MID-AMERICA
TRANSPORTATION CENTER

University of Nebraska Lincoln

K-STATE
Kansas State University

KU
THE UNIVERSITY OF
KANSAS

MISSOURI
S&T
University of
Science & Technology

THE UNIVERSITY OF IOWA

LINCOLN
University
1866

PRAIRIE VIEW A&M UNIVERSITY
1876

Earmarked Revenues and Spending Volatility: The Case of Highway Finance

Phuong Nguyen-Hoang, Ph.D.
Assistant Professor
School of Urban and Regional Planning
Public Policy Center
University of Iowa

William Duncombe, Ph.D.
Professor of Public Administration
Maxwell School of Citizenship and Public Affairs
Syracuse University

THE UNIVERSITY OF IOWA

MATC

Earmarked Revenues and Spending Volatility: The Case of Highway Finance

Phuong Nguyen-Hoang, Ph.D.
Assistant Professor
School of Urban and Regional Planning
Public Policy Center
University of Iowa

William Duncombe, Ph.D.
Professor of Public Administration
Maxwell School of Citizenship and Public Affairs
Syracuse University

A Report on Research Sponsored by

Mid-America Transportation Center

University of Iowa

June 2012

Technical Report Documentation Page

1. Report No. 25-1121-0001-476	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Earmarked Revenues and Spending Volatility: The Case of Highway Finance		5. Report Date June 2012	
		6. Performing Organization Code	
7. Author(s) Phuong Nguyen-Hoang and William Duncombe		8. Performing Organization Report No. 25-1121-0001-476	
9. Performing Organization Name and Address Mid-America Transportation Center 2200 Vine St. PO Box 830851 Lincoln, NE 68583-0851		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Research and Innovative Technology Administration 1200 New Jersey Ave., SE Washington, D.C. 20590		13. Type of Report and Period Covered Final Report July 2011-June 2012	
		14. Sponsoring Agency Code MATC TRB RiP No. 28883	
15. Supplementary Notes			

16. Abstract

Over the last decade, state governments have experienced two recessions (including the recent "Great Recession") which have resulted in significant disruptions in state budgets and highlighted the volatility of the personal income tax and general sales tax. Since infrastructure maintenance funding may be particularly vulnerable to budget cuts during recessions, it is important to identify more stable revenue sources and budgetary institutions. One of the distinguishing characteristics of highway finance in the United States is the heavy use of earmarked revenues linked to highway users. Our key research question is whether an increase in the share of highway funding from earmarked revenues will reduce the volatility of highway budgets. To answer this research question, we have collected extensive data on state highways, state finances, and other socio-politico-economic characteristics of state governments over a 30-year period, and developed an empirical model drawing from previous research in state and local public finance. We found that earmarking of revenue in state highway funds is significantly related to highway expenditure; however, the relationship is more nuanced than we originally hypothesized. An increase in the share of highway funding from transportation-related revenue sources or an increase in the share of transportation-related revenue from motor fuel taxes are associated with a decrease in volatility of state highway spending. On the other hand, an increase in the share of transportation-related revenue used for highways is associated with an increase in budget volatility. Since the major alternative use of state transportation-related revenue is to fund local roads, this result indicates the importance of examining state-local intergovernmental finance on highway spending volatility in future research.

17. Key Words State highways, spending, volatility, filter		18. Distribution Statement	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 70	22. Price

Table of Contents

List of Figures

Acknowledgments

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation's University Transportation Centers Program, in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.

Abstract

Over the last decade, state governments have experienced two recessions (including the recent "Great Recession") which have resulted in significant disruptions in state budgets and highlighted the volatility of the personal income tax and general sales tax. Since infrastructure maintenance funding may be particularly vulnerable to budget cuts during recessions, it is important to identify more stable revenue sources and budgetary institutions. One of the distinguishing characteristics of highway finance in the United States is the heavy use of earmarked revenues linked to highway users. Our key research question is whether an increase in the share of highway funding from earmarked revenues will reduce the volatility of highway budgets. To answer this research question, we have collected extensive data on state highways, state finances, and other socio-politico-economic characteristics of state governments over a 30-year period, and developed an empirical model drawing from previous research in state and local public finance. We found that earmarking of revenue in state highway funds is significantly related to highway expenditure; however, the relationship is more nuanced than we originally hypothesized. An increase in the share of highway funding from transportation-related revenue sources or an increase in the share of transportation-related revenue from motor fuel taxes are associated with a decrease in volatility of state highway spending. On the other hand, an increase in the share of transportation-related revenue used for highways is associated with an increase in budget volatility. Since the major alternative use of state transportation-related revenue is to fund local roads, this result indicates the importance of examining state-local intergovernmental finance on highway spending volatility in future research.

Chapter 1 Introduction

Over the last decade, state governments have experienced two recessions (including the recent "Great Recession") which have resulted in a period of unprecedented fiscal stress. The resulting disruptions to state budgets have highlighted the volatility of the two most important general revenue sources used to fund most of the state budget: personal income tax and general sales tax. Since infrastructure maintenance funding may be particularly vulnerable to budget cuts during recessions, high revenue volatility may lead to significant budgetary volatility for infrastructure budgets and potentially to the long-term deterioration of basic infrastructure necessary for economic growth.

One of the distinguishing characteristics of highway finance in the United States is the heavy use of earmarked revenues linked, directly or indirectly, to highway users. If motor fuel taxes and other transportation-related revenue sources are more stable than income and sales taxes, and earmarking protects them from diversion into the general budget, then earmarking may be an important way to stabilize highway budgets. This study is the first to examine the role of earmarked revenues in affecting the volatility of state highway spending. We hypothesized that states with an increase in highway funding from earmarked revenues will experience a decrease in their highway spending volatility.

To answer this research question, we have collected extensive data on state highways, highway budgets, state revenues, and socio-politico-economic characteristics for most states over a 30-year period. We have drawn from the literature in state and local public finance to develop an empirical model that has identified key variables including several measures of earmarking. We have applied appropriate statistical methods to estimate the multivariate regression model and have checked the robustness of our results in several alternative specifications of the model. We found that earmarking of revenue in state highway funds is significantly related to highway

expenditure volatility; however, the relationship is more nuanced than we originally

hypothesized.

The rest of the report is organized as follows. After the introduction, we begin with a

review of the relevant literature in state and local public finance, which will serve as the

foundation for our empirical model and measures. In Chapter 3, we briefly discuss key aspects of

the financing system for state highways, including federal aid and transportation-related revenue

sources and introduce several different dimensions of earmarking. In Chapter 4, we develop the

empirical model drawing from previous demand, cost, and efficiency models. The data and

measures are presented in Chapter 5 and the empirical methodology discussed in Chapter 6. In

Chapter 7, we present our empirical results and test their robustness in Chapter 8. We conclude

with a brief summary of findings and possible implications for policy and future research in

Chapter 9.

Chapter 2 Literature Review

The research topic presented in this report both draws from and contributes to several bodies of literature. The breadth of the relevant literature precludes us from providing a comprehensive summary in this section. Instead, we will narrow our focus to those studies most relevant our research question: do earmarked revenues reduce highway spending volatility? Specifically, we will briefly discuss three bodies of research in this section of the paper: demand for public services and infrastructure, influence of earmarks, institutional constraints and politics on state budgets and research on state budget volatility.

2.1 Demand for Public Services and Infrastructure

Over the last four decades, there has been a growing research literature, which has focused on the demand for public services with a particular focus on local services. The theoretical foundation for this research is the median voter model, which has its roots in political economy research of Bowen (1943), Downs (1957) and Black (1958). Beginning with the pioneering work of Barr and Davis (1966), Borcherding and Deacon (1972), and Bergstrom and Goodman (1973), they applied the median voter model in a model of demand for local services. The key assumption is that the public choice model for empirical estimation can be simplified to finding the demands of one decisive voter (Inman, 1978). While most of this research has examined demand for non-highway services, especially education, we will discuss the limited research on highways.

2.1.1 Demand Research

The median voter demand model draws heavily from microeconomic demand models for private goods. While private demand functions typically model the behavior of a 'typical consumer,' median voter demand models capture the key factors influencing the demand of a 'decisive voter' for particular public services. These include median income, intergovernmental

aid, the tax price for the service and factors related to differences in preferences across subgroups of the population, which might shift the outcome away from the voter with median income (Inman 1978, 1979; Rubinfeld, 1987). Intergovernmental lump-sum aid augments the income of the decisive voter by reducing the amount of taxes that will have to be raised by that government. The median voter's tax price was typically measured by the median voter's share of local property tax taxes, usually measured as the ratio median house value to total (or per capita) taxable property values. Preference variables often included demographic variables, such as age distribution, home ownership, racial composition, and the share of voters with a particular interest in the service (e.g., share of the population that is Catholic in models for public education).

The assumptions behind the median voter public choice model are most consistent with the public choice process in single purpose governments, where citizens can vote on the local budget as well as elect representatives. Critics have challenged the median voter model on its ability to capture the complex, dynamic, public choice process in large multi-purpose governments (Bailey and Connolly, 1998; Dahlberg and Jacob, 2000; Romer and Rosenthal, 1979). Despite the frequent criticisms of the median voter model, there is some empirical support for the predictive power of the theory (e.g., Holcome, 1980; Inman, 1978; Turnbull and Djoundourian, 1994). Focusing specifically on state highways, Congleton and Bennett (1995) compare the median voter model with the one emphasizing special interest group politics and find that the median voter model fits the data better. Several other studies of highway spending have found that demand variables, such as intergovernmental aid and community income are significantly related to highway spending (Bruce et al., 2007; Gamkhar, 2000, 2003; Knight, 2002; Nesbit and Kreft, 2009).

One of the differences modeling the demand for highways compared to education, for example, is that highways can be classified as basic infrastructure. Highways represent a capital stock, which provides a foundation for other economic activity and the benefits from highways extend beyond the direct users of highways and extend beyond the state where the highways are built (Bruce et al., 2007). The demand for highways can be thought of as a derived demand, since highways are a productive input in the production process for many private (and public) goods and services. Demand for highways is both caused by and influences economic growth. The structure and geography of a state's economy can influence the demand for highways. One of the challenges in modeling the demand for public infrastructure is that it is a stock, not a flow, of public services, such as education. Highways are the product of decades of decisions made about how much to invest, where, and with what technology. Models of infrastructure investment have generally included measures of the condition of the capital stock, or previous levels of investment to account for the effects of past decisions (Holtz-Eakin and Rosen, 1989). We will include standard demand measures and a measure of the value of the capital stock into our models of highway expenditure volatility.

2.1.2 Flypaper Effect

One of the common results of the median voter demand models receiving the most attention is the so-called "flypaper effect." Contrary to the predictions of early economic theories of intergovernmental finance (Bradford and Oates, 1971; Oates, 1972) that local governments would respond the same way to an increase in a lump-sum grant as in community income, demand studies tended to find governments were much more responsive to grants than income, i.e., money sticks where it hits. Given that there are several comprehensive reviews of

the research on flypaper effects (Bailey and Connolly, 1998; Hines and Thaler, 1995; Oates, 1994), we will concentrate on the research related to highways.

The flypaper effect research has highlighted the complex intergovernmental dimension to the provision of many government services. This is particularly true in the case of highways where all three levels of government (federal, state, and local) have an important role to play (see section III). Over the last decade, several studies have examined the relationship between state highway expenditures and federal highway aid.[1] Beginning with Gamkhar (2000), these studies have tried to incorporate the complex federal grant distribution process into the specification and estimation of models of highway expenditures (Bruce et al., 2007; Gamkhar, 2003; Knight, 2002; Nesbit and Kreft, 2009). These studies have found that "a one-dollar increase in federal highway grant receipts causes state and local expenditures to rise by between 52 and 78 cents" (Nesbit and Kreft, 2009, 97). In other words, between 50% and 80 % of federal aid is used to increase spending on state highways, and the remainder has been used to reduce state revenue. We will incorporate the measures and methods developed in these papers.

2.1.3 Cost and Efficiency Research

Initially, demand models included a tax share measure as the only measure of the "tax price" to the decisive voter for one more unit of public service. Beginning with the work of Borcherding and Deacon (1972), there was increasing recognition that the tax price of public services also depends on the marginal cost of producing the service and the efficiency with which it is provided. To capture the marginal cost of providing the service, studies either

---

[1] Some studies have used the term "crowd-out" to refer to a phenomenon similar to the flypaper effect. If there is no flypaper effect then federal grants "crowd-out" local sources, resulting in little increase in total spending. The flypaper effect implies that there is only partial "crowd-out" leading to an increase in spending greater than would be expected if the grants affects demand just like income (Knight, 2002; Nesbit and Kreft, 2009). For the sake of consistency we are going to use flypaper effect rather than crowd-out in this report.

included a marginal cost function (Duncombe, 1991), cost index (Duncombe and Yinger, 1997, 2000), or cost variables, such as factor prices (Wang, Duncombe, and Yinger, 2011) into the demand model. Various approaches have been used to measure for or control efficiency in the demand models (Duncombe, Ruggiero, and Yinger, 1996; Duncombe and Yinger, 2000, 2008). The broader relevance of the cost research for public service demand highlights that factors outside of a government's control, such as being located in a high-wage labor market, the population and geographic size of a government, and the socio-economic characteristics of clients and residents, can affect the marginal cost of providing the service (Duncombe and Yinger, 2008).

While there has been significant research on the cost of providing public education, there have been relatively few cost function studies of the cost of providing state highways. One exception is an article by Levinson and Gillen (1998), which estimates the full-cost for intercity highway transportation.[2] They estimate a cost function for "infrastructure costs" (p. 212) comprised of three input prices and three measures of road users (what they call output). Their input prices include: (1) capital, which they argue is reflected in variation in interest rates (and credit ratings) on state government debt; (2) labor prices, which they measure with average wages for state government employees; and (3) material prices, where a price index for bituminous concrete is used as a proxy. They find that credit ratings (as a proxy for interest rates) and wages rates are positively and significantly related to highway expenditure, but that the price of material was not statistically significant. They also found that there were short-run and long-run diseconomies of scale for automobiles, but increasing returns to scale for trucks. This paper

---

[2] Another related paper is by Levinson and Yerra (2002) which models and estimates the costs and efficiency of different levels of government (state and local) financing different classes of roads.

has served as a foundation for the cost-related variables that we included in our highway expenditure volatility model.

We will briefly review two other types of research indirectly related to the costs of providing highways. There are a significant number of "cost allocation studies," which attempt to calculate the costs imposed on the highway system by different user classes (Transportation Research Board, 2008). While the costing methodologies in this research are different from those required in this study, they do highlight the importance of accounting for the mix of user groups in estimating the determinants of highway expenditures. Another type of cost-related research in transportation estimates is cost indices for the price of construction materials and supplies. Such indices are particularly important in the bidding process for highway construction and maintenance (Skolnik, 2011). While no common set of price indices are available for all states over an extended period of time that we can use in this study, this research does indicate that input prices, such as construction wage rates, need to be included in our expenditure model.

2.2 The Influence of Earmarks, Institutional Constraints and Politics on State Budgets

The limitations of the median voter model in capturing the public choice process in large multi-purpose governments have encouraged the development of models which more accurately capture the state budgeting process. This is especially important for visible infrastructure, such as highways, where there are political (and potentially economic) benefits from the location of highway projects (Bruce et al., 2007; Inman, 1983; Nunn, 1990). Given the breadth of the state and local political economy literature, we will concentrate on research in a few areas most related to the topic of this report.

