# Do State Governments Defer Highway Maintenance Expenditures?

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**Abstract**

Deferring maintenance expenditures in fiscal downturns can be more costly than accumulating debt or cutting pension contributions. This paper takes advantage of the formulary distribution of Federal highway grants to examine the extent and context of highway maintenance deferral. Since the formula factors used in the apportionment of Federal highway grants are always three years old, I can measure exogenous grant shocks as the difference between this year's and previous year's forecast of each state's future grants. I show that state governments respond to a negative grant shock by cutting highway maintenance expenditures more rapidly than other expenditures. The Impulse Response Functions (IRFs) of maintenance expenditures as a share of total expenditures show that states only partially compensate for the initial cuts in the subsequent periods – deferring maintenance expenditures and accumulating maintenance needs. Furthermore, I find that deferral of maintenance expenditures is more pronounced in election years, which suggests that this inefficient behavior is subject to agency problems.

## 1 Introduction

Governments usually face unanticipated revenue shocks. They would best use borrowing to smooth over taxes and expenditures.[1]. Yet, their particular political and institutional environments often reinforce other responses. They may accumulate debt, cut pension fund contributions (Chaney et al., 2002; Giertz and Papke, 2007), sell off public assets, use accounting gimmicks to shift expenses (Costello et al., 2012), or defer maintenance expenditures. State laws or constitutions may diminish debt accumulation or underfunded pension plans. However, deferring some maintenance expenditures may be the worst choice of all. For example, four years of pavement maintenance deferral may push up the costs five folds (see Hicks et al. (1999), for example).

The focal point of this paper is highway maintenance in the united states. Highways on average comprised between 57% of state-funded infrastructure in different states. They are funded using formulary and earmarked federal grants, and states' own funds. This uncertain stream of revenues funds capital outlays, maintenance, and other current expenditures. I rely on formula based distribution of grants to construct unanticipated shocks.

[1]See Barro (1979); Aiyagari et al. (2002); Holtz-Eakin et al. (1994); Buttner and Wildasin (2010) are a few papers among many that have established this result.

As critical as the deferral of maintenance expenditures might be, there are very few papers that have studied governments' maintenance expenditure. This is largely due to lack of data[2]. However, such regulation may receive popular support. For example in 2016 elections, 79% of Illinois voters supported the Transportation Lockbox ballot, which blocks lawmakers from spending transportation funds on anything other than transportation.

This paper provides evidence on the dynamic response of state highway expenditures and borrowing to unanticipated revenue shocks in different political and institutional environments. I first provide an empirical analysis using a rich and novel dataset on state highway finances including maintenance, capital outlays, other expenditures, and borrowing. I focus on highways because Federal Highway Administration uniquely provides consistent data on maintenance expenditures and because the institutional design of federal grants enables me to identify shocks to state highway revenue. Particularly, I rely on formula based distribution of grants to construct unanticipated shocks. The state specific factors used in these formulas are often unrelated to other economic conditions and are also lagged several years. Therefore, formula grants provide states with exogenous source of revenue which is not related to current economic conditions or highway needs[3].

I am able to construct grant shocks because these grants are partially forecastable. State governments know national levels of grants and apportionment formulas in a typical year, but they update their information about expected formula factors every year. I use the same forecast methodology that Federal Highway Administration (FHWA) used in 2005 for the 2005-2009 highway act (Young, 2005), and extend it for years beyond current highway bill by assuming that level of national grants grow at expected inflation rate[4]. Using these forecasts, I construct the unanticipated highway grant shocks as the difference in expected present value of federal grants. Federal grants compose a quarter of state highway revenues, they can flexibility be used for different purposes and over time. Therefore, studying governments' response to these exogenous grant shocks is highly relevant.

I compile state and local government highway finance data for 50 state governments from the annual reports of 1992-2013. FHWA reporting guidelines assure the consistency and accuracy of these data that are reported by the state governments (FHWA, 2016). According to these guidelines capital outlay includes additions, alterations, and replacements to the existing roads and structures, but does not include repair expenditures. On the other hand, general maintenance *does not* include improvements, additions and betterments, or resurfacing, restoration, rehabilitation, and reconstruction expenditures (3R/4R). However, in this dataset, preventative maintenance is not differentiated from critical maintenance.

Using the panel dataset of state governments, I am able to study both within-fiscal-year and dynamic response of state highway administrations to unanticipated federal grant shocks. I use the methodology of Jordà (2005) to study impulse response functions of different variables with respect to shocks. Furthermore, I control for state and year fixed

[2]For example, in the US, maintenance expenditure is aggregated into total current expenditures Survey of Government Finances, and Survey of School District Finances only includes "Operation and Maintenance". Recently available aggregate maintenance data for Canada has been used in Kalaitzidakis and Kalyvitis (2004) and Albonico et al. (2011) which study the macroeconomics of maintenance expenditure.

[3]Leduc and Wilson (2013) use this strategy to study the dynamic macroeconomic effect of infrastructure investment. Kraay (2012) uses the fact that spending on World Bank-financed projects is determined by project approval decisions made in previous years to study the multiplier effect in developing countries.

[4]I follow the methodology of Leduc and Wilson (2013) to create grant shocks.

effects. Therefore, my results are not an artifact of factors that affect all states at the national level, or the fixed underlying characteristics of the state governments or economies. In addition to studying the real and per capita expenditures, I investigate the effect of grant shocks on ratios of these expenditures to total expenditure. Therefore, I can study which expenditures win the budget battle.

I find that maintenance expenditure is the most responsive category of highway expenditures. Furthermore, the U-shaped Impulse Response Functions (IRFs) for maintenance show that state governments increase maintenance expenditures in the period that they receive a negative shock, and subsequently increase maintenance in later periods. This finding confirms that state governments defer maintenance expenditures in response to budgetary shocks, and is robustly found for maintenance share of total expenditure and per capita maintenance expenditure. I calculate that this behavior is inefficient because later increases in maintenance expenditure do not make up for the initial response to the negative shock even if I assume a small annual 5% additional cost of deferring maintenance.

I use the interaction of grant shocks with balanced budget requirement and budget stabilization fund indicators to study whether governments's responses are heterogeneous with respect to borrowing constraints. I find that the deferral of maintenance expenditures is slightly more pronounced for states that may not carry over a deficit to next fiscal year or require referendum debt approval for capital projects. The former is the most stringent one on state general budget. Using the ACIR stringency index (ACIR, 1987), which is an index of all the balanced budget requirements, I find the same result.

Furthermore, I find that the response of maintenance to unanticipated shocks are subject to political power. If government receives a negative shock and next year is house elections, the within-fiscal-year maintenance effects are even more pronounced. In addition, the U-shaped response of maintenance expenditure is clearly less pronounced when political power is divided between the legislature and governorship. Both of these findings suggest that the deferral and accumulation of maintenance needs is not simply explained by voters choices.

Borrowing increases when states receive a positive shock. Therefore, states are using highway borrowing to fund their projects rather than using it to smooth their expenditures. Consistent with my findings about deferral of maintenance expenditures, this suggest that they do not have access to borrowing as an instruments to smooth other expenditures.

My empirical analysis of maintenance expenditures is most closely related to three papers that study the correlation between fiscal and political variables and governments' maintenance expenditure. Borge and Hopland (2015) use the post-2008 Norwegian local government expenditure data to study the correlation between fiscal and political indicators and maintenance expenditure. They show that low levels of maintenance and poor building conditions are associated with low fiscal capacity, and fiscal stress; and a high degree of party fragmentation is associated with low levels of maintenance and poor building conditions[5]. Bumgarner et al. (1991) finds that municipal governments cut maintenance expenditures in fiscal distress to fund other expenditures in a cross-section of 47 cities. Finally, a very recent paper by Can Chen (2016) uses the model of Bumgarner et al. (1991) to study how highway expenditure respond to state governments' general budget deficit and economic variables. The most pronounced finding of the paper is that capital outlays go down in

[5]Also, Gyourko and Tracy (2006) study whether consumers defer maintenance expenditures when they receive revenue shocks. They use American Housing Survey and find small effects.

fiscal and economic downturns. However, maintenance expenditures respond to fiscal stress with lags[6].

I do not find that unanticipated highway grant shocks drive up the total per capita expenditure significantly. Therefore, theses shocks mostly affect the composition of expenditures. It must be that the shocks are crowding out states' contributions to highway revenues from other sources. However, in response to shocks, states reallocate their resources from one task to another[7].

This paper also contributes to the literature on capital expenditures' response to fiscal crisis (Poterba, 1995, 1994). Although capital outlays respond to unanticipated shocks after two periods, I find that unexpected grant shocks are not spent on capital outlays more than any other highway expenditures. Surprisingly, I also find that states with the stringent requirements on general budget respond to shocks by reducing capital outlays in favor of other current expenditures. This may be the result of states with general budget constraints constantly underfunding current expenditures. Therefore, they prefer to spend unanticipated shocks on these projects. The fact that we see the same effect in per capita figures is consistent with the finding that total expenditures do not increase and states just reallocated their resources to different uses. On the other hand, the referendum debt approval results go in the expected direction. Governments with referendum debt approval requirements rely more heavily on grant shocks to fund their capital expenditures. I find that they respond more strongly to unanticipated grant shocks.

Theoretically, it would be optimal for governments to absorb the transitory shocks using borrowing whether the source of revenue uncertainty is volatile tax bases, economics uncertainty, or federal grant shocks. The optimal borrowing literature (Barro (1979), Aiyagari et al. (2002), Holtz-Eakin et al. (1994)) suggests that through borrowing, tax and expenditure smoothing achieves the maximum social welfare. This may not necessarily be the behavior of the short-sighted politicians. Therefore, a lot of governments have established institutions to that hinder free borrowing. While these measures achieve balanced budgets (Bohn and Inman, 1996; Poterba, 1996), under borrowing constraints, governments should optimally form rainy day funds, and still they should forgo tax and expenditure smoothing (Buttner and Wildasin, 2010).

Finally, I discuss that the deferral of maintenance expenditure is not necessarily an inefficient borrowing tool. I employ a dynamic model of a government that chooses critical maintenance, preventative maintenance, and investment to maximize social welfare. Abstracting from the choice of optimal long term infrastructure levels, I impose that governments may have preferences for smoothing the services provided by public infrastructure. I allow for heterogeneous preferences for smoothing through model parameters. These features of the model, are similar to but a more general form of the existing models of optimal borrowing[8], but my model includes government expenditure (similar to Holtz-Eakin et al. (1994); Buttner and Wildasin (2010)). Since my model is to describe the behavior of highway administrations in response to shocks, governments revenues include such shocks in my

[6]All three papers address the endogeneity of fiscal stress variable is by controlling for different variables, while this paper identifies the effects using exogenous and unanticipated shocks.

[7]One other possible reason for this finding may be that states may not easily adjust their labor force.

[8]This theoretical literature originates in Barro (1979). The empirical papers after Sahasakul (1986) include Bohn (1998), and Bohn (2007).

model. Furthermore, governments may face borrowing constraints.

I show that if the ratio of depreciation return to preventative relative and critical maintenance is small enough (compared to consumers discount rate), government should opt to use maintenance deferral as a borrowing tool. Anecdotally, this condition is not often met. I discuss that this may be true for a subset of highway projects, but further research is required to create these measures.

The rest of the paper is organized as follows. The next section provides background information about the Federal-Aid Highway Program and describes how federal highway grants are distributed among states. Furthermore, this section discusses the institutional design and data, and the methodology used to construct the exogenous shocks. In this section, I describe how I construct the highway grant shocks and flexibility of states for using the funds across programs and over time. My empirical methodology and data are described in 3. In section 3.3, I discuss the main empirical findings, including the role of political and institutional environment. I present my theoretical model in section 4, and the last section concludes.

## 2 Institutional Design of Highway Infrastructure Spending

The institutional design of Federal-Aid Highway Program allows me to identify expenditure and borrowing patterns using exogenous shocks. Because the distribution of such grants follow strict formulary rules based on three year old data on various factors, there is little concern about the endogeneity of these shocks with respect to current economics or budgetary conditions of the states. Highway bills are designed to facilitate long term planning which provides the perfect context to study how states maintain steady expenditures. Furthermore, states can quite easily reallocate the grant funds from one grant category to another which makes it relevant to study their choices. Finally, Federal Highway Statistics cover standardized and detailed information on state highway finances which allows me to study composition of expenditures over time. In this section, I provide more details on these features after providing the necessary background information.

The Federal-Aid Highway Program (FAHP) is a collection of grant programs that provide funding to the states. The national level for each program and the distribution formulas are periodically authorized by the congress through multiyear legislation. The four acts since 1990 are the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, covering Fiscal years 1992-97, the Transportation Equity Act for the 21st Century (TEA-21) in 1998, covering Fiscal years 1998-2003; the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) in 2005, covering Fiscal years 2005-09, and Moving Ahead for Progress in the 21st Century Act (MAP-21) in 2012, covering fiscal years 2013-14. The years in between those covered by the acts above were covered using the so called stop-gap funding bills which typically extend the funding for existing programs. Fiscal years 2004, and 2010-12 are such examples.

The FAHP programs cover well beyond interstate highways and help construction, maintenance, and other functions. For example, MAP21 included 19 different federal aid programs totaling $40.6 trillion in 2014. Furthermore, under all acts, local roads are often considered federal-aid highways, their construction and maintenance would be eligible for such grants. However, the federal government will not cover the full cost of projects. Under

FAHP, states get reimbursed for 80 to 90 percent of the cost of eligible projects depending on the program. Therefore, all FAHP grants are categorized as matching grants.

## 2.1 Different Mechanisms for Distribution of Grants

The institutional structure of the distribution of highway grants allows the states to form forecasts about future grants for long term planning, and enables me to construct shocks to explore exogenous variation in state highway revenue. Each highway bill authorizes total available funds at the national level for each program and each year, and sets the apportionment formulas that regulate the distribution of each program between states. For example, for 2009, SAFETEA-LU authorizes $1.29 billion for Highway Safety Improvement Program (HSIP). Furthermore, the same authorization act specifies that HSIP funds are to be distributed according to total lane miles of Federal-aid highways, total vehicle miles traveled on Federal-aid highways, and number of fatalities on the National Highway system with equal weights. At the same time, each state should receive at least 1/2% of total HSIP funds.

A key feature of the highway bills for our analysis is that the mix of the main programs and the apportionment formulas have remained mostly unchanged over consecutive authorization acts. This enables the states to forecast future apportionments that even beyond the current highway bill for long term planning. I explain how these forecast are built and how I used them in section 2.3 below.

In addition to formulary apportionments described above, Highway bills include two other noteworthy features: minimum guarantee and earmarked funds. However, these features do not undermine my identification strategy. According to the legislation since 1982, states receive a guaranteed minimum return on their fuel, tire, and truck-related tax contribution to the Highway Trust Fund. During 1992-2014, the minimum guarantee has ranged from 90 to 92 percent of states' contributions to the HTF. This provision becomes effective if the formulary apportionments are less than the minimum guarantee amount for a state. In that case, the difference between the minimum guarantee and state's total grants is distributed to the state programs according to their shares of total grants. However, since minimum guarantees are separately authorized in the bill, the distribution of funds to other states remains unaffected and follows the formulary apportionments. So, this feature does not undermine forecasting highway apportionments.

Funds that are earmarked for certain projects are also contained in highway bills. The share of such funds in the highway bills has changed from one act to another, but these allocations essentially work parallel to the formulary apportionments. Although these earmarked allocations are clearly influenced by political factors, formulas and authorization mix have experienced little change over time. Hence, earmarked funds are to a large extent orthogonal to formulary apportionments, and do not introduce additional difficulties for my forecasts.

