ANTICIPATED FISCAL ADJUSTMENT AND IDENTIFICATION OF VECTOR AUTOREGRESSIONS

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ABSTRACT. Due to the complex nature of fiscal policy decisions and implementations, fiscal vector autoregressive models have suffered from an underidentification problem that has caused substantial debate about measuring the efficacy of fiscal stimulus. To help resolve this issue this paper incorporates additional information regarding how private agents’ anticipation of fiscal adjustment in the short and medium run to finance the debt innovation induced by an exogenous government spending shocks. I employ robust identification strategies, including pure sign restrictions, elasticity bound restrictions, and frequency domain analyses, to trim the set of admissible model solutions to qualitatively homogenous estimates. Under the reasonable a priori assumptions on fiscal news perceived by economic agents, I arrive at the following results: (i) government spending shocks accompanying with anticipation of transfer adjustments nest the multiplier values documented by traditional VAR literature on fiscal policy (ii) government spending shocks associated with anticipation of distortionary tax adjustments substantially hinder stimulus effects of the fiscal intervention (iii) spending reversals, dynamic fiscal financing achieved by further reduction of government spending in the future to the initial spending hike, are rare options for fiscal financing in the postwar U.S. data, and exogenous increases in government spending are rather financed either by tax hikes or by transfer cuts.

Keywords: identified VARs, fiscal policy, anticipated fiscal policies

JEL Codes: C5, C52, E62, H30

1. INTRODUCTION

The recent episode of the global recession of 2007-2009 called for a fundamental government intervention in the economy, whether through spending increases, tax cuts or a policy-mix. Not surprisingly, there has been increasing interest in measuring the efficacy of fiscal policy. In diagnosing such effects, the structural vector autoregression (SVAR) has become a main empirical tool for analyzing fiscal policy. Due to the complex nature of fiscal policy decisions and implementation, however, fiscal VAR models have suffered from an underidentification problem that has caused substantial debate about measuring the efficacy of fiscal stimulus. Facing this fiscal complexity, Leeper (2010) recently lists three different transmission mechanisms that affect the consequence of fiscal interventions: how the policy is implemented;
whether the stimuli are anticipated; and how debt induced by the fiscal intervention is financed in the future.1

This paper takes a close look at the second and the third issues and combines them to alleviate the underidentification problem in fiscal VAR analyses, whereas the first issue is mute by focusing on the consequences of government spending shocks. The approach here exploits identification information emerging from various fiscal adjustments to debt induced by a spending increase.2 In particular, I draw on the earlier literature documenting that distortionary fiscal adjustments (e.g., taxes) result in totally different macroeconomic consequences from non-distortionary adjustments (e.g., lump-sum transfers). Baxter and King (1993) examine the quantitative importance of different fiscal financing schemes, lump-sum transfers and income tax rates. Within a standard real business cycle (RBC) framework, they demonstrate that the government spending multiplier of output becomes negative when income tax rates adjustments are anticipated, whereas a positive multiplier is restored for the transfer adjustment case. This is because agents reduce their work effort and investment during the period of anticipated high taxes on labor and capital incomes. Sims (1998) studies how the imposition of the government intertemporal budget constraint on rational expectation models alters the short-run respond of private agents to a fiscal shock substantially. Agents’ prediction of future tax rates based on the government’s intertemporal budget constraint conveys strong substitution effects, displaying positive accumulation of capital in the short and the medium-run. These earlier findings underscore that the anticipation effect about future fiscal adjustments provides significant amount of information in understanding the short- and medium-run equilibrium dynamics of macroeconomic models for fiscal policy analyses.3

Regarding the fiscal adjustment dynamics, further government spending reversal in the future is a possible option of fiscal financing schemes. Corsetti, Meier, and Müller (2009) observe the crowding-in of private consumption in the short-run and the crowding-out of output and private consumption taking place in the medium-run when there is anticipated government spending slashed below its trend to an exogenous government spending shock. Wieland (2010) critically reviews their work based on rational that supplementary discretionary fiscal actions in the future cannot be retroactive to alter the current behavior of economic agents.

In line of reasoning with Wieland (2010), this work focuses on two fiscal financing dynamics—tax and transfer adjustments—to the initial surge in government spending increase. To be

1Another stream of research studies the time-varying nature of fiscal stimuli. Fiscal multipliers under the zero lower bound on nominal interest rates are extensively studied by Christiano, Eichenbaum, and Rebelo (2009), Cogan, Cwik, Taylor, and Wieland (2010), Erceg and Lindé (2010), and Uhlig (2010). From a different prospective, Auerbach and Gorodnichenko (2010) measures the stimulus effect of taxes and government spending presuming that fiscal multipliers vary considerably across business cycle regimes.

2The fiscal adjustments considered in this work differ from a stream of literature on expansionary fiscal consolidation illustrating whether a fiscal retrenchment can actually be a fiscal stimuli (for example, Giavazzi and Pagano (1999), Bertola and Drazen (1993), Alesina and Ardagna (1998), Perotti (1999), Leigh, Devries, Friedman, Guajardo, Laxton, and Pescatori (2010), among many others). Whereas this literature focuses on the drastic fiscal policy changes implemented within one or two years that keep the government solvent by running a primary surplus and reducing the debt-to-GDP ratio, this paper’s main concern is to analyze the macroeconomic consequences of the various fiscal adjustment taking place moderately over many years.

3There are many papers highlighting the long-term consequences of fiscal financing, including Leeper, Plante, and Traum (2010), Leeper, Walker, and Yang (2010), and Uhlig (2010).
concrete, however, I provide evidence that the observed government spending reversals in the medium-run might be attributable to automatic stabilizer components of government spending caused by a misspecification of the econometric model.

An intrinsic nature of fiscal policy is that changes in the policy are anticipated by private agents due to two kinds of lags: the legislative and the implementation lags. There is a plethora of recent literature taking this stylized fact of fiscal policy more explicitly. Leeper, Walker, and Yang (2011) formalize the problem by showing that there is no VAR representation corresponding to the anticipated structural tax shock in a simple neoclassical growth model. They propose the \textit{ex-ante} approach to resolve this issue, in that incorporating fiscal news variables in a VAR system to expand the econometrician’s information set. Evidence of fiscal foresight in government spending shocks is documented by a number of researches. Ramey (2011) establishes the anticipated aspect of government spending shocks by showing that the identified shock via the structural VAR (SVAR) approach as in Perotti (2007) is Granger-caused by the forecast of government spending from the Survey of Professional Forecasters. Fisher and Peters (2009) employ stock prices of large US military contractors and identify exogenous shocks on these variables interpreted as news shocks to government spending. Mertens and Ravn (2010) propose a way to mitigate the non-invertibility issue in government spending shocks by embedding the root-flipping Blanchke matrix established by Lippi and Reichlin (1994). Despite the vast consideration on fiscal foresight, this paper maintains the assumption that the anticipation effect of government spending shocks is empirically negligible, and thus an exogenous government spending shock can be mapped from reduced-form residuals by traditional SVAR approaches as in Blanchard and Perotti (2002) or in Perotti (2007). Clearly, this assumption is in line with the empirical findings of Mertens and Ravn (2010) documenting that the role of anticipation effects of government spending foresight on fiscal policy analyses is minuscule. Rather, I focus on tax and transfer news arriving at agents’ information set simultaneously with an exogenous spending shock.\footnote{Prototypical examples of tax news accompanying with government spending changes can be found in Romer and Romer (2008). They regard spending-driven tax rate changes as an important motive of endogenous countercyclical tax policy renovations.}

Despite a vast theoretical consideration, fiscal VAR studies have ignored the anticipated fiscal financing aspect by assuming fiscal shocks are either debt-financed or adjusted by lump-sum taxes to balance the government budget. Chung and Leeper (2009) is the first application of anticipated debt financing dynamics to the empirical characterization of fiscal interventions using a VAR approach. By posing a plausible assumption that the economic agents’ information set is coarser than that of the econometrician’s, the authors enlighten how incorporating the fiscal financing aspect alters the empirical findings from the VAR models with the dynamics unspecified. In order to quantify how key economic variables move under various anticipated scenarios of fiscal financing, this paper takes up the reduced-form model of Chung and Leeper (2009) as the baseline VAR specification. Hence, the debt innovation induced by an exogenous government spending shock should be supported by future movement of fiscal instruments appearing in the government intertemporal budget constraint.

The identification of the VAR model is achieved by imposing a sequence of exclusion restrictions to narrow down the set of structural models, reminiscent of Kilian and Murphy (2010). In analyzing the relative importance of oil demand and supply shocks to the real price oil determination, they illuminate that imposing sign restrictions itself may not narrow
down the solution set enough to support a specific economic theory in determining the oil price and this problem can be resolved by augmenting elasticity restrictions on oil supply and demand. I adapt to a similar approach to Kilian and Murphy (2010), in that government spending shocks are identified by sign and elasticity restrictions where these set of solutions are pruned out further by additional restrictions of different anticipated fiscal adjustments.

More specifically, I identify a set of government spending shocks consistent with sign restrictions and elasticity bound restrictions illustrated below. To begin, I consider the pure-sign-restriction approach established in Uhlig (2005a) and Uhlig (2005b). By the nature of inequality restrictions, sign identified VAR models do not pin down a unique structural model and render a set of solutions that are all equally consistent with the identifying assumptions. However, a substantial portion of the sign-identified solutions imply implausible non-fiscal variable (e.g., output) elasticities of fiscal variable (e.g., taxes). To take into account this feature, I access an important finding of Caldara and Kamps (2010) in which they derive analytical properties of a sign restriction solution so that it can map into the non-fiscal variable elasticities of fiscal variables as in Blanchard and Perotti (2002). Under the 2-variable VAR model setup consists of taxes and output, they show that there exists a pair of elasticities—output elasticity of taxes and tax elasticity of output—corresponding to each sign restriction solution. I extend their analytical property to higher dimensional VAR models where there are multiple fiscal variables to obtain an admissible solutions discerned jointly by sign restrictions and elasticity bound restrictions.

Then the next step is to select structural models associated with the tax or transfer adjustment case from the set identified above. I define anticipated tax adjustments as future tax rate hikes so that the tax change over agent fiscal foresight horizons is positive.\textsuperscript{5} This definition necessitates to identify two objects, future tax rates hikes and the forecasting horizon of agents. First of all, I use sign restrictions on the spread of municipal and treasury bonds to identify future tax rate hikes. Leeper, Walker, and Yang (2011) survey the role of the spreads between municipal and treasury bonds as a news variable about upcoming tax rate changes based on the tax-exempt feature of municipal bonds. I employ their approach and demonstrate that the sign of the spread variable at impact period and beyond can be a crucial identification device differentiating anticipated tax adjustments from the other. Second, I figure out the anticipation horizon of agents by assuming that the agents’ foresight horizon is identical to the period over which discretionary fiscal policy changes occur. To figure out the horizons of discretionary fiscal changes, I conduct the frequency domain decomposition of impulse responses based on the identification information emerging from a dynamic stochastic general equilibrium (DSGE) model. A simulation study based on the DSGE model in Leeper, Plante, and Traum (2010) reassures the findings in line with Lucas (1990), in that the high frequency movements in a fiscal variable are only attributable to the exogenous shock in the relevant fiscal variable, not to a technological shock which accounts for the low frequency movements in fiscal variables.

Throughout the identification strategies depicted above I confirm the following main points. First, government spending shocks accompanying with anticipation of transfer adjustments nest the multiplier values documented by traditional VAR literature. Second, government spending shocks associated with anticipation of distortionary tax adjustments hinder the

\textsuperscript{5}Anticipated transfer adjustments can be defined by flipping signs of this definition.
stimulus effect of the intervention substantially. Third, spending reversals can hardly be options for fiscal adjustment dynamics observed in the postwar U.S. data. Rather, exogenous increases in government spending are financed either by tax hikes or by transfer cuts.

2. Theory

This section examines the effects of anticipated future fiscal adjustment in a DSGE framework. I demonstrate that the stimulus effect of an exogenous government spending varies across the type of fiscal adjustment anticipated by the agents in the economy. For this purpose, I take into account the neoclassical growth model in Leeper, Plante, and Traum (2010) augmented with plausible fiscal policy specifications that has been fit to U.S. data.

2.1. The Model. Following Leeper, Plante, and Traum (2010), I employ a conventional DSGE model with external habit formation, investment adjustment costs, variable capacity utilization, and proportional taxes levied against capital and labor incomes as well as consumption, which are used to finance government spending and transfers to households. Households are assumed to derive utility from private consumption and leisure. Technology is assumed to be Cobb-Douglas, where the level of productivity follows a AR(1) process. To model the anticipation of taxes and transfers, the labor and capital taxes and the transfer payments are specified as an ARMA(1, q) process where q controls the degree of fiscal foresight, the period over which the economic agents’ anticipation on taxes and transfers to be formed. The news about upcoming changes in taxes and transfer payments arrives at the agents’ information set simultaneously with the exogenous government spending shock. The forward looking economic agents react to the change in government spending under consideration of the future fiscal adjustment.

Preferences over consumption and leisure are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t u^b_t \left[ \frac{1}{1 - \gamma} (c_t - hC_{t-1})^{1-\gamma} - u^{1+\kappa}_t \right],$$

where $\gamma, \kappa \geq 0$ and $\beta \in (0, 1)$. The preference shocks $u^b_t$ and $u^l_t$ follow AR(1) processes given by

$$\ln(u^b_t) = \rho^b \ln(u^b_{t-1}) + \sigma^b \epsilon^b_t, \quad \epsilon^b_t \sim N(0, 1)$$

and

$$\ln(u^l_t) = \rho^l \ln(u^l_{t-1}) + \sigma^l \epsilon^l_t, \quad \epsilon^l_t \sim N(0, 1).$$

The household’s flow budget constraint is given by

$$(1 + \tau^e_c) c_t + i_t + b_t = (1 - \tau^l_t) w_t l_t + (1 - \tau^k_t) R^k_t v_t k_{t-1} + R_{t-1} b_{t-1} + z_t,$$

where $v_t$ measures capacity utilization in period $t$, $z_t$ is lump-sum transfers from the government, $i_t$ is investment in physical capital, $b_t$ denotes one-period risk-free bonds, $R_t$ is a gross interest rate, and $R^k_t$ is the rental rate of capital. $\tau^e_c, \tau^l_t,$ and $\tau^k_t$ are tax rates on consumption, labor income, and capital income.