2.2.1 Earmarks and Other Institutional Constraints

Over the last three decades, a growing body of research has emerged examining how institutional constraints imposed on the state budget process affect budget outcomes. With the passage of Proposition 13 in California in the late 1970s, much of the attention has been focused on tax and expenditure limitations (TELs). There is now a rich body of research on whether TELs have actually reduced the growth and size of government.[3] Besides their effect on the overall level of state spending, TELs may influence the allocation of state budgets across types of services (Mullins and Joyce, 1996) and may affect the ability of state governments to borrow by raising their borrowing cost (Poterba and Rueben, 1999). With respect to state highway spending, Mullins and Joyce (1996) found that "state limits are associated with an initial reduction in the relative level of expenditures made by the state but expenditures tend to regain lost ground over time." Besides TELs, other fiscal institutions which could affect state budgets for highways include debt limits, line-item vetoes, and balanced budget requirements (Clingermayer and Wood, 1995; Holtz-Eakin, 1988; Hou and Smith, 2010). For this report, we have included measures of balanced budget requirements in the regression models. In future analysis we will also add measures of state-level TELs and debt limitations.

A fiscal institution receiving less attention but directly related to the topic of this report is tax earmarking. "Earmarking is the budgeting practice of dedicating tax or other revenues to a specific program or purpose. This practice typically involves depositing tax or other revenues into a special account from which the legislature appropriates money for the designated purpose." (Michael, 2008, p. 1). Michael (2008) lays out some of the key distinctions between types of earmarking, including: (1) statutory versus constitutional authorization; (2) full versus

---

[3] Good literature reviews on the effects of TELs on state spending include Mullins and Wallin (2004) and Mullins and Joyce (1996).

9

partial earmark; and (3) direct versus legislative appropriation of funds. We will discuss these distinctions in more detail in section 2.3.

The theoretical literature related to the efficiency impact of earmarks has developed over the last 50 years (Buchanan, 1963; Brennan and Buchanan, 1978; Deran, 1965; Oakland, 1985). While several papers examined the effects of earmarked (especially lottery) revenues on educational (both K-12 and college) spending (Bhatt, Rork, and Walker, 2011; Borg and Mason, 1990; Evans and Zhang, 2007; Novarro, 2005), we are aware of only a couple of empirical studies of the impact of earmarking on highway spending. Dye and McGuire (1992) examined the effects of earmarking on several state government functions and found for highways that a one dollar increase in earmarked taxes for highways was associated with a $0.19 increase in highway spending. While they recognized the potential endogeneity of the earmarking variable, they were not able to find an appropriate instrument for highways. More recently, Nesbit and Kreft (2009) examined the impact of highway earmarks on spending and found that a dollar increase in earmarked highway revenues was associated with almost a dollar increase in spending. However, they did not treat earmarked revenues as endogenous. We will follow Nesbit and Kreft (2009) by including both federal aid and earmarked revenues in our model but will treat both as endogenous variables.

2.2.2 Influence of Political Factors on State Budgets

Research examining how institutional constraints affect state budgets have included political variables in the models as well. Common state-level political variables considered are party affiliation of the governor and legislature and whether there was divided government across parties. Given the important role of the federal government in funding highways, committee membership in congressional transportation committees is also included. Congleton

and Bennett (1995) and Knight (2002) explicitly modeled the political bargaining process related to highway spending. Congleton and Bennett (1995) emphasized the role of special interest groups in state legislative decisions by including measures of trucking employment, railroad employment and whether the state was a right-to-work state. Focusing on the role of seniority and representation of a state's congressional delegation on congressional transportation committees, Knight (2002) used the congressional political variables as instruments for the federal aid in an instrumental regression model. In general, political variables have not been found to be strong predictors of state highway expenditures (Bruce et al., 2007; Congleton and Bennett, 1995; Knight, 2002; Nesbit and Kreft, 2009). We included state and federal political variables in our regression model.

Another dimension to considering the role of politics in state budget decisions is whether interstate competition might influence highway spending levels. Beginning in the 1990s, there has been a growing literature on whether state governments mimic each other in terms of tax policy or the adoption of specific programs (Case, Rosen, and Hines, 1993; Heyndels and Vuchelen, 1998). While most of this research has focused on tax competition, there are a few studies that have looked at whether there is interstate competition over highway spending (Bruce et al., 2007; Case, Rosen, and Hines, 1993; Nesbit and Kreft, 2009). One way to operationalize interstate competition is to include a weighted average of the spending in neighboring states in the regression model.[4] While Case, Hines and Rosen (1993) found that spending by neighboring states on highways tends to prompt a state to spending more on highways, Bruce et al. (2007) found the opposite result.

---

[4] Studies have also corrected for "spatial autocorrelation' which might bias the standard errors.

2.3 Research on Budget Volatility

Given our focus in this report on highway expenditure volatility, we conclude the literature review with a summary of some of the research related to volatility of state budgets. Most of the research on state budget volatility has focused on state revenues. A common argument in the last decade is that state revenue volatility has been increasing as a result of increasing instability of state economies (Crain, 2003), changes in the portfolio of state tax revenue sources (Cornia and Nelson, 2010; Crain, 2003), specific provisions in states sales and income taxes (Kwak, 2011) and problems in state revenue forecasting (Thompson and Gates, 2007).

While the deleterious effects of revenue volatility on state budget deficits (Gamage, 2010) and the government efficiency (Crane, 2003) have been examined, there is much less research on other determinants of state budget volatility.[5] Breunig and Koski (2011) have recently examined the relationship between interest group density (share of interest groups focusing on a specific spending area) and spending volatility. In their model, they also included other institutional variables and political variables. Only the measure of interest group density was a statistically significant determinant of spending volatility.

One research area related to state budget volatility receiving attention addresses the question of whether state savings, either in budget stabilization funds or general fund balances, has helped to stabilize or destabilize state budgets. In a series of papers, Hou (2003, 2005, 2006) examined both the determinants of state savings behavior and whether state savings stabilizes budgets. Using panel data and an extensive set of covariates, he found that budget stabilization funds appear to stabilize budgets during downturn years, but not general fund balances. We drew

---

[5] While Crane (2003) has undertaken probably the most ambitious study of the link between economic and revenue volatility and growth, he didn't examine explicitly the determinants of state spending volatility.

significantly from Hou's research in developing our measures and model of highway spending

volatility.

Chapter 3 Financing State Highways

The financing of state highways is part of a complex intergovernmental finance system involving all three levels of government and significant transfers of resources between levels. As illustrated in table 3.1, nationally approximately 67% of revenues used by states for highways in 2008 came from state sources, 30% from the federal government and 3% from local governments. Over 70% of state revenue came from highway-user revenue, such as motor fuel taxes and motor vehicle/motor carrier taxes and fees. However, these national summary statistics mask significant variation across states in how they finance highways. The complexity of the system precludes us from providing a broad description in this report. Instead, we will concentrate on several aspects of the system most related to the topic of this report.

Table 3.1 Distribution of Revenues Used by States for Highways, 2008

State	Percent of Total Receipts				Per Capita Total Receipts[2]
	Highway-User Revenue[1]	Other State Revenue	From Federal Government	From Local Government	
National average	47.6	19.7	29.8	2.8	$469.1
Average variation	13.3	12.9	10.7	5.0	180
Minimum	11.5	0.0	15.1	0.0	269
10th percentile	29.8	3.7	24.3	0.0	307
Median	48.0	13.9	32.1	0.9	409
90th percentile	64.3	42.7	50.2	5.0	646
Maximum	71.5	49.2	63.0	34.2	1,097

[1] Amounts shown represent only those highway-user revenues that were expended on state or local roads.
[2] Total receipts do not include bond proceeds, since these are not a source of revenue.
Source: Receipts are from Federal Highway Administration, Highway Statistics 2008, Table SF-1. Population estimates for 2008 are from the U.S. Census Bureau.

3.1 Federal Aid to State Governments

For close to a century, the federal government has played a crucial role in the financing

of the country's roads and highways. As a result of several presidential vetoes made in the early

19th century, the federal role in planning and constructing transportation infrastructure was

limited (Goodrich, 1960). Instead, the federal government could provide financial support to

states for the construction and maintenance of highways and attach requirements to the receipt of

federal assistance. The first federal highway acts passed in 1916 and 1921 established the

precedent of federal aid to states provided in the form of matching grants, which in turn were

responsible for project selection, construction, and maintenance.[6] Since the development and

financing of the federal highway system has been well documented in other sources (Dilger,

2011; USDOT, 1976), we will focus on the process used to distribute funds through the Federal-

Aid Highway Program (FAHP) to state governments. For our brief summary, we draw heavily

from the detailed description of the FAHP provided in the Federal Highway Administration's

(FHWA) publication, *Financing Federal-Aid Highways*. The distribution of most funds

(apportionments) in the FAHP to states is through a series of formulae for each program. Most

grants are best described as closed-ended matching grants, although some of the grants are lump-

sum in nature. The formula components vary across each aid program; most include some

measure of lane miles and vehicle miles. The FAHP also imposes restrictions on states on how

funds can be distributed within the state. Besides apportionments by formulae, additional funds,

---

[6] The Federal Aid Road Act of 1916 and the Federal Highway Act of 1921 played a crucial role in
establishing the fiscal relations between the federal and state governments and in encouraging close
collaboration between the federal and state governments in highway planning (Paxson, 1946; USDOT,
1976).

called "allocations," are provided to states with no formula and may be made at any time during the fiscal year.[7]

While states are apportioned a certain amount of funding each year, the actual funds provided to states are reimbursements for actual costs incurred on approved projects. Typically, the state has already spent a portion (if not all) of the funds before they are reimbursed. Because of the reimbursement nature of the program, apportioned or allocated funds do not have to be incurred in the year they are apportioned or allocated. Instead, the state has four years from the time the funds are first apportioned or allocated to spend the money (or obligate it).[8] This implies that there may be up to a four-year lag between the apportionment or allocation of funds and expenditure. It also implies that states have significant influence over federal expenditure but have less influence on apportionments or allocations.

Table 3.2 provides some information on expenditures and apportionments per capita of FHWA funds in FY 2008. Since federal highway grant expenditures in 2008 may include apportionments made up to three years earlier, we included apportionment data from 2005 to 2008. There are a couple of conclusions which can be drawn from this table. First, it is clear that the distribution of federal expenditures and apportionments are very highly related with correlations over 0.9 for all years. In fact, federal expenditures in 2008 are just as correlated with apportionments in 2005 as they are with apportionments in 2008. Second, the ratio of apportionments to expenditures varies significantly across states. Apportionments are on average 30% higher than expenditures with an average variation of 20%.

---

[7] There is also the Equity Bonus program (formerly known as the Minimum Guarantee program) to assure that states receive no less than a certain percent (92% in 2008) of their contributions to the Highway Account of the Highway Trust Fund.

[8] An obligation occurs when an approved project's eligible costs are actually incurred. It involves the Federal government's promise to pay a state for the Federal share of the eligible costs.

Table 3.2 Per Capita Apportionments and Expenditures of Federal Highway Administration Funds by States

| State | Total Apportionments | | | | | Expenditures (2008) | Ratio of Average Apportionments to Expenditures |
	2005	2006	2007	2008	Average (2005-2008)		
National average	$102.8	$102.7	$114.1	$114.1	$108.4	$83.4	1.30
Average variation	78	77	84	81	78	56	0.20
Minimum	77	79	82	81	80	50	0.76
10th percentile	83	83	92	93	86	66	1.08
Median	118	115	125	123	119	96	1.31
90th percentile	260	259	283	277	266	231	1.56
Maximum	422	417	461	455	432	277	1.88
Correlation with Expenditures	0.932	0.937	0.934	0.932	0.936		

Source: Federal Highway Administration. *Highway Statistics*, 2005 to 2008, Tables FA-3 and FA-4. Population estimates are from the Census.

3.2 State Highway Revenues and Earmarks

        State governments in most states provide the majority of the funding for state highways through their own sources of revenue (table 3.3). What makes highways unique among state functions is that the majority of state funding comes from taxes that are at least partially related to highway use.[9] Highway-user, or transportation-related, revenue includes taxes on motor fuels, motor vehicle/motor carrier taxes and fees (e.g., driver's licenses, vehicle title), and tolls.[10] Highway-user taxes are typically recorded in separate special revenue fund(s).

        While there are many interesting dimensions to a state highway finance system, we are going to focus in this section on earmarking of state highway-user related revenues. Drawing on

---

[9] There is significant debate about how closely motor fuel taxes approximate a user charge and how much of funding for highways they actually cover (Puentes and Prince, 2003; U.S. PIRG Education Fund, 2011; Williams, 2007).

[10] FHWA did not consider tolls as part of highway-user revenues until 1995. Also, twenty states do not have any revenue from tolls. We exclude tolls as a component of highway-user revenues from now on.

a recent study of all 50 states by Rall et al. (2011), we first examined what legal and institutional restrictions might be in place to limit the use of these revenues for non-highway purposes. As table 3.3 indicates, a number of states have restrictions in place, which should limit the amount of highway-user revenue used for non-highway and non-transportation uses. Twenty-three states have constitutional and three have statutory restrictions, respectively, on the use of fuel taxes for non-highway or non-road use. Legislatures may be tempted to use other sources of highway revenue, such as federal highway aid, for non-highway purposes, especially during fiscal crises. In 15 states, federal funds go directly to the state department of transportation (DOT) and not to the legislature for allocation. Given that highway projects often span multiple years, surpluses in the highway funds are common, which makes them tempting targets for balancing state budgets. In 26 states, the state DOT is able to retain surplus funds for use in future years, and in 13 states, they can retain a portion of the surplus. State budget control systems often restrict the movement of funds across projects without legislative (or budget office) approval limiting the ability of state DOT from adjusting their budget to changing circumstances. In over half of the states (27), legislative approval is required to move funds between projects. These survey results seem to indicate that earmarking of highway-user revenue may be effective in a number of states.

However, in reading the detailed survey responses of states, legislatures appear to retain much more authority to reallocate money in highway funds than legal and institutional restrictions might suggest. The fungibility of state resources across accounting funds makes it possible to move money out of a highway fund even with legal restrictions. For example, in New York the Dedicated Highway and Bridge Trust Fund (DHBTF) "was intended to be the primary funding source for the construction and rehabilitation of State-owned roads and bridges." (New York State Comptroller, 2009, p. 1). Instead of using the fund to pay for capital projects, the state

diverted a portion of the fund to pay for "other noncapital transportation activities…" which had

been funded out of the state's general fund (p. 1). To maintain the highway capital program, the

state issued significant amounts of debt. In essence, the state used a back-door mechanism to

divert money from the highway fund into non-highway uses.

Table 3.3 Earmarking and Control in the State Highway Budget Process

	Number of States
Dedication of fuel tax revenues for highway use	
Constitutional	23
Statutory	3
Allocation of federal funds directly to state DOT	15
State DOT retains surplus funds	
Full	26
Partial	13
Legislative approval required to move funds between projects	27
Source: Rall et al. (2011).	