## 2.2 Planning Process and Reallocation of Grants

States have ample time to plan how they spend grant funds. In particular, they have four years to obligate the funds from a given year of grants, and the funds are released to the states during the course of or the completion of the projects. The process underlying these

lags is well detailed in FHWA (2007) and the timing of obligations is studied in Leduc and Wilson (2013). After apportionment of grants, states write contracts with vendors, obligating funds from current and past grants. During the course of or after completion of projects, the contractors' bills are submitted to the FHWA by the state. FHWA instructs the US treasury to transfer funds to the states using which they pay the contractors. This is only when the funds show up in highway statistics as expenditures.

Accordingly, grants may not necessarily have an immediate impact on expenditures. That said, Leduc and Wilson (2013) show that about 75% of grants show up as outlays within the first three years, 65% of which happens during the first two years. However, it is noteworthy that the whole process from grants to outlays can take up to seven years. Therefore, I study of longer term implications of grant shocks as well.

The funds from each program can flexibly be used for variety of projects. For example, Interstate Maintenance funds are not intended for only maintenance. According to FHWA guidelines, these funds can be used for resurfacing, restoration, rehabilitation, and reconstruction; the reconstruction or new construction of bridges, interchanges, and over crossings along existing Interstate routes; capital costs for operational, safety, traffic management, or intelligent transportation systems (ITS) improvements; and preventive maintenance. Most of these categories are in fact categorized as capital outlays.

Furthermore, grants do not only affect the expenditure of their specific program. In fact, all expenditure categories of state governments are affected in two ways by FHWA funds apportioned to specific programs. The indirect channel works through freeing up the other state funds for all expenditures when, for example, grants for constructing new projects are apportioned to the state. This is the spillover effect which works through substituting of own funds with grant funds.

Furthermore, states can explicitly transfer funds across Federal-Aid Highway programs. States have the flexibility to reallocate grants from one program to another. A state may transfer up to 50 percent of the states' apportionment in any fiscal year to its apportionment of National Highway System or Surface Transportation Program. The same transfer can be done from any program to another, but for up to 40 percent of funds. Furthermore, if a transfer is requested by the State transportation department and is approved by the Secretary as being in the public interest, the Secretary may approve the transfer of 100 percent of the apportionment under one such program to the apportionment under any other one. (23 U.S.C. 104 - Apportionments, 2006)

## 2.3 Constructing Grant Shocks

In this section, I measure highway grant shocks using the data on authorizations and actual apportionments. At the beginning of each period, governments know the national authorization and apportionment formulas for the current and future periods that are in the same highway bill. Furthermore, they know the values of the formula factors for current period. However, they do not know the values of formula factors in future periods. As a result, highway grants are partially forecastable. I build the measures of unanticipated shock using the forecast errors in a very similar fashion to Leduc and Wilson (2013) that in turn extend the forecast methodology of FHWA office Young (2005).

The forecasts are made by assuming that for each of the grant programs states' formula

factors, relative to national levels, remain the same as current period levels over the forecast period. This effectively implies that the grant share of state will remain the same as current share for the future periods. As a result, forecasts of future apportionments for each program are given by the current share of each state for that program funds multiplied by the national level of authorizations in the future, which is known for the future periods in the current highway bill. This methodology is used by FHWA(2005), and Leduc and Wilson (2013) extend it by assuming that authorizations for the periods beyond the current highway bill grow at the expected inflation rate and the formulas remain the same[9]. For each state, I use the same method to form the forecasts for each program, and sum up the future forecast of all highway programs to calculate total grant forecast.

Using future forecasts, I measure shocks to grant expectations as the difference between current forecast and last year's forecast of future highway grants. First, I write the expected present value of future grants as

$$E_t[PV_j] = \sum_{s=0}^{5} \frac{E_t[G_{j,t+s}]}{(1+r)^s} + \frac{E_t[G_{j,t+5}]}{(1+r)^5} \frac{1}{1-\beta_t} \tag{1}$$

where $E_t[G_{j,t+s}]$ is the time $t$ forecast of the total grants for year $t+s$ in state $j$, and $\beta_t = (1+\pi_t^e)/(1+r_t)$. The second term on the right hand side reflects that beyond five years, grants are assumed to grow at the expected inflation rate. I use the ten-year trailing average of the ten-year Treasury bond rate as of the beginning of the fiscal year $t$ as the discount rate $r_t$. The expected inflation rate, $\pi_t^e$ is measured using the median five or ten year ahead inflation forecast for the first quarter of the fiscal year from the Survey of Professional Forecasters (SPF)[10].

Finally, I construct the measure of unanticipated grant shocks as the difference between this year's expected grants and that of the previous year. To be comparable across states, I turn these dollar values to percentage terms using the symmetric percentage formula:

$$\text{shock}_t = \frac{E_t[PV_{j,t}] - E_{t-1}[PV_{j,t}]}{0.5 \times (E_t[PV_{j,t}] + E_{t-1}[PV_{j,t}])} \tag{2}$$

When the unanticipated shocks deal with forecasts within the same highway bill, they are the result of changes in the formula factors. These changes are amplified by the weights of different highway programs in the later years because I am calculating present value of future grants. For example, an update from last year that vehicle miles traveled on the Interstate System is larger than last year will have a larger impact if future highway authorizations for the Interstate Maintenance program are to be larger than this year. Furthermore, compared to the shock measures calculated using one-period-ahead forecasts, these measures are more successful at reflecting forecast of the longer horizons. This feature is critical for highway expenditures that may require longer term planning.

When the shocks are built for years that cover two different highway bills, they also reflect the changes in expectations of national authorizations. However large these changes

[9] I am able to closely replicate the highway grant forecasts of both and shock measures of the former (See Appendix A.1)

[10] These measures are chosen to reflect the long term trends in inflation and interest rates. To facilitate replicating Leduc and Wilson (2013), I use exactly their measures.

may be, they affect all state governments. Because I control for year fixed effects in my regressions, my main results are not identified from such changes.

It is also critical for my identification strategy that the formula factors are lagged three years, since real time information is not readily available to the FHWA. Although some formula factors are exogenous to economics activity and other revenue generating process of the highway administration, others, such as payments into the HTF, are not. Using three year old data by the highway administration mitigates concerns about contemporaneous movements of formula factors and other revenue generating processes.

# 3 Empirical Model & Data

In this section, I present an empirical model to evaluate how the levels and composition of different expenditures, revenue, and borrowing respond to unanticipated grant shocks. Then, I discuss the different data sources that I use to conduct this study.

## 3.1 Empirical Framework

I use the constructed measure of highway grant shocks to study how governments reallocate their expenditure in response to unanticipated fluctuations in revenues. My basic specification is:

$$y_{j,t} = \beta shock_{jt} + X'_{jt}\zeta + \gamma_j + \delta_t + \varepsilon_{jt} \tag{3}$$

As I discuss below, $y_{j,t}$ is a measure of state taxes, borrowing, or expenditure for year $t$, and $shock_{jt}$ is the grant shock defined before. $X_{jt}$ represents other control variables which are included for robustness checks. In different specifications, $X_{jt}$ includes factors that may affect maintenance needs or factors that may offer any additional forecastablity of grant shocks. Finally, $\gamma_j$ and $\delta_t$ are the state and year fixed effects, and $\varepsilon_{jt}$ is the error term.

To focus on the expenditure composition effect of the grant shocks I can measure borrowing, maintenance expenditure, and capital outlay as shares of total highway expenditure. Using this strategy, I am measuring which payments lose the budgetary battle between different expenditures. In other words, I can measure which expenditures are the easy targets. We already expect that higher grants lead to higher expenditure. Therefore, I use this model to measure which payments respond to a higher extent. However, I measure state gasoline taxes as dollars per gallon.

As mentioned earlier, the response of governments to shocks may not be limited to current period. To assess the dynamics of such response, I can simply run the model in equation 3 for different horizons. Effectively, by separately estimating the equations below, I can estimate impulse response functions (IRFs) in a panel data setting (Jordà, 2005). Formally, I estimate

$$y_{j,t+h} = \beta^h shock_{jt} + X'_{jt}\zeta^h + \gamma_j^h + \delta_t^h + \varepsilon_{j,t+h} \tag{4}$$

where I am repeatedly estimating the same equation in (3) for different horizons, $h$. Recently Leduc and Wilson (2013), and Auerbach and Gorodnichenko (2011) used this direct projection estimator to estimate the dynamic effect of government spending in panel data settings. According to Jordà (2005), direct projections are more robust to misspecification,

such as too few lags in the model or omitted endogenous variables, than vector autoregression (VAR). More importantly, this method easily accommodates IRF confidence intervals that are robust to clustering and heteroscedasticity whereas VAR based IRFs must be computed using delta method or bootstrapping. Finally, it is easy to extend direct projection method to study asymmetric effects such as different responses to positive and negative shocks.

As state governments operate in different economic, political, and institutional environments, we expect heterogeneous effects with respect to these factors. For example, credit constrained governments may use the deferral of maintenance expenditures to respond to unanticipated shocks, or spend their unanticipated revenue on the underfunded capital outlays. To assess this, I estimate the differential effect of highway shocks on states with different balanced budget requirements. The regression equation in this approach is modified as follows:

$$y_{j,t+h} = \beta^h shock_{jt} + \sum_k \alpha_k^h VI_{j,t+h}^k + \sum_k \beta_k^h VI_{j,t+h}^k \times shock_{jt} + \tag{5}$$

$$\sum_k \beta_l^h FI_j^l \times shock_{jt} X_{jt}' \zeta^h + \gamma_j^h + \delta_t^h + \varepsilon_{j,t+h} \tag{6}$$

where $VI_{j,t+h}^k$ and $FI_j^k$ are time varying and fixed political and institutional indicators such as Balanced Budget Stringency measures and state partisanship indicators. These indicators are discussed in more details in the data section.

### 3.2 Data

My primary response variables are maintenance expenditures, capital outlays, taxes, and borrowing for state and local highways from 1993 to 2013[11]. These data are drawn from the annual tables of Highway Statistics, published by FHWA. These measures and total expenditures are separately reported for state and local governments. I use these measures in real dollars at levels, per capita, and as shares of total expenditure.

The collection process of Federal highway statistics guarantees consistency and detailed level data over time. Federal legislation and policy requires highway data from the states for FHWA for Congress and other interested entities. Therefore, each year, FHWA receives detailed data on fuel, vehicle, road conditions, and highway finances directly from the states. FHWA in turn audits the data for reasonableness, completeness, consistency, and compliance with data reporting guidelines and publishes the data in different tables which are also available online.

FHWA reporting guidelines carefully differentiate between maintenance and capital outlays. Capital outlay includes additions, alterations, and replacements to the existing roads and structures, but does not include repair expenditures. The term maintenance is defined as the function of preserving and keeping the entire highway, including surface, shoulders, roadsides, structures, and traffic control devices, as close as possible to the original condition

[11] Although state governments are the ones that receive the federal grants, the expenditures by state and local governments may be substitutes or complements to each other. Furthermore, states may have different jurisdictional divisions for state and local roads responsibilities. Therefore, I use total expenditure and borrowing by state and local governments as my main measures.

as designed and constructed. Maintenance also includes preventive maintenance activities. These activities extend pavement and bridge service life to at least achieve the design life of the facility. Preventive maintenance involves programs that delay or eliminate the necessity for future resurfacing, restoration, rehabilitation, and reconstruction of the roads or structures. On the other hand, general maintenance does not include improvements, additions and betterments, or resurfacing, restoration, rehabilitation, and reconstruction expenditures (3R/4R) which should be recorded as capital outlays[12].

Therefore, FHWA statistics provide high quality data on three pieces of information: 1) Grant authorization and apportionment formulas; 2) Final Grant Apportionments; and 3) Composition of expenditures. The first item is in the text of highway bills, while highway statistics provide details information on the next two.

The descriptive statistics dependent variables are reported in table (3.2). We can see that on average states spend $175 on maintenance and $355 on capital outlays per person. The bottom three rows show that these expenditures compose 75% of highway expenditure. The other highway expenditures, which compose 25% of total expenditure, include administration, highway police and safety, and interest payments.

Average gasoline tax rate is measured by dividing fuel tax revenue by total volume taxed. On average, states receive 26 cents per gallon of fuel taxed. While most of the capital outlays are done by state governments (79.6%), the burden of maintenance is almost equally divided between state and local governments. Also, note that the average borrowing is positive in this period, but it is only $24 per person.

The balanced budget rules and stabilization fund indices are from Bohn and Inman (1996) and Wagner and Elder (2005), respectively. These measures are summarized in tables (4) and (**??**) in appendix A.2. The balanced budget rules were directly approved by the state's citizens (constitutional constraints) or by the state's legislature (statutory constraints) prior to 1970[13], and have not changed over time. On the other hand, some of the budget stabilization funds we established as recently as 2000. Therefore, the balanced budget rules do not reflect the preferences of the current residents of the states today, but the stabilization fund indices do. Therefore, the stabilization fund result should be interpreted with care. As Poterba (1996) notes, one possible strategy that researchers have used to mitigate this endogeneity issue is controlling for political indicators.

The political environment of the states may also affect their behavior. To capture this, I use political party indicators of the states' governor, house of representative, and senate; an indicator for split legislature; an indicator for divided government; and an indicator for whether the governor is up for reelection when it is not the governor's last term. I use the Klarner (2013b) and Klarner (2013a) data which I have updated for years 2011-13 from NCSL (2016).

Furthermore, I check the robustness of the main results to controlling for lags of state

[12] "Roadway maintenance includes all expenditures for routine roadway surface, shoulder, roadside and drainage operations. Structure maintenance includes expenditures for repair and maintenance of bridges, tunnels, subways, overhead grade separations, and other structures, including substructure, superstructure, stream bed operations, and bridge painting. Highway and structure maintenance also includes: spot patching and crack sealing of roadways and bridge decks, the maintenance and repair of highway utilities and safety devices, including repair and painting of route markers, signs, guard rails, fences, signals and highway lighting." (FHWA, 2016)

[13] In most cases the law came into effect at the date of the state's admission to the union.

Table 1: Summary Statistics on Dependent Variables

| | (1) Mean | (2) Std. Dev. | (3) Min | (4) Max |
|---|---|---|---|---|
| Total Disb. (state and local) (Per Cap.) | 7.05 | 2.51 | 1.83 | 24.74 |
| Total Disb. (local) (Per Cap.) | 2.44 | 1.32 | 0.45 | 12.36 |
| Total Disb. (state) (Per Cap.) | 5.32 | 2 | 2.60 | 16.17 |
| Gas Tax (real $) | 0.26 | 0.07 | 0 | 0.56 |
| Maintenance (Per Cap.) | 1.75 | 0.81 | 0.06 | 5.85 |
| (state) % | 47.25 | 18.33 | 10.74 | 100 |
| (local) % | 52.75 | 18.33 | 0 | 89.26 |
| Capital Outlays (Per Cap.) | 3.55 | 1.56 | 0.47 | 15.32 |
| (state) % | 79.63 | 29.31 | 0 | 900.76 |
| (local) % | 21.85 | 15.84 | 0 | 99.56 |
| Other Highway Expenditures (Per Cap.) | 1.77 | 0.90 | 0.48 | 9.56 |
| (state) % | 99.98 | 44.43 | 17.23 | 311.91 |
| (local) % | 43.20 | 21.85 | 0.09 | 225.15 |
| Highway Borrowing (Per Cap.) | 0.24 | 0.76 | -6.13 | 4.62 |
| (state) % | 89 | 1,896 | -12,367 | 55,875 |
| (local) % | 10.84 | 1,896.14 | -55,775 | 12,467.57 |
| Maintenance (Expenditure Share) | 0.25 | 0.08 | 0.03 | 0.52 |
| Capital Outlays (Expenditure Share) | 0.50 | 0.09 | 0.16 | 0.79 |
| Other Highway Expenditures (Expenditure Share) | 0.25 | 0.08 | 0.07 | 0.71 |
| Highway Borrowing (Expenditure Share) | 0.04 | 0.09 | -0.44 | 0.65 |

Source: Difference sources, 1993-2013. Per capita and adjusted for inflation. The per capita measures are in hundreds of 2014 dollars.

