple of categories that do not seem to be affected by the news-shock: motor fuels tax (collected by the state or local governments), liquor revenue, license taxes, and sales taxes. The increase in property taxes suggests that home values increase due to the increased spending.[24]

1.4.3 Robustness Checks

Testing Shock Anticipation

To confirm whether the proposed timing of the shock is adequate, I test anticipation effects by checking if the news-shock has any impact on lagged output, or lagged spending. To do this, I run the reduced form and first stage regressions using $\frac{Y_{i,t-p} - Y_{i,t-4}}{Y_{i,t-4}}$ and $\frac{G_{i,t-p} - G_{i,t-4}}{Y_{i,t-4}}$ for $p = 0$ to 2 as dependent variables. Control variables are lagged 2 quarters for consistency. As in the preferred specification, the measure of G used corresponds to all local and state spending. Notice that for $p = 0$ the specification is similar to the initial horizon of section 1.4.1 (with the only difference being the additional lags in the controls).[25]

The IRFs, plotted in figure 1.14, show no significant anticipation effects. Note that for ease of interpretation, the scale of the shock is adjusted just as in the baseline specification.

Testing for Outliers

To evaluate whether some state is leading the results, I re-estimate the 15-year cumulative relative multiplier 48 times, each time excluding one of the 48 states. The

[24]In a recent study, McIntosh et al. (2018) find that infrastructure investment in poor low-income urban neighborhoods in Mexico lead real estate values to increase by 2 USD for every USD invested.

[25]In constructing the news-shock, the general rule was to set the timing to 1 quarter before the public law was passed. Therefore $p = 0$ is also relevant for anticipation.

results presented in Figure 1.15 suggest a balanced amount of positive and negative outliers. For example, excluding Montana lowers the estimate of the multiplier to 1.23, while excluding New York raises it to 2.52. If both of these states are excluded, then an estimate of 1.94 is obtained.

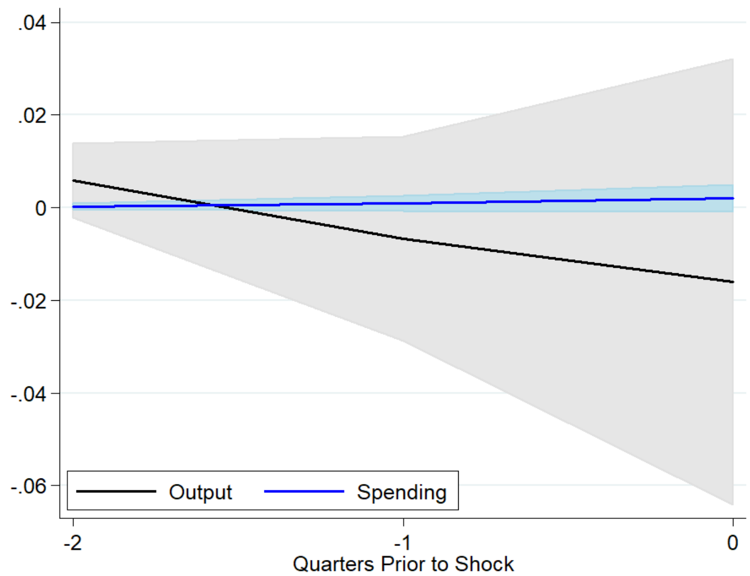
1.5 Spillovers

So far, we have focused on estimating the relative multiplier $\mu^R \equiv \Delta Y_{it}/\Delta G_{it}$. In this section I look for spillovers from spending in a state to other states. To do this, let $\tilde{G}_{i,t}$ sum up government spending from a set of states different than i. For example, $\tilde{G}_{i,t} = \sum_{j \neq i} G_{j,t}$ or $\sum_{j \in N_i} G_{j,t}$ where N_i is the set of $i's$ neighbors. Then, the objective of this section is to estimate the spillover multiplier $\mu^S \equiv \Delta Y_{it}/\Delta \tilde{G}_{it}$.

It's imperative to ask, if both μ^R and μ^S are known, then what can we say about the aggregate multiplier? Dupor and Guerrero (2017) argue that the sum of these 2 parameters can be used to approximate the aggregate multiplier. In their paper, $\tilde{G}_{it}$ only includes one state (the major trading partner). Since each state has on average 4.27 neighbors, the analogous conclusion in this analysis would be that $\mu^A = \mu^R + 4.27\mu^S$ where μ^A is the aggregate multiplier. Besides assuming that the set to create $\tilde{G}_{i,t}$ is correctly specified, this reasoning completely omits possible effects from raising G_{it} and G_{jt} simultaneously. Therefore, μ^R and μ^S provide insufficient information to identify the aggregate multiplier.

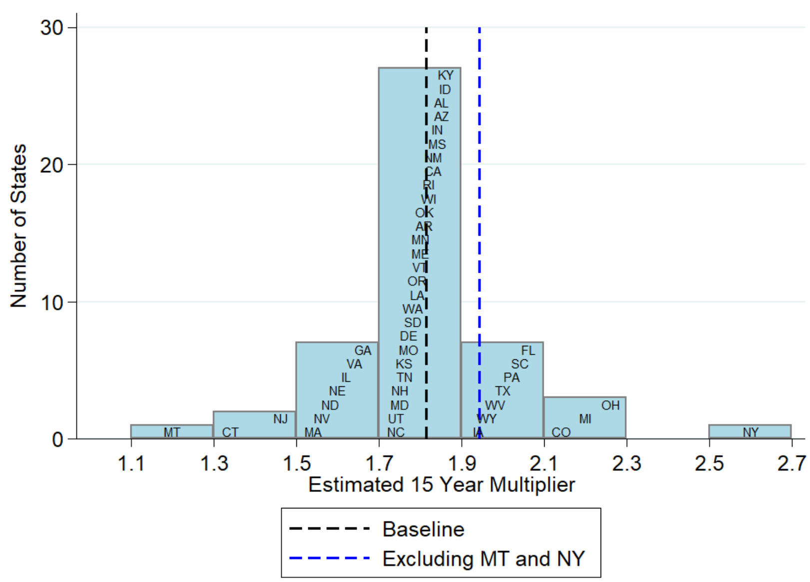
1.5.1 Estimation Technique

Theoretically, states contiguous to i should be the ones more impacted by spending in i. Therefore, in what follows I focus on the case where $\tilde{G}_{i,t} = \sum_{j \in N_i} G_j$.



Notes: Shaded areas correspond to 90% confidence intervals. Each estimate is based on a regression with a sample size of 7,632: N=48 and T=159 (1954:Q1-1993:Q3).

Figure 1.14: IRFs Testing Shock Anticipation



Notes: Excluding states whose codes are placed further to the right leads to a higher estimate of the 15-year multiplier.