Given the loopholes which may exist even in tightly restricted highway funds, it is

difficult to use these characteristics to identify states with and without strong earmarking of

highway revenues. Instead, we are going to adopt the approach in other empirical studies of

highway earmarking (Dye and McGuire, 1992; Nesbit and Kreft, 2009) of using the actual

allocation of revenue across functions to measure earmarking. Specifically, we are going to use

three different (but related) measures to capture different dimensions of earmarking. In the next

section, we will provide the theoretical foundation for using these measures. In this section we

will concentrate on explaining them intuitively. States have several choices related to

earmarking. First, how much of the highway-user revenues (i.e., motor fuel taxes and motor

vehicle/motor carrier taxes and fees) should the state devote to highways compared to other uses,

including transportation-related aid to local governments? In table 3.4 summary statistics are provided for this measure in 2008 (column 5). On average, less than half of the highway-user revenue collected by states is used for state-administered highways; however, there is significant variation in this share (average variation of 27%). The other main uses of highway-user revenues are for local roads and streets (close to 30%) and mass transit (12%). The ability of states to earmark taxes may vary between motor fuel taxes and motor vehicle/motor carrier taxes and fees. The ratio in column 6 of table 3.4 measures the percent of total highway-user revenues being derived from motor fuel taxes. Approximately 55% of total highway-user taxes came from motor fuel taxes in 2008, with average variation of 13%. While the variation is not as large as for the highway share, it is still substantial. Another measure more in line with what has been used in previous research is the share of total highway receipts coming from highway-user taxes. If highway-user taxes have more restrictions on their use, then a higher ratio would indicate that a state had a higher level of earmarking. In 2008, this ratio averaged 50% with variation of 13.5% (column 8). While none of these measures fully captures the level of earmarking in a state, together they may provide a broader picture of state earmarking.

Table 3.4 Distribution of Per Capita State Own-Source Receipts Across Purpose and Type of Revenue, 2008

	Motor Fuel Taxes		Motor Vehicle/Motor Carrier Taxes		Highway Share of Total Highway-User Revenues (percent)	Motor Fuel Share of Highway-User Revenues (percent)	Total Highway Receipts	Highway-User Revenue Share of Total Highway Receipts (percent)
	State Highways	Other Purposes	State Highways	Other Purposes				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
National average	$62	$61	$43	$59	46.6	54.6	$450.7	49.8
Average variation	38	39	37	43	26.6	13.0	189	13.5
Minimum	0	0	0	0	0.1	26.8	179	0.0
10th percentile	28	6	13	8	24.6	38.8	297	10.6
Median	71	62	39	48	46.9	61.2	406	27.5
90th percentile	115	109	117	114	92.8	73.6	671	49.9
Maximum	197	159	159	190	126.3	77.6	1,097	55.4

Note: Because data is being drawn from different tables, the estimates should be viewed as approximations.
Source: Federal Highway Administration, *Highway Statistics 2008*, Tables SF-3, MF-1, MV-2. Population estimates for 2008 are from the U.S. Bureau of the Census.

Chapter 4 The Empirical Model

In developing a model of highway expenditure volatility, we incorporated several other models, such as demand for highways, cost of producing highways, efficiency in the production of highways, and models of what affects expenditure volatility. We made several assumptions during this model development process to derive a linear estimation demand model.[11]

4.1 Demand Model for Highway Expenditures

Highway expenditures are the product of the output for highways multiplied by its average cost. This implies that any model of highway expenditures is going to need to incorporate a model for the demand for highway output and a cost model.

A key issue for the demand function of highway expenditures is identifying the output for highways. In a production function, output would be the number of lane miles constructed or maintained in a particular year. From the standpoint of the voters, they care about the quantity of roads available (lane miles) and quality of roads (road condition). A combination of these elements would be a measure of highway outcomes, such as the total number of lane miles of a given quality. One of the challenges modeling demand for highways is that the outcome of interest to voters (e.g., quality adjusted lane miles) is a stock but the output of government is a flow (e.g., miles of road resurfaced in a given year). We are going to start the modeling process by ignoring this distinction and will address it later in this section.

Following Congleton and Bennett (1995), we developed a median voter model for highway spending. Assume that the median voter has in her utility function two goods: A, which is transport dependent, and B, which is not. For this model we are going to ignore the distinction

---

[11] While it would be more general to allow for a non-linear empirical model, this would add significantly the time required in estimation and won't necessarily result in a solution.

between goods and services produced in the private sector and the public sector. The utility function for the median voter can be represented as

$$U = u(A, B). \tag{4.1}$$

4.1.1 Median voter budget constraint

The budget constraint for the median voter includes median income (Y) on the left hand. Earning income is assumed to require commuting; it is thus sensitive to the time it takes to get to work, which is affected by distance to work (D) and quality-adjusted lane miles (R); or $Y(D, R)$. On the right side of the budget constraint are expenditures on B (assumed to be the numeraire), expenditures on A (or, $P_a A$ where P_a is the price of A),[12] and expenditures on gasoline (or, $(P_g + t)G$ where P_g is the before-tax price of gasoline, t is the gasoline tax rate, and G represents the gasoline consumption by the median voter. The median voter's budget constraint can be expressed as equation 4.2:

$$Y(D, R) = B + P_a A + (P_g + t)G. \tag{4.2}$$

Following Congleton and Bennett (1995), gasoline consumption is assumed to be a function of the amount of A consumed, distance to work (D), and quality-adjusted lane miles (R):

$$G = g(A, D, R) \tag{4.3}$$

---

[12] We assume for this model that P_a does not include shipping costs within the state.

Substituting equation 4.3 into 4.2 produces

$$Y(D,R) = B + P_a A + (P_g + t)g(A, D, R). \tag{4.4}$$

4.1.2 Highway program budget constraint

On one side of the highway program budget constraint are expenditures on the highway

program (*E*). The cost function includes the cost of producing highway output (quality-adjusted

lane miles, *R*), the price of labor (P_w), price of capital (P_k),[13] and environmental factors (*Z*),

which affect the translation of inputs into road quality. Environmental factors might include

differences in weather conditions, the nature of the terrain, and the share of heavy trucks using

the roads. Highway expenditures are a function of costs and efficiency (*e*) as[14]

$$E = C(R, P_w, P_k, Z)/e. \tag{4.5}$$

On the other side of the budget constraints are funds to support highways, which come

from transportation-related sources of revenue and other sources. The major sources of revenue

for highways are taxes on motor fuels. For simplicity we are going to assume that all motor fuel

taxes are directly related to the gas tax revenue, which can be represented as the gas tax rate

multiplied by aggregate gas consumption, $t \sum G_i$, where G_i is the gas consumption in state *i*. We

combine other transportation-related revenues into one measure, O_{TR}, which consists of motor

---

[13] For our empirical analysis we are assuming that there are not significant differences across states in the price of materials and supplies. The finding of Levinson and Gillen (1998) that the price of materials was not statistically significant in their cost function estimates, suggests that this is not an unreasonable assumption.

[14] What is being assumed by equation 4.5 is that there is a function that converts road outputs (*X*), and environmental factors (*Z*) into outcomes, $R = f(X, Z)$. The inverse of this is substituted into the cost function for *X*. Efficiency (*e*) is an index from 0 to 1, where 1 indicates that a state is fully efficient.

vehicle/motor carrier taxes and fees. As discussed in the previous section, states can decide what share of transportation-related revenue to use for highways, other transportation services, or non-transportation services. Let M denote the share of total transportation-related revenue used for highways, which is a measure of the amount of transportation-related revenue "earmarked" for highways. (In table 3.4, descriptive statistics on M in 2008 are presented in column 5.) Besides transportation-related revenue, states can use other own sources of revenue (O_{GR}), such as income and sales taxes, to fund highways. Finally, states receive federal highway grants (F) to support highway construction and maintenance.[15] The highway program budget constraint can be represented as

$$\frac{C(R,P_W,P_k,Z)}{e} = F + M(t \sum G_i + O_{TR}) + O_{GR}. \tag{4.6}$$

We adopt the assumption in Congleton and Bennett (1995) that median gasoline consumption (G) is the same as average gasoline consumption. This implies that $\sum G_i = NG$, where N is the population count. Substituting this into equation 4.6 and rearranging the revenue side of the equation, the budget constraint can be represented as

$$\frac{C(R,P_W,P_k,Z)}{e} = F + \left(tNG(M)\left(1 + \frac{O_{TR}}{tNG}\right)\right)\left(1 + \frac{O_{GR}}{M(tNG+O_{TR})}\right) \tag{4.7}$$

The term, $(1+(O_{TR}/tNG))$, equals $((O_{TR} + tNG)/ tNG))$. The inverse of this ratio, which we label H_{TR}, is the share of transportation-related revenues from motor-fuel taxes. (Descriptive

---

[15] We are ignoring revenue to states from local governments since they represent a small share of total state highway revenues (table 3.1).

statistics for H_{TR} in 2008 are presented in column 6 of table 3.4.) The term,

$(1+(O_{GR}/(M(tNG+O_{TR}))))$, equals $(((M(O_{TR}+tNG))+O_{GR}))/M(O_{TR}+tNG)))$. The inverse of this

ratio, which we label H_{GR}, is the share of total highway revenue from transportation-related, or

highway-user, revenues. (Descriptive statistics for H_{GR} in 2008 are presented in column 8 of

table 3.4.) Solving equation 4.7 for t yields

$$t = (C(R,P_w,P_k,Z)e^{-1} - F)H_{TR}H_{GR}/(MNG) \tag{4.8}$$

Substituting equation 4.8 into the median voter's budget constraint 4.4 for the gas tax rate

(t) results in the combined budget constraint,

$$Y(D,R) + \frac{F}{N}(M^{-1}H_{TR}H_{GR}) = B + P_aA + P_gg(A,D,R) +$$

$(C(R,P_w,P_k,Z)e^{-1})(M^{-1}H_{TR}H_{GR})/N. \tag{4.9}$

The left hand side can be viewed as the augmented income of the median voter, where

F/N is per capita federal highway grants. The impact on the decisive voter of another dollar of

federal aid depends on the size of the population, the share of transportation-related revenue used

for highways (M), the share of highway-user revenues from motor fuel taxes (H_{TR}) and the share

of total highway receipts from transportation-related revenues (H_{GR}). Multiplied by F, the term,

$(M^{-1}H_{TR} H_{GR}/N)$, is similar to the tax share term used in median voter studies of local demand.

Solving equation 4.9 for B and substituting this into the utility function 4.1 yield

$$U = u\big(A, Y(D,R) - (P_a A + P_g g(A,D,R) + (C(R, P_w, P_k, Z)e^{-1} -$$

$F)\,(M^{-1}H_{TR}H_{GR})/N)\big).$ (4.10)

The derivative of 4.10 with respect to A is

$$U_A' = \big(P_a + P_g G_A'\big)U_B'$$ (4.11)

where,

U_A' and U_B' are marginal utilities and G_A' is the increase in gasoline consumption from a one unit increase in consumption of A.

Dividing 4.11 by U_B' results in

$$U_A'/U_B' = \big(P_a + P_g G_A'\big).$$ (4.12)

The marginal rate of substitution between A and B is equal to the full price of consuming A, which includes both the price of A (before transportation) and the marginal expenditure on gasoline used to transport one unit of A.

We can take the derivative of equation 4.10 with respect to road outcomes (R) and rearrange terms to obtain

$$Y_R' - P_g G_R' = C_R' e^{-1}(M^{-1}H_{TR}H_{GR})/N$$ (4.13)

where,

Y_R', G_R', and C_R' are the increase in income, gas consumption, and highway costs from a one unit increase in R.

The left hand side of equation 4.13 can be interpreted as the marginal benefits to the median voter of improving road quality, which equals the marginal increase in income minus the marginal increase in gasoline expenditures. Since gasoline consumption is assumed to go down as road outcomes improve, then G_R is negative and $-P_g G_R$ is positive. The right hand side can be interpreted as the marginal expenditures for the decisive voter of improving road quality. Although we are not using equation 4.13 in the empirical model, the equation highlights the decision rule with respect to selecting the optimal level of R.

4.1.3 Demand Function for R

If we were to solve equation 4.12 for A, substitute it into equation 4.13 and solve for R, substitute this into the utility function, and solve for R, this would be the demand function for R as[16]

$$R = f(Y_R(R,D), F/N, P_a, P_g, G_R(R,D)C_R(R,P_w,P_k,Z)/N,$$

$$(M^{-1}H_{TR}H_{GR}), e^{-1}, J) \tag{4.14}$$

where,

J represents preference variables that could shift the median voter preferences.

Included in this demand function are four other functions: 1) a marginal cost function, 2) an efficiency function, 3) a marginal gas consumption function, and 4) a function for marginal

---

[16] This is similar to the use of the implicit function rule mentioned by Congleton and Bennett (1995).

income with respect to road improvements.[17] For simplicity, we assume that the demand function

for R has a constant elasticity form as[18]

$$R = a_1 Y^{\varepsilon_1} \left((f\,F/N)(M^{-1}H_{TR}H_{GR}) \right)^{\varepsilon_1} P_g^{\mu_1}$$

$$\left((C_R/N)(M^{-1}H_{TR}H_{GR}) \right)^{\mu_2} e^{-\mu_3} G_R^{\nu} J^{\rho} \tag{4.15}$$

where,

ε_1 is income elasticity; f is a parameter to capture a possible flypaper effect; μ_1, μ_2, and

μ_3 are price elasticities with respect to gasoline, marginal costs per capita, and marginal changes

in efficiency; ν is the parameter with respect to marginal consumption of gasoline; and ρ is the

parameter with respect to the preference variables.

Preference variables could include demographic changes across state and time, and

cultural and political differences across states, which could affect political decisions about taxes,

spending, and debt.

Assume for simplicity that $G(R,D)$ is a constant elasticity function, then G_R can be

represented as

$$G_R = \alpha_1 \phi_1 R^{\phi_1 - 1} D^{\phi_2}. \tag{4.16}$$

---

[17] The second and fourth functions are not in Congleton and Bennett (1995). We are going to treat Y as exogenous for the rest of this model section.
[18] This assumption could be challenged because it is not clear what utility function this comes from and whether it meets all the established properties of demand functions. This functional form for government demand functions is, however, common practice.

Substituting equation 4.16 into 4.15 and solving for R results in a demand function of the form

$$R =$$

$$\left(a_3 Y^{\varepsilon_1}\left((f\,F/N)(M^{-1}H_{TR}H_{GR})\right)^{\varepsilon_1} P_g^{\mu_1}\left((C_R/N)(M^{-1}H_{TR}H_{GR})\right)^{\mu_2} e^{-\mu_3} D^{\phi_2 \nu} J^{\rho}\right)^{\phi^*} \qquad (4.17)$$

where,

$$\phi^* = 1/(1 - (\phi_1 - 1)\nu). \text{ If } \phi_1 = 1, \text{ then } \phi^* = 1.$$

4.1.3.1 Cost Function

The demand function includes the marginal cost with respect to $R(C_R)$. If we assume Cobb-Douglas technology in the production of highways, then the marginal cost can be represented as

$$C_R = \alpha_4 R^{\delta-1} P_w^{\beta_1} P_k^{\beta_2} N^{\eta_1} Z^{\eta_2} \qquad (4.18)$$

where,

δ captures economies of quality scale with respect to changes in R (see Duncombe and Yinger, 1993); β_1 and β_2 are elasticities with respect to labor and capital; and η_1 and η_2 are elasticities with respect to population and other environmental variables affecting cost.

The elasticity of η_1 captures economies of population scale, or what has been called economies of size.