Gross Domestic Product and state highway expenditure, climate indicators, and storm events. I explain the outcomes in the results section. State GDPs are taken from Bureau of Economic Analysis (BEA). After 1997 the estimation methodology of BEA changes as the industry classification transitions from SIC to NAICS. Furthermore, pre-1997 estimates are more consistent with Gross domestic income (GDI) than GDP. However, the differences are small and controlling for year fixed effects captures a lot of the accounting differences.

Table (3.2) present summary statistics on independent variables. Both shocks, which are based on the present value of forecast errors, and forecast errors are constructed as ratios. Notice that the constructed shocks, which present value of forecast errors, have a smaller standard deviation. The rest of the table lists and presents the average ratios of balanced budget rules and political indicators, and averages of climate measures that I use. The temperatures are in Fahrenheit.

### 3.3 Estimation Results

I present the within-fiscal-year and dynamic response of outcome variables to unanticipated highway grant shocks. Then, I investigate which political and institutional factors are related to this response. Most of the response is compositional. My most robust finding is that in the short run, maintenance expenditures positively respond to the shocks and in later periods they go down. However, the responses of capital outlays and other highway expenditures are typically observed in later periods and are more heterogeneous than that of maintenance expenditure.

Table 2: Summary Statistics on Independent Variables

| | (1) Mean | (2) Std. Dev. | (3) Min | (4) Max |
|---|---|---|---|---|
| Shock | 0.08 | 0.12 | -0.65 | 0.83 |
| Forecast Error | 0.05 | 0.17 | -0.61 | 1.15 |
| State General Budget Deficit (% of Revenue) | 0.72 | 5.40 | -55.68 | 31.31 |
| ACIR Stringency Index | 8.08 | 2.60 | 0 | 10 |
| May Carry Over A Deficit | 0.80 | 0.40 | 0 | 1 |
| Gov. Submits Balanced Budget | 0.24 | 0.42 | 0 | 1 |
| Leg. Passes Balanced Budget | 0.18 | 0.38 | 0 | 1 |
| May Not Carry Over Into Next Biennium | 0.22 | 0.41 | 0 | 1 |
| May Not Carry Over Into Next Fiscal Year | 0.59 | 0.49 | 0 | 1 |
| Elected State Supreme Court | 0.47 | 0.50 | 0 | 1 |
| Referendum Debt Approval | 0.37 | 0.48 | 0 | 1 |
| Governor Has Line Item Veto | 0.84 | 0.36 | 0 | 1 |
| Indep Governor | 0.02 | 0.13 | 0 | 1 |
| Dem Governor | 0.45 | 0.50 | 0 | 1 |
| House Split | 0.02 | 0.14 | 0 | 1 |
| House Controlled by Democrats | 0.53 | 0.50 | 0 | 1 |
| Senate Split | 0.03 | 0.16 | 0 | 1 |
| Senate Controlled by Democrats | 0.50 | 0.50 | 0 | 1 |
| Split Legislature | 0.23 | 0.42 | 0 | 1 |
| Divided Government | 0.53 | 0.50 | 0 | 1 |
| Gov. Elec. Year, not Lame | 0.21 | 0.41 | 0 | 1 |
| Senate Election Next Year | 0.45 | 0.50 | 0 | 1 |
| House Election Next Year | 0.48 | 0.50 | 0 | 1 |
| Senate Close Election | 0.10 | 0.30 | 0 | 1 |
| House Close Election | 0.12 | 0.32 | 0 | 1 |
| Min Temp Jan. | 20.81 | 11.60 | -20.20 | 54.50 |
| Max Temp Jan. | 40.05 | 12.90 | -5.40 | 74.70 |
| Heating Degree Days | 438.57 | 173.82 | 44.75 | 900.83 |
| Max Temp Avg. | 63.14 | 8.94 | 31.80 | 82.80 |
| Min Temp Avg. | 40.86 | 8.19 | 16.32 | 62.21 |
| Storm Property Damage | 11.52 | 121.23 | 0 | 3,464.18 |
| Number of Storms | 2,811.93 | 2,467.55 | 3 | 16,737 |

Source: Difference sources, 1993-2013. Per capita and adjusted for inflation.

### 3.3.1 Within-Fiscal-Year Effects

Table (3) presents the results of estimating equation (3) for different outcomes aggregated for state and local governments. All outcomes are in logs except for borrowing, which is in linear[14]. The three panels of this table present the within-fiscal-year effects of grant shocks on real outcomes, per capita outcomes, and outcomes as shares of total expenditure.

The results in table (3) suggest that except for maintenance expenditures, state and local highway expenditure do not respond to grant shocks. Furthermore, column (5) of panels I and II shows that in the short run, total expenditure does not consistently increase with positive grant shocks.

As panel III of table (3) presents, states reallocate some of their resources to do maintenance expenditure when they receive a positive shock. That is, while total expenditure does not go up by much, the share of maintenance expenditure goes up while the shares of capital outlays and other expenditures go down. However, these effects are not precisely estimated. One likely reason for larger standard deviations for total expenditure shares of capital outlay and other highway expenditures is that different states reallocate different resources to maintenance expenditures. However, small responses for capital expenditure are not surprising since investments typically require more planning time.

Columns (1) and (6) show the response of borrowing and gasoline tax respectively. States immediately borrow when they receive grant shocks. This complementarity between borrowing and grants is interesting. It shows that borrowing is not used as a tool for smoothing over shocks, but rather when states have a guaranteed source of future income, they are more likely to commit to borrowing. Finally, I find no short run effect for gasoline tax in column (6).

Tables (5) and (6) in the Appendix A.3 show that the maintenance results are very robust to controlling for state specific time trends and three lags of GDP and total expenditure. Furthermore, the same results are found when excluding local government expenditures. The negative effects for other expenditure effects are more pronounced after these controls, and borrowing effects are less pronounced when excluding local governments. In addition, the maintenance results are robust to controlling for climate indexes, using forecast error as the shock indicator, or excluding years beyond 2005 (not presented in the paper). Since the 2005 highway bill included more ear-marked grants, and those years coincided with the financial crisis. Therefore, these results are not driven by neither the financial crises nor the earmarked grants.

### 3.3.2 Dynamic Effects

The short term maintenance results can be interpreted as states putting off accumulated maintenance needs until they receive grant shocks, or maintenance expenditures being easier to adjust in the short run. Therefore, I further look at the effect of shocks in later periods.

As figure (1) presents, the IRF of share of maintenance expenditure is U-shaped: in response to a shock, governments substitute maintenance expenditures of future periods with current period expenditure[15]. Therefore, states systematically use maintenance expendi-

[14]Borrowing takes negative values. Therefore, I cannot specify it in logs.

[15]As mentioned before, the impulse response functions are simply the effect of current period shock on the level of outcome in current and future horizons which are the result of estimating equation (5).

Table 3: Within-Fiscal-Year Response of different state and local outcomes to grant shocks

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Borro. (Linear) | Cap. Out | Maint. | Other | Total Disb. | Gas Tax $ |
| Normalization | Level | Level | Level | Level | Level | |
| Shock | 1065.386 | 0.041 | 0.207*** | -0.046 | 0.052 | |
| | (1047.054) | (0.064) | (0.074) | (0.068) | (0.043) | |
| Normalization | Per Cap. | Per Cap. | Per Cap. | Per Cap. | Per Cap. | |
| Shock | 0.268* | 0.035 | 0.201*** | -0.053 | 0.045 | |
| | (0.154) | (0.064) | (0.072) | (0.062) | (0.039) | |
| Normalization | Tot Exp Share | Tot Exp Share | Tot Exp Share | Tot Exp Share | | Level |
| Shock | 0.041* | -0.016 | 0.146*** | -0.098 | | -0.007 |
| | (0.024) | (0.038) | (0.046) | (0.064) | | (0.033) |
| Fixed Effects | State,Year | State,Year | State,Year | State,Year | | State,Year |

Standard errors in parentheses, clustered over state. Significance levels: * 10 percent, ** 5 percent, *** 1 percent.

ture to respond to negative and positive shocks like they would use borrowing to absorb the shocks. This substitution effect is even present in levels and per capita. Figures (8) and (9) in Appendix A.4 show these U-shaped IRFs for maintenance expenditure.

As deferring maintenance expenditures is costly, we need to consider if it might be justified. Let's suppose that maintaining the same road to a given quality next year costs 5% more than doing it this year. By calculating the present value of the effect of a one percent grant shock on maintenance expenditure at this depreciation rate, we can evaluate how costly deferring maintenance is. Accordingly, the response of per capita maintenance expenditure to 1% negative grant shock on per capita expenditure is -4.55% or -$0.0797 for the ten year horizon. This means that later increases in maintenance expenditure do not make up for the initial decrease in response to a negative shock. In other words, states would accumulate maintenance needs.

Figure (1) also shows that capital outlays respond to grant shocks after two periods. However, the average response of all states is not differentially much higher than all other expenditures. In other words, unexpected grant shocks are not spent on capital outlays more than they are spent on anything else. Figures (8) and (9) in appendix A.4 show that both capital outlays and total expenditures go up after two years. Both of these estimates are statistically significant at 10% level.

Finally, we can see that borrowing goes up in the fifth year. This period is of significance because states have four years to obligate funds from a given year of grants. The increased borrowing may be needed to finish the work on the projects that were started in previous periods. Same effect is observed in per capita borrowing and in levels.

[Figure 1 about here.]

### 3.3.3 Heterogeneity of the Main Effects

I have established how states government finances respond to unanticipated grant shock, on average. However, states operate in different political and institutional environments that may affect their behavior. In this section, I present the role of balanced budget rules, budget stabilization rules, and states' political environment. Since it is advantageous to control for state and year fixed effects, I include interaction of these variables with the grant shocks. However, because of the large number of political and institutional indicators relative to the number of states, I include these interactions one at a time[16].

I discuss the important highlights of this analysis below[17] My most robust finding is that the U-shaped IRFs for maintenance share of total expenditure in the first six years are found almost across all of the specifications. Robustness of the shape of maintenance IRF implies that deferring maintenance expenditures is a result of technical characteristics of maintenance being an easy target, and states' lack of alternative tools for smoothing expenditures.

I find that the deferral of maintenance expenditures is slightly more pronounced for states that may not carry over a deficit to next fiscal year or require referendum debt approval for capital projects. The deferral of maintenance expenditure is slightly less pronounced when state government and legislature are of different parties. Other balanced budget rules are less stringent, and they do not differentially affect the dynamic response of maintenance expenditures. Both in governors' election year, house election years, and with political power divided within government, the U-shaped maintenance IRF is less pronounced.

The differential response of capital outlays to balanced budget rules and political environment interactions is more pronounced. In states with more stringent balanced budget rules, capital outlays have a negative response to unanticipated shocks while other expenditures absorb the positive shock. This is particularly true for states with higher ACIR balanced budget stringency index, and that may not carry over a deficit to next fiscal year. In states that require referendum debt approval for capital projects or have a larger budget stabilization fund, we observe the opposite effect. Similar to what I found with average effects in section 3.3.2, unanticipated shocks only result in substitution between different expenditures rather than an increase in total expenditure.

As I discuss, the capital outlay result with referendum debt approval requirement is expected. However, the fact that some states are reducing capital outlays in response to shocks is surprising. This may be due to differential trends in state funding for capital outlay and other highway expenditures in states with stringent balanced budget requirements for general budget.

***Balanced Budget Rules and Enforcement***

Figures (2) and (3) show the relationship between balance budget requirements and the dynamic response of maintenance expenditures and capital outlays to shocks, respectively. In these figures, the left graph is the differential response of states with balanced budget requirements while the right graph is the average response after controlling for the shock

[16]For example, if I include the interactions of all balanced budget indicators with the grant shocks, some of the coefficients are still precisely estimated. However, interpreting these coefficients would be equivalent to comparing the response of two or three states compared to others.

[17]The full set of IRFs after controlling for all different shock interactions is available upon request.

interaction term. Because 25% of state highways are funded by contribution from general budget, these balanced general budget requirements are relevant to state highway finances. Not being able to carry over deficit to the next fiscal year is the tightest of the constraints that govern general budget. On the other hand, referendum debt approval requirements directly regulate states borrowing for capital projects. These requirements are then expected to directly affect highway expenditures.

The left hand side graphs in figures (2a) and (2b) shows the differential response of maintenance expenditure in states with the general and capital budget restrictions mentioned above, respectively. The average maintenance response found earlier is robust and slightly more pronounced with this requirement. Although the confidence intervals of the interaction terms are wide, within-fiscal-year effects are larger for states with these requirements. Furthermore, both graphs suggest that states with these requirements compensate less for the initial responses. This effect is most pronounced for the fifth period after the shock in figure (2b).

[Figure 2 about here.]

show that this requirement is correlated with differential response of the outcomes share of total expenditure and per capita outcomes. However,

Figure (3a) show that states that may not carry over debt reduce capital outlays relative to highway expenditures when they receive a positive shock. Reducing capital expenditure to increase other highway expenditures in response to a positive shock is surprising. However, this may be the case that states with general budget constraints can more easily fund capital expenditures while they may rely on federal grants to fund current expenditures. Note that this would not be captured by state fixed effects because it only becomes active when states receive a grant shock. Another possible explanation is that states with credit constraints on general budget may be less flexible to commit to longer term investments required for capital projects. Spending the unanticipated funds on other expenditures solves this problem. Figure (10b) in appendix A.5 shows that in these states even per capita capital outlay go down with positive grant shocks while the per capita other highway expenditures go up. Again, this fact plus insignificant response of total expenditure highlights the possibility that states respond to unanticipated shocks by mostly reallocating their resources across different departments. In figure (11) in the appendix, we see the mirror images of the capital outlay and other expenditure IRFs of figures (10a) and (10b) with respect to the size of the budget stabilization fund. This is expected because both larger budget stabilization fund and less stringent balance budget requirements help government to absorb the shock more easily. Therefore, these results are consistent with each other.

[Figure 3 about here.]

However, figure (3b) show that with referendum debt approval requirements, capital outlays go up more rapidly than other highway expenditures. States that cannot fund capital projects through borrowing rely more heavily on highway grants to fund these projects. Therefore, when these states receive an unanticipated positive grant shock, they spend it on capital outlays. I observe opposite effects for per capita and expenditure shares of other

highway expenditures in figures (12a) and (12b) in appendix A.5. Again, this finding is consistent with lack of strong response in total highway expenditures.

***Political Indicators***

Finding that states' political environment affects their highway finance choices supports that the observed behavior is inefficient. For example, reducing maintenance expenditures in fiscal downturns may mean that quality of roads has a higher income elasticity[18] than new roads and policing. If this behavior is more pronounced in election years, we can conclude that income elasticity is not the only driver of government behavior because voters are highly unlikely to have different income elasticities in election years. In this section, I study if the dynamic effects are different in election years, when political power is split between legislature and governorship. Figures (4) and (5) show that in contrast to balanced budget requirements, the correlation of these political indicators are more strongly correlated with maintenance expenditures than they are with capital outlays.