Figure 1.15: Outlier Analysis

Consider the following specification:

$$\sum_{h=0}^{H} y_{i,t+h} = \mu_H^R \sum_{h=0}^{H} g_{i,t+h} + \mu_H^S \sum_{h=0}^{H} \tilde{g}_{i,t+h} + \alpha_{i,H} + \gamma_{t,H} + \boldsymbol{\psi_H x}_{i,t} + \varepsilon_{i,t,H} \tag{1.12}$$

To estimate μ_H^R and μ_H^S jointly, I propose 2 different approaches. The first approach assumes that $\tilde{G}_{it}$ is endogenous to $Y_{i,t}$. A situation like this would occur if, for example, we had a data generating process similar to that of equation 1.2 and $u_{i,t}$ was correlated across neighbors. The second approach assumes $\tilde{G}_{it}$ is exogenous.

1. **$\tilde{G}_{it}$ is endogenous.** I follow the work of Dupor and Guerrero (2017), and Auerbach et al. (2019). The basic idea is to use $\phi_{it}^{(A)}$ and $\phi_{it}^{(P)}$ as instruments for $g_{i,t}$, and $\tilde{\phi}_{it}^{(A)}$ and $\tilde{\phi}_{it}^{(P)}$ as instruments for $\tilde{g}_{i,t}$. For $j \in \{A, P\}$ the variable $\tilde{\phi}_{i,t}^{(j)}$ is defined as $\tilde{\phi}_{it}^{(j)} = \tilde{s}_i^{(j)} \Phi_t / Y_{i,t-1}$ where $\tilde{s}_i^{(j)}$ sums up area or initial population shares across i's neighbors.

2. **$\tilde{G}_{it}$ is exogenous.** This simply adds the spillover term as an exogenous variable in the regression.

1.5.2 Results

The results for the cumulative multiplier are shown in table 1.7. Column (1) repeats the baseline specification where spillovers are not estimated. Columns (2) and (3) estimate spillovers using the approach where $\tilde{G}_{i,t}$ is endogenous. While column (2) has exactly the same controls as the baseline specification, a few more controls based on lags of $\tilde{G}_{i,t}$ are added in column (3). Finally, columns (4) and (5) are analogous to (2) and (3) for the case where $\tilde{G}_{i,t}$ is treated as an exogenous variable. The results consistently indicate that:

1. There is an absence of spillovers from neighbor's spending. While point estimates of spillovers are negative, they are very small and in general statistically

insignificant.

2. The estimation of spillovers raises the estimate of the relative multiplier. Since the point estimate for the spillover is negative, and spending is spatially correlated across neighbors, not considering spillovers biases the relative multiplier downwards. For the case where $\tilde{G}_{i,t}$ is treated as an endogenous variable, the estimate of the relative multiplier raises from 1.81 to 2.77 when we allow for spillovers.

Table 1.7: Cumulative IV-GMM Spillover Estimates
(15-year horizon, all local and state spending, weighted)

	(1)	(2)	(3)	(4)	(5)
	Baseline	$\tilde{G}_{i,t}$ endog.		$\tilde{G}_{i,t}$ exog.	
$\hat{\mu}^{(R)}$	1.81***	2.77***	2.77***	1.99***	2.40***
	(0.30)	(0.32)	(0.30)	(0.31)	(0.31)
$\hat{\mu}^{(N)}$		-0.04***	-0.02	-0.01	-0.01
		(0.01)	(0.02)	(0.005)	(0.01)
G_j Controls	No	No	Yes	No	Yes
Hansen's J	0.97	0.85	0.95	0.91	0.80
R^2	0.55	0.53	0.54	0.55	0.55

Notes: Driscoll-Kraay SEs in parentheses. Hansen's J refers to the P-value from the overidentification test. Regression sample of 7,776 observations.

Table 1.8 reproduces the results for the case of the discounted relative multiplier. Importantly, the main conclusions remain unchanged.

Table 1.8: Discounted IV-GMM Spillover Estimates
(15-year horizon, all local and state spending, weighted)

	(1)	(2)	(3)	(4)	(5)
	Baseline	$\tilde{G}_{i,t}$ endog.		$\tilde{G}_{i,t}$ exog.	
$\hat{\mu}^{(R)}$	2.30***	3.13***	3.10***	2.50***	2.89***
	(0.31)	(0.32)	(0.31)	(0.31)	(0.31)
$\hat{\mu}^{(N)}$		-0.04***	-0.02	-0.01	-0.01
		(0.01)	(0.02)	(0.01)	(0.01)
G_j Controls	No	No	Yes	No	Yes
Hansen's J	0.84	0.76	0.88	0.77	0.68
R^2	0.53	0.50	0.50	0.52	0.51

Notes: Driscoll-Kraay SEs in parentheses. Hansen's J refers to the P-value from the overidentification test. Regression sample of 7,776 observations.

In Chapter 2 I study the circumstances under which we can expect transportation spending to have no spillovers. In theory, gains from trade should provide substantial positive spillovers. However, other effects such as capital reallocation to contiguous states may lead to substantial negative spillovers. Together, both of these effects can cancel each other out.

1.6 Conclusions

The Federal-Aid Highway Act of 1956 envisioned that completing the IHS would require 13 years of federal funds, and 28 billion dollars. However, both the cost and the construction time of the IHS were greatly underestimated. The system continued receiving funding until 1996 and cost 2.2 times its initial cost-estimate (inflation adjusted). Today, the IHS accounts for 25% of all distance traveled by vehicles, and is the most important system of highways in the U.S.

I argue that depending on its category, government spending can have very different effects on output. Most of the work estimating multipliers looks at fluctuations in military spending, which is likely to be less productive. There are not too many investment projects that can boost productivity as much as building an initial system of highways that connects a country. Today, with only 1% of the nation's road mileage, the IHS account for 25% of all distance traveled by vehicles in the U.S. A second interstate, or any other highway built today in the U.S., is likely to generate fewer productivity gains. I expect my estimates to be more relevant for developing countries in the early stages of building their transportation infrastructure.

In this chapter I show how to use news of future IHS spending, along with institutional knowledge, to construct a measure of exogenous IHS news-shocks. Then, I use the news-shocks as an instrument in an IV local projection framework and estimate a cumulative relative multiplier of 1.8 and a discounted relative multiplier of 2.3. Moreover, when allowing for spillovers across neighboring states, I find that highway spending in one state does not affect the output of its neighbors. Theoretically, this can be explained by positive and negative spillovers canceling each other out in the aggregate. In Chapter 2 I look further into this.

Regarding the estimation of the multiplier, this chapter makes the following contributions: (1) It combines the news-shock methodology with institutional knowledge specific to the IHS in order to tackle both endogeneity and anticipation concerns; and (2) It shows the importance of spending crowd-in in this context, and how by not considering the response of other types of spending one can easily overestimate the returns to highway spending. (3) It estimates geographic spillovers under a different set of assumptions.