4.1.3.2 Efficiency Function

The efficiency of the production of R (e) is potentially affected by the budget constraint facing the median voter ($M^{-1}H_{TR}\,H_{GR}/N$), the marginal cost per capita highways (C_R/N), the price

of gasoline (P_g), and other factors that might affect the efficiency of production (Q). These other factors might include institutional constraints such as TELs, balanced budget requirements (BBR), or debt limits, and the power of public employee unions. In notation terms,

$$e = \alpha_5 Y^{\kappa_1}((f\,F/N)(M^{-1}H_{TR}H_{GR}))^{\kappa_2}P_g^{\kappa_3}$$

$$\left((C_R/N)(M^{-1}H_{TR}H_{GR})\right)^{\kappa_4}Q^{\kappa_5} \tag{4.19}$$

where,

κ represents efficiency elasticities.

4.1.3.3 Full Demand Model

Substituting equation 4.18 into 4.19 results in

$$e = \alpha_5 Y^{\kappa_1}((f\,F/N)(M^{-1}H_{TR}H_{GR}))^{\kappa_2}P_g^{\kappa_3}$$

$$\left(\left(\left(\alpha_4 R^{\delta-1}P_w^{\beta_1}P_k^{\beta_2}N^{\eta_1}Z^{\eta_2}\right)/N\right)(M^{-1}H_{TR}H_{GR})\right)^{\kappa_4}Q^{\kappa_5}. \tag{4.20}$$

Substituting equations 4.18 and 4.20 into 4.17 and solving for R results in the demand model in a form that could be estimated, or

$$R = \left(a_7 Y^{(\varepsilon_1-\mu_3\kappa_1)}(f\,F/N)^{(\varepsilon_1-\mu_3\kappa_2)}P_g^{(\mu_1-\mu_3\kappa_3)}\right)^{\mu^{**}}$$

$$\left((M^{-1}H_{TR}H_{GR})^{(\varepsilon_1+\mu_2-\mu_3(\kappa_2+\kappa_4))}\left(P_w^{\beta_1}P_k^{\beta_2}N^{\eta_1}Z^{\eta_2}\right)^{\mu^*}N^{(\mu^*(\eta_1-1))}Z^{(\mu^*\eta_2)}D^{\phi_2 v}J^{\rho}Q^{-\mu_3\kappa_5}\right)^{\mu^{**}} \tag{4.21}$$

where,

$\mu^* = \mu_2 - \mu_3\kappa_3$ and $\mu^{**} = \phi^*/(1-(\delta-1)\mu^*\phi^*)$.

It is, however, difficult to identify the structural parameters without making assumptions. If there are constant returns to scale ($\delta = 1$) and if $\phi_1 = 1$ and then $\mu^{**} = 1$.

4.2 Measuring Highway Outcomes

One of the challenges of modeling the demand for highway outcomes is that the outcome is the quality and quantity of infrastructure. Quality-adjusted lane miles this year (R_t) is a stock, which is dependent on the investments made this year (I_t) but also by the quality-adjusted lane miles last year (R_{t-1}) and the level of depreciation (d), or

$$R_t = I_t + (1 - d)R_{t-1}. \tag{4.22}$$

Substituting equation 4.22 into 4.21 for R yields

$$I_t + (1 - d)R_{t-1} = \left(a_7 Y^{(\varepsilon_1 - \mu_3 \kappa_1)}(f\,F/N)^{(\varepsilon_1 - \mu_3 \kappa_2)}\right)^{\mu^{**}}$$

$$\left(P_g^{(\mu_1 - \mu_3 \kappa_3)}(M^{-1}H_{TR}H_{GR})^{(\varepsilon_1 + \mu_2 - \mu_3(\kappa_2 + \kappa_4))}\left(P_w^{\beta_1}P_k^{\beta_2}N^{\eta_1}Z^{\eta_2}\right)^{\mu^*}N^{(\mu^*(\eta_1 - 1))}\right)^{\mu^{**}}$$

$$\left(Z^{(\mu^* \eta_2)}D^{\phi_2 \nu}J^\rho Q^{-\mu_3 \kappa_5}\right)^{\mu^{**}}. \tag{4.23}$$

Since it is very difficult to measure quality-adjusted lane miles of roads, we can multiply both sides by the average cost for highways outcomes. With Cobb-Douglas technology, the average cost is a constant proportion ($1/\delta$) of marginal cost, MC. We can then multiply both sides of equation 4.23 by $(1/\delta)MC$ to re-express the left-hand side in terms of highway expenditures (HE) and the value of the highway infrastructure last year (HE_{t-1}). While we don't have a measure of the highway capital stock, we do have data on highway spending starting in

1970. If we assume a baseline depreciation rate (d) of 2.02% based the depreciation rate calculated by the U.S. Bureau of Economic Analysis for state and local government highways,[19] we can construct HE_{t-1} as the sum of depreciated highway spending over the previous 9 years. Equation 4.23 can be expressed as

$$HE_t + \sum_{i=0}^{T}\left(HE_{t-(T-i)}(1-d)^{T-i}\right) = \left(a_7 Y^{(\varepsilon_1 - \mu_3 \kappa_1)}\right)^{\mu^{**}}$$

$$\left((f\,F/N)^{(\varepsilon_1 - \mu_3 \kappa_2)} P_g^{(\mu_1 - \mu_3 \kappa_3)}(M^{-1}H_{TR}H_{GR})^{(\varepsilon_1 + \mu_2 - \mu_3(\kappa_2 + \kappa_4))}\left(P_w^{\beta_1} P_k^{\beta_2} N^{\eta_1} Z^{\eta_2}\right)^{\mu^*} N^{(\mu^*(\eta_1 - 1))}\right)^{\mu^{**}}$$

$$\left(Z^{(\mu^*\eta_2)} D^{\phi_2 v} J^\rho Q^{-\mu_3 \kappa_5}\right)^{\mu^{**}} \tag{4.24}$$

where,

> T=9.

Since we are interested in highway expenditure volatility, we want the dependent variable to be highway expenditures (HE). By rearranging terms in equation 4.24, we can get a model of highway expenditures as

$$HE_t = \left(a_7 Y^{(\varepsilon_1 - \mu_3 \kappa_1)}(f\,F/N)^{(\varepsilon_1 - \mu_3 \kappa_2)}\right)^{\mu^{**}}$$

$$\left(P_g^{(\mu_1 - \mu_3 \kappa_3)}(M^{-1}H_{TR}H_{GR})^{(\varepsilon_1 + \mu_2 - \mu_3(\kappa_2 + \kappa_4))}\left(P_w^{\beta_1} P_k^{\beta_2} N^{\eta_1} Z^{\eta_2}\right)^{\mu^*} N^{(\mu^*(\eta_1 - 1))}\right)^{\mu^{**}}$$

$$\left(Z^{(\mu^*\eta_2)} D^{\phi_2 v} J^\rho Q^{-\mu_3 \kappa_5}\right)^{\mu^{**}}\left(1 + (1/HE_t)\sum_{i=0}^{T}\left(HE_{t-(T-i)}(1-d)^{T-i}\right)\right)^{-1} \tag{4.25}$$

---

[19] U.S. Bureau of Economic Analysis, available at:
http://www.bea.gov/National/FA2004/Tablecandtext.pdf

4.3 Modeling Highway Expenditure Volatility

The final step in developing this model is to expand equation 4.25 to include variables related to highway expenditure volatility (*HEV*). The policy variables of direct interest in this project are the three measures capture different dimensions of highway revenue earmarked (M^{-1} H_{TR} H_{GR}). In addition, we might expect that expenditure volatility might be affected by volatility of the state economy (*EV*) because of how economic volatility affects the volatility of tax bases and the volatility of demand for highways. There is no real theory to help in specifying the relationship between economic volatility and highway expenditure volatility. We therefore assume, purely for convenience, that EV can be added to the model as a multiplicative term,

$$HE_t = \left(a_7 Y^{(\varepsilon_1 - \mu_3 \kappa_1)}(f\,F/N)^{(\varepsilon_1 - \mu_3 \kappa_2)}\right)^{\mu^{**}}$$

$$\left(P_g^{(\mu_1 - \mu_3 \kappa_3)}(M^{-1}H_{TR}H_{GR})^{(\varepsilon_1 + \mu_2 - \mu_3(\kappa_2 + \kappa_4))}\left(P_w^{\beta_1}P_k^{\beta_2}N^{\eta_1}Z^{\eta_2}\right)^{\mu^*}N^{(\mu^*(\eta_1 - 1))}\right)^{\mu^{**}}$$

$$\left(Z^{(\mu^*\eta_2)}D^{\phi_2}\nu^J{}^\rho Q^{-\mu_3\kappa_5}\right)^{\mu^{**}}\left(1 + (1/HE_t)\sum_{i=0}^{T}\left(HE_{t-(T-i)}(1-d)^{T-i}\right)\right)^{-\sigma 1}(EV^{\pi_1}) \qquad (4.26)$$

where,

σ is the estimated effect of the cumulative highway spending on highway expenditure volatility.

Taking the natural log of both sides gives us a log-linear model which can be estimated with linear regression techniques. While equation 4.26 assumes that *M*, H_{TR}, and H_{GR} have the same elasticities, this is not necessarily the case. Therefore, we estimated the empirical model using different elasticities for each and tested whether they were the same.

Chapter 5 Data and Measurement

This study employs a 30-year data panel between 1979 and 2008. (Table 5.1 provides the descriptive statistics for the variables used in our statistical analysis.)

5.1 Measure of Highway Spending Volatility

The dependent variable is a measure of volatility in state spending on state-administered highways.[20] A time series of highway spending is used to divide highway spending for each year t (HE_t) into a trend component (τ_t) and a cyclical (or, business cycle) component (c_t), or $HE_t = \tau_t + c_t$. Trends and cycles can be thought of in terms of data frequencies. Low- or high-frequencies (i.e., trends or cycles) have long or short periods of oscillations. In other words, low- or high-frequency time series moves infrequently or frequently from peaks to troughs.

There are two steps in computing state highway spending volatility. We first need to determine the cyclical component. There are several methods of detrending (i.e., separating the cyclical component from the trend component), such as first-differencing, regressions on trend variables, and filtering.[21] Filtering can be thought of as an algorithm to process a time-series for a more meaningful statistic (van Norden, 2002). Several filtering techniques have developed over decades (see Mills (2009) for a recent review of many of the filters used in this report). We chose the Hodrick-Prescott (HP) filter proposed by Hodrick and Prescott (1997) to report the estimation results. Although the HP filter has been criticized for inducing spurious business cycle fluctuations (Cogley and Nason, 1995; Harvey and Jaeger, 1993), Pedersen (2001) showed that even an ideal filter would have similar distortionary effects as applied to the HP filter. Since this filter "has withstood the test of time" (Ravn and Uhlig, 2002), it is still arguably the most widely

---

[20] Spending on locally-administered highways is excluded. State-administered highways will be hereinafter referred to as state highways for short.

[21] Filtering can be thought of as an algorithm to process a time-series for a more meaningful statistic (van Norden, 2002)

used filter. The robustness of these results by the HP filter will be tested with other detrending techniques, namely different filters, regressions, and first-differencing.

The HP filter removes the trend component in highway spending series by solving the minimization problem in equation 5.1:

$$min_{\tau_t} \sum_{t=1}^{T} \left[(HE_t - \tau_t)^2 + \lambda \big((\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1}) \big)^2 \right] \quad (5.1)$$

where,

λ is the smoothing parameter penalizing the acceleration in the trend relative to the cyclical component.

Ravn and Uhlig (2002) demonstrate empirically that the optimal value for the smoothing parameter is 6.25 for annual data. Once the cyclical component is calculated for each year in the time series (c_t), the measure of volatility we use for state highway spending is the standard deviation. In previous studies of state spending volatility (Hou 2003), the volatility measure is calculated for each year using a rolling window of years. The length of the rolling window used in previous research typically ranges from five years (e.g., Bekaert, Harvey, and Lundblad, 2006; Blanchard and Simon, 2001; Buch, Döpke, and Pierdzioch, 2005) to ten years (e.g., Ferreira-Lopes and Sequeira, 2012) because the typical length of a business cycle falls in this range. To preserve as many observations as possible, we adopt a five-year rolling window. Because the volatility measure is going to be our dependent variable, it should not precede the explanatory variables in the model. To preserve the correct time order, our measure of the volatility of state highway spending in year *t* is the estimated standard deviation of the cyclical component from *t* to *t+4*.

Table 5.1 Summary Statistics and Data Sources

Variable	Mean	Standard deviation	Minimum	Maximum	Data sources
State highway spending per capita	421	188	136	1,537	(1)
State highway spending volatility by the HP6.25 filter	46	37	6	247	(2) & (1)
Earmarking Measures					
% of total transportation-related revenues earmarked for highways (M)	60.15	17.31	6.97	100	(2) & (1)
% of total transportation-related revenues from total gas tax revenues (H_{TR})	60.42	11.30	28.20	82.40	(2) & (1)
% of total revenues for highways from transportation-related revenues (H_{GR})	41.13	12.79	3.87	82.18	(2) & (1)
Demand Variables					
Cumulative state highway spending $(1 + (1/HE_t) \sum_{t-1}^{T} HE_{t-1}(1-d)^{T-t})$	9.22	1.54	4.24	15.25	(2) & (1)
Federal highway grant expenditures per capita	143.63	76.70	39.67	630.93	(1), (4)
Median household income	53,875	8,443	35,016	82,101	(3)
State-administered highway lane miles per capita	0.010	0.008	0.001	0.039	(1), (4)
Cost-Related Variables					
Total state population (in thousands)	5,400	5,800	451.85	37,000	(4)
Pre-tax gas prices (P_g)	1.04	0.52	0.45	2.92	(5)
Average construction salary (P_w)	32,157	6,865	16,961	56,441	(4)
Dummy indicating Standard & Poor's AAA rating of state general obligation (GO) bonds	0.20	0.40	0	1	(6)
Dummy indicating Standard & Poor's AA+ rating of state GO bonds	0.21	0.41	0	1	(6)
Dummy indicating Standard & Poor's lower-than-AA rating of state GO bonds	0.21	0.41	0	1	(6)
Registered trucks per state-administered lane miles	47.3	42.2	4.7	282.6	(1)
Annual average Standardized Precipitation Index	0.10	0.77	-2.54	2.48	(7)
Annual average Palmer Drought Severity Index	0.44	2.07	-6.11	7.13	(7)

Efficiency-Related Variables					
Dummy indicating if the governor is Republican	0.48	0.50	0	1	(8)
% of Republican members in the state House	43.89	17.32	1.90	87.14	(9)
% of Republican members in the state Senate	43.53	17.89	0	91.18	(9)
% of state membership in the U.S. House Transportation Authorization Committee from the state	2.25	5.32	0	33.33	(10)
Dummy indicating if the state has membership in the U.S. Senate Transportation Authorization Committee	0.22	0.42	0	1	(10)
Dummy indicating if the governor must prepare balanced budget	0.81	0.39	0	1	(11)
Dummy indicating if the state legislature must pass balanced budget	0.74	0.44	0	1	(11)
Dummy indicating if the governor must sign balanced budget	0.62	0.49	0	1	(11)
Dummy indicating if year-end deficit can be carried over	0.23	0.42	0	1	(11)
% of wage and salary public employees who are union members	32.74	16.80	5.17	73.11	(12)
Economy-Related Volatility Variables					
Personal income per capita volatility measure	479	215	109	2,556	(2) & (4)
GSP per capita volatility measure	771	383	230	3,333	(2) & (4)
Total employment per capita volatility measure	0.00596	0.00207	0.00188	0.01522	(2) & (4)

Notes: Monetary variables (e.g., state highway spending per capita, federal aid per capita) are adjusted for inflation (using state and local government price indexes published the Bureau of Economic Analysis) and in 2008 dollars.