Figure (4a) and (5a) show the differential effects when government receives a grant shock and house election is next year for maintenance and capital outlays, respectively. For example, in figure (4a), a differential positive effect in year four means that if the government received a positive shock four years ago and next year is house election year, the effect is differentially stronger. Also, the within-fiscal-year effects in this graph show that deferral of maintenance expenditures is driven by house elections. The graphs in figure (5a) do not present any capital outlay effects until five years after the shock. These zig-zag shape of these IRF in later years leads us to conclude the same no-effects for capital outlays.

Figure (13) in appendix A.5 shows that incumbent governors use their political power in election years. After controlling for election years when the state governor is not a lame duck[19], the shape of the maintenance IRF persist. However, in election years compensating for deferred maintenance expenditures is slightly less pronounced. Furthermore, the interaction of grant shocks with election years shows that if highway administration received a positive shock in period zero and horizons one to three are election years, borrowing increases more rapidly. Furthermore, we can see that states tend to increase capital outlays and decrease other expenditures. This feature is observable in the main effects in the earlier horizons and interaction effects in horizons two through eight. Therefore, the incumbent governors seem to find capital outlays more appealing to voters.

[Figure 4 about here.]

When state legislature and governorship are controlled by different political parties, using political power tends be more difficult. Figures (4b) and (5b) show the IRFs of maintenance and capital outlays as shares of total expenditure when the government is divided, respectively. We can observe the tendency to spend more of unanticipated grants on capital outlays rather than other highway expenditures. Furthermore, the U-shaped response of maintenance expenditure is clearly less pronounced when political power is divided within state government. However, we can see through the main effects of divided government that maintenance expenditures is smaller when government is divided (figure

[18] I am using the term income elasticity as if governments' revenues were an individual's income. Clearly, the voters have different preferences for quality of roads relative to other highway services.

[19] If governor is a lame duck, he or she is in the last possible term in office.

(14b)). Therefore, both the share of total expenditure and the dynamic response of highway outcomes are subject to political environment.

[Figure 5 about here.]

# 4 Deferring Maintenance Expenditures and Optimality

I show that governments use the deferral of maintenance expenditures in response to revenue shocks. In this section I investigate whether this behavior may be optimal by solving a simple economic model of government behavior. Defining preventative maintenance as the expenditure that only affects the depreciation rates in the future periods, deferring preventative maintenance can be regarded as purely financial transaction, similar to borrowing. For example, crack sealing the asphalt or painting the bridge foundations only affect the quality of the infrastructure in the future periods. This is because it is possible to do "critical" maintenance to make up for the deferred preventative maintenance. Efficacy of such deferral depends on how costly this transaction might be when compared to states' interest rates and consumers discount factor.

## 4.1 Basic Model

In my model, the benevolent government is maximizing a social welfare function. The objective function of this social welfare function could be viewed as that of a representative household. This represents a world where government serves a population of households which are identical[20].

$$E_t[\sum_{s=t}^{\infty} \beta^{s-t}\{x_s + U(K_s) + V(G_s)\}] \tag{7}$$

where government is optimizing at time $t$ for the periods $s = 0, 1, 2, ...$ . $\beta$ is the discount factor for consumers who consume private goods, $x_s$, services from public capital, $K_s$, and other public goods, $G_s$.

I focus on the intertemporal nature of the government side of the problem. Consumption smoothing and government expenditure have both been studied extensively in the literature, therefore inclusion of these details makes my model overly complicated without yielding any new results. To abstract from private consumption smoothing, I assume that instantaneous utility is quasilinear in $x_s$. Similarly, I assume that other government expenditures, $G_s$, are exogenously fixed for clearer equations. The latter assumption can be easily relaxed without loss of generality within the framework of this model.

The resource constraint of the government restricts its revenues plus debt to be less than its expenditures in each period.

$$I_s + M_s^c + M_s^p + G_s + rB_s = \tau_s + z_s + B_{s+1} - B_s \tag{8}$$

The government revenue, in each period, is $\tau_s + z_s$. Government sets taxes and fees to receive the revenue, $\tau_s$. However, the tax base is uncertain and the government may also

[20]This model extends the dynamic general equilibrium models of Barro (1979), Holtz-Eakin et al. (1994), and Buttner and Wildasin (2010). Therefore its solutions are comparable with that of those models.

receive grants. $z_s$, which represents this stochastic component of government revenue. The government can borrow , $B_s$, at the fixed interest rate $r$. However, its borrowing may be constrained by institutional and financial restrictions. On the expenditure side, the government can invest its resources to build new infrastructure, $I_s$, provide consumable goods, $G_s$, pay off debt, or maintain the existing infrastructure through critical or preventative maintenance expenditures, $M_s^c$ and $M_s^p$.

The stock of infrastructure evolves according to the following equation.

$$K_{s+1} = I_s + (1 - \delta(M_s^c, M_{s-1}^p, K_s))K_s \tag{9}$$

In this formulation, the rate of depreciation, $\delta(M_s^c, M_{s-1}^p, K_s)$, is a function of the critical maintenance and last period preventative maintenance expenditures in relationship to the stock of infrastructure.

The preventative maintenance is modeled to only affect the depreciation rate one period forward. While this simplification keeps the model tractable, the model still captures the substitutability of preventative and critical maintenance. Therefore, I can still capture the mechanism through which maintenance deferral savings work.

When modeling maintenance, we need the following conditions for the $\delta(M_s^c, M_{s-1}^p, K_s)$ function to be technically feasible.

1. $M_s \geq 0, \forall s$
2. $\delta(0, 0, .) = \delta_0$
3. $\frac{\partial \delta()}{\partial M_{s-1}^p} < 0$ and $\frac{\partial \delta()}{\partial M_s^c} < 0$
4. $\frac{\partial^2 \delta()}{\partial (M_s^c)^2} > 0$ and $\frac{\partial^2 \delta()}{\partial (M_{s-1}^p)^2} > 0$
5. $\lim_{M_{s-1}^p \to \infty} \delta(M_{s-1}^p) = 0$ and $\lim_{M_s^c \to \infty} \delta(M_s^p) = 0$

Conditions (1) and (2) guarantee that maintenance expenditure is non-negative, and without any maintenance condition existing infrastructure depreciates at the rate $\delta_0$. Condition (3) means that more maintenance will result in lower depreciation rate. Condition (4) is twofold and captures the technological structure of maintenance and the optimizing behavior of the government. On the technological side, the government does not have access to infinite maintenance opportunities with high yields. On the behavioral side, it is assumed that the government will spend the first dollar of maintenance expenditure on the most productive maintenance project, which is the project that will reduce the depreciation rate the most. Therefore, the next project always has a lower yield. Condition (5) insures that the maintenance expenditure is not capital improving, which is true by definition of maintenance.

It is widely known that government taxation is associated with dead weight loss. As $\tau_s$ denotes taxation, let $h(\tau_s)$ be the function that denotes the dead-weight loss of taxation. In this setting, if taxes on consumer income are $\tau_s$, their after tax income is $Y_s^\tau = Y_s - \tau_s - h(\tau_s)$.

### 4.2 Solution to the Model

To clarify the role of maintenance deferral in the government's optimization problem, I derive the first order conditions of the government's problem and discuss the Euler equations. The conditions can be compared with those of Barro (1979) (no borrowing constraints), and Buttner and Wildasin (2010) (constrained borrowing with endogenous capital). I show that the deferral of maintenance expenditures may play the same role as borrowing.

I first write the following Lagrangian by substituting for $I_s$ in (9) from (8).

$$\begin{aligned}\mathcal{L} = E_t[\sum_{s=t}^{\infty} \beta^{s-t}\{Y_s - \tau_s - h(\tau_s) + U(K_s) + V(G_s)\} \\ + \beta^{s-t+1}\lambda_{s+1}\{B_{s+1} - (1+r)B_s + (1-\delta(M_s^c, M_{s-1}^p, K_s))K_s - K_{s+1} \\ - (G_s + M_s^p + M_s^c - \tau_s - z_s)\}]\end{aligned} \tag{10}$$

Using the first order conditions in appendix A.6, it is straightforward to derive the following Euler equations for taxes, infrastructure, borrowing, and maintenance expenditures.

$$t : \frac{E_t[1+h'(\tau_{s+1})]}{E_t[1+h'(\tau_s)]} = \frac{E_t[\lambda_{s+2}]}{E_t[\lambda_{s+1}]}] \tag{11}$$

$$K : \frac{E_t[U'(K_{s+1})]}{E_t[U'(K_s)]} = \frac{E_t[\lambda_{s+1}] - \beta E_t[\lambda_{s+2}\{(1-\delta(M_{s+1}^c, M_s^p, K_{s+1})) - \frac{\partial\delta(.,.,K_{s+1})}{\partial K_{s+1}}K_{s+1}\}]}{E_t[\lambda_s] - \beta E_t[\lambda_{s+1}\{(1-\delta(M_s^c, M_{s-1}^p, K_s)) - \frac{\partial\delta(.,.,K_s)}{\partial K_s}K_s\}]]} \tag{12}$$

$$B : \frac{E_t[\lambda_{s+1}]}{E_t[\lambda_{s+2}]} = \beta(1+r) \tag{13}$$

$$M^p : \frac{E_t[\lambda_{s+2}]}{E_t[\lambda_{s+1}]} = \frac{E_t[\lambda_{s+3}\frac{\partial\delta(M_{s+2}^c, M_{s+1}^p, K_{s+2})}{\partial M_{s+1}^p}K_{s+2}]}{E_t[\lambda_{s+2}\frac{\partial\delta(M_{s+1}^c, M_s^p, K_{s+1})}{\partial M_s^p}K_{s+1}]} \tag{14}$$

$$M^c : \frac{E_t[\lambda_{s+2}]}{E_t[\lambda_{s+1}]} = \frac{E_t[\lambda_{s+2}\frac{\partial\delta(M_{s+1}^c, M_s^p, K_{s+1})}{\partial M_{s+1}^c}K_{s+1}]}{E_t[\lambda_{s+1}\frac{\partial\delta(M_s^c, M_{s-1}^p, K_s)}{\partial M_s^c}K_s]} \tag{15}$$

where $\delta(.,.,K_{s+1})$ is $\delta(M_{s+1}^c, M_s^p, K_{s+1})$. Using equations (21) and (22), I can write

$$\frac{E_t[\lambda_{s+2}]}{E_t[\lambda_{s+1}]} = \frac{E_t[\lambda_{s+2}\frac{\partial\delta(M_{s+1}^c, M_s^p, K_{s+1})}{\partial M_{s+1}^c}K_{s+1}]}{\beta E_t[\lambda_{s+2}\frac{\partial\delta(M_{s+1}^c, M_s^p, K_{s+1})}{\partial M_s^p}K_{s+1}]} \tag{16}$$

The familiar equation (13) shows that in the equilibrium the relative shadow value of funds equals $\beta(1+r)$ which is typically assumed to equal one. When we consider a maintenance technology through which the government can transfer funds over time, equation (16) represents a different relationship between shadow price of funds in two periods. Specifically, preventative and critical maintenance expenditures are done in such a way that the relative

value funds equal the relative responsiveness of depreciation to the two types of maintenance.

With no borrowing constrains, optimal taxes are constant over time. Furthermore, when $\delta() = \bar{\delta}$ is constant, optimal infrastructure will also be constant over time[21].

### 4.3 Log Linearization

To derive more specific equations, let me use the following quadratic approximations.

$$U(K_s) = \eta(K_s - \frac{1}{2}K_s^2)$$
$$h(\tau_s) = \frac{h}{2}\tau_s^2$$

Furthermore, let us assume that the depreciation function has the following functional form:

$$\delta(M_s^c, M_{s-1}^p, K_s) = \bar{\delta}e^{-\gamma_c \frac{M_s^c}{K_s} - \gamma_p \frac{M_{s-1}^p}{K_s}}$$

This functional form satisfies the feasibility conditions described earlier. Using this specific functional form for the depreciation, I can rewrite equation (16) to show

$$\frac{E_t[\lambda_{s+1}]}{E_t[\lambda_{s+2}]} = \frac{\beta\gamma_p}{\gamma_c} \tag{17}$$

Suppose that the governments' borrowing is constrained. That is $B_{s+1} \leq \bar{B}$. If $\frac{\beta\gamma_p}{\gamma_c} = 1$, it is optimal for the government to be on the same taxation and investment paths that it would have been in the non-constrained borrowing case with $\beta(1+r) = 1$. This is the case where the present value of returns to preventative maintenance equals the return to critical maintenance.

On the other hand, if $\frac{\beta\gamma_p}{\gamma_c} > 1$, the present value of returns to preventative maintenance is larger than critical maintenance. So, saving through the deferral of maintenance expenditures is more costly than is suggested by the consumers' discount factor. Therefore, in the optimum, it is always better to do preventative maintenance. Consequently, in the optimum, the shadow value of funds in the earlier periods is larger than those in the later periods. This case is the counterpart of the situation where government is facing very high interest rates or when borrowing is capped.

The solution to the constrained borrowing problem is provided by Buttner and Wildasin (2010), and it applies here. They solve the optimal taxation and capital outlays with credit constraints where shadow value of funds is larger in earlier periods. They first show that taxes are going to be decreasing over time. That is, the government optimally saves money in earlier periods and spend them later. Next, they show that for any initial conditions, taxes are going to be higher and investments lower than the case with no credit constraints. And finally, they show that in the presence of borrowing restrictions, current investment expenditures move together with income shocks. The resulting movements in the capital stock adjustments are expected to be partially reversed in the following period.

[21] See Buttner and Wildasin (2010) for a detailed explanation.

### 4.4 Theory in Application

As discussed in section 3.3.2, even when year to year cost of deferring maintenance expenditure is only 5% on average, current behavior of the state government is costly. Maintaining the ad hoc 5% assumption, the model suggests that if all of the maintenance expenditures deferred are preventative expenditures, and state governments are facing interest rates that are higher than 5%, this behavior is optimal. However, the government should compensate for the deferred maintenance expenditure in later periods.

One limitation of state highway maintenance data is that it does not differentiate between preventative and critical maintenance. Furthermore, there are no reliable estimates of cost of deferring maintenance[22]. The latter plays a more important role in assessing the efficacy of government behavior, while it is possible to calibrate the former at different values. One possibility for estimating cost of deferring maintenance is to use road level data on state highway administration expenditures[23]. This is an avenue that I will pursue in later editions of this project.

However, note that constant returns to maintenance is not a realistic assumption. That is, $\gamma_p$ and $\gamma_c$ are more likely to be functions of available maintenance projects. In practice, governments are dealing with individual units of infrastructure with varying $\frac{\beta\gamma_p}{\gamma_c}$ ratios. It is only optimal for the government to differ maintenance of project $i$, when $\frac{\beta\gamma_p^i}{\gamma_c^i} \leq 1$. In this sense, deferring maintenance expenditures, presents the government with a secondary source of borrowing which is itself constrained. Ideally, we would use the distribution of $\frac{\beta\gamma_p^i}{\gamma_c^i}$ to determine to what extent the deferral of maintenance expenditures will still be efficient.

## 5 Conclusions

This papers studies the dynamic response of different highway expenditures and borrowing to unanticipated federal grant shocks. Because the distribution of federal grants follow formulary apportionments that use three years old formula factors, I am able to construct grant shocks that are unrelated to current economics conditions and highway needs. I use these shocks to study the within-fiscal-year and dynamic response of maintenance, capital outlay, borrowing, and other highway expenditures.