Chapter 2

Local and Aggregate Effects

Applied macroeconomists recently began to take advantage of state-level data to estimate the effects of government spending (see e.g. Shoag 2010; Nakamura and Steinsson 2014; Clemens and Miran 2012; Leduc and Wilson 2013; Suárez Serrato and Wingender 2016; Chodorow-Reich 2019). Unfortunately, estimating multipliers across sub-national units does not lead directly to macroeconomic estimates (Ramey 2011a, 2019b). By adding fixed effects into the estimating equation, these studies net out any macroeconomic effects and estimate only *relative* effects. For this reason, estimates of the government spending multiplier derived from cross-sectional data are usually referred to as *relative*, *local*, or *cross-sectional* multipliers. The relative multiplier is the answer to: ”if state *i* spends \$1 more than the average state, by how much does its output change relative to the average state?” While this question is interesting in its own right, its answer is only indirectly related to the aggregate multiplier.

To infer the aggregate multiplier from the relative multiplier one must use a model. This chapter does exactly that. Building on estimates of the relative multiplier and across state spillovers from Chapter 1, I ask what is the aggregate multiplier derived from the construction of the IHS. I find the answer relies heavily on one parameter: the elasticity of substitution across goods produced in different states. To see why, consider a two sector model where public investment raises TFP. If the sectors produce perfect complements, then it is worthwhile to invest in both sectors proportionally. However, if the sectors produce perfect substitutes, the economy is better off by raising TFP in one sector and shutting down production in the other sector. Therefore, when goods are more substitutable investing in only one sector leads to higher returns as opposed to investing in all sectors simultaneously. The model built in this chapter carries this key mechanism in a multi-region setting with mobile capital.

In the model, an increase in highway spending in region 1 (G_1) has two direct effects:

1. **Bilateral transportation costs decrease between region 1 and every other region ($\downarrow \tau_{1i}$).** This raises output in every region ($\uparrow Y_i$), creating *positive spillovers*.

$$\uparrow G_1 \rightarrow \downarrow \tau_{1i} \ \forall i \rightarrow \uparrow Y_i \ \forall i$$

2. **Increases TFP in region 1 ($\uparrow A_1$).** This leads to factor reallocation towards region 1, creating negative spillovers (as long as the elasticity of substitution across goods produced in different regions is greater than 1).

$$\uparrow G_1 \rightarrow \uparrow A_1 \rightarrow \uparrow Y_1, \downarrow Y_i \text{ for } i \neq 1$$

If these two effects are calibrated in the right way they can produce zero spillovers and a long-run relative multiplier of 1.8. Then, the model can be used to create a counterfactual "*aggregate shock*" scenario under which spending increases in all regions simultaneously. With the aggregate shock the model predicts an aggregate multiplier of 2.54 (with an elasticity of substitution of 8.00). If the elasticity is 4.55

instead, then the aggregate multiplier is predicted to be 3.16.[1]

The rest of the chapter is organized as follows. Section 2.1 offers a literature review that complements that of Chapter 1. Section 2.2 goes over the model, section 2.3 focuses on the calibration of parameters, and section 2.4 presents the results. Finally, section 2.5 concludes.

2.1 Literature Review

Nakamura and Steinsson (2014) were the first to build a model to relate the relative and aggregate multipliers. They argue that monetary policy will not respond to government spending in one region, while it will respond to spending increasing in every region simultaneously. Using this reasoning in a New Keynesian model they conclude that the relative multiplier is an upper bound of the aggregate multiplier. Because of this conclusion other studies simplify their analysis by stating that their results hold at the zero-lower bound (where monetary policy is not responsive). The model I build in this chapter is similar in that regard (see footnote 1). Chen (2018) builds on Nakamura and Steinsson (2014) and finds that labor reallocation amplifies the aggregate output multiplier by 30 percent. Chen makes the valuable contribution of looking into how the aggregate multiplier responds to factor reallocation.

Chodorow-Reich (2019) works on a theory of cross sectional multipliers. He identifies key mechanisms by which the relative and aggregate multiplier are likely to differ:

1. **Expenditure switching.** By purchasing local output, government spending may cause the price of local output to rise relative to goods produced in other regions. This effect makes the relative multiplier smaller than the aggregate

[1] Note that these predictions are only valid at the zero-lower bound. If monetary policy was responsive then the predictions of the aggregate multiplier would be even lower. For more information see Nakamura and Steinsson (2014).

multiplier.

2. **Income Effects.** The local multiplier also depends on total private spending by local agents, as any increase in demand leaks into other regions. This effect also makes the relative multiplier a lower bound for the aggregate multiplier.

3. **Factor Mobility**. Factor mobility may push up local multipliers relative to aggregate multipliers.

Using his theoretical framework, and a relative spending multiplier of 1.8 he predicts a closed economy, deficit-financed, no-monetary-policy-response multiplier of about 1.7 or above.

In another paper, Chodorow-Reich (2020) offer some advice for applied macroeconomists using regional data. Using a Rubin (1978) potential outcomes framework, he finds 3 reasons for which the impact of a shock in a single region can differ from the aggregate effect:

1. Small spillovers to untreated areas.

2. Having these spillovers sum up to a relevant magnitude.

3. National variables endogenously responding to national shocks but not to local shocks.

Similar to Chapter 1, Dupor and Guerrero (2017) estimate the relative multiplier, as well as spillovers, from state-level defense contracts. They find a small relative multiplier of 0.18 and a spillover of 0.07. Summing these up, they find a "*total multiplier*" of 0.25. They argue that by summing up the relative multiplier and spillovers one may obtain an estimate that should be close to the aggregate effect. I argue this is not necessarily true. This reasoning omits any possible effects from raising government spending in all regions simultaneously. For example, in the case of transportation spending, creating a network of connected highways should create an additional benefit that would not be captured by the relative multiplier or spillover term. Moreover, this reasoning also neglects how national variables endogenously respond to national shocks but not to local shocks (e.g. monetary policy). Indeed, a model with identifying assumptions is required to estimate the aggregate multiplier based on state-level data. As Ramey (2019b) notes: "*There is no applied micro free lunch for macroeconomists. Identification of macroeconomic effects must always depend on macroeconomic identification assumptions.*" Still, estimating spillovers can be very useful for identification. In this chapter I use spillovers as an additional moment to target in the model.

Another recent paper that estimates the relative multiplier and spillovers is by Auerbach et al. (2019). Using U.S. Department of Defense contracts, the authors find strong positive spillovers across locations and industries. Their results are very intuitive; they find that geographical spillovers dissipate quickly with distance.