The law of motion for capital is given by

$$k_t = (1 - \delta(v_t)) k_{t-1} + \left[ 1 - s \left( \frac{u^l_t l_t}{i_{t-1}} \right) \right] i_t,$$

where $\delta(\cdot)$ is the depreciation rate.
where \( s \) is the investment adjustment cost such that \( s(1) = s'(1) = 0 \) and \( s''(1) > 0 \). In addition, the adjustment cost is subject to a shock \( u_t^i \) which follows the AR(1) process
\[
\ln(u_t^i) = \rho^i \ln(u_{t-1}^i) + \sigma^i \epsilon_t^i, \quad \epsilon_t^i \sim N(0,1). \tag{6}
\]
\( u_t^i \) is an investment specific shock that captures exogenous variations in the efficiency with which investment can be transformed into physical capital. Owners of physical capital can control the intensity with which the capital stock is utilized. As in Schmitt-Grohe and Uribe (2008), the intensity of capital utilization entails a cost in the form of a faster rate of depreciation. In particular, they adopt a quadratic form for the function \( \delta \):
\[
\delta(v_t) = \delta_0 + \delta_1(v_t - 1) + \frac{\delta_2}{2}(v_t - 1)^2. \tag{7}
\]

The household maximizes utility subject to its budget constraint, (4), and the law of motion for capital, characterized by (5) and (7).

The representative firm rents capital and labor from the household to maximize profit given by
\[
u_t^a(v_t k_{t-1})^{\alpha} l_t^a - w_t l_t - R_t^k v_t k_{t-1} \tag{8}
\]
where \( \alpha \in [0,1] \) and \( u_t^a \) denotes a neutral technology shock that is assumed to follow the AR(1) process
\[
\ln(u_t^a) = \rho^a \ln(u_{t-1}^a) + \sigma^a \epsilon_t^a, \quad \epsilon_t^a \sim N(0,1). \tag{9}
\]
Total output at period \( t \) is given by \( y_t = u_t^a(v_t k_{t-1})^{\alpha} l_t^a \). From the solution to the firm’s problem, wages and capital rental rates are given by
\[
w_t = \frac{(1 - \alpha) y_t}{l_t}, \quad R_t^k v_t = \frac{\alpha y_t}{k_t} \tag{10}
\]

Each period the government levies taxes and issue one-period nominal bonds to finance its interest payments as well as government spending and transfers to households. The government budget constraint is
\[
B_t + \tau_t^k R_t^k v_t K_{t-1} + \tau_t^l w_t L_t + \tau_t^C C_t = R_{t-1} B_{t-1} + G_t + Z_t \tag{11}
\]
where \( G_t \) is government expenditure. As mentioned, I assume that fiscal variables are governed by the following ARMA(1,q) processes:
\[
\hat{G}_t = \rho^g \hat{G}_{t-1} - (1 - \rho^g) (\varphi^g \hat{Y}_t + \gamma^g \hat{B}_{t-1}) + \sigma^g \epsilon_t^g, \tag{12}
\]
\[
\hat{\tau}_t^k = \rho_k \hat{\tau}_t^k - (1 - \rho_k) (\varphi_k \hat{Y}_t + \gamma_k \hat{B}_{t-1}) + \phi_{kl} \tau_l^k + \sum_{j=0}^q \theta_{k,j}^k \epsilon_{t-j}^k, \tag{13}
\]
\[
\hat{\tau}_t^l = \rho_l \hat{\tau}_t^l - (1 - \rho_l) (\varphi_l \hat{Y}_t + \gamma_l \hat{B}_{t-1}) + \phi_{kl} \tau_l^k + \sum_{j=0}^q \theta_{l,j}^l \epsilon_{t-j}^l, \tag{14}
\]
\[
\hat{\tau}_t^C = \rho_C \hat{\tau}_t^C + \sigma_{tC} \epsilon_t^C, \tag{15}
\]
\[
\hat{Z}_t = \rho_z \hat{Z}_{t-1} - (1 - \rho_z) (\varphi_z \hat{Y}_t + \gamma_z \hat{B}_{t-1}) + \sum_{j=0}^q \theta_{z,j}^z \epsilon_{t-j}^z, \tag{16}
\]
where hats denote log-deviations of variables and each of the $\epsilon$’s is distributed i.i.d. $N(0, 1)$. The moving average coefficients, the $\theta$’s, completely specify the news process.

To close the model, the aggregate resource constraint is given as

$$Y_t = C_t + I_t + G_t.$$  \hspace{1cm} (17)

In addition, any equilibrium must satisfy the transversality conditions for debt and capital accumulation. Note that equilibrium implies $\chi_t = X_t$ for any variable $\chi$.

I derive the equilibrium conditions and log-linearize them around the steady state. The log-linearized model is solved using Sims (2001) gensys algorithm with the median parameter estimates in Leeper, Plante, and Traum (2010) and Traum and Yang (2010). In particular, I use the median parameter values from the posterior distribution of the case in which all fiscal instruments finance debt. The posterior odds comparison in Leeper, Plante, and Traum (2010) demonstrates that this fiscal adjustment is most preferred by the U.S. data. The fiscal foresight parameters, $\theta$’s, are borrowed the empirical study of Leeper, Richter, and Walker (2010). By using a standard DSGE model, they figure out that the horizon and intensity of fiscal foresight are highly time-varying and characterize various degrees of fiscal foresight embedded in the parameter $\theta$’s above. To highlight the effect of tax and transfer anticipation to a government spending shock, I adapt to the high degree of foresight case. Unfortunately, there is no investigation on the parameter $\theta$’s for the anticipated transfer case and I use the negative value of the tax anticipation parameters for the experiment. Table 1 summarizes the baseline parameter values.

2.2. Dynamic Impacts of Anticipated Tax and Transfer Changes. [TBW.]

3. Data and VAR Methodology

3.1. Data. The empirical model of this paper is a quarterly VAR using U.S. data over the period from 1947:Q1 to 2007:Q4. All components of the U.S. national income account are from the National Income and Product Accounts (NIPA) tables. To accord with the fiscal financing aspect of this work, I only consider the federal governmental level data for the fiscal variables. The monetary data such as the interest rate and monetary base is downloaded from the Federal Reserve Economic Data (FRED) website of the Federal Reserve Board of St. Louis.

The main empirical model with the present-value government budget constraint consists of 12 variables including taxes, government spending, transfers, output, three-month Treasury bill rate, price level, the 10-year Treasury bond yield, monetary base, private consumption, gross private domestic investment, the spread between municipal and treasury bonds of 1-year maturity, and debt. Above all, the fiscal data series for this work—taxes, government spending, and transfers—are calculated to best match the theoretical model delineated in Chung and Leeper (2009). More specifically, Federal taxes are defined as the sum of Federal current tax receipts and contributions for government social insurance net of timing differences. Federal government spending is the sum of Federal consumption expenditures, gross

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6As emphasized in Leeper, Walker, and Yang (2010), the Federal government budget is balanced over a long time horizon rather than period-by-period in the United States whereas the budget of state and local government tends to be cleared period-by-period.
government investment, and net purchases of non-produced assets subtracted by consumption of fixed capital. Federal transfer payments are defined as the sum of Federal current transfer payments, capital transfer payments, subsidies, Federal employee retirement plan transactions, and financial transactions, netting of current transfer receipts, capital transfer receipts, current surplus of government enterprises, and wage accruals less disbursements. Being defined slightly different from the definitions commonly used, the adjustments made for each fiscal variable bring small numerical differences, and thus the fiscal variables of this work can be regarded as the Federal-government-only data corresponding to that of the previous works, BP and MU. Finally, a Federal debt series is constructed to satisfy the government flow budget constraint by using the fiscal variables generated above. Appendix D gives details on definitions and data sources for all variables used in the empirical analyses.

3.2. Two identification schemes in fiscal VARs. To begin with, it is useful to digress by contrasting two prominent methods to recover the exogenous structural shocks in fiscal VARs—the Blanchard-Perotti approach and the sign restriction approach proposed by Uhlig (2005a) and Uhlig (2005b)—which will be the baseline specifications in identifying various fiscal shocks in this paper.

In order to quantify the effect of fiscal shocks on output, Blanchard and Perotti (2002) construct a quarterly VAR that consists of a non-fiscal variable of interest (GDP) together with the two fiscal variables (taxes and government spending). Presuming that discretionary changes in fiscal variables take more than a quarter due to the lags in making fiscal policy decision, the authors discern that the only plausible within-quarter variation of fiscal variables is their automatic movements driven by business cycle fluctuations. Under this assumption, they gauge the cyclically adjusted portion of fiscal variables by utilizing external information about the tax system in the economy and estimating the non-fiscal variable elasticity of fiscal variables. Together with the zero restriction on the elasticity between fiscal variables, equivalent to assume implicitly that a spending decision is made ahead of a tax decision (or vice versa), the model is just-identified and the dollar-valued output multipliers of fiscal shocks are measured.

Uhlig (2005b) proposes a different solution in identifying a monetary policy shock, which directly imposes sign restrictions on the structural impulse responses for a certain number of periods. From a Bayesian prospective, he proposes two methodologies—the pure-sign-restriction approach and the penalty-function approach—to resort a set of solutions admissible with the sign restrictions imposed. The intuition of the pure-sign-restriction approach is to keep the posterior draw of structural shocks if the impulse responses calculated from the shock satisfy a given set of sign restrictions or to discard it otherwise. On the other hand, the penalty-function approach finds shocks that minimize a specific criterion function that penalizes the shocks violating the given sign restrictions. In particular, this penalty-function

\footnote{Instead of imposing sign restrictions on the impulse responses, Canova and Nicoló (2002) impose sign restrictions on the crosscorrelations of variables to identify monetary policy disturbances.}
Sign restrictions are inequality restrictions. Hence, it is agnostic but delivers a set of solutions that accord with the identification assumptions imposed on the impulse responses. Regarding fiscal VARs, this underidentification problem entails a large set of fiscal multipliers that raises skepticism on VAR approaches in conducting fiscal policy analyses. Therefore, understanding what constitutes the large set of sign identified solutions is important in figuring out the source of the fiscal multiplier morass. To resolve this issue, I accessing the main finding of Caldara and Kamps (2010), in that every sign restriction solution from a fiscal VAR model can map into a set of Blanchard-Perotti elasticities. This analytical characterization of the sign restriction solutions unveils a certain value of output multiplier can be achieved under which combination of different category Blanchard-Perotti elasticities.

3.3. Imposing sign restrictions on VAR. Consider the reduced-form VAR model of the $n$-dimensional endogenous vector $X_t$ expressed as

$$X_t = \mu + B(L)X_{t-1} + u_t,$$

where $\mu$ is a constant, $B(L)$ is a finite-order autoregressive lag polynomial, and $u_t$ is a $n$-dimensional vector of reduced-form innovations with $E[u_t] = 0$, $E[u_tu_t'] = \Sigma_u$, and $E[u_tu_{t+s}'] = 0$ for $s \neq t$. For the empirical work, I follow Chung and Leeper (2009) and set the lag length to be five quarters. Let $e_t$ denote the corresponding structural VAR model innovations identified via sign restrictions on impulse responses. The VAR identification problem utilizing sign restrictions requires an estimate of the $m$ number of columns of an $n \times n$ matrix $A$ satisfying $u_t = Ae_t$ and $E[e_t'\epsilon_t] = I$. Note that $m \leq n$ which indicates that the sign restriction approach is a partial identification scheme. Put differently, it is not necessary that the number of identified shocks be the same as the number of variables. This is a feature of sign-restriction identifications different from the classical SVAR literature such as recursive approaches. As in Uhlig (2005b), the implementation of sign restrictions begins with a decomposition of the matrix $A$ into $A = \tilde{A}Q$ where $\tilde{A}$ is the lower triangular Cholesky decomposition of $\Sigma_u$ and $Q$, an orthonormal matrix with $QQ' = I$. Here I note that the usage of the Cholesky decomposition of $\Sigma_u$ in obtaining the matrix $\tilde{A}$ is not necessary. Rather, it is just a matter of convenience. Then there is a wide range of possibilities for $Q$ by drawing at random from

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8However, using the specific penalty-function to identify fiscal policy shocks is faced formidable challenges. Caldara and Kamps (2010) demonstrate that the policy conclusions made in Mountford and Uhlig (2009) are mainly attributable to the usage of the specific penalty function, and inferences using different penalty functions may result in totally different conclusions. The penalty function itself is a dominating identification assumption that lacks firm theoretical ground.

9Another issue on the Uhlig’s sign restriction approach arises in its inference procedure based on the median responses. Both Uhlig (2005b) and Mountford and Uhlig (2009) use median responses as a summary of the central tendency of impulse responses across different models. However, this approach faces formidable challenges mainly originated from the fact that there is unique structural model backing out the median responses. Fry and Pagan (2010) propose a method to find a structural model that renders the closest impulse responses from the median responses. Being an inequality restriction, Inoue and Kilian (2011) show that median responses from sign identified models are not an appropriate measure to evaluate the central tendency that yield biased inferences. Instead they suggest inferences evaluated at posterior modes.