Within-fiscal-year effects show that maintenance expenditures go down with a negative grant shock. Furthermore, the U-shaped impulse response functions for maintenance expenditure show that governments defer these expenditures when they receive unanticipated revenue shocks. This behavior does not seem to be mainly driven by balanced budget rules. However, in states with Referendum Debt Approval requirements maintenance expenditures respond more strongly to the grant shocks. Given that the U-shaped IRFs for maintenance are robust in different specifications, the deferral of maintenance expenditures are likely to be the result of maintenance expenditures being easy to adjust. However, maintenance expenditure is less responsive to unanticipated shocks in governors' election year and when

[22] Civil engineering reports suggest very large costs of deferral. However, these reports only refer to specific cases. To make an assessment of the behavior of state governments we need some figures that describe the whole distribution of the deferral costs.

[23] I have obtained this dataset for state of New York.

governorship and legislature are form different political parties. The within-fiscal-year part of this result are comparable to the findings of Borge and Hopland (2015) the effect on political fragmentation. However, I find the opposite of their finding. Even considering that in later periods governments compensate for the within-fiscal-year response to a lesser extent in divided governments, this is a good outcome because the deferral of expenditures is less severe. Furthermore, house election years drive state governments to respond more strongly to the shocks. These findings indicate that accumulation of maintenance needs cannot solely be explained by preferences of the voters.

On average, state capital outlays only respond positively to the shocks in later years. However, I find that some states respond to grant shocks by decreasing capital outlays and increasing other current highway expenditures. Since these are the states that face stricter restrictions to balance general budgets, one possible explanation is that current expenditures may tend to be underfunded in these states. Therefore, when they receive an unanticipated shock, they spend it on current expenditures. I also find that capital outlays are more appealing than current expenditures in incumbent governors' election year, and in divided governments.

Based on my findings, there are two areas of future research. First, I find that the unanticipated shocks mostly affect composition of expenditures rather that increasing total expenditures. This effect may be due to limited flexibility of state highway administrations to adjust their workforce or other resources. On the other hand, it is possible that state government expenditures crowd out local expenditures. This is one area of potential future research.

Second, I identify the important parameters that are necessary to determine the efficacy of maintenance deferral in my theoretical model. We would need to know whether it is preventative or critical maintenance that is getting postponed. Also, we would need the cost distribution of deferring maintenance preventative maintenance. Both of these questions can be answered using road level data that include both maintenance expenditures and road conditions. Such a dataset is potentially accessible to highway administrations, so future research can shed light on efficacy of governments' behavior.

Finally, the main policy suggestion of this paper is to regulate highway expenditures. This is especially true if state governments are deferring preventative maintenance. The deferral of maintenance expenditure is likely to be more costly than accumulation of debt, or cutting pension contributions. and this paper highlights that state governments engage in maintenance deferral. Therefore, there need to be institutions that regulate expenditure of maintenance expenditures alongside those that regulate accumulation of debt. Voters are indeed concerned about this. For example, in a very recent ballot in the state of Illinois the proposed amendment blocks lawmakers from using transportation funds for anything other than their stated purpose. Therefore, another possibility is more transparent data practices that enables both media and the researchers to properly inform the public, making the preventative maintenance expenditures more salient.

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# A Appendix

## A.1 Replicating Leduc and Wilson (2013) and FHWA(2005)

Leduc and Wilson (2013) give a detailed description of how they construct their shock measure in their online appendix. After testing a few alternatives, I was able to replicate their graphs using the same methodology[24][25].

I can closely replicate the 2009 forecasts of FHWA as of 2005. FHWA has published these forecasts in the attachments to Young (2005). In figure (6), I compare my forecasts with those, which shows that my methodology is very close to that of FHWA. Further reassuring is that this graph is almost identical to that of Leduc and Wilson (2013) (Fig. 1 in their paper.)

[Figure 6 about here.]

Next, I present the time series of the grant shocks and forecast errors for the four states of California, New York, Rhode Island, and South Dakota. Both panels of figure (7) show that the shocks can considerably large, and state size or population are not good predictors of shock size or volatility. Comparing these graphs with those of Leduc and Wilson (2013), it is possible to verify that I am closely replicating their measures.

Furthermore, figure (7) shows that there are large shocks in the first years of highway bills (1998, 2005 and post 2009 years). There are also some large shocks in other years, such as 1996 and 2004. However, as discussed in the paper, the shocks that affect all states are not my source of identification because I control for year effects.

[Figure 7 about here.]

## A.2 Balanced Budget Rules

"Five different balanced-budget constraints are listed. The first, and perhaps the weakest of the limitations, only requires the governor to submit a balanced budget at the start of budget deliberations. The second constraint requires the state legislature to pass a balanced budget. Importantly, neither of these two prospective constraints alone imposes any fiscal discipline at the end of the fiscal year. Therefore, states with just these prospective constraints - Illinois, Louisiana, Massachusetts, New Hampshire, New York, and Nevada - are legally allowed to run deficits at the end of a fiscal year.

[24] In addition to the assumptions described by Leduc and Wilson (2013), the treatment of stop-gap years is important. For the years following the stop gap year, I have assumed that nationwide apportionments by program grow at the expected inflation rate based on actual apportionments of that year. The same assumption is made for years beyond 2009, until MAP-21 is passed.

[25] Reallocation of minimum guarantee payments for years before 2007, is another detail that I experimented with in implementing their methodology. The issue arises because starting in 2007, FHWA statistics include the minimum guarantee payments of major programs in that programs allocated funds. To make the data consistent over time, one needs to make a similar adjustment for the years prior to 2007. I reallocate the "Equity Bonus" or Minimum Guarantee according to each programs share of total for that state. I repeat the same for the future periods based on each programs expected share of expected total grants.

States facing the third constraint are allowed to run a deficit at the end of the year, but they are required to explicitly budget for that deficit in the next fiscal year. These states may carry-over a deficit from one year to the next. For example, if Connecticut runs a deficit, then the governor and the legislature must include funds to repay that deficit when they submit and then pass their prospective budget for the next fiscal year. Importantly, however, this constraint never requires the deficit to be actually eliminated. States with this "may carry-over" constraint and prospective budget balance rules- Alaska, California, Connecticut, Maryland, Michigan, Pennsylvania, and Wisconsin - can simply roll their deficits into next fiscal years indefinitely. Here again, there is no effective end-of-the-year fiscal balance requirement.

An effective end-of-the-year balance requirement occurs only in those states which cannot carry-over a deficit from one budget period to the next. In these states, having a C or an S in columns 4 and 5 of table 4, deficits materializing during the budget period must be reduced to zero by the end of the period. This may be accomplished by raising taxes, by collecting additional federal aid, by cutting spending, or by some combination of these fiscal options. Fiscal gimmicks also known as "adjustments" - for example, collecting next fiscal year's taxes or grants early or postponing payment for services into the next fiscal year- may also be used to balance the budget. The aggregate amount of dollars actually available to the state through these bookkeeping gimmicks appears to be limited, however; see U.S. GAO (1993). Rather, real spending and tax adjustments are used to close a deficit gap in the no-carry-over states. If a deficit does remain at the end of a fiscal year after all spending and revenue adjustments are made, it must be carried into the next fiscal year where it again faces the end-of-the-year no-deficit constraint.

States with biennial budget periods may impose the no-carry-over constraint on either a yearly or on a biennial basis; see column 4, table 4. States with a budget period of only one year must meet the no-carry-over constraint within that single fiscal year; see column 5, table 4. Enforcement of these balanced-budget rules is by the state's courts, with the state supreme court the ultimate arbiter. If the state supreme court is appointed by the governor or by the state legislature (i.e., by those accountable for the deficit), it is possible that enforcement of balanced-budget rules will be less strenuous. Appointed supreme courts may behave more like a government agency than a truly independent monitor of fiscal performance.

Independently elected supreme courts, on the other hand, are free of direct gubernatorial or legislative influences and therefore hypothesized to be tougher monitors of fiscal policy. We shall test this proposition in Section 5 below. Table 4, column 6, indicates whether the state supreme court is appointed or elected. The balanced-budget rules listed in table 4 only apply to the general fund account of the state budgets, but states perform fiscal activities through a variety of other accounts as well. In addition to the general fund account, states have capital budgets and bond fund accounts to receive and allocate capital borrowings, sinking fund accounts to collect funds for debt repayments, public employee pension fund accounts to save and disburse funds for employee retirements, insurance trust accounts to save and disburse funds for disability and workmen's compensation, and "rainy-day" fund accounts to save general fund surpluses and to cushion general fund deficits. Each of these accounts is legally entitled to receive funds from the general fund and to allocate funds to the general fund. Constraints on these funds may therefore have implications for the

general fund deficit. We shall test the additional effects of one of these constraints on the general fund deficit: the inability of states to borrow through general obligation long-term debt without prior referendum approval of the voters, ff this constraint is binding, then capital projects must be financed either through (revenue) bonds which do not face the referendum constraint or through a surplus transfer from the general fund account to the capital account. States with a referendum borrowing constraint on the use of long-term general obligation debt are listed in Table 2, column 7.

Peltzman's (1992) argument that voters are fiscal conservatives and hold governors responsible for marginal expansions of state budgets suggests that governors seeking re-election should seek to control spending and taxes. If voters recognize that state deficits represent future taxes, then deficits should be controlled, too. One potential weapon in a governor's budget arsenal is the line-item veto. If this veto is an effective instrument for a fiscally conservative governor, then governors with the item veto are likely to have smaller deficits - particularly in states with no-carry-over rules - than governors without an item veto. In his study of the item veto, Holtz-Eakin (1988) finds that when government power is divided between two parties - one controlling the executive and the other the legislature - the item veto does help governors reduce spending and raise taxes. The item veto may be a useful tool for controlling general fund deficits as well. We shall test this proposition directly. States whose governor can use an item veto are listed in Table 2, column 8."[26]

[26]Bohn and Inman (1996)

Table 4: Budget Rules and Enforcement

| State Abbreviation | (1) Gov. Submits Balanced Budget | (2) Leg. Passes Balanced Budget | (3) May Carry Over A Deficit | (4) May Not Carry Over Into Next Biennium | (5) May Not Carry Over Into Next Fiscal Year | (6) ACIR Stringency Index | (7) Elected State Supreme Court | (8) Referendum Debt Approval | (9) Gov. Has Item Veto |
|---|---|---|---|---|---|---|---|---|---|
| AL | - | - | - | - | C | 10 | E | R | IV |
| AK | S | - | C | - | - | 6 | A | R | IV |
| AZ | - | - | - | - | C | 10 | A | R | IV |
| AR | - | - | - | - | S | 9 | E | NR | IV |
| CA | C | - | C | - | - | 6 | E | R | IV |
| CO | - | - | - | - | C | 10 | A | R | IV |
| CT | S | S | S | - | - | 5 | A | NR | IV |
| DE | - | - | - | - | C | 10 | A | NR | IV |
| FL | - | - | - | - | C | 10 | A | NR | IV |
| GA | - | - | - | - | C | 10 | E | R | IV |
| HI | C | - | - | C | C | 10 | A | NR | IV |
| ID | - | - | - | - | C | 10 | E | R | IV |
| IL | C | C | - | - | - | 4 | E | NR | IV |
| IN | - | - | - | - | C | 10 | A | R | NIV |
| IA | - | - | - | - | C | 10 | A | R | IV |
| KS | - | - | - | - | C | 10 | A | R | IV |
| KY | - | - | - | C | S | 10 | E | R | IV |
| LA | - | C | - | - | - | 4 | E | NR | IV |
| ME | - | - | - | - | S | 9 | A | R | NIV |
| MD | C | C | C | - | - | 6 | A | NR | IV |
| MA | C | - | - | - | - | 3 | A | NR | IV |
| MI | - | - | C | - | - | 6 | E | NR | IV |
| MN | - | - | - | C | - | 8 | E | R | IV |
| MS | - | - | - | - | S | 9 | E | R | IV |
| MO | - | - | - | - | C | 10 | A | R | IV |
| MT | - | C | - | C | C | 10 | E | NR | IV |
| NE | - | - | - | - | C | 10 | A | R | IV |
| NV | S | C | - | - | - | 4 | E | NR | NIV |
| NH | S | - | - | - | - | 2 | A | NR | NIV |
| NJ | - | - | - | - | C | 10 | A | R | IV |
| NM | - | - | - | - | C | 10 | E | R | IV |
| NY | C | - | - | - | - | 3 | A | NR | IV |
| NC | - | - | - | - | C | 10 | E | NR | NIV |
| ND | - | - | - | C | - | 8 | E | R | IV |
| OH | - | - | - | - | C | 10 | E | R | IV |
| OK | - | - | - | - | C | 10 | E | NR | IV |
| OR | - | - | - | C | - | 8 | E | R | IV |
| PA | C | S | C | - | - | 6 | E | NR | IV |
| RI | - | - | - | - | C | 10 | A | R | NIV |
| SC | - | - | C | - | C | 10 | A | R | IV |
| SD | - | - | - | - | C | 10 | E | R | IV |
| TN | - | - | C | - | C | 10 | E | NR | IV |
| TX | - | C | - | C | - | 8 | E | R | IV |
| UT | - | - | - | - | C | 10 | A | R | IV |
| VT | - | - | - | - | - | 0 | A | NR | NIV |
| VA | - | - | - | C | - | 8 | A | R | IV |
| WA | - | - | - | C | - | 8 | E | R | IV |
| WV | - | - | - | - | C | 10 | E | R | IV |
| WI | - | - | C | - | - | 6 | E | R | IV |
| WY | - | - | - | C | - | 8 | A | R | IV |

Columns 1-5: S=Statutory Regulation, C=Constitutional Regulation.
Column 7: E=Elected by the Voters, A= Appointed by Governor or Legislature.
Column 8: R= Referendum Required for Debt Approval, NR= Referendum not Required.
Column 9: IV= Governor has Item Veto, NIV= Governor Does Not Have Item Veto.

Source: ACIR(1987)

## A.3 Robustness Checks for within-fiscal-year effects

Table 5: Robustness Check I: Response of different outcomes to concurrent grant shocks with state specific trends and lags of GDP and total expenditure

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Borro. | Cap. Out | Maint. | Other | Total Disb. | Gas Tax |
| Normalization | Level | Level | Level | Level | Level | |
| Shock | 1779.664 | 0.079 | 0.228*** | -0.096** | 0.052 | |
| | (1205.955) | (0.062) | (0.082) | (0.048) | (0.037) | |
| Normalization | Per Cap. | Per Cap. | Per Cap. | Per Cap. | Per Cap. | |
| Shock | 0.370** | 0.076 | 0.225*** | -0.099** | 0.048 | |
| | (0.151) | (0.060) | (0.080) | (0.049) | (0.035) | |
| Normalization | Tot Exp Share | Tot Exp Share | Tot Exp Share | Tot Exp Share | | Level |
| Shock | 0.048** | 0.014 | 0.170*** | -0.147*** | | 0.006 |
| | (0.023) | (0.037) | (0.056) | (0.053) | | (0.022) |
| Fixed Effects | State,Year, s-trends | State,Year, s-trends | State,Year, s-trends | State,Year, s-trends | | State,Year, s-trends |

Standard errors in parentheses, clustered over state. Significance levels: * 10 percent, ** 5 percent, *** 1 percent.

Table 6: Response of different outcomes to shock in the current period

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Borro. (state) | Cap. Out (state) | Maint. (state) | Other (state) | Total Disb. (state) | Grants to Local (state) |
| Normalization | Level | Level | Level | Level | Level | |
| Shock | 1041.938 | 0.042 | 0.114*** | -0.180*** | -0.017 | |
| | (884.960) | (0.046) | (0.042) | (0.064) | (0.034) | |
| Normalization | Per Cap. | Per Cap. | Per Cap. | Per Cap. | Per Cap. | |
| Shock | -0.025 | -0.073 | 0.114*** | -0.181*** | -0.020 | |
| | (0.347) | (0.125) | (0.043) | (0.064) | (0.035) | |
| Normalization | Tot Exp Share | Tot Exp Share | Tot Exp Share | Tot Exp Share | | Tot Exp Share |
| Shock | 0.007 | -0.037 | 0.126*** | -0.169*** | | 0.043 |
| | (0.048) | (0.101) | (0.045) | (0.054) | | (0.318) |
| Fixed Effects | State,Year, s-trends | State,Year, s-trends | State,Year, s-trends | State,Year, s-trends | | State,Year, s-trends |

Standard errors in parentheses, clustered over state. Significance levels: * 10 percent, ** 5 percent, *** 1 percent.