2.2 Model

Consider an economy composed by J regions. Each region produces a single intermediate good S_{it}. Regions and goods can be indexed by either i or j. Each region is populated by a measure one of households, who own capital and provide labor. Households combine the intermediate goods using a CES aggregator into final goods Y_{it}. They can use the composite good to consume, invest, or pay lump-sum taxes. The taxes are used for government spending in highways, which impact both TFP and transportation costs. The stock of highways is chosen exogenously by the government.

For any variable with 3 subscripts, such as X_{odt}, let the first subscript denote the region of origin o, the second the region of destination d, and the third the time period t.

2.2.1 Firms

Each region i produces a single intermediate good S_{it}. Since just one good is produced in each region, i denotes both the region and the good. S_{it} is produced using private capital and labor with a Cobb-Douglass production function:

$$S_{it} = A_i \left(\sum_j K_{jit} \right)^{\alpha} N_{it}^{1-\alpha} \tag{2.1}$$

Private capital, which is perfectly mobile, can be owned by any region j, but must be physically located in region i (K_{jit}). Therefore $\sum_j K_{jit}$ represents the capital physically located in region i. Labor, which is not mobile, can only be sourced from region i (N_{it}).

A firm selling S_{it} receives p_{it} units of region's 1 composite good Y_{1t} (which is set as the numeraire). I assume perfect competition, so the representative firm's problem from region i is:

$$\max_{\sum_j K_{jit}, N_{it}} p_{it} S_{it} - w_{it} N_{it} - r_t \sum_j K_{jit} \tag{2.2}$$

where w_{it} is the wage rate and r_t is the rental rate of capital.

2.2.2 Trade

By incurring in the iceberg transportation cost $\tau_{ji} \geq 1$, goods from region j can be shipped to region i. That is, if τ_{ji} units of good j are shipped to region i, then only 1 unit arrives (the rest "melts"). Taking these barriers and perfect competition into account, the price a consumer in region i must pay for good j is:

$$p_{jit} = p_{jt} \tau_{ji} \tag{2.3}$$

Let region i consume D_{jit} units from region j's good. Note that in equilibrium this means that:

$$\underbrace{S_{jt}}_{\text{Supply}} = \sum_i \tau_{ji} \underbrace{D_{jit}}_{\text{Demand}} \quad \forall j \tag{2.4}$$

2.2.3 Households

Region i's representative household combines the goods produced across the different regions with a CES aggregator:

$$Y_{it} = \left(\sum_j \pi_j^{1/\eta} D_{jit}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{2.5}$$

where π_j is a taste parameter normalized such that $\sum_j \pi_j = 1$, and η is the elasticity of substitution across goods produced in different regions.

The composite good Y_{it} is associated with price index $P_{it} = \left(\sum_j \pi_j p_{jit}^{1-\eta} \right)^{\frac{1}{1-\eta}}$. By assumption $P_{1t} \equiv 1$. The good Y_{it} can be used for consumption (C_{it}), private investment in any region ($\sum_j I_{ijt}$), or highway spending in region i (G_{it}):

$$Y_{it} = C_{it} + \sum_j I_{ijt} + G_{it} \tag{2.6}$$

Household's utility comes from both consumption and leisure. The maximization problem of region i's representative household is:

$$\max_{C_{it}, N_{it}, K_{i,t+1}} \sum_{t=0}^{\infty} \left[\beta^t \left(\log(C_{it}) - \psi \frac{N_{it}^{1+1/\theta}}{1+1/\theta} \right) \right] \tag{2.7}$$

subject to:

$$P_{it}(C_{it} + \sum_j I_{ijt} + G_{it}) \leq w_{it} N_{it} + r_t \sum_j K_{ijt} \tag{2.8}$$

$$K_{ij,t+1} = (1-\delta) K_{ijt} + I_{ijt} \tag{2.9}$$

where equation 2.8 is the household's budget constraint and equation 2.9 is the law of motion for private capital.

2.3 Calibration

The multipliers presented in this chapter are derived from steady state solutions. There are two ways to incorporate short run dynamics:

1. The cumulative multiplier, where every horizon following the shock is given the same weight.

2. The discounted multiplier, where horizons closer to the shock are given more weight than very distant ones.

See Chapter 1 for more information on this. If the increase in G is permanent and has a long run effect (as is the case here), short run dynamics will not affect the cumulative multiplier. However, they can have some impact in the discounted multiplier. In Chapter Chapter 1, I find a cumulative long-run multiplier of 1.8 and a discounted long-run multiplier of 2.3. For the moment, I focus on the cumulative multiplier and leave any potential differences from short term dynamics in the discounted multiplier to future research.

2.3.1 Initial Steady State

First, I calibrate the model for an initial steady state (before any shock takes place) assuming annual frequency. Table 2.1 shows all parameters, except for τ_{ij}. The number of regions J is set to 48, the same as the number of states in the contiguous U.S. The taste parameter π_i in the CES aggregator (equation 2.5) is set to $1/48$ $\forall i$, so equal preference among goods produced in different regions is assumed. The discount factor β is chosen to be 0.939 (as in King and Rebelo 1999).

The disutility of labor ψ is normalized to 1. The Frisch elasticity of labor supply θ is set to 0.4 (Whalen and Reichling 2017).

The elasticity of substitution η is a key parameter in the model. For the baseline results, I set it equal to 8 (based on Allen and Arkolakis (2019), who study the effects of transportation infrastructure improvements in the U.S.). Then, as a robustness check, I change this parameter to 4.55 (based on Caliendo and Parro (2015) who use data on 30 different countries to calibrate it).

For the share of capital α I use one third (as in King and Rebelo 1999). The depreciation rate on private capital δ is set to 6% (as in Ramey 2019a). Finally, the TFP of every region ($A_i \ \forall i$) is normalized to 1.

Table 2.1: Parameters of the Model
(Annual Frequency)

Parameter	**Value**	**Source / Target**
J	48	Contiguous states
$\pi_i \ \forall i$	1/48	Uniform normalization
β	0.939	King and Rebelo (1999)
ψ	1.00	Normalization
θ	0.40	Whalen and Reichling (2017)
η	8.00	Allen and Arkolakis (2019)
α	0.33	King and Rebelo (1999)
δ	0.06	Ramey (2019a)
$A_i \ \forall i$	1.00	Normalization

To calibrate the iceberg cost τ_{ii}, I assume that goods must travel some distance inside region i. This is associated with an inner iceberg cost of κ_{ii}. To calibrate the iceberg cost τ_{ij} for $i \neq j$, I assume that goods traveling from region i to region j must:

1. First, travel some distance inside region i. This is associated with an inner iceberg cost of κ_{ii}

2. Second, travel the distance separating regions i and j. This is associated with an outer iceberg cost of κ_{ij}

3. Finally, travel some distance inside region j. This is associated with an inner iceberg cost of κ_{jj}

The iceberg cost τ_{ij} is defined as:

$$\tau_{ij} = \begin{cases} \kappa_{ii} & \text{if } j = i \\ \kappa_{ii} * \kappa_{ij} * \kappa_{jj} & \text{if } j \neq i \end{cases} \tag{2.10}$$

Equation 2.10 provides an easy way to calibrate how shocks to a single region can propagate to every other regions.