Sources: (1) "Highway Statistics" published by the Federal Highway Administration; (2) Authors' calculations; (3) Census Bureau; (4) Bureau of Economic Analysis; (5) Energy Information Administration; (6) Prunty & Sugden (2012); (7) National Climatic Data Center; (8) National Governors Association; (9) "Book of the States" published by the Council of State Governments; (10) "Almanac of American Politics" published by the National Journal Group; (11) "Budget Processes in the States" published by National Association of State Budget Officers; (12) http://www.unionstats.com for 1983-2008. The values before 2003 are derived by the predicted values from regressing this variable on total state employment for each state.

5.2 Measures of Revenue Earmarking

The independent variables of interest are the three earmarking measures that are derived algebraically in the preceding section. The first measure, M, indicates the share of total transportation-related revenues earmarked for state highways. Transportation-related highway revenues consist of two sources: motor-fuel (or, gas) [22] taxes, and motor vehicle and motor carrier tax receipts that come primarily from vehicle registrations, titles, and driver licenses. States may devote only a portion of total transportation-related revenues to state highways. The remaining funds may be spent on local roads and streets either directly or via transfers to local governments, on mass transit purposes, or on specific non-highway purposes. A few states, e.g., Georgia, Maryland, Mississippi, put a share of transportation-related revenues in their general fund. By contrast, Delaware, Louisiana, and West Virginia devoted almost all (>95%) of their transportation-related revenues to state highways in several years.[23] In fact, the shares of total transportation-related funds for state highways (M) across the states during the sample period look almost like a normal distribution (fig. 5.1) with a mean of 60 and average variation of 17.5.[24]

---

[22] Motor fuels that states report to the FHWA include gasoline, gasohol, diesel, liquefied petroleum gas (LPS) and other highway fuels. However, we use "gas taxes" to refer to taxes from all of these motor fuel types.

[23] The years in which M was higher than 95% were not fully consistent across the three states. Specifically, although M in these states was higher than 95% in 2006 and 2008, only Delaware, Louisiana, or West Virginia had this high M in 2001, 1982, or 1992, respectively. Also, M was consistently high, rather than an aberration, in these states.

[24] Nebraska had an unusually low share of nearly 7% in 2008, which was much lower than in any other year (mostly over 40%). In fact, this year is unusual for Nebraska in general because the second earmarking measure, H_{TR}, which will be discussed in the succeeding paragraph, is also much lower (4.3%) than the previous years.
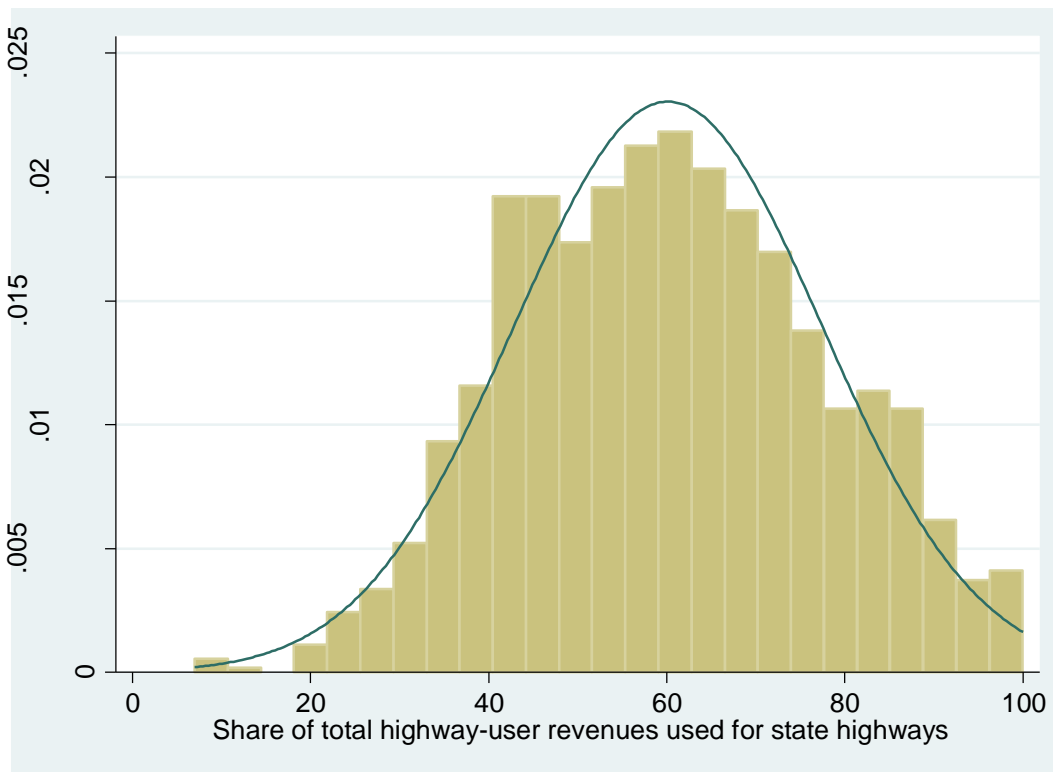
Figure 1.1 Share of Total Highway-User Revenues Used For State Highways
(All states, 1979-2008)

The second measure of earmarking revenues, what we have labeled H_{TR}, $[tNG/(O_{TR} + tNG)]$, is the share of total transportation-related revenues (for highway and non-highway purposes) from total gas tax revenues (for highway and non-highway purposes). This measure indicates the importance of gas tax revenues relative to receipts from motor vehicle and motor carrier taxes and fees. During the sample period of 1979-2008, this share averaged 60% with an average variation of 11%. The smallest averages over this period are for California and Texas (36.5% and 41.3%, respectively) and largest for South Carolina and Utah (77.2% and 75.9%, respectively).

The third earmarking measure, labeled H_{GR}, [$M(O_{TR} +tNG)/(M(O_{TR} +tNG))+O_{GR}$], is the

share of total receipts for highways from total transportation-related revenue for highways. This

measure shows the role of transportation-related revenues relative to other revenue sources (e.g.,

appropriations from general funds, and other state taxes (e.g., sales taxes, severance taxes) in

financing state highways. Three Northeastern states, namely New Jersey, New York, and

Massachusetts, on average, relied the least on transportation-related revenues (21%, 26%, and

28%, respectively) to fund their state highways. By contrast, three Southern states, namely

Texas, South Carolina, and North Carolina, had the highest average shares of transportation-

related revenues in total highway receipts (53%, 56%, and 57%, respectively).

5.3 Demand and Cost-Related Variables

The demand variables in the spending volatility model include the natural logs of

cumulative state highway spending, federal highway grant expenditures per capita, median

household income, and lane miles per capita. Cumulative state highway spending is calculated

with the formula, $\left(1 + (1/HE_t) \sum_{i=0}^{T} \left(HE_{t-(T-i)}(1 - d)^{T-i}\right)\right)$, where T=9.[25] Following the large

literature in education cost studies reviewed in Golebiewski (2011), we included logged

population (N) and the square of logged population as cost variables to capture potential

economies of size. We expected population to have a quadratic relation with highway spending

and possibly with spending volatility. We also included in the estimation model the log of pre-

tax gas prices (P_g), and the log of average construction salary as a proxy for the price of labor

(P_w). We assumed that the price of equipment was determined on a national market, and can

therefore be dropped from the model. Following Levinson and Gillen (1998), we assumed that

variation in the price of capital (P_k) was driven by differences in interest rates across states.

---

[25] For example, we use data on state highway spending per capita between 1970 and 1979 to compute its
1979 value.

Ideally, we would have used yields of state governments' general obligation (GO) bonds as the measure for interest rates. However, data on state GO bond yields were not available for all the years in our sample. We instead used state GO bond credit ratings produced by Standard & Poor's. Previous studies have shown that state bond credit ratings have a strong relationship with bond yields (Liu and Thakor, 1984), or with borrowing costs (Johnson and Kriz, 2005). As shown in table 5.1, we have three dummy variables indicating three state GO bond ratings of AAA, AA+, and lower than AA (with the rating of AA being the omitted category).

Environmental cost factors (Z) in the model include the log of registered trucks per state-administered lane mile because the higher weight associated with trucks can cause greater damage to roads and highways, raising the costs to build and maintain highways (Transportation Research Board, 1990).[26] Rainfall also has several cost-related effects on highways. For instance, excessive rainfall leads to delays and even to complete suspension of highway construction activities, thereby leading to cost overruns (El-Rayes and Moselhi, 2001; Pan, 2005). We therefore specify two weather-related variables in Z, namely annual average Standardized Precipitation Index (SPI) and Palmer Drought Severity Index (PDSI). The SPI indicates the probability of observing a given amount of precipitation in a year, whereby a zero index value indicates the median of the distribution of precipitation, with a -3 and +3 representing a very extreme dry and wet spell, respectively. While the SPI considers only precipitation, the PDSI evaluates water supply (precipitation), demand (evapotranspiration), and loss (runoff). The PDSI ranges from -7 to +7 with negative and positive values denoting dry and wet spells, respectively.

---

[26] The ideal data are registered heavy single-unit trucks per state-administered lane miles. However, the FHWA does not disaggregate data on total trucks into this heavy duty truck type.

5.4 Efficiency-Related Variables

Following Nesbit and Kreft (2009), we included several political variables in the model (represented by Q) including a binary variable indicating if the governor is Republican, and the shares of members in the state Senate and House of Representatives who are Republicans.[27] These variables capture the potential differences in preferences for highway spending between the Republican and Democratic party.[28] Also included in Q are the share of state membership in the U.S. House transportation authorization committee and a dichotomous variable indicating if the state has membership in the U.S. Senate transportation authorization committee.[29] We included the share of wage and salary of public employees, who are union members, to capture the effects of public sector unions on state highway spending and its volatility. Earlier studies, e.g., Marlow and Orzechowsk (1996), found a positive relationship between public sector unionism and state and local public spending.

Although Abrams and Dougan (1986) did not find significant differences in spending levels between states with and without balanced budget requirements (BBRs),[30] these budgetary requirements may have opposing effects on state business cycle fluctuations. On the one hand, these budgetary institutions may constrain state governments' ability to respond to business cycle fluctuations in general and state highway spending volatility in particular. Levinson (1998) found

---

[27] Since Nebraska has unicameral and nonpartisan legislature, we assign the value of 50% for the latter two variables.

[28] While a state governor and members in the state Senate or House of Representatives may not be affiliated with one of the two major parties (independent), very few that fall into this category. For instance, during the whole 30-period in our sample, the Governor self-identified as independent only in Connecticut during 1991-1995, in Maine during 1995-2003, and in Minnesota during 1999-2003.

[29] More specifically, membership is counted in the Appropriations or Authorization Senate and House Committees, Transportation Subcommittees. Also, while Knight (2002) employed similar variables as IVs for federal highway grant expenditures, Nesbit and Kreft (2009) included these variables directly into the state highway expenditure equation. If we followed Knight (2002) and used these two variables as IVs, we would be able to reject the null that the IVs are jointly valid.

[30] See Hou and Smith (2006) for a detailed discussion of nine types of BBRs.

that balanced budget requirements exacerbated state business cycle volatility measured as the standard deviation of the cycle component of per capita personal income during the entire sample period of 1979-1995. On the other hand, fiscal and balanced budget rules may restrict not only counter-cyclical policies but discretionary fiscal policies with destabilizing effects (Alesina and Bayoumi, 1996; Fatás and Mihov, 2006). Following the literature, we included four widely used BBR-related binary variables indicating (1) if a state's governor must submit a balanced budget, (2) if the legislature must pass a balanced budget, (3) if the governor must sign a balanced budget, and (4) if no current year-end deficit can be carried over into the next fiscal year (Hou and Smith, 2006).

Finally, we included several measures of economic volatility to capture the influence of economic fluctuations on the volatility of the state budget. The three measures included are the natural logs of the standard deviation of the cyclical component of personal income per capita, Gross State Product (GSP) per capita, and total employment per capita. These economy-related volatility variables are derived using the same method of business cycle extraction as the dependent variable of state highway expenditure volatility.

Chapter 6 Empirical Methodology

Equation 4.26 can be estimated with an ordinary least squares (OLS) method. However, the OLS estimator produces biased coefficients when any of the explanatory variables are endogenous. Several variables in equation 4.26 are potentially endogenous including the three earmarking measures, federal highway grant expenditures per capita, and the cumulative highway spending variable (as a proxy for the value of the capital stock in the previous years). More specifically, the numerators and denominators of the earmarking measures (e.g., total transportation-related revenues used for state highways, total highway receipts) are partially[31] discretionary choices and determined endogenously in the same budgeting process where decisions are made about state highway spending. As described earlier, federal highway grant expenditures are distributed as reimbursements to states for the highway expenses that the states have already incurred. There is, therefore, potential reverse causality between state highway expenditures (and highway spending volatility) and federal grant expenditures. The cumulative highway spending variable is endogenous because it contains current highway expenditures used to construct the dependent variable of state highway expenditure volatility.

We adopted the two-stage-least-squares (2SLS) estimation approach. This approach requires the identification of exogenous "instrumental variables" (IVs) which are strongly correlated with the endogenous variable. The instruments used for the earmarking measures and the cumulative highway spending variable are rank-based indices. More specifically, the rank-based index for each of these endogenous variables in each year is derived by dividing that variable into thirds (using cut-off values at the 33rd and 67th percentiles), assigning the lowest third a rank of one, the middle third a rank of two, and the top third a rank of three. These indices

---

[31] There may be partial discretion because states are constitutionally or statutorily bound to a certain extent on what to do with these earmarked revenues.

are by construction highly correlated with the endogenous variables. They should also be

orthogonal to (i.e., uncorrelated with) the error term because small changes in omitted factors

influencing the endogenous variables do not result in a change in the value of rank. This may not

hold true for observations near cross-over points. Studies employing this method (Evans and

Kessides, 1993; Globerman and Shapiro, 2008; Kroszner and Stratmann, 2000; Nguyen-Hoang,

2012) use a small number of ranks, hence cross-over points, to reduce this possibility.

Previous studies treat federal highway grant expenditures as endogenous in state highway

spending estimations using federal highway obligations as instruments (Gamkhar, 2000, 2003;

Nesbit and Kreft, 2009). The rationale for the use of obligations is that they occur before state

highway expenditures and are thus pre-determined variables. However, the FHWA Highway

Statistics did not report data on obligations (Table FA-4B) for years before 1986. Federal

highway apportionments that occur even before obligations are also determined before state

highway spending. We therefore use three- and four-year lagged federal highway apportionments

as IVs for federal highway grant expenditures.