## A.4 Impulse Response Functions for Levels and Per Capita Outcomes

[Figure 8 about here.]

[Figure 9 about here.]

## A.5 Study of Heterogeneity in IRFs

### A.5.1 Balanced Budget Requirements

[Figure 10 about here.]

[Figure 11 about here.]

[Figure 12 about here.]

### A.5.2 State Politics

[Figure 13 about here.]

[Figure 14 about here.]

## A.6 First Order Conditions

The first order conditions of the model are accordingly

$$\frac{\partial \mathcal{L}}{\partial \tau_s} = -E_t[1 + h'(\tau_s)] + \beta E_t[\lambda_{s+1}] = 0 \tag{18}$$

$$\begin{aligned}\frac{\partial \mathcal{L}}{\partial K_{s+1}} &= E_t[U'(K_{s+1})] - E_t[\lambda_{s+1}] \\ &\quad + \beta E_t[\lambda_{s+2}\{(1 - \delta(M^c_{s+1}, M^p_s, K_{s+1})) - \frac{\partial \delta(M^c_{s+1}, M^p_s, K_{s+1})}{\partial K_{s+1}} K_{s+1}\}] = 0\end{aligned} \tag{19}$$

$$\frac{\partial \mathcal{L}}{\partial B_{s+1}} = E_t[\lambda_{s+1}] - \beta(1 + r)E_t[\lambda_{s+2}] = 0 \tag{20}$$

$$\frac{\partial \mathcal{L}}{\partial M^p_s} = E_t[\lambda_{s+1}] - \beta E_t[\lambda_{s+2} \frac{\partial \delta(M^c_{s+1}, M^p_s, K_{s+1})}{\partial M^p_s} K_{s+1}] = 0 \tag{21}$$

$$\frac{\partial \mathcal{L}}{\partial M^c_s} = E_t[\lambda_{s+1}(1 + \frac{\partial \delta(M^c_s, M^p_{s-1}, K_s)}{\partial M^c_s} K_s)] = 0 \tag{22}$$

These conditions are used to derive the Euler equations.

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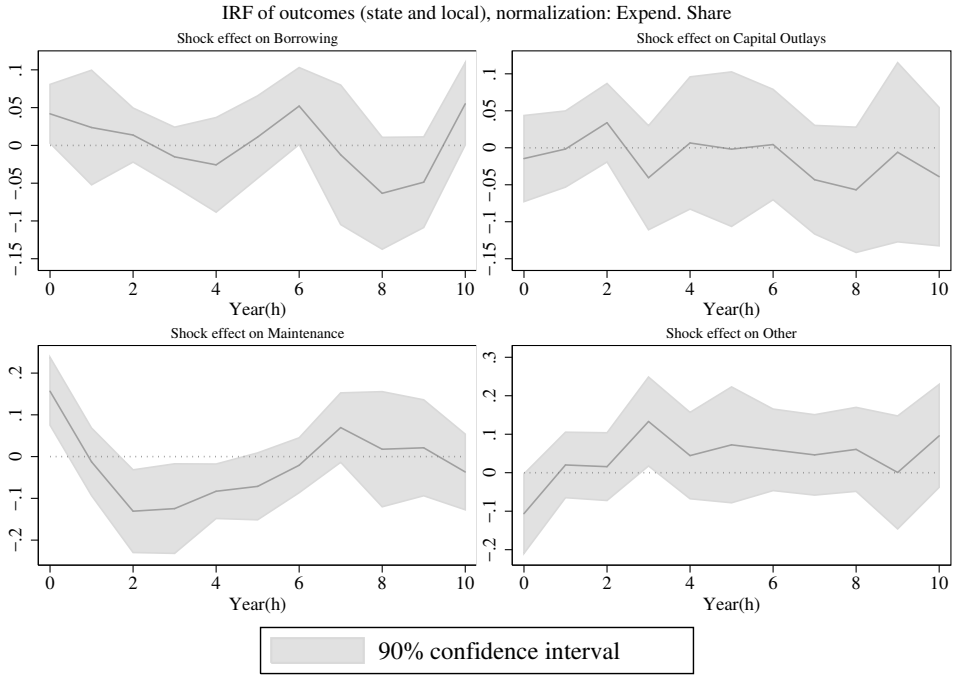
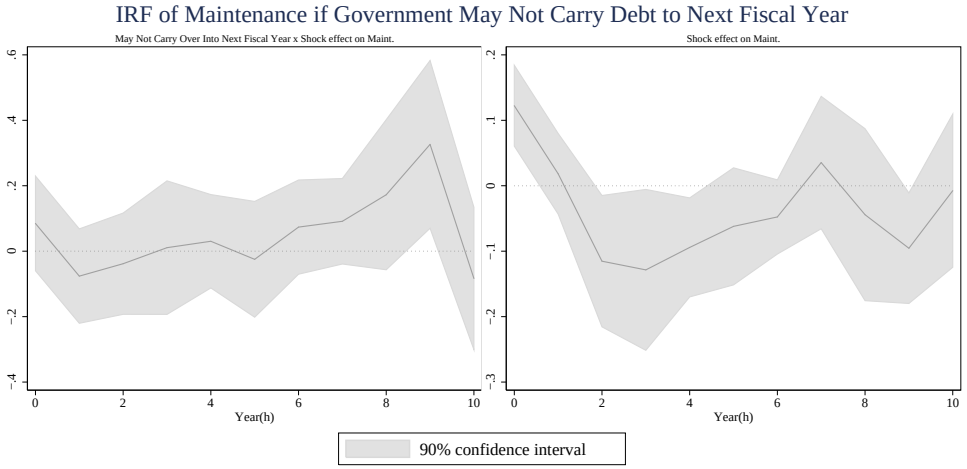
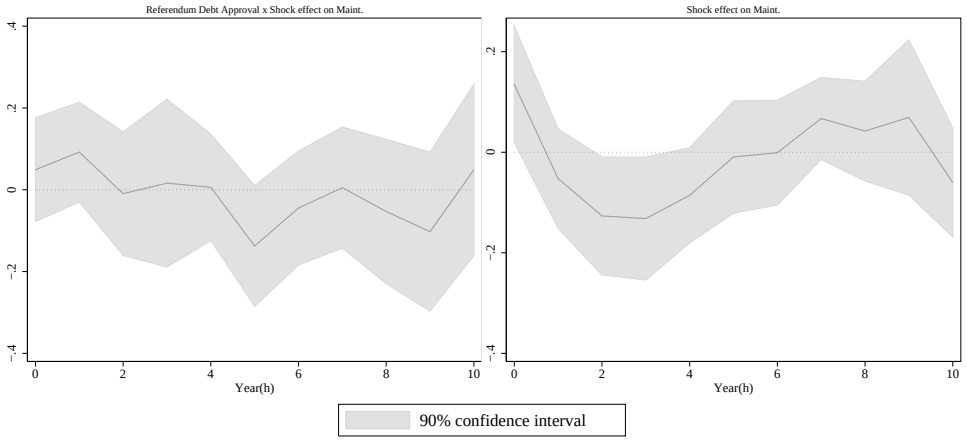



Figure 1: Impulse Response Functions for different outcomes relative to total expenditure.

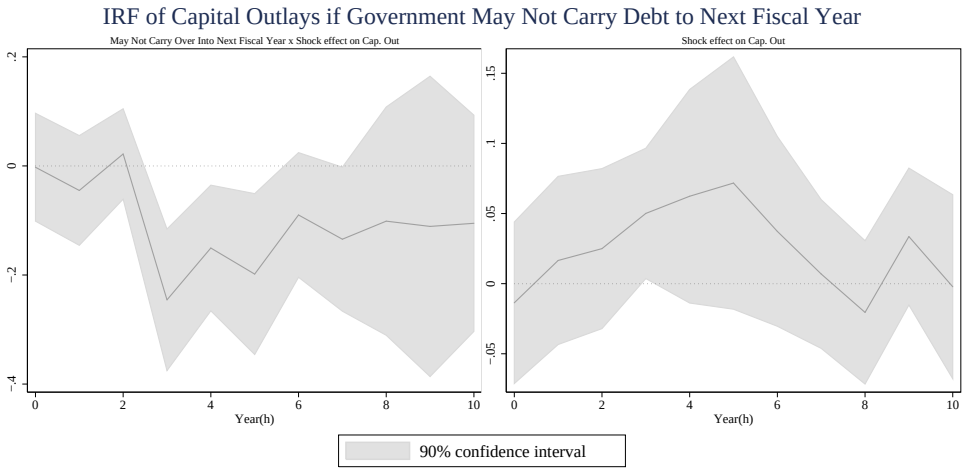



(a) IRF of Maintenance Expenditure with May Not Carry Over Debt to Next Fiscal Year Requirement

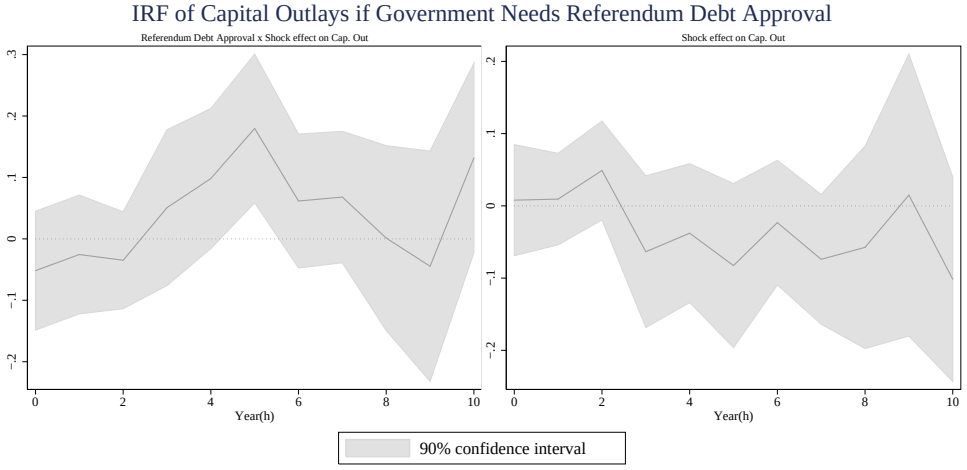



(b) IRF of Maintenance Expenditure with Referendum Debt Approval Requirement

Figure 2: IRF of Maintenance with Capital and General Budget Borrowing Restrictions

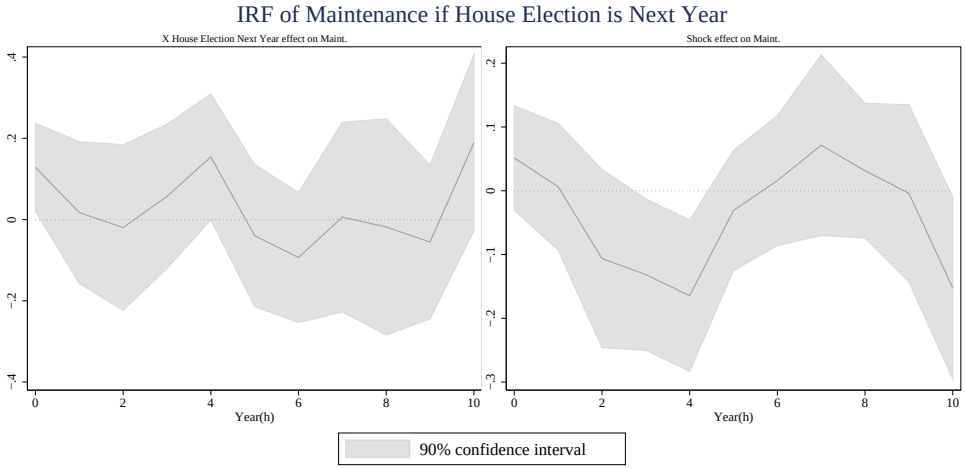



(a) IRF of Capital Outlays Expenditure with May Not Carry Over Debt to Next Fiscal Year Requirement

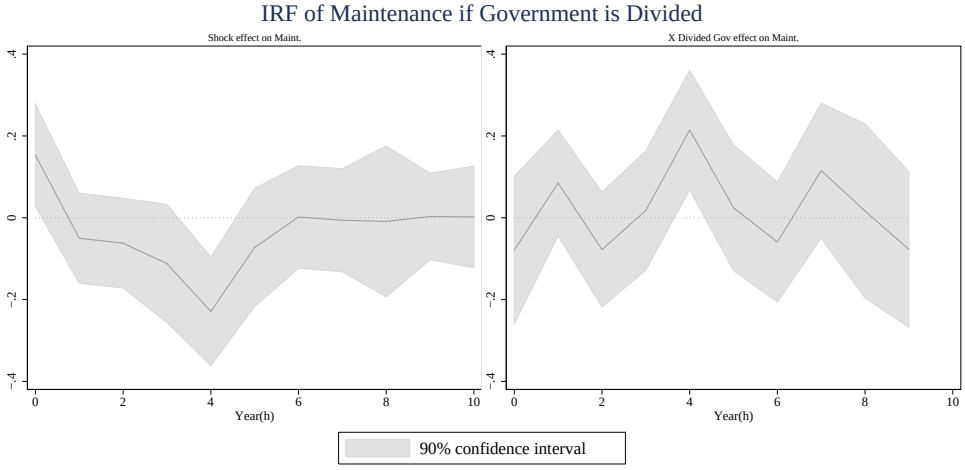



(b) IRF of Capital Outlays with Referendum Debt Approval Requirement

Figure 3: IRF of Capital Outlays with Capital and General Budget Borrowing Restrictions