10This feature makes the sign restriction approaches different identification strategy from the recursive ordering in Sims (1980). The matrix $\tilde{A}$ is recursive but the matrix $A$ is not recursive any more.
the set $Q$ of orthonormal rotation matrices. Following Uhlig (2005b) I construct the set $\tilde{Q}$ of admissible models by drawing from the set $Q$ of rotation matrices and discarding candidate solutions for $\tilde{Q}$ that do not satisfy a set of a priori sign restrictions on the structural impulse response functions. The following steps detail the procedure to find an admissible set $\tilde{Q}$.\footnote{For more detail about the sign restriction approach, see Uhlig (2005a) and Uhlig (2005b). In particular, Uhlig (2005b) utilizes a Bayesian approach to calculate the impulse response functions and to conduct statistical inferences. More precisely, he simulates a draw of the pair $(B(L), \Sigma_u)$ from the posterior distribution of those matrices and computes the IRFs. However, this subsection outlines the corresponding procedure from a frequentist prospective. I maintain this methodology to simplify in solving the identification problem by fixing those matrices evaluated at the OLS estimates. Note that the empirical results presented throughout this paper are robust across the choice of estimation method between a Bayesian approach and a classical approach. Put differently, this choice makes negligible empirical difference in the sense that the 16th, 50th, and 84th percentiles of impulse response functions are almost identical regardless of what estimation method is used. The intuition behind this feature is that Mountford-Uhlig use a prior of infinite variance so that the estimates of the reduced form model via the Bayesian procedure best mimic the OLS estimator. For more discussion on the Bayesian vector autoregressive models, see Sims and Zha (1998) and Del Negro and Schorfheide (2010).}

1. Draw an $n \times n$ matrix $M$ that consists of random variables from i.i.d $N(0,1)$. Derive the QR decomposition of $M$ such that $M = QR$ and $QQ' = I$.
2. Calculate the $i$th impulse vector $a_i$ defined by $a_i = Aq_i$ where $q_i$ is the $i$th column of $Q$. Then $a_i$ is the $i$th column of $A$. Do this step for all the $m$ columns of $Q$ on which the sign restrictions are imposed.
3. Compute the $n$-dimensional structural impulse response functions of $k$th horizon, $r_{ai}(k)$, corresponding to the impulse vector $a_i$ as $r_{ai}(k) = \Xi(k)a_i$, where $\Xi(k)$ denotes the $n \times n$ matrix of the Wold impulse response functions at horizon $k$.
4. If all impulse response functions satisfy the given sign restrictions for all $i$ and $k$ on which those sign restrictions are imposed, retain $Q$. Otherwise discard $Q$.
5. Repeat the first three steps a large number of times, keeping each $Q$ that satisfies the restrictions (and the corresponding structural impulse response functions).

Those $Q$’s captured throughout the above steps constitute the set of admissible structural VAR models.

3.4. Analytics of Sign Restriction Solutions. Sign restriction approaches to fiscal VARs can be understood in the framework of the Blanchard-Perotti identification scheme. Taking up the prospect, this subsection derives and interprets the analytical solutions of sign restriction approaches in the spirit of Blanchard-Perotti. Thus, the following setup is reminiscent of the approach of Caldara and Kamps (2010). Under the 2-variable VAR model setup where a fiscal (tax revenue) and a non-fiscal (output) variable are present, the authors show that there exists a pair of fiscal variable elasticities—the elasticity of non-fiscal variable and the non-fiscal variable elasticity of fiscal variable—corresponding to each sign restriction solution. I extend their analytical property to higher dimensional VAR models where there are multiple fiscal variables to elaborate the aspect of various fiscal financing dynamics in determining future movement of the key non-fiscal variables. Thus, this is the minimal setup that enables a
number of interesting policy scenarios as in Mountford-Uhlig—e.g. a deficit-financed spending increase and a balanced budget spending.

I derive the mapping from the sign identified VAR model to the 3-variable Blanchard-Perotti system in appendix A, where a fiscal variable in the current period is determined solely by its interaction with current output and with other fiscal variables at the current period. However, more recent articles reveal that there are some more variables that have contemporaneous effect on change in fiscal variables. A typical example can refer to Perotti (2004) which uses a five-variable VAR system, including the GDP deflator inflation rate and a short-term interest rate together with the three-variables as in Blanchard-Perotti. Therefore, it is essential to generalize the analytical solutions of sign restriction identifications to higher-dimensional systems.

For a generalization, I consider three fiscal variables—taxes, government spending, and transfer payments—by discerning that future transfer adjustment has a different effect from that of distortionary taxation.\(^\text{12}\) This setting will be maintained for the empirical sections with the 12-variable VAR model as well. Suppose that additional to output, there is one more non-fiscal variable that contemporaneously affects the taxes, spending, and transfers decision.\(^\text{13}\) I use \(x\) to denote the additional non-fiscal variable. Then this system can be written as

\[
\begin{bmatrix}
1 & 0 & 0 & -\alpha_{xy} & -\alpha_{xx} \\
0 & 1 & 0 & -\alpha_{gy} & -\alpha_{gx} \\
0 & 0 & 1 & -\alpha_{zy} & -\alpha_{zx} \\
-\alpha_{xr} & -\alpha_{yg} & -\alpha_{gx} & 1 & -\alpha_{gy} \\
-\alpha_{xr} & -\alpha_{xy} & -\alpha_{xz} & -\alpha_{xy} & 1
\end{bmatrix} \begin{bmatrix}
u_t^x \\
u_t^y \\
u_t^z \\
u_t^x \\
u_t^y \\
u_t^z
\end{bmatrix} = \begin{bmatrix}
1 & \beta_{tg} & \beta_{tz} & 0 & 0 \\
\beta_{gT} & 1 & \beta_{gz} & 0 & 0 \\
\beta_{zT} & \beta_{zg} & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 1
\end{bmatrix} \begin{bmatrix}
\varepsilon_t^x \\
\varepsilon_t^y \\
\varepsilon_t^z \\
\varepsilon_t^x \\
\varepsilon_t^y \\
\varepsilon_t^z
\end{bmatrix}.
\] (19)

One can set up a sign restriction identification scheme corresponding to above system where the \(A\) matrix can be specified as

\[
A = \begin{bmatrix}
A_{x\tau} & A_{xg} & A_{xz} & A_{xy} & A_{xx} \\
A_{g\tau} & A_{gg} & A_{gz} & A_{gy} & A_{gx} \\
A_{z\tau} & A_{zg} & A_{zx} & A_{zy} & A_{zx} \\
A_{y\tau} & A_{yg} & A_{yz} & A_{yy} & A_{yx} \\
A_{x\tau} & A_{xy} & A_{xz} & A_{xy} & A_{xx}
\end{bmatrix}.
\] (20)

Then Appendix B derives the way to calculate the key elasticities in the first two rows in (19) using the elements of \(A\) matrix. Moreover, the appendix shows that the impact spending multipliers of output can be generalized as

\[
\Pi_0^{g,y} = \frac{(A_{yg}/A_{gg})}{1 - \alpha_{gg}(A_{yg}/A_{gg}) - \alpha_{gx}(A_{xy}/A_{gg}) G/Y}.
\] (21)

Note that this equation collapses to the three-variable-case multiplier when there is no contemporaneous effect of the additional non-fiscal variables on government spending, i.e., when \(\alpha_{gy} = 0\).

\(^{12}\)Appendix B details this generalization to a higher order system.

\(^{13}\)Taking into account more than one non-fiscal variables in the system makes no difference for the characteristics of analytical solutions. The analogue here can be easily extended to a system bearing more than one non-fiscal variables.
4. VAR Models with Outstanding Government Debt

This section formally delineates the main empirical VAR model with the present-value government financing constraint.

4.1. Present-Value Financing Constraint. Dynamic rational expectation models state that the real value of debt outstanding should equal the present-value (PV) of net-of-interest surplus minus seigniorage. At heart, what this mechanism delivers is the government debt innovation introduced by an exogenous fiscal shock restricts future paths of fiscal instruments. Moreover, this assumption accounts for the channel in which a fiscal intervention today affects the future movement in key economic variables that reflects the agents’ behavior to the exogenous shock. A forward-looking optimizing agent pays attention to the future path of fiscal variables, instead of the initial response only, which affects the intertemporal choices via her own present-value budget constraint. Hence, imposing the intertemporal government budget constraint on a VAR system can be an appealing laboratory in gauging the efficacy of fiscal interventions. Surprisingly, however, this feature has been greatly disregarded by a plethora of previous fiscal VAR literature by assuming that lump-sum taxes balance the government budget constraint when an exogenous shock in fiscal variables perturbs the system.

To introduce the intertemporal budget rule of the government in the VAR system, I consider the PV government budget constraint accommodating in the form of VAR restriction pioneered by Chung and Leeper (2009). They derive a log-linear approximation of the government PV budget constraint and impose it as a restriction on the VAR coefficients. Under the presence of seigniorage and the three fiscal instruments—taxes, government spending, and transfers—their present-value financing constraint of government can be written as:

\[
\beta \mathbb{B} \left\{ C_v + \frac{\bar{\tau}}{\bar{v}} C_{\tau} - \frac{\bar{g}}{\bar{v}} C_g - \frac{\bar{z}}{\bar{v}} C_z + \left[ \frac{1}{\beta} - \frac{1}{\bar{v}} \right] \left[ \frac{1}{\bar{v}} \right] C_{\pi} \right\} = \left\{ C_v + \left[ 1 - \frac{1}{\beta} \frac{\bar{m}(\bar{R} - 1)}{\bar{\pi}} \right] C_R + \left[ 1 - \frac{1}{\beta} \frac{\bar{m}(\bar{R} - 1)}{\bar{\pi}} \right] C_{\pi} - \frac{1}{\beta} \frac{\bar{m}(\bar{R} - 1)}{\pi} C_m \right\},
\]

where \( \mathbb{B} \) is the companion matrix of the \( \ell \)-th lag reduced-form VAR coefficients with \( n \) variables, \( \beta \) is the discount factor, and \((\bar{m}, \bar{\tau}, \bar{g}, \bar{z}, \bar{v})\) are the steady-state monetary base, taxes, government spending, transfers, and government liabilities respectively where all of these are nominal variables scaled by output. Moreover, \( \bar{R} \) and \( \bar{\pi} \) denote the steady-state nominal interest rate and inflation respectively. \( C_x \) is a vector that selects the variable \( x \) out of a vector containing \( x \).

Note that the VAR constraint (22) is comparable to the present-value financing constraint of government given as:

\[
\hat{v}_t = E_t \sum_{j=1}^{\infty} \beta^j \left[ \left( \frac{\bar{\tau}}{\bar{v}} \right) \hat{\tau}_{t+j} - \left( \frac{\bar{g}}{\bar{v}} \right) \hat{g}_{t+j} - \left( \frac{\bar{z}}{\bar{v}} \right) \hat{z}_{t+j} - \frac{1}{\beta} \hat{\pi}_{t+j-1} \right]
\]

Footnotes:

14Favero and Giavazzi (2007) take up a different approach to incorporate debt in the VAR system. They include the identity between debt and the other fiscal variables in their VAR specification.

15Appendix C details the full government budget constraint with seigniorage imposed on the VAR model of this work as well as the estimation procedure with the constraint.
where $\hat{v}_t, \hat{\tau}_t, \hat{g}_t, \hat{z}_t$ and $\hat{r}_t$ denote the log deviations of debt level held in public, taxes, government spending, transfers, and a short-term real interest rate, from their steady state. I disregard the seigniorage in the equation (23) since the empirical results advocates that the role of seigniorage in financing debt innovation is minuscule. Then this expression provides a decomposition of the fluctuations in real debt into expected changes in the components of net-of-interest surpluses, at constant discount rates, and expected changes in real discount rates.

In sum, the future movement of the financing constraints components when a debt-financed fiscal intervention perturbs the system is governed by the expression (23) (or equivalently by (22)).

4.2. Present-Value Accounting Framework. Imposing the constraint (22) on a VAR system enables us to track down the contribution of each PV constraint element in stabilizing debt induced by an exogenous fiscal shock via the constraint—a present-value accounting. To illustrate this PV accounting framework, suppose that $a$ is a government spending impulse vector identified by given sign restrictions. Then rewriting the VAR constraint of PV budget constraint of the government (22) gives

$$C_v = (I - \beta B)^{-1}(\beta BH_1 - H_0),$$

where

$$H_1 = \tilde{\tau} C_\tau - \tilde{g} C_g - \tilde{z} C_z + \left[ \frac{1}{\beta} - \frac{1}{\beta} \tilde{m}(\tilde{R} - 1) \right] C_\pi,$$

and

$$H_0 = \left[ 1 - \beta \frac{1}{\beta} \tilde{m} \tilde{R} \right] C_R + \left[ 1 - \beta \frac{1}{\beta} \tilde{m}(\tilde{R} - 1) \right] C_\pi - \beta \frac{1}{\beta} \tilde{m}(\tilde{R} - 1) C_m.$$

Define $n \ell \times n$ matrices, $W_1$ and $W_0$, to satisfy

$$H_1 = W_1 \ast 1_{n \times 1} \quad \text{and} \quad H_0 = W_0 \ast 1_{n \times 1},$$

where $1_{n \times 1}$ is an $n$-dimensional column vector of ones. The matrices $W_1$ and $W_0$ decompose the PV constraint matrices $H_1$ and $H_0$ by arraying PV of each variable in its relevant column. Therefore, $F^a$, the component-by-component decomposition of PV funding source vector for a government spending impulse vector $a$, is calculated by

$$F^a = a'(I - \beta B)^{-1}(\beta BW_1 - W_0).$$

(24)

where $F^a$ is an $n$-dimensional row vector. Thus, each element of $F^a$ renders the PV change of each variable in balancing the PV constraint of the government invoked by $a$. Note that the components of $F^a$ are scaled so that their sum equals the initial debt innovation and that PV components help stabilize debt when the sign of the component is the same as the sign of the initial change in debt.