As discussed in the next chapter, the variables treated as endogenous are indeed

endogenous using a Hausman test.[32] The next step is to determine whether the IVs are exogenous

using a test for overidentifying restrictions. Using Hansen's (1982) *J*-statistic, failure to reject the

null hypothesis that the *J*-statistic is zero indicates that the IVs are exogenous (i.e., correctly

excluded from equation 4.26) assuming that at least one of the IVs is indeed valid. The second

instrument test is whether the IVs are strongly or weakly related to the exogenous variable.

Murray (2006) argued that weak IVs may have two problems: (1) 2SLS estimates with weak IVs

---

[32] Although OLS and 2SLS regressions are all consistent when all variables are exogenous, OLS
regressions have greater efficiency (or, smaller variance).

are biased, even in very large samples; and (2) 2SLS estimated standard errors become too small, leading to overstated statistical significance in hypothesis testing.

The diagnostic tests indicate that the data used in the regressions has cross-sectional heteroskedasticity and within-panel autocorrelation.[33] Therefore, we use the heteroskedasticity and autocorrelation (HAC) Newey-West estimator (with a truncation parameter equal to 2)[34] of standard errors. As the name suggests, this estimator is robust to both heteroskedasticity and autocorrelation.

---

[33] These diagnostic tests are done with the Stata command of *estat hettest* and Drukker's (2003) *xtserial*.
[34] The results are robust to a truncation parameter equal to 3 or 4.

Chapter 7 Empirical Results

Table 7.1 provides estimation results with the five variables in italics being treated as endogenous variables. The bottom panel of the table reports the results of various tests on the IVs for the endogenous variables. The endogeneity test indicates that we can reject the null hypothesis that the endogenous variables are exogenous. According to the Hansen *J*-test, we fail to reject the null that the IVs are jointly valid (i.e., our IVs are jointly exogenous). We also believe that our IVs are strong given the high Kleibergen-Paap *rk* statistic.[35]

Table 7.1 Estimation Results (1979-2004)

(Dependent Variable: Log of the State Highway Spending per Capita Volatility Measure)

	Coefficients	*t*-statistics
Earmarking Measures		
% of total transportation-related revenues earmarked for highways (M)	0.0055*	(1.84)
% of total transportation-related revenues from total gas tax revenues (H_{TR})	-0.0099*	(-1.95)
% of total revenues for highways from transportation-related revenues (H_{GR})	-0.010**	(-2.57)
Demand Variables		
Log of cumulative highway spending	-0.093	(-0.57)
Log of federal highway grant expenditures per capita	0.75***	(3.71)
Log of median household income	-0.77**	(-2.23)
Log of state-administered highway lane miles per capita	0.91**	(2.04)
Cost-Related Variables		
Log of population	6.16**	(2.38)
Squared log of population	-0.20**	(-2.04)
Log of pre-tax gas prices	1.11***	(2.58)

---

[35] Stata, the statistical software we use for our empirical work, provides Kleibergen and Papp's (2006) *rk* statistic for the case with heteroskedasticity and autocorrelation (HAC) standard errors. A test for weak IVs directly for multiple endogenous regressors and HAC standard errors is, however, still an open area of research. Baum, Schaffer, and Stillman (2007) suggested applying Stock and Yogo's (2005) critical values for the homoscedastic case to the *rk* statistic with caution. Stock and Yogo provide critical values only for specifications with less than four endogenous regressors. The critical values become smaller with more included endogenous regressors. The *rk* statistic of 17.07 is larger than the critical value of 9.53 used to reject a larger-than-5% relative bias from weak IVs in the 2SLS estimates (at 95% significance). Also, the first-stage *F*- statistics for the IVs are at least 40, which is greater than Staiger and Stock's (1997) rule-of-thumb critical value of 10 (for the case with one IV). The estimates obtained using the Fuller-k estimator (k=4), which is proved to be less subject to bias from weak instruments than 2SLS (Hahn, Hausman, and Kuersteiner, 2004), are almost identical to those using 2SLS.

Log of construction salary per worker	0.12	(0.44)
Dummy indicating Standard & Poor's AAA rating of state general obligation (GO) bonds	-0.13*	(-1.72)
Dummy indicating Standard & Poor's AA+ rating of state GO bonds *(Omitted category is the AA rating)*	-0.11*	(-1.89)
Dummy indicating Standard & Poor's lower-than-AA rating of state GO bonds	-0.065	(-0.99)
Log of registered trucks per state-administered lane miles	0.22	(1.33)
Annual average Standardized Precipitation Index	-0.0033	(-0.09)
Annual average Palmer Drought Severity Index	-0.014	(-0.96)
Efficiency-Related Variables		
Dummy indicating if the governor is Republican	-0.0094	(-0.23)
% of Republican members in state House	-0.010***	(-3.08)
% of Republican members in state Senate	-0.0072***	(-2.69)
% of state membership in the U.S. House Transportation Authorization Committee	-0.014***	(-2.92)
Dummy indicating if the state has membership in the U.S. Senate Transportation Authorization Committee	0.061	(1.18)
Dummy indicating if the governor must prepare a balanced budget	0.026	(0.39)
Dummy indicating if the legislature must pass a balanced budget	-0.074	(-0.98)
Dummy indicating if the governor must sign a balanced budget	-0.072	(-0.93)
Dummy indicating if no deficit can be carried over	-0.00099	(-0.02)
% of wage and salary public employees who are union members	0.013**	(2.18)
Economy-Related Volatility Variables		
Log of the personal income per capita volatility measure	0.15**	(2.44)
Log of the GSP per capita volatility measure	-0.13**	(-2.05)
Log of the total employment per capita volatility measure	0.16**	(2.42)
Observations	1248	
p-value of endogeneity test	0.002	
p-value of Hansen *J*-statistic	0.52	
Kleibergen-Paap *rk* statistic	17.07	

1% (***), 5% (**), 10% (*)

Notes: The regressions are estimated with state fixed effects with *t*-statistics in parentheses. Standard errors are computed using the HAC Newey-West estimator (with a truncation parameter equal to 2). Variables in italics are treated as endogenous with IVs. The IVs for earmarking measures and the cumulative spending variable are rank-based indices while the federal highway grant expenditures per capita is instrumented with lagged three- and four-year federal highway apportionments per capita. Volatility measures of the dependent and economy-related variables are the standard deviation of the HP6.25 cyclical component on an eight-year rolling window.

The regression results for the earmarking measures provides some general support for the hypothesis that earmarked revenues are associated with state highway spending volatility and regression coefficients on all of the three earmarking measures are statistically significant. The inclusion of three different earmarking variables allows us to explore this relationship in more depth.

Looking first at the results for M, the share of total transportation-related revenues used for highways, the coefficient is statistically positive indicating that an increase in the share of transportation-related revenues used for highways is associated with an increase in spending volatility. More specifically, a one-percentage point increase in the share of total transportation-related revenues earmarked for highways is associated with an increase of about 0.6% in the standard deviation of the cyclical component of state highway spending. This result would seem to go against our expectation that earmarking reduces volatility. However, it is important to recognize that the largest other use of transportation-related revenue besides state highways is to fund local roads. What this result may suggest is that states which increase their allocation of transportation-related revenues to local governments relative to state highways are associated with lower spending volatility. In future research, we will try to confirm that this is the case and to understand the reasons.

The results for the other two earmarking variables fit expectations more closely. The role of transportation-related revenues devoted to highways in stabilizing state highway spending is found for the third earmarking measure, H_{GR}. An increase in the share of total highway revenues coming from transportation-related revenue sources is associated with a reduction in highway spending volatility. The finding on H_{TR} suggests that as an important revenue source for total transportation-related revenues, an increase in gas tax revenues relative to other transportation-

related revenue is associated with a reduction in the stability of highway expenditures. A one-percentage point rise in either H_{TR} or H_{GR} is conducive to a one-percent decline in the standard deviation of the cyclical component of state highway spending.

While a change in cumulative highway spending is not significantly related to changes in spending volatility, the other three demand variables are highly significant. An increase in federal highway grant expenditures per capita is associated with an increase in highway spending volatility. While there have been several estimates of how federal highway grants affect state highway spending we provide the first estimates (of which we are aware) of how federal grants affect spending volatility. The results seem to suggest that federal aid may be a fairly unstable source of revenue or at least destabilizing to state highway budgets. In future research, we hope to investigate some of the possible explanations for this finding and whether modifications to federal highway aid might affect these results.

We also found that an increase in state highway lane miles per capita is associated with an increase in spending volatility. It is not surprising that an expansion (or contraction) of a state's highway system could increase fluctuations in per capita highway spending. By contrast, an increase in state median income is associated with lower volatility. If median income is a proxy for the capacity of the state to tax its citizens, then this result suggests that an increase in the fiscal capacity of a state is associated with lower highway spending volatility and the inverse is true during recessions.

We find that population has an inverted U-shaped relationship with volatility. As population goes up spending volatility will increase up to a population increase of 4.88 million. Increases above 5 million are associated with a decrease in volatility. Since annual increases in population in a state are unprecedented, this result implies that population increases may make

51

state highway budgets less stable. In fast growing states, there seems to be a need for expansion of state highways, which could lead to more volatility. The result also seems to imply that the same level of population growth in small states will be more destabilizing than in larger states.

Increases in pre-tax gas prices are associated with increases in spending volatility. An increase in pre-tax gas prices may actually lead to a decrease in motor fuel taxes since gas taxes are per unit (not ad valorem) and fuel consumption may go down in response to higher prices. On the other hand, the cost of providing highway construction and maintenance are likely to go up with rising fuel prices. The combination of rising costs and falling revenues implies that increases in gas prices may lead to unanticipated budget reductions (or tax increases). Our findings for input prices indicate that an increase in the price of capital is associated with less stability in highway budgets.[36] State highway spending volatility does not seem to be correlated with the state's weather conditions, construction salary, or the concentration of trucks.

While not many of efficiency-related variables have statistically significant regression coefficients, several political variables have significant results. An increase in representation on the Transportation Appropriations Committees of the U.S. House of Representatives is associated with a decrease in spending volatility. This result is consistent with the hypothesis that more representation is associated with more stable federal aid. We also found that increases in the share of Republican members in a state's two legislative bodies are associated with more stable highway budgets. While there are several possible explanations for this result, further investigation is required to explain this finding. As expected, a higher share of unionization in the state is associated with greater spending volatility. Finally, we found that an increase in the volatility of personal income and employment is associated with an increase in spending

---

[36] Since the coefficients on the two highest rating classes, AAA and AA+, are negative, this implies that an moving into one of these ratings classes from a lower class will decrease interest rates (and the price of capital), which in turn will decrease spending volatility.

volatility. Surprisingly, we found the opposite result for the volatility of Gross State Product

(GSP) per capita. Given that the volatility of GSP and the volatility of income are highly

related,[37] this result may be partially due to collinearity.

---

[37] There correlation coefficient is nearly 0.6.

Chapter 8 Robustness Tests

We conducted several robustness checks of the results reported in table 7.1. We investigated the sensitivity of the hypothesis testing results by using bootstrapped standard errors instead of the HAC standard errors.[38] The results using bootstrapped standard errors are reported in column 1 of table 8.1; the significance levels are quite similar to those using HAC standard errors.

Table 8.1 Robustness Tests 1

Key Variables	HP6.25 Filter With Bootstrapped Errors	Butterworth Filter	CF Filter
	(1)	(2)	(3)
Earmarking Measures			
% of total transportation-related revenues earmarked for highways (M)	0.0055*	0.0080**	0.0055*
	(1.84)	(2.28)	(1.91)
% of total transportation-related revenues from total gas tax revenues (H_{TR})	-0.0099*	-0.0095*	-0.0080*
	(-1.95)	(-1.65)	(-1.65)
% of total revenues for highways from transportation-related revenues (H_{GR})	-0.010**	-0.013***	-0.0098**
	(-2.57)	(-2.75)	(-2.54)
Demand Variables			
Log of cumulative highway spending	-0.093	-0.14	-0.16
	(-0.57)	(-0.75)	(-1.02)
Log of federal highway grant expenditures per capita	0.75***	0.77***	0.71***
	(3.71)	(3.01)	(3.58)
Log of median household income	-0.77**	-0.97**	-0.75**
	(-2.23)	(-2.42)	(-2.21)
Log of state-administered highway lane miles per capita	0.91**	0.58	1.03***
	(2.04)	(1.18)	(2.69)
Number of Observations	1248	1248	1248

1% (***), 5% (**), 10% (*)
Notes: All of the remaining unreported variables are the same as in table 7.1. All are estimated with district fixed effects and the same IVs as used in table 7.1. The estimates in column 1 are the same as table 7.1 except that hypothesis testing is done with bootstrapped standard errors. For the remaining two columns, the dependent variable and economy-related volatility variables are derived by the logged five-year forward-rolling standard deviation of the cyclical component extracted by alternative methods as indicated.

---

[38] Bootstrapping, which was formally introduced in Efron (1979), is a form of resampling the original dataset to produce a series of datasets from which the standard error of an estimate is derived.

The results in table 7.1 are based on the dependent variable and other economy-related volatility variables derived by the five-year forward-rolling standard deviation of their cyclical components extracted by the HP6.25 filter. Of particular interest is how sensitive these results are to alternative methods of extracting the cyclical components. State highway spending is, therefore, detrended by two alternative standard filters, namely the Christiano-Fitzgerald (CF) band pass filter, as proposed by Christiano and Fitzgerald (2003), and the Butterworth high pass filter. The CF filter was built on the same principles as Baxter and King's (BK) (1999) band pass filter.[39] This CF filter decomposes state highway spending into trend (periodicity greater than five years), cycle (periodicity of 3-5 years), and noise (periodicity less than two years). The Butterworth filter has long been used in electrical engineering and has been proposed for use in economic time series by Pollock (2000, 2001a, 2001b).[40] Pollock's Butterworth square-wave detrending method filters out stochastic cycles at periods larger than five years.[41] The results with these two filters reported in columns 2 and 3 of table 8.1 are in general similar to those using the HP6.25 filter.

Another approach for measuring the cyclical component of state highway spending per capita is to use a time series regression. More concretely, following Klein and Kosobud's (1961) approach, highway expenditures per capita (*HE*), together with other economy-related volatility variables, is regressed on a constant and a time trend, *T*, which is coded from 1 to 30 during the

---

[39] We, however, do not use the BK filter for two reasons. First, while there is no observation being dropped in the CF filter, the BK filter requires setting the order of the symmetric moving average, which means dropping observations on the both ends of the original series. The number of truncated observations could be substantial. For instance, six years of data would be dropped if a BK filter based on a three-year leads and lags truncation (as in Stock and Watson (1999)) were applied. Second, the CF filter dominates the BK alternative in terms of optimality (i.e., converging to the optimal filter) (Christiano and Fitzgerald, 2003).

[40] See Mills (2009) for a recent review of these popular filters.

[41] The results reported in Table 3 for the CF and Butterworth filters are robust if the maximum period for stochastic cycles to be filtered out is set at eight years (instead of five years).

sample period of 1979-2008. As an alternative to this regression, we included both T and its squared value as

$$HE_{it} = \alpha_i + \beta_i T + +\gamma_i (T \times T) + \varepsilon_{it} \qquad (8.1)$$

where,

   α_i is the constant for state i.

The long-term trend is allowed to be non-linear in equation 8.1. The cyclical component is the deviation from this trend represented by the residual, ε_{it}, in 8.1. The dependent variable and other volatility variables were constructed from the five-year forward-rolling standard deviation of their cyclical components just extracted. Columns 1 and 2 of table 8.2 reports the results from time series regressions. The coefficients of the three earmarking measures are quite similar to those with the HP6.25 filter.