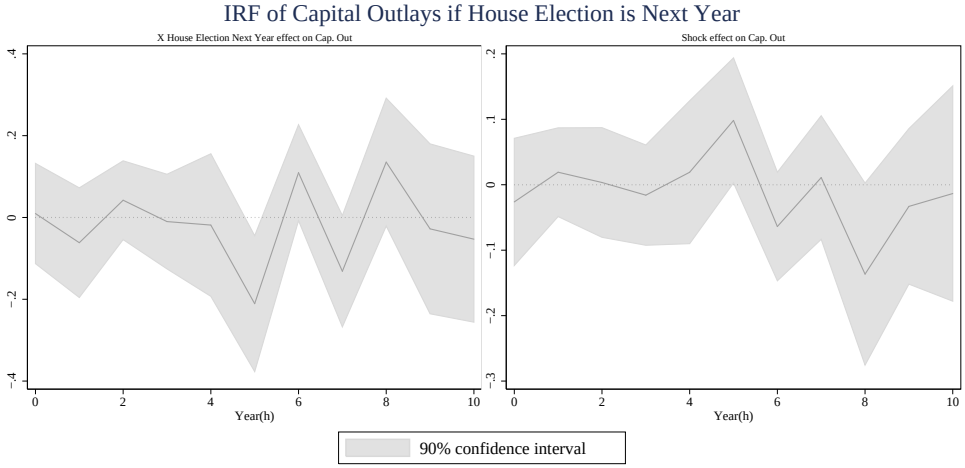



(a) IRF of Maintenance if the House Election is Next Year

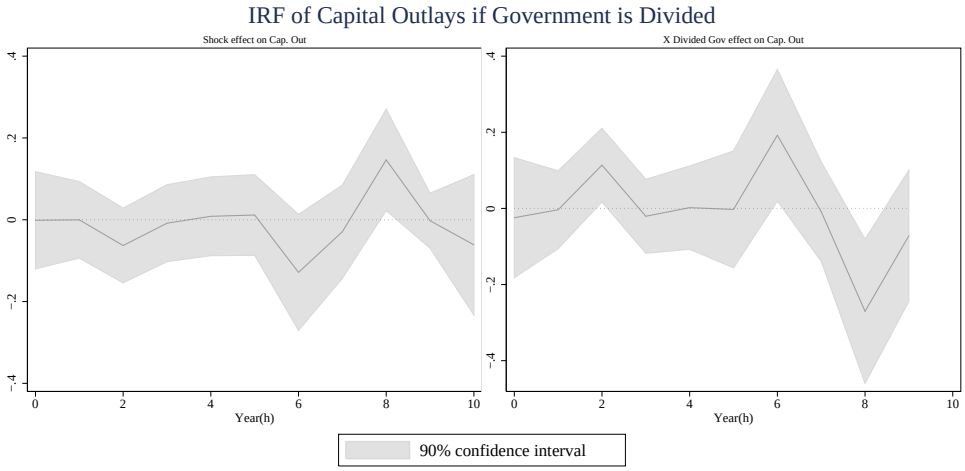



(b) IRF of Maintenance with the Divided Government Interaction

Figure 4: IRF of Maintenance with Political Indicator Interactions




(a) IRF of Capital Outlays if the House Election is Next Year




(b) IRF of Capital Outlays with the Divided Government Interaction

Figure 5: IRF of Capital Outlays with Political Indicator Interactions

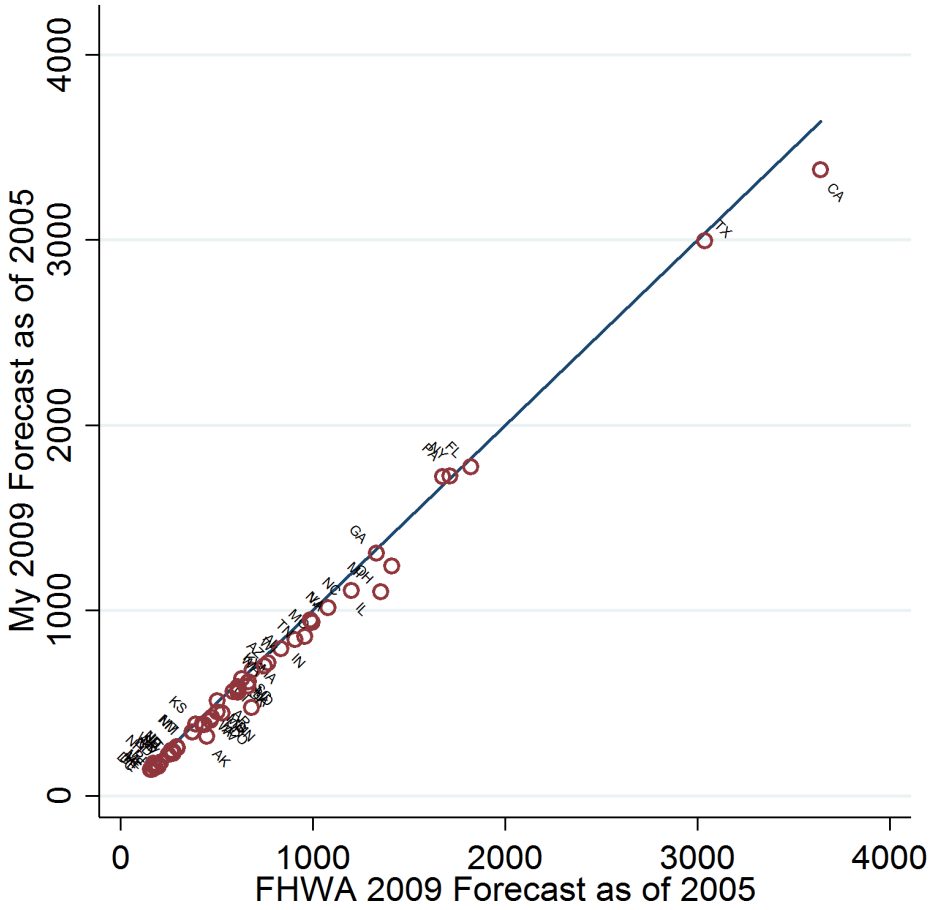
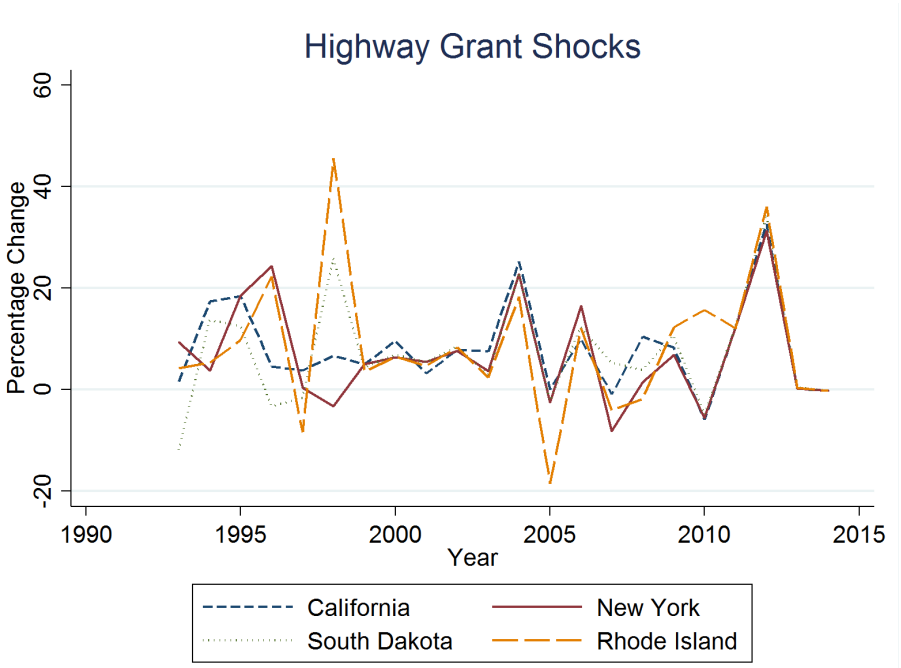
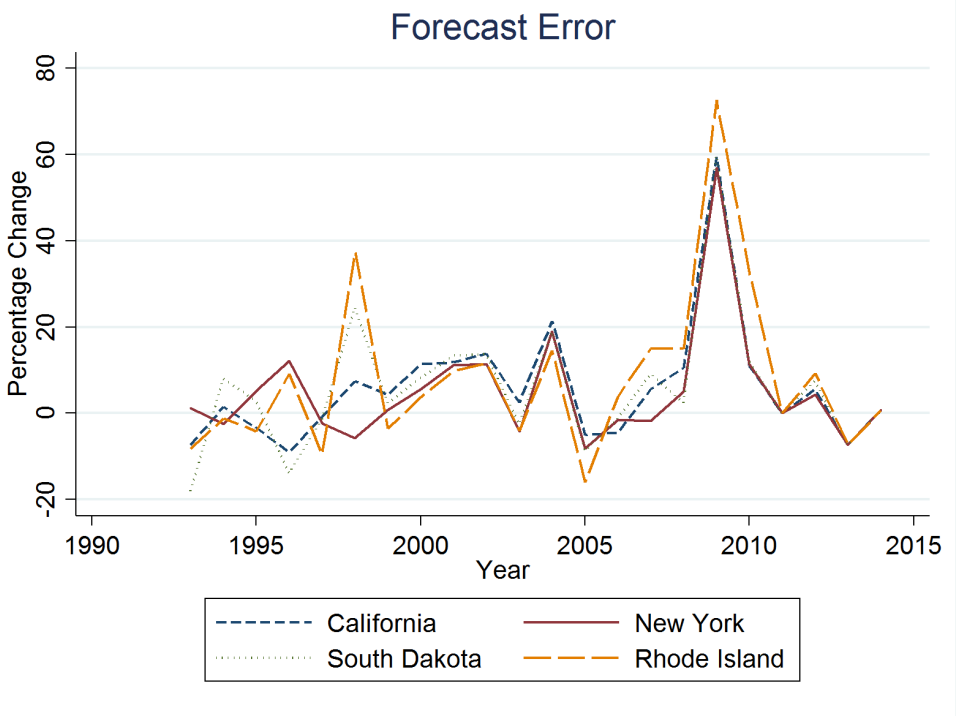



Figure 6: Federal Highway Administration versus my 2009 Grants Forecasts to States as of 2005




(a) Highway Grant Shocks for 1993-2014




(b) Highway Grants Forecast Error for 1993-2014

Figure 7: Unanticipated changes in expected present value of highway grants in selected states

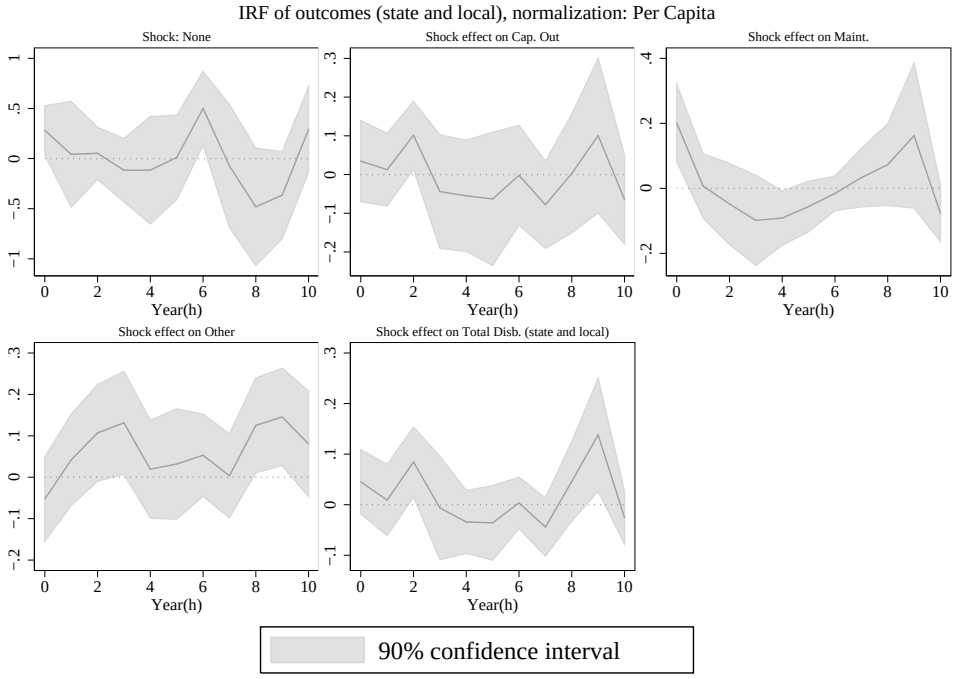



Figure 8: Impulse Response Functions for different outcomes

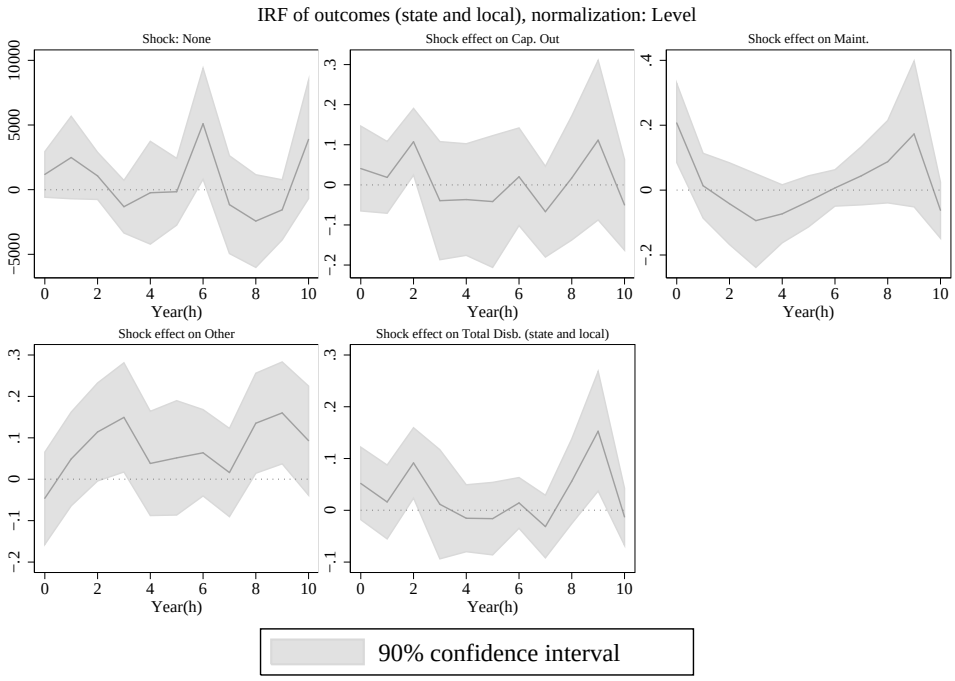
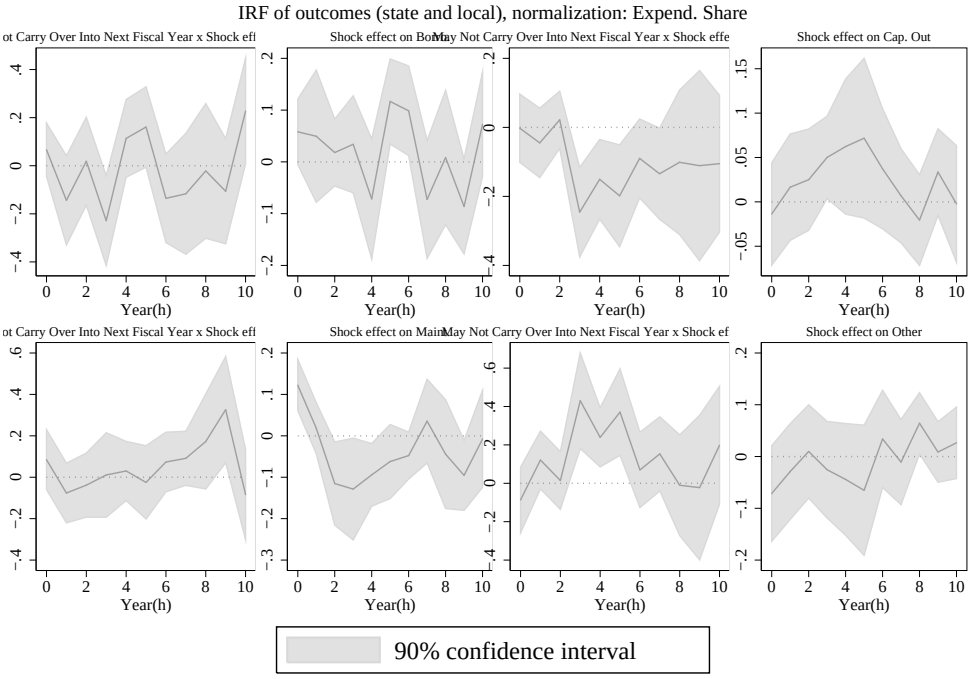
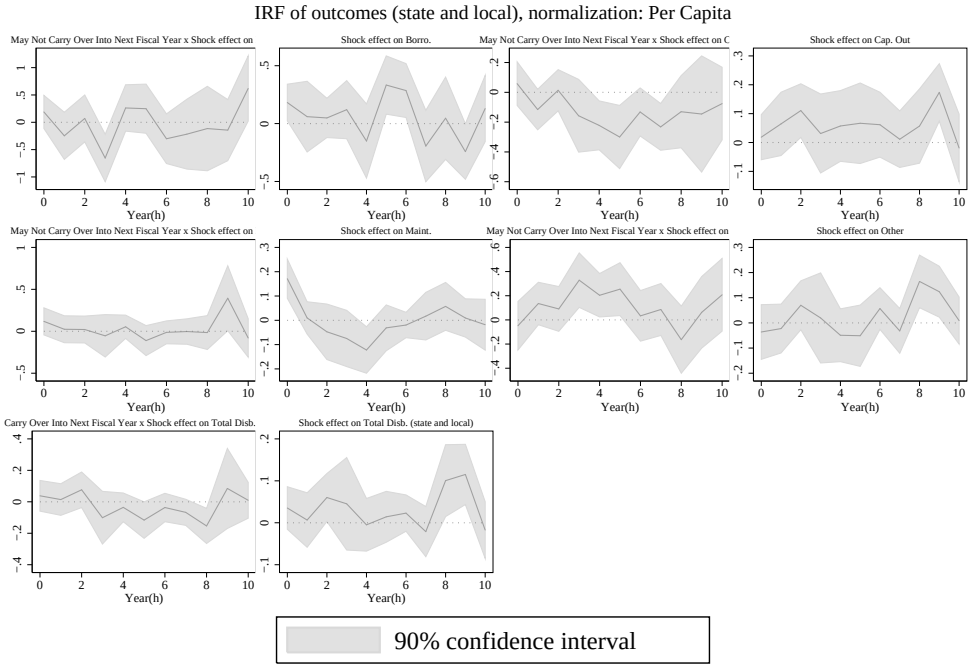