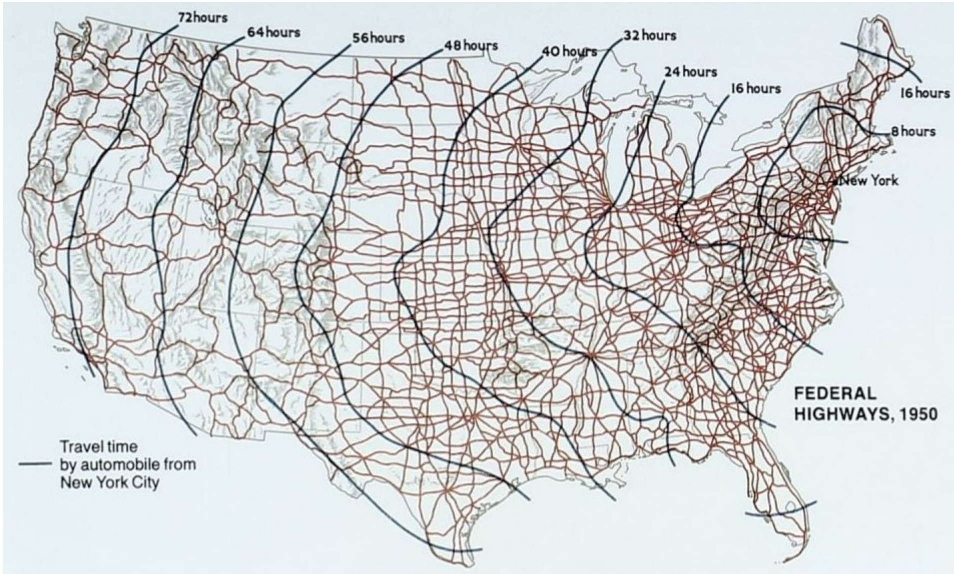
To estimate κ_{ij} $\forall i, j$, I use an equation from Allen and Arkolakis (2019) which relates κ_{ij} to the hours required to travel between regions i and j: $\kappa_{ij} = \exp(0.0108 * \text{Hours}_{ij})$. Note that if $\text{Hours}_{ij} = 0$ the equation implies $\kappa_{ij} = 1$ (i.e. no transportation costs). To estimate the hours required to travel within a region, and between any two regions, note that:

$$\text{Time}_{ij} = \frac{\text{Distance}_{ij}}{\text{Speed}_{ij}}$$

I assume the distance a good is required to travel within a region is proportional to its area. Specifically, I let $\text{Distance}_{ii} = \sqrt{\text{Area}_i/\pi}$ (this is the formula of a circle's radius). For the distance between any two regions, I use the minimum distance connecting the 2 regions. For contiguous states this is 0 by default.

To determine Speed_{ij}, I assume a single speed to travel anywhere by highway. Figure 2.1 shows a map with the travel time by automobile from New York City in 1950 along different "iso-time" curves. By digitizing this map, I find that the average travel time on highways in 1950 was 45 mph.

Finally, to determine the amount of government spending required to keep up the current infrastructure I set G_i such that the ratio of G_i/Y_i is set equal to 2.5% in every region (Kane and Tomer 2019). By assuming $A_{it} = H_{it}^{\sigma}$, where H_{it} is the



Source: National Geographic Historical Atlas of the United States Centennial Edition.

Figure 2.1: Time from New York City in 1950

highway stock and $\sigma > 0$, and noting that $H_{i,t+1} = G_{it} + (1-\delta_H)H_{it}$, then one can calculate the rate of depreciation of highways implied by the model. For the initial steady state, a $G_i/Y_i = 2.5\%$ ratio implies a rate of depreciation of highways of 3.4%. This is between the 3.9% depreciation rate on infrastructure estimated by Ramey (2019a) and the 2.0% depreciation rate on highways estimated by the BEA (2003).

2.3.2 Relative Shock Calibration

To simulate a situation where the relative multiplier can be estimated, only one state is shocked. Without loss of generality suppose region 1 is shocked. A shock to region 1 should be thought of as constructing the IHS in that region alone. When region 1 is shocked G_1 increases. This has 2 effects:

1. Iceberg costs τ_{1j} decrease for all
2. TFP in region 1 (A_1) increases.

Calibration of the relative shock needs to answer the following questions:

1. **By how much should τ_{1j} decrease?** I selected 10 random points along each of the "iso-time" curves of Figure 2.1. For each of these points I asked Google Maps to calculate the travel time from New York City. Using this information I find that currently the average highway speed is 70 mph. I then recalculate κ_{11} using $\text{Speed}_{11} = 70$. Finally I use the updated κ_{11} to obtain $\tau_{1j}\ \forall j$.

2. **By how much should G_1 increase?** G_1 should be such that the multiplier derived from the relative shock equals 1.8.

3. **By how much should A_1 decrease?** A_1 should be such that no spillovers arise from the relative shock. In the baseline calibration, I find A_1 must increase by 4.3%.

2.4 Results

2.4.1 Aggregate Shock Definition

To simulate a situation where the aggregate multiplier can be estimated all states are shocked simultaneously. The aggregate shock consists of G_i increasing in every region. This has 2 effects:

1. Iceberg costs τ_{ij} decrease $\forall i, j$.

2. TFP in every region ($A_i\ \forall i$) increases.

To calibrate the aggregate shock I do the following:

1. **By how much should τ_{ij} decrease?** I recalculate κ_{ij} using $\text{Speed}_{ij} = 70\ \forall i, j$. I use the updated κ_{ij} to obtain $\tau_{ij}\ \forall i, j$.

2. **By how much should G_i increase?** From the relative shock I find that G_1 increased by ΔG_1. I impose the same change to all G_i.

3. **By how much should A_i increase?** From the relative shock I find that A_1 increased by $\%\Delta A_1$. I impose the same change to all A_i.

2.4.2 Findings

The baseline results are shown in table 2.2. The main finding is that if the relative multiplier is 1.80, and there are no spillovers, then the aggregate multiplier is equal to 2.54. With the relative shock, region's 1 output increases by 9.0%, capital by 8.9%, and labor by 2.5%. Output in every other region $j \neq 1$ remains unchanged. With the aggregate shock the overall decrease in transportation costs outweighs the factor stealing effect from raising TFP in other regions. Therefore, with the aggregate shock output increases by 12.9%, capital by 22.8%, and labor just by 1.7%.