To interpret (24) as PV changes in each variable to a unit change in debt innovation, I standardize each element of $F^a$ by the initial change in debt innovation. Let $f^a$ denote such a vector and $f^a_x$ be an element of it corresponding to the variable $x$. Then the PV change in real interest rate to a unit change in debt innovation is calculated by $f^a_r = f^a_R + f^a_o$, where

$^{16}$Derivation of this formula utilizes the geometric series property of $\beta B$. To this series be well defined, eigenvalues of the matrix $\beta B$ has no explosive eigenvalues. The main empirical VAR model with 12 variables satisfies this criterion. The largest eigenvalue of $B$ is 0.991, smaller than one in modulus.
$r$ denotes real interest rate whereas $f_m$ measures PV change in seigniorage to a unit debt change.

The PV accounting outlined above, though useful as a determination of funding sources, reveals little about how the initial debt innovation is financed over time. To take into account the dynamics of various funding schemes, I delineate the way to measure the PV change in each variable up to period $t+k$. Instead of the infinite sum of $\beta B$, I calculate the partial sum of the matrix up to time $t+k$ by defining the matrix $D(k)$ as

$$
D(k) = \begin{cases} 
I, & \text{if } k = 0 \\
I + \sum_{i=1}^{k} (\beta B)^i, & \text{if } k \geq 1.
\end{cases}
$$

Likewise, the PV change of the funding sources by period $t+k$ perturbed by a spending impulse vector $a$, denoted as $F^a(k)$, can be calculated by

$$
F^a(k) = a' D(k)(\beta B W_1 - W_0).
$$

By setting, of course, it is the case that $F^a(k)$ converges to $F^a$ when $k$ goes to infinity. Dividing each element of $F^a(k)$ by the initial debt change yields the element-by-element change of the funding sources with respect to a unit debt change made between period $t$ and $t+k$, denoted as $f^a(k)$, which is analogous to $f^a$.

4.3. VAR Specification with PV Constraint: 12-Variable VAR. I specify the model with the VAR constraint given as a present-value form in (22). This model is 12-variable VAR system including the log of real taxes, $\tau_t$, the log of real government spending, $g_t$, the log of real transfers, $z_t$, the log of real GDP, $y_t$, a short-term interest rate, $R_t$, the GDP deflator price level, $\pi_t$, the 10-year Treasury bond yield, $\ell_t$, the monetary base, $m_t$, private consumption, $c_t$, gross private domestic investment, $i_t$, the 1-year municipal bond spread, $s_t$, and the debt level held in public, $v_t$. The fiscal and monetary variables, $\tau_t$, $g_t$, $z_t$, $R_t$, $\pi_t$, $m_t$, and $v_t$, constitute the present-value VAR constraint whereas GDP and its component variables are included as a key economic variable of interest. Following Chung and Leeper (2009), I assume that certain forward-looking variables can be good approximations how private agents anticipate their own intertemporal budget constraint in the future. Private investment plays the role of forward-looking real variable and the 10-year Treasury yield is included as the forward-looking financial variable. I additionally augment a “fiscal foresight” variable in the model discerning that most of changes in fiscal policy are anticipated due to the legislative lag and the implementation lag. Leeper, Walker, and Yang (2011) convey this fiscal foresight issue and propose an *ex-ante* approach to resolve the problem. The idea of their *ex-ante* approach is to expand econometrician’s information set by including variables that reflect future changes in tax rates. They use the spread between municipal and treasury bonds of the same maturity as the foresight variable since U.S. municipal bonds are tax-exempt. The 1-year municipal-treasury bond spread is included for a treatment of the fiscal foresight issue. [More discussion on the invertibility issue.]

5. Identification Procedure

Identification of the government spending shock coming with the news on various fiscal adjustments necessitates the following two steps. First, I use sign restrictions to identify a
set of government spending shocks. As will be shown below, however, the analytical characterization as described in Subsection 3.4 above reveals that a large fraction of the solutions lacks institutional justification by the public finance system of the U.S. federal government. The sign identified solutions can merely achieve a plausible value for the non-fiscal variable elasticity of fiscal variable. This problem of sign identified models is identification strategy is explored by Kilian and Murphy (2010) to analyze the relative importance of oil demand and supply shocks in determining the real price of crude oil. They illuminate that imposing sign restrictions itself may not narrow down the solution set enough to support a specific economic theory in determining the oil price and this problem can be resolved by augmenting elasticity restrictions on oil supply and demand. I adapt to a similar approach to Kilian and Murphy (2010), adding additional restrictions on the non-fiscal variable elasticities of fiscal variables. Then, the next step categorizes the identified government spending shocks based on the manner of different anticipated fiscal adjustments. Figure 2 graphically summarizes the identification procedure of this paper.

5.1. Government Spending Shock Identified by Sign Restrictions. The first and the most naive identification strategy is to impose the sign restrictions on the impulse response functions only at impact. Unlike Mountford and Uhlig (2009) sign restrictions are not imposed beyond the impact period to preserve the agnosticism of sign identified models. Indeed, imposition of minimal sign restrictions at impact is widely used in literature, e.g., Pappa (2009) and Caldara and Kamps (2010) for identifying fiscal policy shocks and Faust (1998) for identifying monetary policy shocks. Then I identify five shocks—a tax shock, a government spending shock, a transfers shock, a municipal-treasury spread shock, and a non-fiscal shock. Being named in a different manner, the role of a non-fiscal shock is basically similar to that of a “business cycle shock” in Mountford and Uhlig (2009) or a “non-policy shock” in Caldara (2011). This shock is included to capture the automatic stabilizer component of fiscal variable changes to business cycle fluctuations orthogonal to changes in fiscal variables driven by exogenous fiscal shocks themselves. In detail, a non-fiscal shock is defined as a shock that increases output, consumption, investment, and taxes at impact. Note that these sign restrictions on a non-fiscal shock are accepted by vast fiscal VAR literature using sign restrictions. Meanwhile, the fiscal shocks are identified under the assumption that each of them increases the corresponding fiscal variable at impact. Additionally, I impose the relevant sign restriction on the initial debt response to the three fiscal shocks—a plus sign for government spending and transfer shocks and a minus sign for a tax shock—indicating that the fiscal shocks in this model are initially debt-financed. Finally, I restrict the magnitude of uninvoked fiscal variables to be smaller than 1 percent in absolute terms. For example, the tax and transfer responses at impact should be smaller than 1 percent in absolute terms to a government spending shock. This is an essential setting to distinguish the government

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17 As mentioned, sign restriction approaches are the partial identification scheme in that the number of identified shocks can be smaller than the number of variables in the model. Unlike Mountford and Uhlig (2009) a monetary policy shock is not identified since the quantitative effect of the shock is not significant to the empirical results. This finding is also documented by Caldara and Kamps (2008).

18 It should be emphasized that specifying the non-fiscal variable elasticities of fiscal variables renders sufficient information to pin down a non-fiscal shock, e.g. by matching coefficients between reduced-form and structural variance-covariance matrices. This is the channel through which the usage of a specific penalty function in Mountford and Uhlig (2009) itself is a dogmatic identification restriction of the fiscal multipliers in the paper. For more discussion, see Caldara and Kamps (2010).
spending shock from tax or transfer shocks. Similarly, Forni and Gambetti (2010) impose a negative sign restriction on taxes to identify the government spending shock. However, it turns out that this negative sign restriction alone is not enough, in that in many cases the negative tax response is bigger than the positive government spending response and thus the stimulus effect of government spending shocks is overestimated.

Once the shocks are identified throughout the sign and the magnitude restrictions, each impulse vector can be inverted and scaled via the procedure depicted in Subsection 3.4. Then the scaled coefficients of each of these inverted impulse vectors maps into the non-fiscal variable elasticities of the fiscal variables as in Blanchard and Perotti (2002). For instance, the coefficients from the inverted tax impulse vector $A_p$, after scaling by the coefficient coefficient, will yield the elasticities of taxes to output, interest rate, price, the 10-year treasury yield, monetary base, consumption, private investment, the municipal-treasury spread, and debt. Likewise, each impulse vector has a Blanchard-Perotti interpretation.

Table 2 presents the 84th, 50th, and 16th percentile elasticity values mapped from the sign restriction model solutions. For a robust result, I draw 10,000 number of rotation matrices and find that the 64 percent ranges display wide dispersion of the elasticities. Sign identified models assume that all solutions in the admissible set of sign restrictions are equality likely. However, it is difficult to reconcile this assumption with the empirical findings about U.S. public finance system. For instance, the 84th percentile of $\alpha_{gy}$ to be 19.36 is far from what one observes from the U.S. historical data, implying that 1 percent increase in output drives up more than 19 percent in government spending. Therefore, it is reasonable to consider plausible ranges of the elasticities for fiscal policy analyses. The next subsection explores previous empirical findings about the elasticities to use them an additional constraint in reducing the range of admissible set of structural models.

5.2. Survey on Non-Fiscal Variable Elasticities of Fiscal Variables. A plethora of researches exploit institutional information on the non-fiscal variable elasticities of the fiscal variables, e.g., Blanchard and Perotti (2002), Perotti (2004), Chung and Leeper (2009), and Caldara (2011). The consensus in the literature is that the non-fiscal variable elasticities of the fiscal variables except for output and inflation are close to zero. In other words, there is no contemporaneous effect on the fiscal variables coming from the non-fiscal economic variables other than output and inflation. This assumption is utilized by many previous fiscal VAR works including Perotti (2004), Caldara and Kamps (2008), and Caldara (2011). I maintain this assumption with a small amount margin, $\pm 0.1$. Thus, the admissible ranges for the non-fiscal variable elasticity (except for inflation and output) of the fiscal variables are given as $\alpha_{pq} = [-0.1, 0.1]$ where $p = \{\tau, g, z\}$ and $q = \{s, r, \ell, m, i, c, v\}$.

Then I follow Perotti (2004) and Chung and Leeper (2009) for the inflation elasticities of the fiscal variables. Given that the salaries of government employer is a large portion of government spending, Perotti (2004) elucidates that the nominal wage rigidity of the employers makes the real wage fall when inflation surges. He then sets $\alpha_{\tau\pi}$ to be -0.5. Regarding the inflation elasticities of taxes and transfers, Chung and Leeper (2009) set $\alpha_{\tau\pi}$ and $\alpha_{z\pi}$ to be 0.31 and -1, respectively. For the additional elasticity restrictions, I maintain these elasticity values with a margin of $\pm 0.1$. In sum, the intervals for the inflation elasticities of the fiscal variables are given as $\alpha_{\tau\pi} = [0.21, 0.41]$, $\alpha_{g\pi} = [-0.6, -0.4]$, and $\alpha_{z\pi} = [-1.1, -0.9]$. 
As demonstrated formally in Leeper, Walker, and Yang (2011), municipal-treasury bond spread is used for the proxy of agents’ anticipation of upcoming tax rate hike. In this sense, the spread variable plays a role as the news shock in implicit tax rates. Hence, it is reasonable to assume that news contained in municipal-treasury spreads has no contemporaneous impact on the other variables in the VAR model. This assumption sets all the elasticities of municipal-treasury spread to zero, i.e., $\alpha_{sp} = 0$ where $p = \{\tau, g, z, y, r, \pi, \ell, m, i, c, v\}$. I also allow a margin of ±0.1 for these elasticities.

However, far less consensus about the output elasticities of the fiscal variables is made among the literature. To resolve this issue, I consider wide enough ranges for them to encompass all plausible values documented by the previous works. In terms of the output elasticity of taxes observed in the U.S. data, Blanchard and Perotti (2002) and Perotti (2004) use 2.16 and 1.85 for the elasticities, respectively. Whereas the penalty-function approach in Mountford and Uhlig (2009) sets the elasticity between 0 and 15. Chung and Leeper (2009) use 3.15 for the elasticity calibrated from the work by Leeper and Yang (2004). Recent work by Caldara (2011) estimates a probability distribution for the elasticity using various priors postulated from the U.S. disaggregated tax data as well as from a DSGE model as in Leeper, Plante, and Traum (2010) and concludes that the median elasticity is 2.26. Hence, the range for the output elasticity of taxes predicted by the previous studies is summarized by $\alpha_{\tau y} = [1.85, 3.15]$. Regarding the output elasticity of government spending, there is more unequivocal view across various works by assuming that it is identical to zero, i.e., government spending is acyclical. An exception may refer to Caldara (2011) who documents a slight negative elasticity that has the median value $-0.06$ and is statistically different from zero. On the other hand, a DSGE modeling approach by Leeper, Plante, and Traum (2010) provides a posterior distribution of the output elasticity of government spending whose 90% range becomes $[0.0064, 0.084]$. Finally, Chung and Leeper (2009) set the output elasticity of transfers to be $-0.15$ advocating that the contemporaneous relationship between transfer payments and a business cycle movement of output is negative. However, Leeper, Plante, and Traum (2010) report different results, in that the output elasticity of transfers is procyclical which ranges from 0.049 to 0.24.

Another prominent strategy of gauging the output elasticities of the fiscal variables is to find the elasticities that maximize the contribution of a non-fiscal shock to the forecast error variance of output for a finite horizons, fixing the other elasticities at their benchmark values. This approach is closely related to Faust (1998), Francis, Owyang, and Roush (2007), and Barsky and Sims (2011). Faust (1998) utilizes the identification strategy to demonstrate that the importance of monetary policy shocks in explaining output fluctuations by analyzing the worst case scenario in which monetary disturbances have small contribution to the forecast error variance of output. In line with Francis, Owyang, and Roush (2007), a recent work by Barsky and Sims (2011) employ a medium-run restriction, in that a shock on future total factor productivity (TFP) is defined as a shock maximizing its contribution on the future output fluctuations for finite horizons and conclude that the reactions to news shocks on TFP are similar to those predicted by standard neoclassical growth models augmented with TFP news. To apply this method, I hold the non-output elasticities of the fiscal variables to be fixed at the reference values discerned in Chung and Leeper (2009), $\alpha_{\tau x} = 0.31$, $\alpha_{g x} = -0.5$.