Figure 9: Impulse Response Functions for different outcomes




(a) IRFs of outcomes (share of total expenditure) with May Not Carry Over Debt to Next Fiscal Year Requirement




(b) IRFs of Per Capita outcomes with May Not Carry Over Debt to Next Fiscal Year Requirement

Figure 10: Impulse Response Functions with May Not Carry Over Debt to Next Fiscal Year Requirement

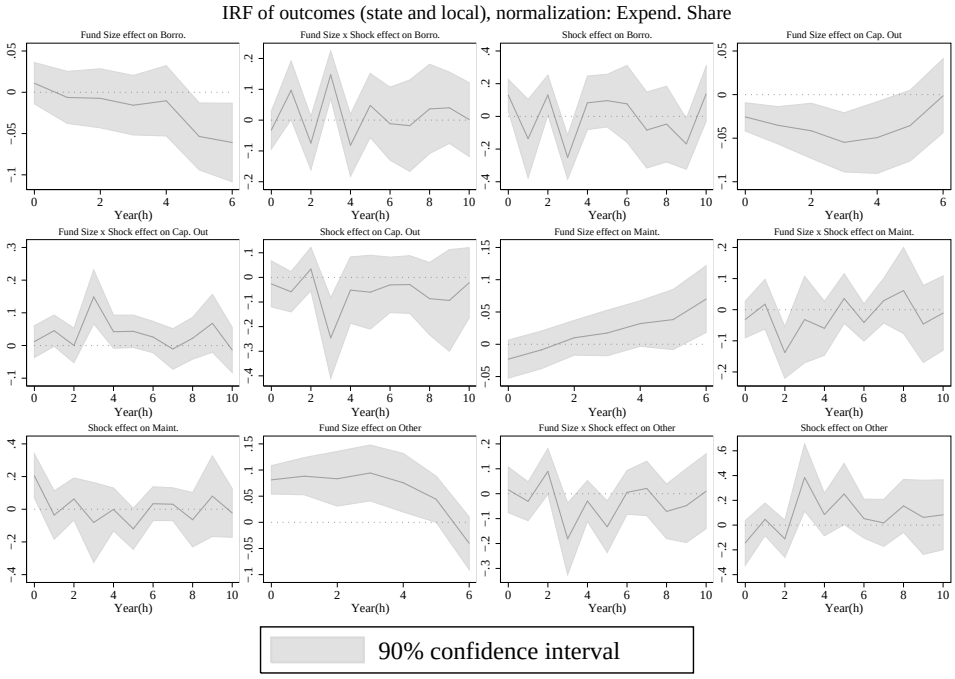
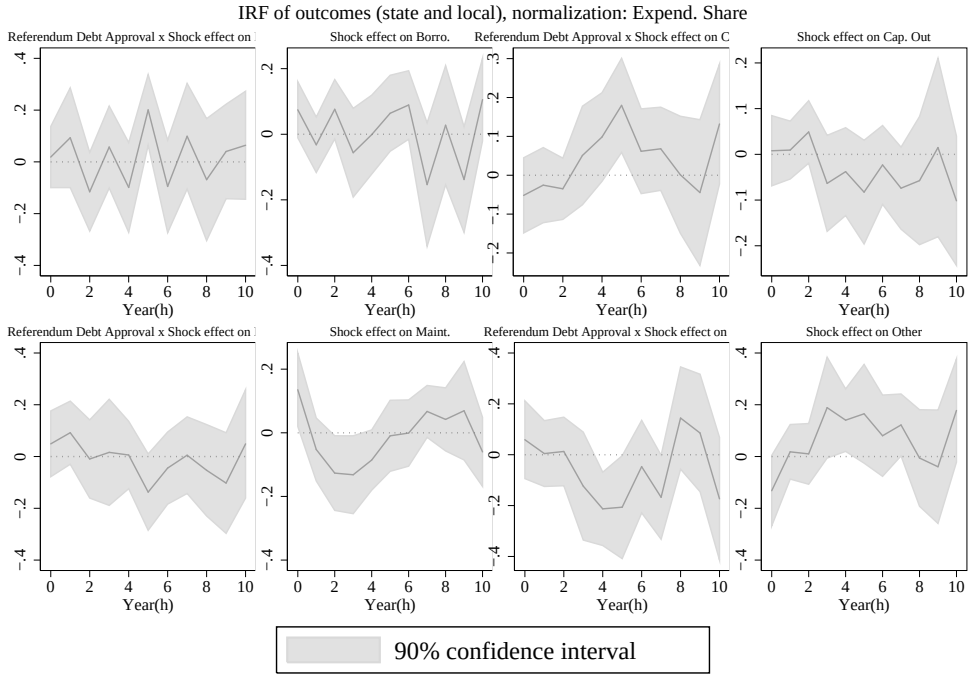
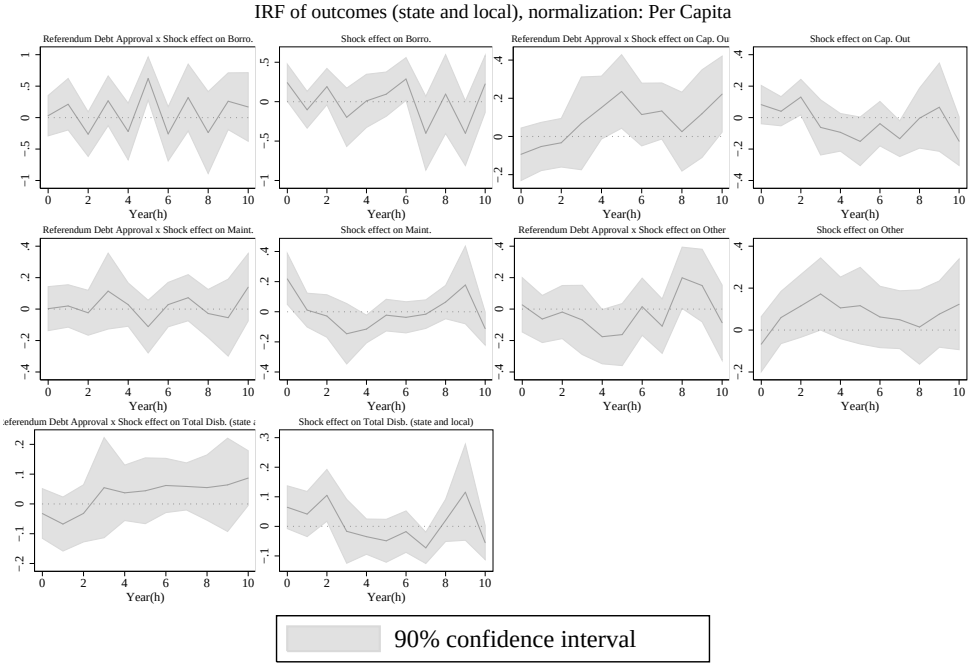



Figure 11: IRFs of outcomes (expenditure share) with Budget Stabilization Fund Size




(a) IRFs of outcomes (expenditure share) with Referendum Debt Approval Requirement




(b) IRFs of Per Capita outcomes with Referendum Debt Approval Requirement

Figure 12: Impulse Response Functions with Referendum Debt Approval Requirement

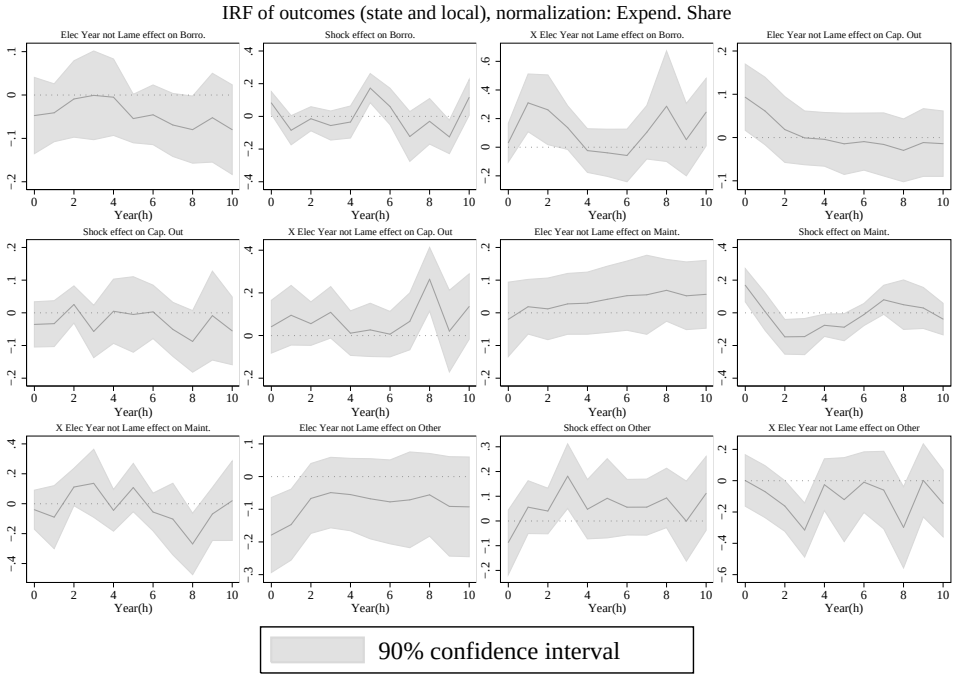
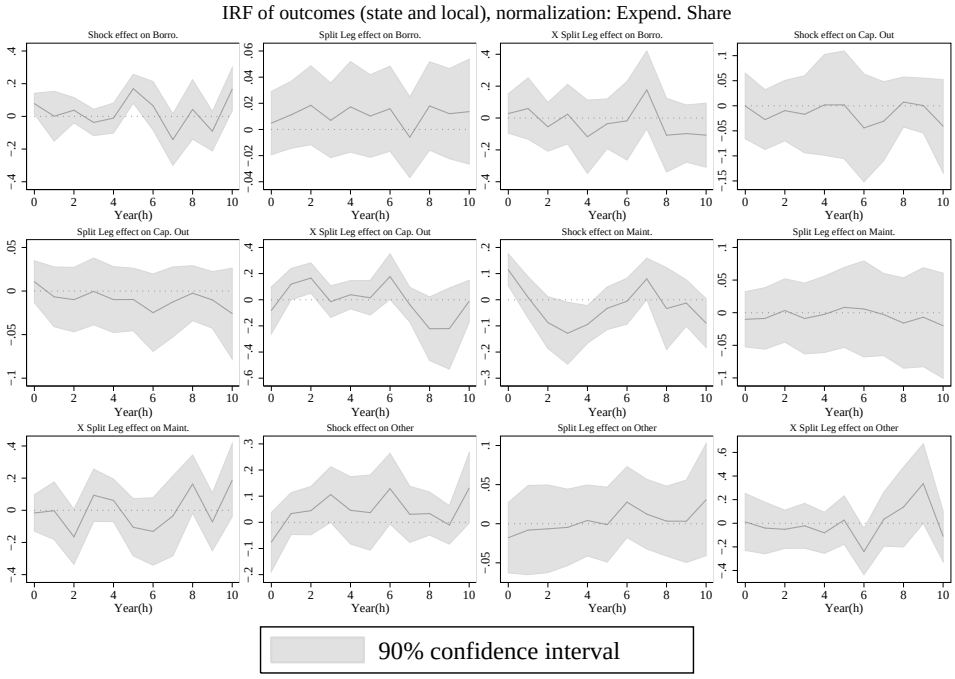
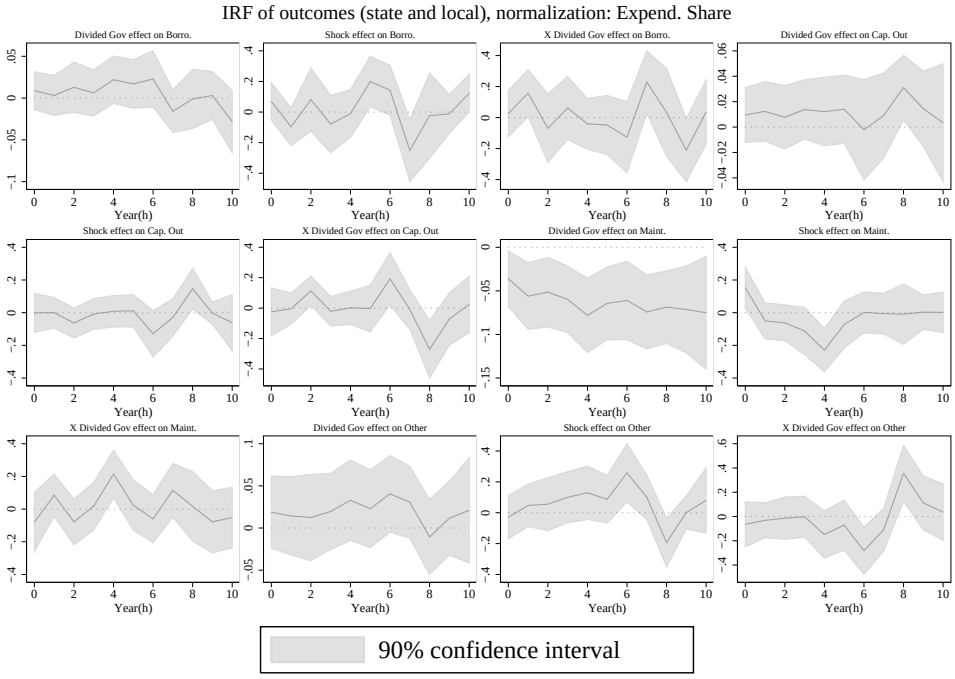



Figure 13: Impulse Response Functions with Governors' Election Year interactions (when governor is not a lame duck)




(a) Impulse Response Functions with Split Legislature Indicator




(b) Impulse Response Functions with Divided Government Indicator

Figure 14: Impulse Response Functions with Government Partisanship Indicators