Table 2.2: Baseline Results ($\eta = 8.00$)

		Relative	**Aggregate**
Multiplier		1.80	2.54
Per Cent Increase From Initial Steady State (%)	Y_1	9.0	12.9
	Y_j	0.0	12.9
	K_1	8.9	22.8
	K_j	0.0	22.8
	N_1	2.5	1.7
	N_j	0	1.7

As mentioned above, the choice of the CES parameter η in equation 2.5 is extremely important. To see this, first note that the no spillovers effect can't be achieved for $\eta \leq 1$. Second, for $\eta > 1$ the choice of η can greatly impact the predictions of the model. Table 2.3 presents results if one choses $\eta = 4.55$ instead (as in Caliendo and Parro 2015). In this case the aggregate multiplier becomes 3.16. Moreover, to explain zero-spillovers an increase of 5.7% in TFP is required (compared to 4.3% before). Notably, if the elasticity of substitution decreases, then the potential for factor stealing is lower, so TFP needs to increase more.

Table 2.3: Additional Calibration ($\eta = 4.55$)

		Relative	Aggregate
Multiplier		1.80	3.16
Per Cent Increase From Initial Steady State (%)	Y_1	8.4	15.0
	Y_j	0.0	15.0
	K_1	2.1	25.3
	K_j	0.0	25.3
	N_1	2.8	1.5
	N_j	0	1.5

By comparing tables 2.2 and 2.3 we obtain an interesting prediction: as the elasticity of substitution is higher, the aggregate multiplier is lower. The intuition behind this is simple. Assume investing raises TFP. If two sectors produce perfect substitutes, it is not worthwhile to invest in both. Moreover, if they are perfect complements, investing in just one will not be efficient.

2.5 Conclusions

Estimating the effects of government spending with regional level data has become an essential tool for any applied macroeconomist. Unfortunately estimates of the government spending multiplier across sub-national units lead to relative, and not to aggregate multipliers. To infer the aggregate multiplier from the relative multiplier a model must be used.

In this chapter, I build a multi-region model where government spending decreases transportation costs and increases TFP. I find that, with an elasticity of substitution greater than 1, these two mechanisms can alone explain a relative multiplier of 1.8 along with no across state spillovers. My baseline calibration, with an elasticity of substitution equal to 8, predicts an aggregate multiplier of 2.54. Moreover, if the elasticity of substitution is 4.55 instead, then the aggregate multiplier is predicted to equal 3.16.

The model makes an interesting prediction: if the elasticity of substitution is higher, the aggregate multiplier is lower. The intuition behind this is simple. Assume investing raises TFP. If two sectors produce perfect substitutes, it is not worthwhile to invest in both. Moreover, if they are perfect complements, investing in just one will not be efficient. Future research relating the relative and the aggregate multipliers should be cautious in whether factors of production are mobile, and also consider how substitutable goods are across different regions.

Chapter 3

Government Spending and Reelections

The effect of government spending on elections has long been studied by economists and political scientists (see e.g. Rogoff 1987, Rogoff and Sibert 1988, Blais and Nadeau 1992). As politicians have incentives to target spending where it will benefit them the most in the upcoming election, the causal effect of government spending on votes received by the incumbent party can't be uncovered with a simple OLS analysis.

Using an instrumental variables (IV) methodology that exploits the 1947 plan of the Interstate Highway System (IHS), and county-level gubernatorial elections data from 1950 to 1972, this chapter estimates the causal effect of opening one highway mile during an election year on votes received by the incumbent party. The results suggest that opening one extra highway mile causes the incumbent party's share of votes to increase by 0.6 percentage points. A simple OLS analysis provides a downward biased estimate, suggesting that incumbents target spending on areas where they are less popular.

The chapter is organized as follows. Section 3.1 goes over relevant literature on voting behavior. Section 3.2 provides background information on the IHS. Section 3.3 describes the methodology and data used. Section 3.4 presents the results, and finally section 3.5 concludes.

3.1 Literature Review

There is limited research on how government spending impacts the reelection possibilities of the incumbent party or politician, mainly due to the endogeneity between these two variables. Levitt and Snyder (1997) provide the first attempt to identify this causal effect. Using an IV methodology, the authors find evidence that federal spending benefits congressional incumbents: an additional $100 spending per capita in the election year and the year preceding the election leads to a 2 percentage point increase in the incumbent party's share of votes.

Manacorda et al. (2011), and Pop-Eleches and Pop-Eleches (2012) studied this question in the context of conditional cash transfer programs. Manacorda et al. (2011) estimate the impact of a large anti-poverty program in Uruguay, which consisted of a monthly transfer for a period of roughly two and a half years. The authors exploit the discontinuity in program assignment based on pre-treatment score and find that beneficiary households are 21 to 28 percentage points more likely to favor the current government. On the other hand, Pop-Eleches and Pop-Eleches (2012) study a Romanian government program that distributed coupons worth 200 Euros to poor families. The authors find that the beneficiaries were significantly more likely to support the parties of the incumbent governing coalition.

Wantchekon (2003) conducts a randomized field experiment in Benin to study the impact of clientelism on voting behavior. The results show clientelism works for all types of candidates but particularly well for local and incumbent candidates.

3.2 Interstate Highway System

The Federal-Aid Highway Act of 1944 gave birth to the IHS, back then called the National System of Interstate Highways. The Act called for the designation of a highway system of 40,000 miles to connect metropolitan areas, cities and industrial centers, as well as to connect the U.S. with Canada and Mexico at key border points. In 1947 the selection of the first 37,700 miles was announced. However, at the time there was no plan on how to fund the system, nor an estimate of how much it would cost, so its construction was uncertain. A map of the 1947 plan is presented in Figure 3.1.

Highways in the 1947 plan received minimal federal funding before the Federal Aid Highway Act of 1956 was approved. The 1956 Act set forth a plan for completing the IHS by creating the Highway Trust Fund and committing the federal government to pay 90% of the construction costs. States were to be in charge of constructing the system, and the federal share was to be paid as reimbursement to the states as work progressed. States decided which routes to construct at each time, but had to honor the routes of the plan. In fact, to receive federal funding highways had to be approved by the Federal Highway Administration prior to construction.

As years progressed a few more routes were added into the system, and others deleted. Figure 1.2 presents a digitized version of the 1947 map[1] together with a digital map of the IHS as of May 2014.[2] Visual inspection of Figure 1.2 shows that the IHS followed the 1947 plan very closely. In fact, at the county-level, the correlation between the number of miles received by each county according to the 1947 plan, and the observed IHS (as of May 2014) is equal to 86%.[3]

[1] The digitization was done by myself, using the USA Contiguous Equidistant Conic projection, which closely matched the layout of the 1947 plan.

[2] Interstate highways according to the National Highway Planning Network, version 14.05.