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19I do not take into account the range provided by the pure-sign-restriction approach due to the findings in the previous subsection.
and $\alpha_{z\pi} = -1$. The other parameters, $\alpha$’s, are set to zero under the evidenced provided above. Under these elasticity values, I examine the set of elasticities, $[\alpha_{\tau y}, \alpha_{gy}, \alpha_{zy}]$, which maximizes the forecast error variance of output for many finite horizons. It turns out that those elasticity values are not heavily dependent upon the horizon selection. For example, the solutions are $[2.41, 0.01, -0.11]$ for the one quarter horizon, $[2.35, -0.11, -0.17]$ for the one year horizon, and $[2.37, -0.24, 0.07]$ for the two year horizon, respectively.

In order to nest all of these plausible output elasticities of the fiscal variables, I set the admissible sets of the elasticities as $\alpha_{\tau y} = [1.85, 3.15]$, $\alpha_{gy} = [-0.5, 0.5]$, and $\alpha_{zy} = [-0.5, 0.5]$. Table 3 summarizes the admissible range of elasticities outlined above.

5.3. Role of Municipal-Treasury Spread. For a set of rotation matrices satisfying the sign restrictions and the elasticity bound restrictions discerned as above, the next step is to categorize each of them into corresponding fiscal adjustment. Before proceed, I address some issues in analyzing future tax changes.

Using aggregated economic data, it is difficult to disentangle tax rate changes from overall tax revenue fluctuations. Since changes in tax rates is the main object that alter the agents’ intertemporal choices, specifying tax changes caused by variation in tax rates correctly is the major issue to identify accurate fiscal adjustment dynamics.

By utilizing the fact that U.S. municipal bonds are tax exempt, Leeper, Richter, and Walker (2010) show that the difference between municipal and treasury bonds can be a good proxy for the implicit tax rates. Moreover, if various risk embedded on both bonds are identical and the bond market participants are forward looking the spread contains substantial information on impending changes in individual tax rates. Leeper, Walker, and Yang (2011) use the spread as a tax news variable that resolves the non-invertibility problem in fiscal VAR analyses by expanding econometrician’s information set. And they demonstrate that spreads between short maturity bonds capture the tax rate information better than long maturity bonds. Based on this line of findings, the authors take into account the spread between 1-year maturity municipal and treasury bonds as the tax news variable and analyze the spread-augmented Blanchard-Perotti and Mountford-Uhlig VAR models.

To better understand the role of the spread, I compare the historical data of the spread with the average marginal tax rate series constructed in Barro and Redlick (2011). Since the spread casts implicit income tax rates, I only consider their federal income tax rates for this comparison.

[Figure 3]

[Figure 4]

5.4. Foresight Horizon of Agents. This subsection postulates the forecasting horizon about fiscal variable changes upon which economic agents’ intertemporal decisions are based. Standard fiscal policy analyses assume that there are two components of fiscal variable

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20There are a few exceptions. Barro and Redlick (2011) who assume changes in average marginal income-tax rates are the main driving force of the U.S. tax changes. Romer and Romer (2010) measure tax revenue forecasts by multiplying tax rate changes extracted from the narrative sources and tax base forecasts from the macroeconomic forecasting agencies.
adjustment—discretionary changes and automatic stabilizers. Discretionary changes in distortionary fiscal variables alter agents’ intertemporal behavior whereas automatic stabilizers do not. As pointed out in Mountford and Uhlig (2009), separating out these two components is crucial in drawing logical conclusions in data-driven fiscal policy analyses. Unless one extreme case occurs when the automatic movement of fiscal variables to output dominates discretionary fiscal policy changes quantitatively—taxes increase substantially due to the surge in output, not the other way round.

To make this analysis feasible, I make two crucial assumptions on the agents’ forecasting behavior. First, I assume that the agents’ anticipation horizon on fiscal variable changes coincides with the period when discretionary fiscal changes occur. Second, agents have perfect foresight on future tax and transfer changes, in that the anticipated changes in those fiscal variables are always identical to their realization. [Evidence of these two assumptions.]

The central question is, therefore, how to verify the horizon over which discretionary fiscal variable changes take place after an exogenous fiscal intervention in the given VAR model? Unfortunately, however, a VAR system does not render a clear-cut criterion for the question. One might suggest that the output elasticity of the fiscal variables as in Blanchard and Perotti (2002) can control the automatic stabilizer over time. However, those elasticities only captivates the contemporaneous change in the fiscal variables to the output fluctuation, not applicable over time. Hence, it is necessary to take up additional identification information emerging from outside the VAR model to disentangle discretionary changes in the fiscal variables from automatic stabilizers. To resolve this issue, the I scrutinize the frequency domain property of the equilibrium time series data simulated from a DSGE model presented in Leeper, Plante, and Traum (2010). All the model features are identical to those outlined in Section 2 except for the fiscal policy specification. To consider the interaction between fiscal variables, I adapt to their original fiscal policy setup given as

\[ G_t = -\varphi_g \hat{Y}_t - \gamma_g \hat{B}_{t-1} + \hat{u}_t^g, \quad \hat{u}_t^g = \rho_g \hat{u}_{t-1}^g + \sigma_g \epsilon_t^g, \quad (26) \]
\[ \hat{r}_t^k = \varphi_k \hat{Y}_t + \gamma_k \hat{B}_{t-1} + \phi_{k1} \hat{u}_t^l + \phi_{k2} \hat{u}_t^c + \hat{u}_t^k, \quad \hat{u}_t^k = \rho_k \hat{u}_{t-1}^k + \sigma_k \epsilon_t^k, \quad (27) \]
\[ \hat{r}_t^l = \varphi_l \hat{Y}_t + \gamma_l \hat{B}_{t-1} + \phi_{l1} \hat{u}_t^l + \phi_{l2} \hat{u}_t^c + \hat{u}_t^l, \quad \hat{u}_t^l = \rho_l \hat{u}_{t-1}^l + \sigma_l \epsilon_t^l, \quad (28) \]
\[ \hat{r}_t^c = \varphi_{k1} \hat{u}_t^k + \varphi_{l1} \hat{u}_t^l + \hat{u}_t^c, \quad \hat{u}_t^c = \rho_{c1} \hat{u}_{t-1}^c + \sigma_{c1} \epsilon_t^c, \quad (29) \]
\[ \hat{Z}_t = -\varphi_z \hat{Y}_t + \gamma_z \hat{B}_{t-1} + \hat{u}_t^z, \quad \hat{u}_t^z = \rho_z \hat{u}_{t-1}^z + \sigma_z \epsilon_t^z, \quad (30) \]

that alters (12)-(16) in Section 2. The main difference of this policy specification from the previous setup is interactions between tax rates of various categories. In particular, the correlation between capital and labor income taxes and consumption taxes are explicitly modeled which potentially affects the frequency domain results of fiscal policy. Table 4 displays the co-movement parameters drawn from Leeper, Plante, and Traum (2010).

The frequency domain property of fiscal policy shocks in a neoclassical growth model dates back to Lucas (1990), investigating the growth effect of tax shocks. One important lesson can be drawn that analyzing the different frequency property of various shocks in a model may provide useful information in distinguishing between different shocks. Inspired by the work, examining the frequency domain properties of various shocks in the DSGE model outlined above may help uncovering the two different components in fiscal variable movements.
More specifically, I use the solution of the above linearized system to simulate equilibrium data under which only one specific shock perturbs the dynamics. In particular, I focus on the frequency domain property of technological, various tax rates, government spending, and transfer shocks, respectively. I then estimate the spectral density of key economic variables for each simulated data under the presence of a specific shock listed above. Since the spectral density estimation is only applicable for stationary series, I take the first difference of each simulated data. I iterate this 1,000 times and obtain the average spectral density of the variables to uncover to what frequency a specific shock affect on different variables.

In practice, non-parametric kernel density estimation technique is extensively used for spectral density estimations. Like the other non-parametric methods, this technique necessitates the choice of a lag window and a lag truncation number. Since there is no rule-of-thumb for a selection of the truncation number, I try various numbers and figure out that the results are not varying substantially by the selection of the number. For the lag window, I use the Parzen window which assigns the greatest weight to the observation being smoothed in the center of the window, and increasingly smaller weights to values that are further away from the center.

Figure 5 and 6 present the estimated spectral density of key variables to various exogenous shocks. The first feature of these figures is that a technological shock is indeed a low frequency shock. It mainly accounts for the growth component of fiscal variables as well as of output. One exception is the capital tax revenue in which a technological shock is responsible for the biannual fluctuation of the variable. Second, each fiscal shock, unlikely to a technological shock, causes high frequency fluctuations of its own. Transfer is one extreme of this case, in that high frequency changes in the variable can only be driven by a transfer shock. Third, each tax shock can cause high frequency movements in other tax variables. This is a direct consequence of modeling the serial correlation between different tax rates in the DSGE model.

A crucial identification assumption what the DSGE experiment delivers is that high frequency movements in fiscal variables can only be attributable to exogenous fiscal shocks and the contribution of a technological shock in those movements is negligible. This finding paves the way to an economic understanding of fiscal financing dynamics in the VAR system illustrated in previous sections.

To apply this finding to the VAR model, I decompose the structural impulse responses of admissible models pruned out by sign and elasticity bound restrictions. There are several filters used to decompose economic time series into different frequencies. I consider various filters (e.g., the Hodrick-Prescott (1997) filter, the bandpass filter by Christiano and Fitzgerald (2002), and the Baxter-King (1999) filter) for robustness and find that the results are not sensitive to a choice of the filter. Figure 7 plots the frequency domain decomposition of a specific impulse responses in the admissible set using two filters. The left and the right three figures correspond to the decomposition based on the Hodrick-Prescott (1997) and the Christiano-Fitzgerald (2002) filters, respectively. Regardless of the filter used, the high-frequency component of the fiscal variables is observable up to 30 quarters and the fiscal variable movement beyond the horizon is attributable to the low-frequency component of
impulse responses. In line with this finding, I set the agents’ anticipation horizon on future fiscal policy changes to be 30 quarters.\textsuperscript{21}

5.5. Definition of Government Spending Shock with Tax or Transfer Anticipation. This subsection summarizes the identification restrictions discussed above. First of all, the definition of government spending shocks with anticipated tax adjustment is formalized as follows.

**Definition 1.** A government spending shock with anticipated tax adjustment is a rotation matrix $Q$ that satisfies the following conditions.

1. **Sign restriction (with magnitude):** it increases government spending and debt at impact while the magnitude of taxes and transfers responses are smaller than 1 percent in absolute terms at impact.
2. **Elasticity bound restriction:** the implied elasticities from the impulse matrix $A$, defined as $A = A\hat{Q}$, satisfy the elasticity bound restrictions as in Table 3.
3. **Sign restriction on the spread:** the impulse responses of the spread are positive at impact and the next horizons.
4. **Sign restriction on fiscal variable changes in present-value terms:** the present-value change in taxes and transfers up to the agents’ anticipation horizon are all positive, i.e., $f_{\tau}^a(H) > 0$ and $f_{z}^a(H) < 0$ where $a$ is a column of the matrix $A$ corresponding to government spending and $H$ is the agents’ anticipation horizon.

Likewise, a government spending shock with anticipated transfer adjustment can be defined by altering the restrictions (3) and (4) above.

**Definition 2.** A government spending shock with anticipated tax adjustment is a rotation matrix $Q$ that satisfies the following conditions.

1. **Sign restriction (with magnitude):** it increases government spending and debt at impact while the magnitude of taxes and transfers responses are smaller than 1 percent in absolute terms at impact.
2. **Elasticity bound restriction:** the implied elasticities from the impulse matrix $A$, defined as $A = A\hat{Q}$, satisfy the elasticity bound restrictions as in Table 3.
3. **Sign restriction on the spread:** the impulse responses of the spread are negative at impact and the next horizons.
4. **Sign restriction on fiscal variable changes in present-value terms:** the present-value change in taxes and transfers up to the agents’ anticipation horizon are all negative, i.e., $f_{\tau}^a(H) < 0$ and $f_{z}^a(H) > 0$ where $a$ is a column of the matrix $A$ corresponding to government spending and $H$ is the agents’ anticipation horizon.

In sum, the above definitions depict a case in which only one fiscal variable (either taxes or transfers) plays a dominant role in financing the initial debt innovation invoked by an exogenous government spending increase.

\textsuperscript{21}\textsuperscript{21}However, the later empirical subsection (Subsection 6.5) investigates the results with respect to various foresight horizons.
6. Empirical Results

6.1. Spending Multipliers Identified by Sign Restrictions and Elasticity Bound Restrictions. The dollar-valued impulse responses to the identified government spending shocks via sign and elasticity restrictions are plotted in Figure 8. More specifically, Figure 8 displays the 84th and 16th impulse response bands of the 1,000 admissible structural models. Government spending shocks increase output and decrease private investment at impact in terms of the 68% bands, but their effect on private consumption is ambiguous. The consumption responses at impact from the admissible models take both positive and negative signs. As Table 5 reconfirms, the admissible models render consumption multiplier at impact from −0.12 to 0.20 in terms of the 68% bands.

This finding may suggest that the identification restriction posed for government spending shocks is insufficient to draw a line between compelling economic theories. In particular, the sign of consumption response at impact ignites debates in measuring the efficacy of exogenous government spending increases. Traditional structural VAR approaches advocate that government spending shocks raise consumption at the initial period (e.g., Blanchard and Perotti (2002); Perotti (2004); Caldara and Kamps (2008); Galí, López-Salido, and Vallés (2007); Monacelli and Perotti (2008)). On the other hand, narrative approaches on military spending document initial consumption crowding-out to government spending raises (e.g., Ramey and Shapiro (1998); Ramey (2011)). Hence, additional identification information is necessary to sharpen the set of admissible models. Anticipated fiscal adjustment does a such role.