Table 8.2 Robustness Tests 2

Key Variables	Regression on the Trend Variable (*T*)	Regression on the Trend Variable (*T*) and T^2	First Differencing
	(1)	(2)	(3)
Earmarking Measures			
% of total transportation-related revenues earmarked for highways (M)	0.0052**	0.0058**	0.0068**
	(1.97)	(2.29)	(2.12)
% of total transportation-related revenues from total gas tax revenues (H_{TR})	-0.014***	-0.014***	-0.010*
	(-3.32)	(-3.24)	(-1.86)
% of total revenues for highways from transportation-related revenues (H_{GR})	-0.0089**	-0.011***	-0.011**
	(-2.38)	(-3.11)	(-2.41)
Demand Variables			
Log of cumulative highway spending	0.28*	0.27*	-0.033
	(1.95)	(1.93)	(-0.19)
Log of federal highway grant expenditures per capita	0.72***	0.55***	0.73***
	(3.84)	(2.93)	(3.21)
Log of median household income	-0.53*	-0.55*	-0.96***
	(-1.70)	(-1.77)	(-2.69)
Log of state-administered highway lane miles per capita	0.71**	0.79**	0.56
	(2.05)	(2.18)	(1.21)
Number of Observations	1248	1248	1248

1% (***), 5% (**), 10% (*)
Notes: All of the remaining unreported variables are the same as in table 7.1. All are estimated with district fixed effects and the same IVs as used in table 7.1. The dependent variable and economy-related volatility variables are determined by the logged five-year forward-rolling standard deviation of the cyclical component extracted by alternative methods as indicated.

To examine whether the results are robust, if the data we used were generated by a difference (rather than trend) stationary process,[42] the cyclical component of highway spending is the difference of highway spending in year *t* and the previous year, *t* – 1. The dependent variable and the other economy-related volatility measures were determined by the five-year

---

[42] A difference stationary time series does not have a deterministic linear trend (or, trend stationary) but evolves as a drifting, and possibly correlated, random walk (Mills, 2003).

forward-rolling standard deviation of their first-differenced values. Again, the results reported in column 3 of table 8.2 are robust to first differencing.

Following the literature, e.g., Buch, Döpke, and Pierdzioch (2005), Buch and Schlotter (Forthcoming), Döpke (2004), and Klomp and de Haan (2009), other robustness checks were conducted with variables constructed on five-year non-overlapping windows, or six five-year subperiods during 1979-2008 (i.e., 1979-1983, 1984-1989,…, 2004-2008). Non-overlapping, rather than rolling, windows are intended to avoid the potential problem of serial correlation (Meller, 2009) at the expense of dropped observations. For each subperiod, the dependent variable and economy-related volatility variables are the logged standard deviations of their cyclical components while the remaining independent variables are (logged) average values. Table 8.3 documents the results from this approach. The two earmarking measures of M and H_{GR} are highly significant while another measure of earmarking, H_{TR}, becomes insignificant. This table also shows that the coefficients of M and H_{GR} are four and five times, respectively, larger in absolute magnitude than those in table 7.1 (0.04 v. 0.01 for H_{GR} and 0.03 v. 0.006 for M). These findings may be due to the substantial reduction in the number of observations.

Table 8.3 Robustness Tests 3

Key Variables	Five-Year Non-Overlapping Windows		
	HP6.25 Filter	Butterworth Filter	CF Filter
	(1)	(2)	(3)
Earmarking Measures			
% of total transportation-related revenues earmarked for highways (M)	0.027***	0.028***	0.026***
	(3.06)	(3.19)	(3.28)
% of total transportation-related revenues from total gas tax revenues (H_{TR})	-0.0084	-0.0087	-0.0094
	(-0.91)	(-0.91)	(-1.06)
% of total revenues for highways from transportation-related revenues (H_{GR})	-0.042***	-0.044***	-0.040***
	(-3.49)	(-3.46)	(-3.53)
Demand Variables			
Log of cumulative highway spending	0.14	0.088	-0.13
	(0.32)	(0.20)	(-0.32)
Log of federal highway grant expenditures per capita	0.35	0.34	0.26
	(0.70)	(0.65)	(0.53)
Log of median household income	-1.24	-1.55*	-1.59*
	(-1.42)	(-1.71)	(-1.92)
Log of state-administered highway lane miles per capita	1.67*	1.56*	1.51**
	(1.95)	(1.75)	(2.01)
Number of Observations	288	288	288

1% (***), 5% (**), 10% (*)
Notes: All of the remaining unreported variables are the same as in table 7.1. All are estimated with district fixed effects and the same IVs as used in table 7.1. The dependent variable and economy-related volatility variables are the standard deviations of their cyclical components extracted by the indicated methods in each of the six five-year subperiods between 1979 and 2008, while the other independent variables are average values for each subperiod.

In sum, while the three earmarking measures prove to be robust with robustness tests in tables 8.1 and 8.2, only the first (*M*) and third (H_{GR}) earmarking measures are consistently significant in table 8.3. The robustness checks stress the important role played by transportation-related revenues earmarked for highways (as a share of total transportation-related revenues or of total highway receipts) in state highway spending volatility.

Chapter 9. Summary and Policy Implications

The practice of earmarking is a constitutional or statutory designation of a given revenue source for certain public purposes. Heavy use of revenues earmarked for highways is one of the distinguishing characteristics of state highway finance in the United States. The revenues designated for state-administered highway purposes are linked directly or indirectly to highway users, and consist primarily of motor fuel taxes and other transportation-related revenue sources (e.g., fees from vehicle registrations, titles, driver licenses). Given that funds for infrastructure construction and maintenance are highly vulnerable to raids from other budget lines during economic recessions, earmarking may be an important way to stabilize state highway budgets. More specifically, state highway spending may be less volatile when highway-user revenues are more stable than other state general revenue sources (e.g., personal income and sales taxes) and when earmarking can protect these highway-user revenues from diversion into the general budget during recessions.

This is the first study to examine how revenues earmarked for highways affect the volatility of state highway expenditures. We hypothesized that states with an increase in the share of highway funding from earmarked revenues will have less volatile highway spending. To answer this research question, we have developed an empirical model drawing from the literature in state and local public finance. This model identifies several measures of earmarking and multiple determinants of state highway expenditure volatility. We employed extensively collected data on state highways, highway budgets, state revenues, and socio-politico-economic characteristics during the period of 1979-2008 to estimate the multivariate regression model. We also checked the robustness of our results in several alternative specifications of the model.

Our key finding is that earmarking of revenue in state highway funds is significantly related to highway expenditure volatility; however, the relationship is more nuanced than we

originally hypothesized. As we hypothesized, an increase in the share of highway funding coming from transportation-related revenue sources is associated with a decrease in highway spending volatility. Since transportation-related revenue is typically accounted for in a state highway fund and there are restrictions in most states on how money in the fund can be used, our finding is consistent with the hypothesis that earmarking reduces spending volatility.

We also found that an increase in the share of transportation-related revenue from total motor fuel taxes was associated with a decrease in the volatility of state highway spending. One possible explanation for this finding is that motor fuel taxes are less volatile than other sources of transportation-related revenue (i.e., motor vehicle and motor carrier taxes and fees). Another possible explanation is that motor fuel taxes are more tightly restricted in their use (i.e., stronger earmarking). In future research, we hope to investigate whether either of these hypotheses at least partially explains this finding.

On the other hand, an increase in the share of transportation-related revenue used for state highways compared to alternative transportation or non-transportation uses is associated with an increase in state highway budget volatility. Since this result seems to run counter to what we hypothesized, it requires further investigation. The major alternative use of state transportation-related revenue besides state-administered highways is to fund local roads (and mass transit). These findings suggest that an increase in the share of transportation-related funds being used for local roads may actually lead to more stability in state highway budgets. While we do not presently have the data to examine empirically possible explanations for this finding, it does raise a number of interesting questions about an area not receiving significant attention to date, state and local intergovernmental financing of highways and roads.

Another important finding from this study about intergovernmental financing of highways is related to federal highway aid. We found that an increase in federal aid per capita was associated with an increase in state highway spending volatility. While research in the past has found that an increase in federal aid is associated with more state highway spending, this is the first study to look at the implications on spending volatility. Our finding suggests that federal aid is a mixed blessing for state Departments of Transportation (DOT). On the one hand, it does help increase highway spending, but on the other hand it can make highway budgets less stable, which may affect the ability to plan and implement highway capital and maintenance programs. More information is needed from state DOT staff on whether this finding is consistent with their own experience and, if so, which federal aid programs or components of programs are more volatile or difficult to predict.

The last finding we would like to discuss is related to the role of politics in affecting spending volatility. We found that an increase in the share of state representatives on the Transportation Appropriations Committees of the U.S. House of Representatives was associated with an increase in the stability of state highway budgets, which is consistent with the hypothesis that political representation in a key authorizing committee helps to protect federal aid going to a state, particularly during recessions. We, however, did not find a similar relationship with regard to representation on the U.S. Senate Transportation Appropriations Committee. Whether this is because of important differences in the roles these two committees play in federal funding for highways needs further investigation in future research.

References

Abrams, Burton A., and William R. Dougan. 1986. "The Effects of Constitutional Restraints on Governmental Spending." *Public Choice* 49 (2): 101–116.

Alesina, Alberto, and Tamim Bayoumi. 1996. *The Costs and Benefits of Fiscal Rules: Evidence from U.S. States*. NBER Working Paper. National Bureau of Economic Research. http://ideas.repec.org/p/nbr/nberwo/5614.html.

Bailey, S. J., and S. Connolly. 1998. "The Flypaper Effect: Identifying Areas for Further Research." *Public Choice* 95 (3): 335–361.

Barr, James L., and Otto A. Davis. 1966. "An Elementary Political and Economic Theory of the Expenditures of Local Governments." *Southern Economic Journal* 33 (2): 149–165.

Baum, Christopher F., Mark E. Schaffer, and Steven Stillman. 2007. "Enhanced Routines for Instrumental Variables/generalized Method of Moments Estimation and Testing." *Stata Journal* 7 (4): 465–506.

Baxter, Marianne, and Robert G. King. 1999. "Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series." *Review of Economics and Statistics* 81 (4): 575–593.

Bekaert, Geert, Campbell R. Harvey, and Christian Lundblad. 2006. "Growth Volatility and Financial Liberalization." *Journal of International Money and Finance* 25 (3): 370–403.

Bergstrom, Theodore C., and Robert P. Goodman. 1973. "Private Demands for Public Goods." *American Economic Review* 63 (3): 280–296.

Bhatt, Rachana, Jonathan C. Rork, and Mary Beth Walker. 2011. "Earmarking and the Business Cycle: The Case of State Spending on Higher Education." *Regional Science and Urban Economics* 41 (4): 352–359.

Black, Duncan. 1958. *The Theory of Committees and Elections*. Cambridge: Cambridge University Press.

Blanchard, Olivier, and John Simon. 2001. "The Long and Large Decline in US Output Volatility." *Brookings Papers on Economic Activity* 2001 (1): 135–164.

Borcherding, Thomas E., and Robert T. Deacon. 1972. "The Demand for the Services of Non-Federal Governments." *American Economic Review* 62 (5): 891–901.

Borg, Mary O., and Paul M. Mason. 1990. "Earmarked Lottery Revenues: Positive Windfalls or Concealed Redistribution Mechanisms?" *Journal of Education Finance* 15 (3): 289–301.

Bowen, Howard R. 1943. "The Interpretation of Voting in the Allocation of Economic Resources." *Quarterly Journal of Economics* 58 (1): 27–48.

Bradford, David F., and Wallace E. Oates. 1971. "Towards a Predictive Theory of Intergovernmental Grants." *American Economic Review* 61 (2): 440–448.

Brennan, Geoffrey, and James M. Buchanan. 1978. "Tax Instruments as Constraints on the Disposition of Public Revenues." *Journal of Public Economics* 9 (3): 301–318.

Breunig, Christian, and Chris Koski. 2011. "Capture, Rupture, and Deadlock: Interest Groups and Budget Volatility". Paper prepared for the Competitive Agendas Project—4th Annual Conference.

Bruce, Donald, Deborah A. Carroll, John A. Deskins, and Jonathan C. Rork. 2007. "Road to Ruin? A Spatial Analysis of State Highway Spending." *Public Budgeting & Finance* 27 (4): 66–85.

Buch, Claudia, Jörg Döpke, and Christian Pierdzioch. 2005. "Financial Openness and Business Cycle Volatility." *Journal of International Money and Finance* 24 (5): 744–765.

Buch, Claudia, and Martin Schlotter. Forthcoming. "Regional Origins of Employment Volatility: Evidence from German States." *Empirica*: 1–19.

Buchanan, James M. 1963. "The Economics of Earmarked Taxes." *Journal of Political Economy* 71 (5): 457–469.

Case, Anne C., Harvey S. Rosen, and James R. Hines. 1993. "Budget Spillovers and Fiscal Policy Interdependence: Evidence from the States." *Journal of Public Economics* 52 (3): 285–307.

Christiano, Lawrence J., and Terry J. Fitzgerald. 2003. "The Band Pass Filter." *International Economic Review* 44 (2): 435–465.

Clingermayer, James. C, and B. Dan Wood. 1995. "Disentangling Patterns of State Debt Financing." *American Political Science Review* 89 (1): 108–120.

Cogley, Timothy, and James M. Nason. 1995. "Effects of the Hodrick-Prescott Filter on Trend and Difference Stationary Time Series Implications for Business Cycle Research." *Journal of Economic Dynamics and Control* 19 (1-2): 253–278.

Congleton, Roger D., and Randall W. Bennett. 1995. "On the Political Economy of State Highway Expenditures: Some Evidence of the Relative Performance of Alternative Public Choice Models." *Public Choice* 84 (1): 1–24.

Cornia, Gary C., and Ray D. Nelson. 2010. "State Tax Revenue Growth and Volatility." *Federal Reserve Bank of St. Louis Regional Economic Development* 6 (1): 23–58.

Crain, W. Mark. 2003. *Volatile States: Institutions, Policy, and the Performance of American State Economies*. Ann Arbor, MI: University of Michigan Press.

Dahlberg, Matz, and Johanna Jacob. 2000. "Sluggishness, Endogeneity and the Demand for Local Public Services". Working paper. Department of Economics, Uppsala University.

Deran, Elizabeth. 1965. "Earmarking and Expenditures: A Survey and a New Test." *National Tax Journal* 18 (4): 354–361.

Dilger, Robert Jay. 2011. *Federalism Issues in Surface Transportation Policy: Past and Present*. Congressional Research Service.

Döpke, Jörg. 2004. "How Robust Is the Empirical Link Between Business-Cycle Volatility and Long-Run Growth in OECD Countries?" *International Review of Applied Economics* 18 (1): 103–121.

Downs, Anthony. 1957. *An Economic Theory of Democracy*. 1st ed. New York: Harper and Row.

Drukker, David M. 2003. "Testing for Serial Correlation in Linear Panel-data Models." *Stata Journal* 3 (2): 168–177.

Duncombe, William D. 1991. "Demand for Local Public Services Revisited: The Case of Fire Protection." *Public Finance Review* 19 (4): 412–436.