[3] This calculation uses the county boundary definitions from the 2015 census, and the 48 contiguous U.S. states. Based on 3,107 observations.

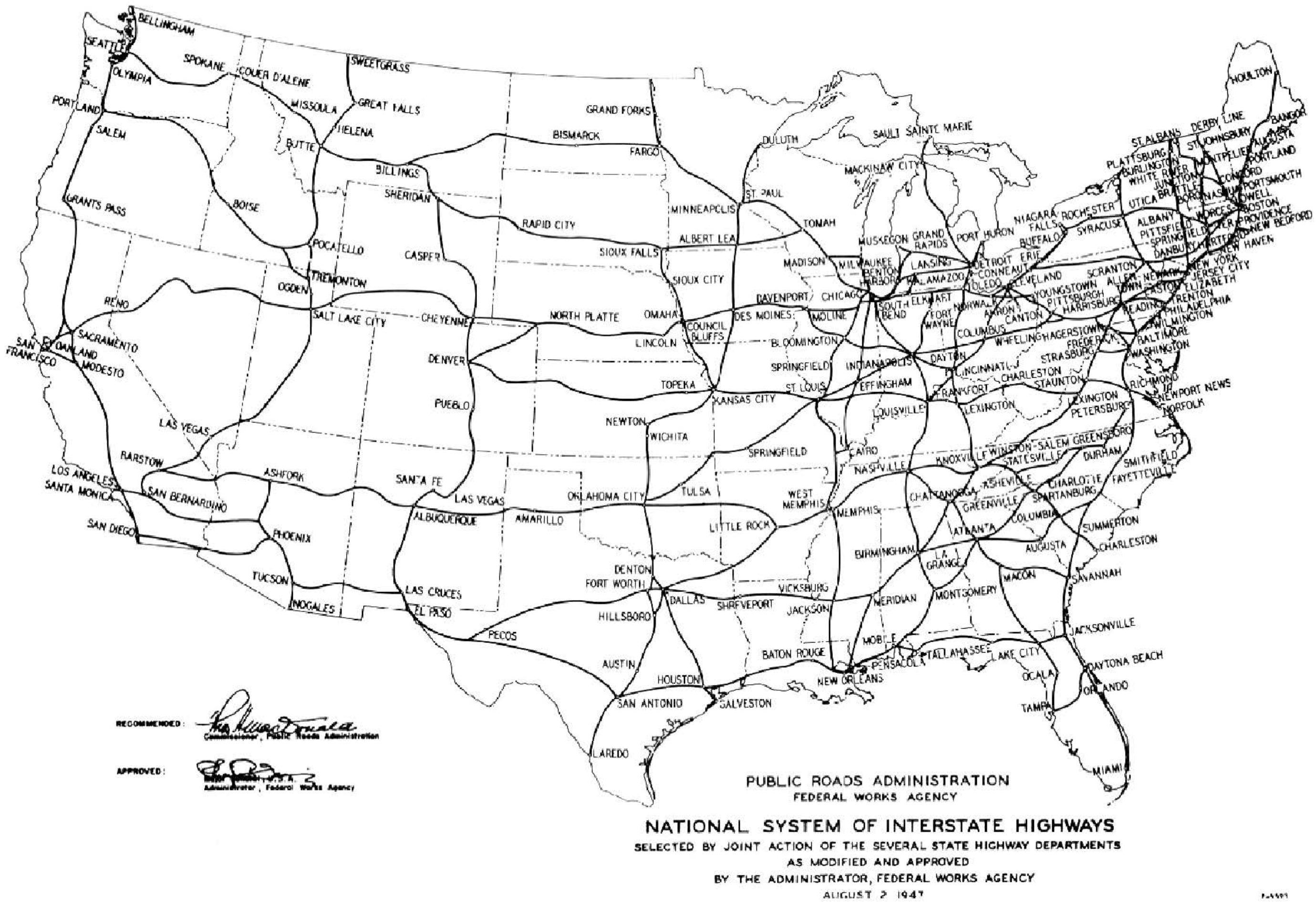


Figure 3.1: The Interstate Highway System Plan in 1947

3.3 Methodology & Data

Throughout the chapter i indexes counties, and t indexes years. Available data covers elections from 1950 to 1972, and 3058 counties with time-consistent boundaries.[4]

Let Y_{it} denote the share of votes received by the gubernatorial incumbent party in county i, during the gubernatorial election of year t. Moreover, let X_{it} denote the number of interstate highway miles opened in county i during year t. To estimate the effect of opening an extra mile, consider the following specification:

$$Y_{it} = \beta X_{it} + \mu_i + \gamma_t + \varepsilon_{it} \tag{3.1}$$

where β is the parameter of interest, μ_i are fixed effects (at the county-level), γ_t are time dummies, and ε_{it} is the error term. Note that since gubernatorial elections are scheduled to occur every 2 or 4 years (depending on the state), the database to estimate equation (3.1) is by construction an unbalanced panel.

Data on votes to the incumbent party is calculated using two databases from the Inter-university Consortium for Political and Social Research: (1) General Election Data for the United States, 1950-1990, and (2) Candidate Name and Constituency Totals, 1788-1990. Data on the number of miles opened in each county, in each year, is obtained from Baum-Snow (2007), who created the data by combining the PR-511 data set,[5] with a digital map of the interstate system.

As explained before, an OLS regression of equation (3.1), would deliver a biased estimate of β as political parties have incentives to assign X_{it} where it will

[4] A Cartographic Boundary Shapefile at the county-level for the year 2000 was downloaded from the United States Census Bureau. This file included a total of 3108 counties for the 48 contiguous states. Using Census information on *Substantial Changes to Counties and County Equivalent Entities*, I aggregated counties and obtained 3058 counties with time-consistent boundaries from the year 1940 to the year 2000.

[5] The PR-511 data set was created by the government, by requiring each state to report the completion month of each interstate highway within its borders.

be the most beneficial. With the addition of fixed effects only within variation is used. Fixed effects are important to control for the fact that the number of miles assigned across counties is not random. Counties assigned more miles are likely to be different than those that are assigned less miles. Importantly, fixed effects do not completely address the endogeneity problem as a timing selection problem remains: in each year state governments chose where to build the next portion of the interstate system. To address this problem, I use an instrument motivated by Baum-Snow (2007). The idea is to instrument the newly constructed highway miles with the miles that would have been constructed had state governments allocated interstate highway construction uniformly across the federally assigned jurisdictions.