6.2. Adding Fiscal Adjustment Anticipation Restrictions. The consequences of government spending shocks categorized by the anticipated tax or transfer adjustment criterion are summarized in Table 6 and Figure 9, delivering the same story. Based on the 68% bands, government spending shocks under both adjustments raise output in the short- and medium-run, whereas their impact on private investment fluctuates across different signs over time. More striking evidence is observable at impact, in that output, consumption, and investment multipliers at the impact period tend to be bigger when future transfer adjustment is anticipated to a government spending shock. More specifically, the initial consumption crowding-in is occurred when transfer adjustment is anticipated to government spending shocks. In contrast, the tax anticipation case shows slightly negative impact on consumption. Regarding the investment multipliers, tax adjustments crowd out private investment heavier than transfer adjustments. These facts bring forth the bigger output multipliers corresponding to the transfer adjustment case. In terms of the consumption responses at impact period, the consequences of government spending shocks accompanying with anticipated transfer adjustments advocate the evidence by traditional structural VAR approaches as in Blanchard and Perotti (2002) and Galí, López-Salido, and Vallés (2007). Moreover, output multipliers at impact period of the transfer adjustment case are consistent with previous literature assuming that fiscal shocks are either debt-financed or adjusted by lump-sum taxes to balance the government budget (e.g., Blanchard and Perotti (2002)’s government spending multiplier at impact period is 0.9 and that of Mountford and Uhlig (2009) is 0.65).
However, the empirical results of this work suggest that there are possible solutions when there is another option for fiscal adjustments. And it turns out that anticipated tax adjustments hinder the efficacy of government spending increase to stimulate the economy. This effect is applicable not for the impact period but for the short- and medium-run. Dollar-valued output multipliers tend to be smaller when tax adjustments are anticipated than the transfer case for the period up to 10 years.

6.3. Corresponding Structural Models Under Fiscal Adjustment Anticipation. The identification strategy in this work consists of several inequality restrictions as summarized by the two definitions in Subsection 5.5 above. By the nature of inequality restrictions, therefore, the identification procedure results in a set of equally probable solutions, without pinning down a specific structural model. This fact creates the cacophony of what the plausible inference procedure for set identified VAR models. Uhlig (2005b) conducts inferences based on the median responses of admissible models and Mountford and Uhlig (2009) apply this approach for the fiscal policy analysis. However, Fry and Pagan (2010) and Inoue and Kilian (2011) raise a problem of using the median response based inferences with the reasoning that there is no unique structural model generating the identical impulse responses to the median responses. To resolve this issue, Fry and Pagan (2010) propose a method figuring out a single structural model that renders the closest impulse responses to the median responses. In contrast, the treatment by Inoue and Kilian (2011) is to find the most probable model among the set solutions, inferences based on the posterior mode.

To resolve this issue also appeared in the identification procedure of this work, I propose the median-elasticity method in spirit of Fry and Pagan (2010).\textsuperscript{22} The method is to find the closest impulse responses to median responses by using a structural model evaluated at the median elasticities of a set of admissible models. Surprisingly, as Figure 10 confirms, this method captures extremely well the behavior of impulse responses represented by median responses in both tax and transfer adjustment cases.

Figure 11 and 12 exhibit the dollar-valued impulse responses of the two structural models, the anticipated tax and transfer cases respectively, with one-standard-deviation bands. As in Chung and Leeper (2009), confidence intervals are computed from 5,000 Monte-Carlo draws using the OLS estimates of the 12-variable VAR model as the data-generating process and assuming normal innovations.

More specifically, Table 7 and 8 display the dollar-valued multipliers of output, private consumption, and private investment in the both adjustment cases. For the anticipated tax adjustment case, the initial responses of output and consumption is not statistically different from zero whereas private investment is heavily crowded out. There are output and consumption crowding-in in the medium-run, but these effects becomes statistically insignificant after 5 years (output) and 7 years (consumption), respectively. Despite of the initial crowding-out, private investment stays in one-standard-deviation bands beyond the two-year horizon. In contrast, anticipated transfer adjustments result in rather distinguishable consequences. At the impact period, output and consumption are statistically significant positively.\textsuperscript{22} Another issue about using median responses to capture the central tendency of the set solutions is raised in Inoue and Kilian (2011), in that the median responses might induce biased inferences because the inequality restriction truncates the admissible solutions of a specific sign. This work does not pursue their approach further.

\textsuperscript{22}Another issue about using median responses to capture the central tendency of the set solutions is raised in Inoue and Kilian (2011), in that the median responses might induce biased inferences because the inequality restriction truncates the admissible solutions of a specific sign. This work does not pursue their approach further.
of debt financing dynamics is another aspect to be pointed out. The transfer case takes about 5 years for debt to resort its initial level, but the tax case expedites this dynamics so that the flipping sign of debt responses occurs around 4 years after the initial government spending hike.

6.4. Sensitivity Analysis: Various Foresight Horizons. This subsection examines the consequences of assuming various agents’ horizons over the fiscal adjustments. Unlike the assumption of this work, Leeper, Richter, and Walker (2010) elucidate that news on tax or government spending displays three to five quarter lags, depending upon economic situations or taking office of different president. Therefore, it is necessary to investigate how alteration of the foresight horizon assumption affects the empirical results outlined above.

For the sensitivity check with respect to the foresight horizon, I consider a range of the horizon from one year as in Leeper, Richter, and Walker (2010) to 30 quarters as in this work. Figure 13 and Table 9 depict the multipliers of key economic variables at impact period as a function of the foresight horizon. More or less, these figures demonstrate that the anticipated tax or transfer adjustments can be a clear-cut criterion to distinguish two sets of solutions displaying unequal property in terms of fiscal multipliers. This effect is the most conceivable when 4- to 5-year horizon is assumed throughout the truncated present-value accounting.

6.5. Comments on Spending Reversal. The empirical strategy taken into account here helps understand one of the government’s debt financing option, spending reversals. Corsetti, Meier, and Müller (2009) observe the private consumption crowding-in in the short-run and crowding-out of output and private consumption taking place in the medium-run when there is anticipated government spending slashed below its trend to an exogenous government spending shock. Wieland (2010) critically reviews their work based on rational that additional fiscal actions in the future cannot be retroactive to alter agents’ behavior at current periods by expanding their information set. In addition, Wieland (2010) attributes the observed spending reversals in Corsetti, Meier, and Müller (2009) as automatic stabilizer components of fiscal variables caused by misspecification of the econometric model.

To shed light on this aspect, I conduct the frequency decomposition analysis of impulse responses from tax and transfer adjustment models. Figure 14 illustrates the results with impulse responses of output and consumption. Spending reversals defined as in Corsetti, Meier, and Müller (2009) are observed in those two models, between 28 and 49 quarter horizons for tax model and 25 and 50 quarter horizons for transfer model. Unlikely to the finding by Corsetti, Meier, and Müller (2009), however, there is neither output nor consumption crowding-out happened in the medium-run. More important, the fluctuation in government spending at the horizons over which spending reversals occur is attributable to the low-frequency movement of spending changes, in turn is interpretable as government spending’s co-movement with output fluctuations. In sum, the empirical results here render evidence in favor of Wieland (2010)’s criticism on the work by Corsetti, Meier, and Müller (2009). Historical data suggests that spending reversals are quite rare option for financing U.S. government debt.
7. Conclusion

This paper offers an empirical characterization of government spending shocks accompanying with news on future fiscal adjustments to stabilize debt induced by the initial government spending surge. To identify government spending shocks categorized by various dynamics of anticipated fiscal adjustments, I employ various identification strategies of VARs, including sign restrictions on impulse responses, inequality restrictions on implied elasticities, and frequency domain decompositions of impulse responses. This approach renders sufficiently narrowed down set solutions of homogeneous estimates for anticipated fiscal financing dynamics. Moreover, the results are robust across the choice of fiscal foresight horizon of economic agents.

Throughout the robust identification scheme, I figure out that the efficacy of government spending increases varies across the agents’ anticipation about future fiscal financing dynamics. In particular, two empirical findings emerge from the analyses. First, government spending shocks accompanying with anticipation of transfer adjustments nest the multiplier values documented by traditional VAR literature as Blanchard and Perotti (2002) and Mountford and Uhlig (2009). Second, government spending shocks associated with anticipation of distortionary tax adjustments hinder the stimulus effect of the intervention substantially. Output multiplier at impact period becomes 23 cents to a dollar increase in government spending, whereas the anticipated transfer adjustment case raises output by 87 cents to the same amount of spending increase. This result is in line with the earlier findings of RBC literature illuminating the huge output crowding-out of distortionary means compared to non-distortionary fiscal financing dynamics (e.g., Baxter and King (1993); Sims (1998); Leeper and Yang (2008); Leeper, Plante, and Traum (2010)). Finally, spending reversals can hardly be options for fiscal adjustment dynamics observed in the postwar U.S. data. Rather, exogenous increases in government spending are financed either by tax hikes or by transfer cuts.
Appendix A. Analytics of Sign Restrictions: Blanchard-Perotti Model

A.1. Blanchard-Perotti Interpretation of Sign Restriction Solutions. I consider the $L$-th order reduced-form VAR model as

$$X_t = \mu + B(L)X_{t-1} + u_t,$$

where $X_t = [\tau_t \ g_t \ y_t]'$ and $u_t = [u^\tau_t \ u^g_t \ u^y_t]'$. I denote $\Sigma_u$ as the variance-covariance matrix of the reduced-form innovations $u_t$ expressed as

$$\Sigma_u = \begin{bmatrix} \sigma_{\tau\tau} & \sigma_{\tau g} & \sigma_{\tau y} \\ \sigma_{g\tau} & \sigma_{gg} & \sigma_{gy} \\ \sigma_{y\tau} & \sigma_{yg} & \sigma_{yy} \end{bmatrix}.$$  (32)

In general, the off-diagonal elements of $\Sigma_u$ are non-zero and the reduced form innovations are correlated. In order to identify the economically meaningful uncorrelated shocks, Blanchard and Perotti (2002) set up a contemporaneous restriction between the reduced-form and the structural innovations as

$$\begin{bmatrix} 1 & 0 & -\alpha_{\tau y} \\ 0 & 1 & -\alpha_{g y} \\ -\alpha_{y\tau} & -\alpha_{yg} & 1 \end{bmatrix} \begin{bmatrix} u^\tau_t \\ u^g_t \\ u^y_t \end{bmatrix} = \begin{bmatrix} 1 & \beta_{\tau g} & 0 \\ \beta_{g\tau} & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon^\tau_t \\ \varepsilon^g_t \\ \varepsilon^y_t \end{bmatrix}.$$  (33)

or more succinctly as

$$A_0u_t = B_0\varepsilon_t$$

where $\varepsilon_t = [\varepsilon^\tau_t \ \varepsilon^g_t \ \varepsilon^y_t]'$ denotes the corresponding structural innovations whose variance-covariance matrix can be written as

$$\Sigma_\varepsilon = \begin{bmatrix} \epsilon_{\tau\tau} & 0 & 0 \\ 0 & \epsilon_{gg} & 0 \\ 0 & 0 & \epsilon_{yy} \end{bmatrix}.$$  (34)

Premultiplying the inverse of $B_0$ to both sides of (33) and arranging terms yield

$$\begin{align*}
  u^\tau_t &= (\alpha_{\tau y} - \alpha_{yg}\beta_{\tau g})u^g_t + \beta_{\tau g}u^y_t + (1 - \beta_{g\tau}\beta_{\tau g})\varepsilon^\tau_t \\
  u^g_t &= (\alpha_{gg} - \alpha_{y\tau}\beta_{g\tau})u^\tau_t + \beta_{g\tau}u^y_t + (1 - \beta_{\tau g}\beta_{g\tau})\varepsilon^g_t \\
  u^y_t &= \alpha_{y\tau}u^\tau_t + \alpha_{yg}u^g_t + \varepsilon^y_t.
\end{align*}$$  (35)

In the meantime, the identification problem given by sign restriction approaches is

$$\begin{bmatrix} u^\tau_t \\ u^g_t \\ u^y_t \end{bmatrix} = \begin{bmatrix} A_{\tau\tau} & A_{\tau g} & A_{\tau y} \\ A_{g\tau} & A_{gg} & A_{gy} \\ A_{y\tau} & A_{yg} & A_{yy} \end{bmatrix} \begin{bmatrix} \varepsilon^\tau_t \\ \varepsilon^g_t \\ \varepsilon^y_t \end{bmatrix}.$$  (36)

where the structural innovations $\varepsilon_t$ satisfy $E(\varepsilon_t\varepsilon_t') = I$, i.e.,

$$\Sigma_\varepsilon = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}.$$  (37)

It should be emphasized that the reduced-form innovations are purely dependent on data and identical regardless of the choice of a VAR identification scheme. The structural innovations, however, vary upon which identification schemes one selects and, thus, the two
structural innovations, \( \varepsilon_t \) and \( e_t \), are different from each other in general. Therefore, I pre-
multiply the inverse of \( A \) matrix to both sides of (36) to express the sign restriction identifi-
cation problem as a relationship among the reduced-form innovations.\(^{23}\) Then this algebraic manipulation yields

\[
\begin{align*}
\mathbf{u}_t^\tau &= \frac{A_{gg}A_{yy} - A_{gy}A_{gg}}{A_{yy}A_{gg} - A_{gy}A_{yy}} \mathbf{u}_t^\tau + \frac{A_{gg}A_{yy} - A_{gy}A_{gg}}{A_{yy}A_{gg} - A_{gy}A_{yy}} \mathbf{u}_t^g + \Lambda^\tau \varepsilon_t^\tau, \\
\mathbf{u}_t^g &= \frac{A_{gy}A_{yy} - A_{ty}A_{gy}}{A_{ty}A_{yy} - A_{gy}A_{ty}} \mathbf{u}_t^\tau + \frac{A_{gy}A_{yy} - A_{ty}A_{gy}}{A_{ty}A_{yy} - A_{gy}A_{ty}} \mathbf{u}_t^g + \Lambda^g \varepsilon_t^g, \\
\mathbf{u}_t^y &= \frac{A_{gg}A_{ty} - A_{gt}A_{gg}}{A_{ty}A_{gg} - A_{gt}A_{ty}} \mathbf{u}_t^\tau + \frac{A_{gg}A_{ty} - A_{gt}A_{gg}}{A_{ty}A_{gg} - A_{gt}A_{ty}} \mathbf{u}_t^y + \Lambda^y \varepsilon_t^y,
\end{align*}
\]

where

\[
\Lambda^\tau = \frac{\det(A)}{A_{yy}A_{gg} - A_{gy}A_{yy}}, \quad \Lambda^g = \frac{\det(A)}{A_{ty}A_{yy} - A_{gy}A_{ty}}, \quad \text{and} \quad \Lambda^y = \frac{\det(A)}{A_{ty}A_{gg} - A_{gt}A_{ty}}
\]

and \( \det(A) \) denotes the determinant of the matrix \( A \).