Duncombe, William D., John Ruggiero, and John Yinger. 1996. "Alternative Approaches to Measuring the Cost of Education." In *Holding Schools Accountable: Performance-Based Reform in Education*, ed. Helen F. Ladd, 327–356. Washington, DC: The Brookings Institution.

Duncombe, William D., and John Yinger. 1993. "An Analysis of Returns to Scale in Public Production, with an Application to Fire Protection." *Journal of Public Economics* 52 (1): 49–72.

———. 1997. "Why Is It so Hard to Help Central City Schools?" *Journal of Policy Analysis and Management* 16 (1): 85–113.

———. 2000. "Financing Higher Student Performance Standards: The Case of New York State." *Economics of Education Review* 19 (4): 363–386.

———. 2008. "Measurement of Cost Differentials." In *Handbook of Research in Education Finance and Policy*, ed. Helen F. Ladd and Edward B. Fiske, 257–275. Mahwah, NJ: Lawrence Erlbaum Associates.

Dye, Richard F., and Therese J. McGuire. 1992. "The Effect of Earmarked Revenues On the Level and Composition of Expenditures." *Public Finance Quarterly* 20 (4): 543–556.

Efron, B. 1979. "Bootstrap Methods: Another Look at the Jackknife." *Annals of Statistics* 7 (1): 1–26.

El-Rayes, Khaled, and Osama Moselhi. 2001. "Impact of Rainfall on the Productivity of Highway Construction." *Journal of Construction Engineering and Management* 127 (2): 125–131.

Evans, W. N., and I. Kessides. 1993. "Localized Market Power in the US Airline Industry." *Review of Economics and Statistics* 75 (1): 66–75.

Evans, William N., and Ping Zhang. 2007. "The Impact of Earmarked Lottery Revenue on K–12 Educational Expenditures." *Education Finance and Policy* 2 (1): 40–73.

Fatás, Antonio, and Ilian Mihov. 2006. "The Macroeconomic Effects of Fiscal Rules in the US States." *Journal of Public Economics* 90 (1-2): 101–117.

Ferreira-Lopes, Alexandra, and Tiago Neves Sequeira. 2012. "Business Cycles Association in a Small Monetary Union: The Case of Switzerland." *Spatial Economic Analysis* 7 (1): 9–30.

Gamage, David. 2010. "Preventing State Budget Crises: Managing the Fiscal Volatility Problem." *California Law Review* 98: 749–809.

Gamkhar, Shama. 2000. "Is The Response of State and Local Highway Spending Symmetric to Increases and Decreases in Federal Highway Grants?" *Public Finance Review* 28 (1): 3–25.

———. 2003. "The Role of Federal Budget and Trust Fund Institutions in Measuring the Effect of Federal Highway Grants on State and Local Government Highway Expenditure." *Public Budgeting & Finance* 23 (1): 1–21.

Globerman, Steve, and Daniel Shapiro. 2008. "The International Mobility of Highly Educated Workers Among OECD Countries." *Transnational Corporations* 17 (1): 2–35.

Golebiewski, Julie Anna. 2011. "An Overview of the Literature Measuring Education Cost Differentials." *Peabody Journal of Education* 86 (1): 84–112.

Goodrich, Carter. 1960. *Government Promotion of American Canals and Railroads, 1800-1890*. New York: Columbia University Press.

Hahn, Jinyong, Jerry Hausman, and Guido Kuersteiner. 2004. "Estimation with Weak Instruments: Accuracy of Higher-order Bias and MSE Approximations." *Econometrics Journal* 7 (1): 272–306.

Hansen, L. P. 1982. "Large Sample Properties of Generalized Method of Moments Estimators." *Econometrica* 50 (4): 1029–1054.

Harvey, A. C, and A. Jaeger. 1993. "Detrending, Stylized Facts and the Business Cycle." *Journal of Applied Econometrics* 8 (3): 231–247.

Heyndels, Bruno, and Jef Vuchelen. 1998. "Tax Mimicking Among Belgian Municipalities." *National Tax Journal* 51 (1): 89–102.

Hines, James R., and Richard H. Thaler. 1995. "Anomalies: The Flypaper Effect." *Journal of Economic Perspectives* 9 (4): 217–226.

Hodrick, Robert J., and Edward C. Prescott. 1997. "Postwar US Business Cycles: An Empirical Investigation." *Journal of Money, Credit, and Banking* 29 (1): 1–16.

Holcombe, Randall G. 1980. "An Empirical Test of the Median Voter Model." *Economic Inquiry* 18 (2): 260–274.

Holtz-Eakin, Douglas. 1988. "The Line Item Veto and Public Sector Budgets: Evidence from the States." *Journal of Public Economics* 36 (3): 269–292.

Holtz-Eakin, Douglas, and Harvey S. Rosen. 1989. "The 'rationality' of Municipal Capital Spending: Evidence from New Jersey." *Regional Science and Urban Economics* 19 (3): 517–536.

Hou, Yilin. 2003. "What Stabilizes State General Fund Expenditures in Downturn Years— Budget Stabilization Fund or General Fund Unreserved Undesignated Balance?" *Public Budgeting & Finance* 23 (3): 64–91.

———. 2005. "Fiscal Reserves and State Own-Source Expenditure in Downturn Years." *Public Finance Review* 33 (1): 117–144.

———. 2006. "Budgeting for Fiscal Stability over the Business Cycle: A Countercyclical Fiscal Policy and the Multiyear Perspective on Budgeting." *Public Administration Review* 66 (5): 730–741.

Hou, Yilin, and Daniel L. Smith. 2006. "A Framework for Understanding State Balanced Budget Requirement Systems: Reexamining Distinctive Features and an Operational Definition." *Public Budgeting & Finance* 26 (3): 22–45.

———. 2010. "Do State Balanced Budget Requirements Matter? Testing Two Explanatory Frameworks." *Public Choice* 145 (1): 57–79.

Inman, Robert P. 1978. "Testing Political Economy's' As If' Proposition: Is the Median Income Voter Really Decisive?" *Public Choice* 33 (4): 45–65.

———. 1979. "The Fiscal Performance of Local Governments: An Interpretative Review." In *Current Issues in Urban Economics*, ed. Peter M. Mieszkowski and Mahlon R. Straszheim, 270–321. Baltimore: Johns Hopkins University Press.

———. 1983. "Anatomy of a Fiscal Crisis." *Business Review of the Federal Reserve Bank of Philadelphia* (October): 15–22.

Johnson, Craig L., and Kenneth A. Kriz. 2005. "Fiscal Institutions, Credit Ratings, and Borrowing Costs." *Public Budgeting & Finance* 25 (1): 84–103.

Kleibergen, Frank, and Richard Paap. 2006. "Generalized Reduced Rank Tests Using the Singular Value Decomposition." *Journal of Econometrics* 133 (1): 97–126.

Klein, L. R, and R. F Kosobud. 1961. "Some Econometrics of Growth: Great Ratios of Economics." *The Quarterly Journal of Economics* 75 (2): 173–198.

Klomp, Jeroen, and Jakob de Haan. 2009. "Political Institutions and Economic Volatility." *European Journal of Political Economy* 25 (3): 311–326.

Knight, Brian. 2002. "Endogenous Federal Grants and Crowd-out of State Government Spending: Theory and Evidence from the Federal Highway Aid Program." *American Economic Review* 92 (1): 71–92.

Kroszner, R. S., and T. Stratmann. 2000. "Congressional Committees as Reputation-building Mechanisms." *Business and Politics* 2 (1): 35–52.

Kwak, Sunjoo. 2011. "Revenue Volatility: The Determinants and Consequences". Ph.D. Dissertation, Rutgers-Newark, State University of New Jersey. http://mss3.libraries.rutgers.edu/dlr/showfed.php?pid=rutgers-lib:35881.

Levinson, Arik. 1998. "Balanced Budgets and Business Cycles: Evidence from the States." *National Tax Journal* 51 (4): 715–732.

Levinson, David M., and David Gillen. 1998. "The Full Cost of Intercity Highway Transportation." *Transportation Research-D* 3 (4): 207–223.

Levinson, David M., and Bhanu Yerra. 2002. "Highway Costs and Efficient Mix of State and Local Funds." *Transportation Research Record* 1812: 27–34.

Liu, Pu, and Anjan V. Thakor. 1984. "Interest Yields, Credit Ratings, and Economic Characteristics of State Bonds: An Empirical Analysis: Note." *Journal of Money, Credit and Banking* 16 (3): 344–351.

Marlow, Michael L., and William Orzechowski. 1996. "Public Sector Unions and Public Spending." *Public Choice* 89 (1): 1–16.

Meller, Barbara. 2009. "The Two-Sided Effect of Financial Globalization on Output Volatility". Working Paper.

Michael, Joel. 2008. *Earmarking State Tax Revenues*. Policy Brief. St. Paul, MN: Minnesota House of Representatives, Research Department.

Mills, Terence C. 2003. *Modelling Trends and Cycles in Economic Time Series*. New York: Palgrave Macmillan.

———. 2009. "Modelling Trends and Cycles in Economic Time Series: Historical Perspective and Future Developments." *Cliometrica* 3 (3): 221–244.

Mullins, Daniel R, and Philip G Joyce. 1996. "Tax and Expenditure Limitations and State and Local Fiscal Structure: An Empirical Assessment." *Public Budgeting & Finance* 16 (1) (March 1): 75–101.

Mullins, Daniel R., and Bruce A. Wallin. 2004. "Tax and Expenditure Limitations: Introduction and Overview." *Public Budgeting & Finance* 24 (4): 2–15.

Murray, Michael P. 2006. "Avoiding Invalid Instruments and Coping with Weak Instruments." *Journal of Economic Perspectives* 20 (4): 111–132.

Nesbit, Todd M., and Steven F. Kreft. 2009. "Federal Grants, Earmarked Revenues, and Budget Crowd-Out: State Highway Funding." *Public Budgeting & Finance* 29 (2): 94–110.

New York State Comptroller. 2009. *The Dedicated Highway and Bridge Trust Fund: Where Did the Money Go*. Albany, NY: New York Office of the State Comptroller.

Nguyen-Hoang, Phuong. 2012. "Cost Function and Its Use for Intergovernmental Educational Transfers in Vietnam." *Education Economics* 20 (1): 69–91.

van Norden, Simon. 2002. *Filtering for Current Analysis*. Working paper. Bank of Canada.

Novarro, Neva K. 2005. "Earmarked Lottery Profits: A Good Bet for Education Finance?" *Journal of Education Finance* 31 (1): 23–44.

Nunn, Samuel. 1990. "Budgeting for Public Capital: Reinterpreting Traditional Views of Urban Infrastructure Provision." *Journal of Urban Affairs* 12 (4): 327–344.

Oakland, William H. 1985. "Earmarking and Decentralization." *Proceedings of the 77th Annual Conference of Taxation*: 274–277.

Oates, Wallace E. 1972. *Fiscal Federalism*. New York: Harcourt Brace Jovanovich.

———. 1994. "Federalism and Government Finance." In *Modern Public Finance*, ed. John Quigley and Eugene Smolensky, 126–151. Cambridge, MA: Harvard University Press.

Pan, Nang-Fei. 2005. "Assessment of Productivity and Duration of Highway Construction Activities Subject to Impact of Rain." *Expert Systems with Applications* 28 (2): 313–326.

Paxson, Frederic L. 1946. "The Highway Movement, 1916-1935." *American Historical Review* 51 (2): 236–253.

Pedersen, Torben M. 2001. "The Hodrick-Prescott Filter, the Slutzky Effect, and the Distortionary Effect of Filters." *Journal of Economic Dynamics and Control* 25 (8): 1081–1101.

Pollock, D. S. G. 2000. "Trend Estimation and De-trending via Rational Square-wave Filters." *Journal of Econometrics* 99 (2): 317–334.

———. 2001a. "Filters for Short Non-stationary Sequences." *Journal of Forecasting* 20 (5): 341–355.

Pollock, D.S.G. 2001b. "Methodology for Trend Estimation." *Economic Modelling* 18 (1): 75–96.

Poterba, James M., and Kim S. Rueben. 1999. *Fiscal Rules and State Borrowing Costs: Evidence from California and Other States*. San Francisco, CA: Public Policy Institute of California.

Prunty, Robin, and John Sugden. 2012. "History of U.S. State Ratings". Standard & Poor's.

Puentes, Robert, and Ryan Prince. 2003. *Fueling Transportation Finance: A Primer on the Gas Tax*. Transportation Reform Series. Washington, DC: The Brookings Institution.

Rall, Jaime, Alice Wheet, Nicholas J. Farber, and James B. Reed. 2011. *Transportation Governance and Finance: A 50-State Review of State Legislatures and Departments of Transportation*. Washington, DC: National Conference of State Legislatures and AASHTO Center for Excellence in Project Finance.

Ravn, Morten O, and Harald Uhlig. 2002. "On Adjusting the Hodrick-Prescott Filter for the Frequency of Observations." *Review of Economics and Statistics* 84 (2): 371–376.

Romer, Thomas, and H. Rosenthal. 1979. "The Elusive Median Voter." *Journal of Public Economics* 12 (2): 143–170.

Rubinfeld, Daniel L. 1987. "The Economics of the Local Public Sector." In *Handbook of Public Economics*, ed. Alan J. Auerbach and Martin Feldstein, Volume 2:571–645. Amsterdam: Elsevier Science Publishers. http://www.sciencedirect.com/science/article/pii/S157344208780006X.

Skolnik, Jonathan. 2011. *Price Indexing in Transportation Construction Contracts*. Transportation Research Board and AASHTO Standing Committee on Highways.

Staiger, D., and J. H. Stock. 1997. "Instrumental Variables Regression with Weak Instruments." *Econometrica* 65 (3): 557–586.

Stock, J. H., and M Yogo. 2005. "Testing for Weak Instruments in Linear IV Regression." In *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*, ed. M. Andrews and J. H. Stock, 80–108. New York: Cambridge University Press.

Stock, James H., and Mark W. Watson. 1999. "Business Cycle Fluctuations in US Macroeconomic Time Series." In *Handbook of Macroeconomics*, ed. John B. Taylor and Michael Woodford. Vol. 1. Amsterdam: North-Holland.

Thompson, Fred, and Bruce L. Gates. 2007. "Betting on the Future with a Cloudy Crystal Ball? How Financial Theory Can Improve Revenue Forecasting and Budgets in the States." *Public Administration Review* 67 (5): 825–836.

Transportation Research Board. 1990. *Truck Weight Limits: Issues and Options*. Transportation Research Board.

———. 2008. *State Highway Cost Allocation Studies*. Transportation Research Board.

Turnbull, Geoffrey K., and Salpie S. Djoundourian. 1994. "The Median Voter Hypothesis: Evidence from General Purpose Local Governments." *Public Choice* 81 (3): 223–240.

U.S. Department of Transportation. 1976. *America's Highways 1776-1976*. http://archive.org/details/AmericasHighways1776-1976.

U.S. PIRG Education Fund. 2011. *Do Roads Pay for Themselves? Setting the Record Straight on Transportation Funding*. U.S. PIRG Education Fund.

Wang, Wen, William D. Duncombe, and John Yinger. 2011. "School District Responses to Matching Aid Programs for Capital Facilities: A Case Study of New York's Building Aid Program." *National Tax Journal* 64 (3): 759–794.

Williams, Jonathan. 2007. *Paying at the Pump: Gasoline Taxes in America*. Washington, DC: Tax Foundation.