Let $Plan47_i$ be the number of miles assigned to county i in the 1947 plan. This variable is estimated by digitizing the 1947 plan (see Figure 1.2), and measuring the number of miles inside each county using the USA Contiguous Equidistant Conic projection. Then, the instrument, denoted by Z_{it}, can be calculated by:

$$Z_{it} = \left(\frac{Plan47_i}{\sum_{i \in S(i)} Plan47_i} \right) \sum_{i \in S(i)} X_{it} \tag{3.2}$$

where $S(i)$ is a function that assigns each county to its respective state. For example, the 1947 plan assigned San Diego county 7.7% of all interstate miles in California. Then, San Diego's instrument for year t multiplies 7.7% times all the miles opened in California in year t. The 1947 plan should be a valid instrument as long as its creation was not influenced by the reelection strategies of incumbent parties between 1950 and 1972.

It is important to note a small source of misspecification arising from the timing of the variables: in the U.S., elections generally occur in November, while data on the number of opened miles covers the whole calendar year. In my data, 98.3% of the observations are for elections that happened in November, while the other 1.7% occurred before October. To avoid misspecification as best as possible I only consider November elections, which results in 23,413 observations (which originate from a total of 359 gubernatorial elections across the 48 contiguous states).

Another possible source of misspecification in equation (3.1) might arise due to counties having different areas. Generally speaking, a new highway mile should have less impact on the share of votes in a county that has more area. To overcome this obstacle, I normalize the variables X_{it} and Z_{it} by area A_i, in the following way: $x_{it} = (X_{it}/A_i)\bar{A}$ and $z_{it} = (z_{it}/A_i)\bar{A}$, where $\bar{A} = \sum_i A_i/N$ and $N = 3,058$. The addition of $\bar{A}$ in the formula simply scales the β coefficient to give it the same interpretation as before: the effect of opening an extra mile in county i on the share of votes received by the incumbent. The area for each of the 3,058 counties was calculated using the USA Contiguous Albers Equal Area Conic projection.

3.4 Results

Panel A of table 3.1 presents the results of estimating equation (3.1) using different estimation methods and control variables. For every specification Driscoll-Kraay standard errors are presented in parentheses (these are robust to heteroscedasticity, autocorrelation, and cross-sectional dependence).

Column (1) estimates the equation by OLS, with time dummies and no fixed effects. The results show no significant correlation between new highway miles and votes to the incumbent party. Column (2) adds fixed effects to the specification. The estimate jumps up to 0.126 and becomes significant. The favorite specification is presented in column (3), which estimates the equation with the instrument Z_{it} discussed before, and fixed effects. The new point estimate is equal to 0.647, with the 95% confidence interval between 0.320 and 0.974. The fact that the point estimate is higher with IV suggests that political parties seem to target spending in counties where they have less of a voting base. Instead of spending where political support is already high, politicians seem to target spending where they are less liked, which is also where they can gain more votes. It is important to note that the first-stage F-statistic of specification (3) is equal to 3,331, far above the standard weak instrument threshold of 10 Staiger and Stock (1997).

With a back of the envelope calculation I find that the 0.647 estimate translates into a 0.652 percentage point increase when spending is increased by $100 per capita (in 2019 dollars).[6] To compare this results with that of Levitt and Snyder (1997), note that in 1990 dollars the increase is equal to 1.183 percentage points. This is relatively lower than their estimate of 2.09 percentage points. A reason this might occur is that their measure of spending is different. Instead of the interstate, Levitt and Snyder (1997) use data from the Federal Assistance Awards Data System (FAADS), which includes expenditures such as social security, medicare, payments to agricultural producers, community development grants, and highway improvement funds.

Column (4) and (5) present results of two small extensions of the baseline model. In column (4) I add a lag of the new highway miles variable to control for the possibility that previous spending might also have an effect. Since political parties might choose where to invest today, thinking about the election of the upcoming year, it is also necessary to instrument this variable. Therefore, I add both $Z_{i,t}$ and $Z_{i,t-1}$ as instruments for $X_{i,t}$ and $X_{i,t-1}$. The estimate of this new parameter is statistically insignificant.

Finally, column (5) asks whether opening a highway mile in a county that shares a border with county i (I denote this set of counties by $N(i)$) might impact

[6] Using information from the Highway Statistics series from 1957 to 1966 I find that each interstate highway mile has an average cost of $5.95 million (in 2019 dollars). In the sample, each county has about 60 thousand people; if each contributes $100 then a total of $6 million is obtained. Finally, $(6/5.95) * 0.647 = 0.652$.

Table 3.1: Regressions on Votes to Incumbent Party

Panel A: Not Normalized by Area

	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	IV	IV	IV
X_{it}	-0.017	0.126***	0.647***	0.884**	0.624***
	(0.033)	(0.034)	(0.167)	(0.384)	(0.167)
$X_{i,t-1}$				-0.481	
				(0.512)	
$\sum_{i \in N(i)} X_{i,t}$					0.011
					(0.016)
Time Dummies	Yes	Yes	Yes	Yes	Yes
Fixed Effects	No	Yes	Yes	Yes	Yes
Obs.	23,413	23,349	23,349	21,352	23,349
First Stage F			3,331	999	3,429

Panel B: Normalized by Area

	(6)	(7)	(8)	(9)	(10)
	OLS	OLS	IV	IV	IV
x_{it}	-0.007	0.037	0.642*	0.882*	0.851*
	(0.014)	(0.024)	(0.340)	(0.458)	(0.509)
$x_{i,t-1}$				-0.493	
				(0.506)	
$\sum_{i \in N(i)} x_{i,t}$					-0.066
					(0.057)
Time Dummies	Yes	Yes	Yes	Yes	Yes
Fixed Effects	No	Yes	Yes	Yes	Yes
Obs.	23,413	23,349	23,349	21,352	23,349
First Stage F			27	24	10

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Driscoll-Kraay standard errors in parentheses, robust to heteroscedasticity, autocorrelation, and cross-sectional dependence.

the votes to the incumbent in *i*. The results suggest that new highway miles in neighboring states do not impact the share of votes received by the incumbent party.

Panel B presents the results when the explanatory variable of interest (new highway miles) and the instrument are normalized by the county's area as described in section 3.3. The estimates do not change much with this transformation. For example, specification (8) presents the analogous version of the baseline estimate, where the point estimate is equal to 0.642, instead of 0.647.

3.5 Conclusion

While it is generally believed that incumbent parties can influence the behavior of voters with government spending, there are only a handful of papers that attempt to measure the magnitude of this causal effect. For the most part, research on the subject has been limited due to the endogeneity between these two variables. As politicians have incentives to target spending where it will benefit them the most in the upcoming election, a simple OLS regression is likely to deliver a downward-biased estimate of the causal effect of interest.

In this chapter, I digitize the 1947 plan of the IHS and use it in an IV framework to estimate the causal effect of opening one highway mile, during an election year, on votes received by the incumbent party. The results suggest that receiving one extra highway mile causes the share of votes to the gubernatorial incumbent party to increase by 0.65 percentage points. Additionally, I find no effect from opening a highway mile in a contiguous county, or one year before the election.

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