It follows by matching coefficients between (35) and (38) that

\[
\begin{align*}
\alpha_{ty} - \alpha_{gy}\beta_{ty} &= \frac{A_{ty}A_{yy} - A_{gy}A_{ty}}{A_{yy}A_{gg} - A_{gy}A_{yy}} \beta_{ty} = \frac{A_{ty}A_{yy} - A_{gy}A_{ty}}{A_{yy}A_{gg} - A_{gy}A_{yy}}, \\
\alpha_{gy} - \alpha_{ty}\beta_{ty} &= \frac{A_{ty}A_{yy} - A_{gy}A_{ty}}{A_{yy}A_{gg} - A_{gy}A_{yy}}, \quad \beta_{ty} = \frac{A_{ty}A_{yy} - A_{gy}A_{ty}}{A_{yy}A_{gg} - A_{gy}A_{yy}}, \\
\alpha_{ty} &= \frac{A_{gg}A_{ty} - A_{gt}A_{gg}}{A_{ty}A_{gg} - A_{gt}A_{ty}}, \quad \text{and} \quad \alpha_{gy} = \frac{A_{gg}A_{ty} - A_{gt}A_{gg}}{A_{ty}A_{gg} - A_{gt}A_{ty}}.
\end{align*}
\]

Moreover, by solving the first four equations in (39) for \( \alpha_{ty} \) and \( \alpha_{gy} \), we have

\[
\alpha_{ty} = \frac{A_{ty}}{A_{yy}} \quad \text{and} \quad \alpha_{gy} = \frac{A_{gg}}{A_{yy}}.
\]

A.2. **Impact Fiscal Multipliers of Output.** In order to derive the analytical expression for the impact fiscal multipliers, I premultiply the inverse of \( A_0 \) to both sides of (33) and have \( u_t = A_0^{-1}B_0\varepsilon_t \). Then the third row of this matrix representation exhibits how the output variable relates to three exogenous shocks as

\[
\begin{align*}
\mathbf{u}_t^y &= \frac{\alpha_{gy} + \alpha_{gy}\beta_{ty}}{1 - \alpha_{ty}\alpha_{gy} - \alpha_{gy}\alpha_{gg}} \varepsilon_t^\tau + \frac{\alpha_{ty}\beta_{ty} + \alpha_{gy}}{1 - \alpha_{ty}\alpha_{gy} - \alpha_{gy}\alpha_{gg}} \varepsilon_t^g + \frac{1}{1 - \alpha_{ty}\alpha_{gy} - \alpha_{gy}\alpha_{gg}} \varepsilon_t^y.
\end{align*}
\]

Note that the coefficients of \( \varepsilon_t^\tau \) and \( \varepsilon_t^g \) measure percentage change in output with respect to one percent change in taxes and government spending, respectively. To restore fiscal multipliers defined as dollar change in output to a dollar change in fiscal variables, I multiply

\(^{23}\)By construction, the \( A \) matrix is non-singular and hence invertible.
the average GDP share of corresponding fiscal variable which yields the impact government spending multiplier of output as

$$\Pi_{g} = \frac{\alpha_{y} \beta_{g} + \alpha_{g}}{1 - \alpha_{ty} \alpha_{g} - \alpha_{gy} \alpha_{g} G/Y}$$

(42)

Furthermore, by using the relationship between two identification coefficients as in (39) and (40) one can express the multipliers in sign restriction terminologies as

$$\Pi_{g} = \frac{\alpha_{y} \beta_{g} + \alpha_{g}}{1 - \alpha_{ty} \alpha_{g} - \alpha_{gy} \alpha_{g} G/Y} = \frac{A_{yy} A_{g}}{A_{gg} A_{g} - A_{gg^2} G/Y}$$

(43)

APPENDIX B. ANALYTICS OF SIGN RESTRICTIONS: GENERALIZATION

B.1. Analytical Solutions for Elasticities of Fiscal Variables. Consider a VAR system which consists of the three fiscal variables, output, and a non-fiscal and non-output component variable x that has contemporaneous effect on the fiscal variables and output. Following Blanchard and Perotti (2002) and Perotti (2004) this system can be expressed as

$$A_{0} u_{t} = B_{0} \varepsilon_{t}.$$ 

(44)

where

$$A_{0} = \begin{bmatrix} 1 & 0 & 0 & -\alpha_{ty} & -\alpha_{tx} \\ 0 & 1 & 0 & -\alpha_{gy} & -\alpha_{gx} \\ 0 & 0 & 1 & -\alpha_{zy} & -\alpha_{zx} \\ -\alpha_{ty} & -\alpha_{gy} & -\alpha_{gx} & 1 & -\alpha_{yx} \\ -\alpha_{tx} & -\alpha_{zx} & -\alpha_{gx} & -\alpha_{zx} & 1 \end{bmatrix}, \quad B_{0} = \begin{bmatrix} 1 & \beta_{tg} & \beta_{tx} & 0 & 0 \\ \beta_{yt} & 1 & \beta_{yz} & 0 & 0 \\ \beta_{zt} & \beta_{zy} & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix},$$

and

$$u_{t} = \begin{bmatrix} u_{t}^{x} \\ u_{t}^{y} \\ u_{t}^{z} \\ u_{t}^{g} \\ u_{t}^{\tau} \end{bmatrix}, \quad \varepsilon_{t} = \begin{bmatrix} \varepsilon_{t}^{x} \\ \varepsilon_{t}^{y} \\ \varepsilon_{t}^{z} \\ \varepsilon_{t}^{g} \\ \varepsilon_{t}^{\tau} \end{bmatrix}.$$.

Premultiplying $B_{0}^{-1}$ to both sides of (44) and arranging terms give

$$u_{t}^{x} = \begin{bmatrix} \kappa_{11} \alpha_{ty} + \kappa_{12} \alpha_{gy} + \kappa_{13} \alpha_{gx} & \kappa_{14} \alpha_{zx} \end{bmatrix} u_{t}^{y} - \begin{bmatrix} \kappa_{11} \alpha_{ty} + \kappa_{12} \alpha_{gy} + \kappa_{13} \alpha_{gx} + \kappa_{14} \alpha_{zx} \end{bmatrix} u_{t}^{x} - \begin{bmatrix} \kappa_{12} \alpha_{ty} + \kappa_{13} \alpha_{gy} + \kappa_{14} \alpha_{gx} \end{bmatrix} u_{t}^{g} - \begin{bmatrix} \kappa_{13} \alpha_{gy} + \kappa_{14} \alpha_{gx} \end{bmatrix} u_{t}^{z} - \begin{bmatrix} \kappa_{14} \alpha_{gx} \end{bmatrix} u_{t}^{\tau},$$

(45)
where

\[ K = \begin{bmatrix} \kappa_{11} & \kappa_{12} & \kappa_{13} \\ \kappa_{21} & \kappa_{22} & \kappa_{23} \\ \kappa_{31} & \kappa_{32} & \kappa_{33} \end{bmatrix} = \begin{bmatrix} 1 - \beta_{gz} \beta_{zg} & \beta_{gz} \beta_{z\tau} - \beta_{g\tau} & \beta_{g\tau} \beta_{zg} - \beta_{z\tau} \\ \beta_{rz} \beta_{zg} - \beta_{r\tau} & 1 - \beta_{r\tau} \beta_{z\tau} & \beta_{r\tau} \beta_{zg} - \beta_{zg} \\ \beta_{rg} \beta_{zg} - \beta_{r\tau} & \beta_{rz} \beta_{g\tau} - \beta_{g\tau} & 1 - \beta_{r\tau} \beta_{g\tau} \end{bmatrix}. \]

and the expressions corresponding to the last two rows of (44) are not presented because they are unnecessary to calculate the key elasticities. Note that the key elasticities are output and the variable \( x \) elasticities of fiscal variables, i.e., \( \alpha \)'s in the expression (44).

To express these elasticities in terms of the elements of the sign restriction identification matrix \( A \), let us consider the following model given as

\[ u_t = Ae_t, \tag{46} \]

where

\[ A = \begin{bmatrix} A_{\tau\tau} & A_{\tau g} & A_{\tau z} & A_{\tau y} & A_{\tau x} \\ A_{g\tau} & A_{g g} & A_{g z} & A_{g y} & A_{g x} \\ A_{z\tau} & A_{z g} & A_{z z} & A_{z y} & A_{z x} \\ A_{y\tau} & A_{y g} & A_{y z} & A_{y y} & A_{y x} \\ A_{x\tau} & A_{x g} & A_{x z} & A_{x y} & A_{x x} \end{bmatrix} \quad \text{and} \quad e_t = \begin{bmatrix} e_{t\tau}^\tau \\ e_{t\tau}^g \\ e_{t\tau}^z \\ e_{t\tau}^y \\ e_{t\tau}^x \end{bmatrix}. \]

As mentioned, a sign restriction approach is partial identification, in that the number of shocks does not need to be the same as the number of variables. The three-variable case is in fact an exceptional case where the number of shocks coincides with the number of variables in the system. Throughout this work, however, the higher-dimensional systems only identify four shocks—a non-fiscal shock, a tax shock, a government spending shock, and a transfer shock. In the matrix representation (46), this corresponds to the identification of the first four columns of \( A \) which causes a problem of inverting the \( A \) matrix. However, this problem can easily be resolved by using Uhlig’s (2005b) methodology suggested in Proposition A.2. Suppose that \( a \) is the first column of \( A \) matrix. Assuming that \( \Sigma_u \) is regular, the first row of \( A^{-1} \) matrix can be calculated by finding a five-dimensional vector \( b \) satisfying

\[ (\Sigma_u - aa') b = 0 \]

and

\[ b'a = 1. \]

Let \( b_{ij} \) denote the element of \( A^{-1} \) corresponding to the row for variable \( i \) and the column for variable \( j \) calculated by the above step. Then the first three rows of \( A^{-1} \), denoted by \( A_{(1:3)}^{-1} \), can be written as

\[ A_{(1:3)}^{-1} = \begin{bmatrix} b_{\tau\tau} & b_{\tau g} & b_{\tau z} & b_{\tau y} & b_{\tau x} \\ b_{g\tau} & b_{g g} & b_{g z} & b_{g y} & b_{g x} \\ b_{z\tau} & b_{z g} & b_{z z} & b_{z y} & b_{z x} \end{bmatrix}. \]
Hence, the sign restriction identification system (46) is rewritten as

\[
\begin{align*}
    u_t^\tau &= -\frac{b_{\tau y}}{b_{\tau \tau}} u_t^y - \frac{b_{\tau x}}{b_{\tau \tau}} u_t^x - \frac{b_{\tau g}}{b_{\tau \tau}} u_t^g - \frac{b_{\tau z}}{b_{\tau \tau}} u_t^z,
    \\
    u_t^g &= -\frac{b_{g y}}{b_{g g}} u_t^y - \frac{b_{g x}}{b_{g g}} u_t^x - \frac{b_{g z}}{b_{g g}} u_t^z - \frac{b_{g \tau}}{b_{g g}} u_t^\tau,
    \\
    u_t^z &= -\frac{b_{z y}}{b_{z z}} u_t^y - \frac{b_{z x}}{b_{z z}} u_t^x - \frac{b_{z g}}{b_{z z}} u_t^g - \frac{b_{z \tau}}{b_{z z}} u_t^\tau.
\end{align*}
\]

(47)

For simplicity, define \( S_{ij} = -\frac{b_{ij}}{b_{ii}} \), where \( i = \tau, g, z \) and \( j = \tau, g, z, y, x \). Then matching coefficients of (45) and (47) yields the analytical solution for \( \beta \)'s with respect to the sign restriction notions as

\[
\begin{align*}
    \beta_{\tau g} &= \frac{S_{gr} + S_{gz}S_{zt}}{1 - S_{gz}S_{zt}}, & \beta_{\tau z} &= \frac{S_{zt} + S_{g\tau}S_{gr}}{1 - S_{gz}S_{zt}}, \\
    \beta_{gt} &= \frac{S_{gr} + S_{tz}S_{zt}}{1 - S_{tz}S_{zt}}, & \beta_{g\tau} &= \frac{S_{gz} + S_{zt}S_{g\tau}}{1 - S_{zs}S_{zt}}, \\
    \beta_{zt} &= \frac{S_{zt} + S_{gr}S_{gz}}{1 - S_{gt}S_{gr}}, & \beta_{g\tau} &= \frac{S_{gz} + S_{zt}S_{g\tau}}{1 - S_{zs}S_{zt}}.
\end{align*}
\]

The elasticities of fiscal variables solves

\[
\begin{bmatrix}
    \alpha_{\tau y} \\
    \alpha_{gy} \\
    \alpha_{zy}
\end{bmatrix} = \begin{bmatrix}
    1 & \frac{\kappa_{12}}{\kappa_{11}} & \frac{\kappa_{13}}{\kappa_{11}} \\
    \frac{\kappa_{21}}{\kappa_{22}} & 1 & \frac{\kappa_{23}}{\kappa_{22}} \\
    \frac{\kappa_{31}}{\kappa_{33}} & \frac{\kappa_{32}}{\kappa_{33}} & 1
\end{bmatrix}^{-1} \begin{bmatrix}
    S_{\tau y} \\
    S_{gy} \\
    S_{zy}
\end{bmatrix}
\]

and

\[
\begin{bmatrix}
    \alpha_{\tau x} \\
    \alpha_{gx} \\
    \alpha_{zx}
\end{bmatrix} = \begin{bmatrix}
    1 & \frac{\kappa_{12}}{\kappa_{11}} & \frac{\kappa_{13}}{\kappa_{11}} \\
    \frac{\kappa_{21}}{\kappa_{22}} & 1 & \frac{\kappa_{23}}{\kappa_{22}} \\
    \frac{\kappa_{31}}{\kappa_{33}} & \frac{\kappa_{32}}{\kappa_{33}} & 1
\end{bmatrix}^{-1} \begin{bmatrix}
    S_{\tau x} \\
    S_{gx} \\
    S_{zx}
\end{bmatrix}.
\]

B.2. Impact Fiscal Multipliers of Output. To derive the analytical solutions for impact government spending multipliers I use a guess and verify method. From the three-variable case, I deduce that the government spending multiplier is expressed as

\[
\Pi_{0y}^{g,y} = \frac{(A_{gy}/A_{gg})}{1 - \alpha_{gy}(A_{gy}/A_{gg}) - \alpha_{gx}(A_{gx}/A_{gg}) G/Y}.
\]

(48)

For the verification I use the analytical solutions obtained in the previous subsection and calculate the \( \Pi_0 \) values. I compare these results with the corresponding element of \( A_0^{-1}B_0 \), where \( A_0 \) and \( B_0 \) are given in (44). This procedure confirms that (48) is indeed correct conjecture.
C.1. The VAR Restriction of PV Constraint: Formula. Consider the $\ell$th order reduced-form VAR model given as (18). The companion form representation transforms a VAR($\ell$) model in a larger scale VAR(1) system as

$$X_t = X_0 + B'X_{t-1} + U_t,$$

where $X_t$ and $U_t$ are $n\ell$-dimensional column vectors and $B$ is an $n \times n\ell$ matrix of VAR coefficients as

$$X_t = \begin{bmatrix} X_t \\ X_{t-1} \\ \vdots \\ X_{t-\ell+1} \end{bmatrix}, \quad B_0 = \begin{bmatrix} \mu \\ 0 \\ \vdots \\ 0 \end{bmatrix}', \quad B = \begin{bmatrix} B_1 & \cdots & B_{\ell-1} & B_{\ell} & \gamma \end{bmatrix}', \quad U_t = \begin{bmatrix} u_t \\ \vdots \\ 0 \end{bmatrix},$$

$U_t \sim N(0, \Sigma_U)$, and $B_i$ is the $i$th lag order VAR coefficient, $i = 1, \ldots, \ell$. Let us further define an $n\ell$-dimensional variable selection vector $C_x$ as

$$x_t = X_t'C_x,$$

i.e., $C_x$ chooses a model variable $x$ from the vector $X_t$.

Then as Chung and Leeper (2009) discern, the log-linearized intertemporal budget constraint (IBC) of government implies the present-value restriction on the VAR coefficient matrix $B$ as:

$$\beta B \left\{ C_v + \frac{\bar{z}}{\bar{v}} C_r - \frac{\bar{g}}{\bar{v}} C_g - \frac{\bar{z}}{\bar{v}} C_z + \left[ 1 - \frac{1}{\beta} \frac{1}{\bar{v}} \delta \left( \bar{R} - 1 \right) \right] C_v \right\} = \left\{ C_v + \left( 1 - \beta \frac{1}{\bar{v}} \delta \bar{R} \right) C_R + \left[ 1 - \beta \frac{1}{\bar{v}} \delta \left( \bar{R} - 1 \right) \right] C_R - \beta \frac{1}{\bar{v}} \delta \left( \bar{R} - 1 \right) C_m \right\},$$

where $\beta$ is the discount factor and $(\bar{m}, \bar{r}, \bar{g}, \bar{z}, \bar{v})$ are the steady-state nominal variables scaled by output. Moreover, $\bar{R}$ and $\bar{\pi}$ denote the steady-state nominal interest rate and inflation respectively. I use the sample mean of each variable as the steady-state values. Note that the discount factor plays a crucial in PV accounting and I calculate the value $\beta$ from the period-by-period flow budget constraint of the government at the steady state imposing that $1/\beta = \bar{R}/\bar{\gamma}\bar{\pi}$, where $\bar{\gamma}$ is the steady-state real output growth. This value for the sample period from 1947:Q1 to 2007:Q4 is 0.9944.

C.2. The VAR Restriction of PV Constraint: Estimation. Suppose there are $T$ number of observations for each variable, i.e., $t = 1, \ldots, T$. As the equation (50) imposes a constraint on the reduced-form VAR coefficients, a least-squares method minimizes the VAR residual in (49) subject to the restriction (50) as

$$\min_{\ell=\ell+1} \sum_{t=\ell+1}^{T} u_t'\Sigma_u^{-1}u_t \text{ subject to (50)}. \quad (51)$$

---

24 For more detailed derivation, see Chung and Leeper (2009).
To obtain a feasible estimator for the problem (51), define

\[
Y \equiv \begin{bmatrix} X'_{t+1} \\ X'_{t+2} \\ \vdots \\ X'_T \end{bmatrix}, \quad Y_- \equiv \begin{bmatrix} X'_1 & X'_{t-1} & \cdots & X'_t \\ X'_{t+1} & X'_{t-2} & \cdots & X'_2 \\ \vdots & \vdots & \ddots & \vdots \\ X'_{T-1} & X'_{T-2} & \cdots & X'_{T-t} \end{bmatrix},
\]

\( Y_- \equiv [1, Y_-] \), and \( b \equiv \text{vec}([\mu, B_1, \ldots, B_\ell]) \). Then the part of the objective function (51) incorporating \( b \) can be written as

\[
\min_b (b - \hat{b})' S (b - \hat{b}),
\]

where \( S = \Sigma_u^{-1} \otimes (Y_- Y_-) \) and \( \hat{b} = \text{vec}([Y_- Y_-]^{-1} Y_- Y) \).

Then the minimization problem (51) is expressed as

\[
\min_b (b - \hat{b})' S (b - \hat{b}) - \lambda (C_1 b - C_0),
\]

(52)

where \( C_1 \) and \( C_0 \) are defined by

\[
C_1 \equiv \beta \left\{ C_v + \frac{\tilde{\tau}}{\tilde{v}} C_\tau - \frac{\tilde{\gamma}}{\tilde{v}} C_g - \frac{\tilde{\zeta}}{\tilde{v}} C_z + \left[ \frac{1}{\beta} - \frac{1}{\tilde{v}} \frac{\tilde{m}(\tilde{R} - 1)}{\pi} \right] C_\pi \right\}' \otimes I
\]

and

\[
C_0 \equiv \left\{ C_v + \left[ 1 - \beta \frac{1}{\tilde{v}} \frac{\tilde{m}\tilde{R}}{\pi} \right] C_R + \left[ 1 - \beta \frac{1}{\tilde{v}} \frac{\tilde{m}(\tilde{R} - 1)}{\pi} \right] C_\pi - \beta \frac{1}{\tilde{v}} \frac{\tilde{m}(\tilde{R} - 1)}{\pi} C_m \right\},
\]

where \( I \equiv [I_{n \ell \times 1}, I_{n \ell}] \). The first order condition (FOC) of (52) is given as \( S (b - \hat{b}) = C_1' \lambda' \). Together with the equation \( C_1 b = C_0 = C_1 \hat{b} + C_1 S^{-1} C_1' \lambda' \), it follows

\[
b = \hat{b} + S^{-1} C_1'(C_1 S^{-1} C_1')^{-1}(C_0 - C_1 \hat{b}).
\]

The estimation of this work uses a feasible GLS procedure iterated until convergence is achieved. In practice, 50 number of iterations is sufficient to fulfill this criterion.

**Appendix D. The Data**

All the data I use is accessible publicly, except for the spread data between the municipal bond yields and the government treasury yields.

All components of the U.S. national income account are obtained from the National Income and Product Accounts (NIPA) tables available at Bureau of Economic Analysis website (http://www.bea.gov/national/nipaweb/SelectTable.asp). To incorporate present-value government budget constraint into the analysis, I only use the federal governmental level data for the fiscal variables—taxes, government spending, transfers, and debt. The monetary data such as the interest rate and monetary base is downloaded from the Federal Reserve Economic Data (FRED) website (http://research.stlouisfed.org/fred2/) of the Federal Reserve Board of St. Louis.

All the components of national income are in real terms and are transformed from the nominal values by dividing them by the GDP deflator (NIPA Table 1.1.4, Line 1). Each
data series is extracted as follows from the table and row numbers as per each organization’s relevant data file. The non-fiscal variables uses the data as follows:

- GDP: ‘Gross Domestic Product’ (NIPA Table 1.1.5, Line 1).
- Consumption: ‘Personal Consumption Expenditures’ (NIPA Table 1.1.5, Line 2).
- Investment: ‘Gross Private Domestic Investment’ (NIPA Table 1.1.5, Line 7).
- 10-year Treasury Bond Rate: ‘10-Year Treasury Constant Maturity Rate’ (FRED Series ID: GS10).
- Price: ‘GDP deflator’ (NIPA Table 1.1.4, Line 1).

As in Chung and Leeper (2009), the fiscal data series for this work—taxes, government spending, and transfers—are calculated to best match the theoretical model delineated above. In particular, taxes and transfers are adjusted to recover the timing differences of tax collection, to include contributions to Federal employee retirement funds, and to include financial transactions. A Federal debt series is calculated to meet the government flow budget constraint by using the fiscal variables generated above. More precisely, the fiscal variables and debt series are obtained as follows:

- Taxes: ‘Current Tax Receipts’ (NIPA Table 3.2, Line 2) plus ‘Contributions for Government Social Insurance’ (NIPA Table 3.2, Line 11) minus ‘Timing Differences’ (NIPA Table 3.18A and 3.18B, Line 12).
- Government Spending: ‘Consumption Expenditures’ (NIPA Table 3.2, Line 21) plus ‘Gross Government Investment’ (NIPA Table 3.2, Line 42) plus ‘Net Purchases of Nonproduced Assets’ (NIPA Table 3.2, Line 44) minus ‘Consumption of Fixed Capital’ (NIPA Table 3.2, Line 45).
- Transfers: ‘Current Transfer Payments’ (NIPA Table 3.2, Line 22) minus ‘Current Transfer Receipts’ (NIPA Table 3.2, Line 16) plus ‘Capital Transfer Payments’ (NIPA Table 3.2, Line 43) minus ‘Capital Transfer Receipts’ (NIPA Table 3.2, Line 39) plus ‘Subsidies’ (NIPA Table 3.2, Line 32) minus ‘Current Surplus of Government Enterprises’ (NIPA Table 3.2, Line 19) minus ‘Wage Accruals less Disbursements’ (NIPA Table 3.2, Line 33) plus ‘Federal Employee Retirement Plan Transactions’ (NIPA Table 3.18A and 3.18B, Line 21) plus ‘Financial Transactions’ (NIPA Table 3.18A and 3.18B, Line 30).
- Federal Debt ($V_t$): 
  \[ V_t = V_{t-1} - \text{Net Lending}_t - \text{Seigniorage}_t \]

where

\[
\text{Net Lending}_t = \text{Taxes}_t - \text{Government Spending}_t - \text{Transfers}_t 
+ \text{‘Interest Receipts’} \text{ (NIPA Table 3.2, Line 13) at period } t 
- \text{‘Interest Payments’} \text{ (NIPA Table 3.2, Line 29) at period } t
\]
and

\[ \text{Seigniorage}_t = \text{Monetary Base}_t - \text{Monetary Base}_{t-1}. \]

Note that the initial level of debt (at 1947:Q1) uses the corresponding market valued privately held gross federal debt data by Cox and Hirschhorn (1983) available at the Federal Reserve Bank of Dallas website (http://www.dallasfed.org/data/data/natdebt.tab.htm).

Finally, I use the Leeper-Walker-Yang bond spread data calculated by the difference between AAA municipal bond yields and government treasury yields of similar maturity around 1-year.\(^{25}\) As they demonstrate in the paper, this data successfully expands the econometrician’s information set facing the fiscal foresight issue and accounts for the dynamics of tax variables as economic theory predicts, equipped both with the Blanchard-Perotti and the Mountford-Uhlig VAR models.

\(^{25}\)For a more detailed description of the data the reader is referred to Leeper, Walker, and Yang (2011). I thank Todd Walker for providing the data.
### Appendix E. Tables

<table>
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<tr>
<th>Calibrated Parameters</th>
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Note: superscript $j$ is defined as $j = \{k, l, z\}$ and negative values of $\theta$'s are used for the transfer foresight.

Table 1: Calibrated or Estimated Parameters for the DSGE Model drawn from Leeper, Plante, and Traum (2010), Traum and Yang (2010), and Leeper, Richter, and Walker (2010).
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**Table 2:** Summary Statistic of the Elasticities Calculated from Sign Identified Models from 10,000 Draws of the Rotation Matrices.
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<tr>
<th>Elasticity Type</th>
<th>Estimated Parameters</th>
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<th>Minimum</th>
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<td>-0.1</td>
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<td>govt. spending</td>
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<td>transfers</td>
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<td>-0.1</td>
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<td>0.1</td>
<td>-0.1</td>
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<td>$\alpha_{cg}$</td>
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<td>-0.1</td>
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<td>-0.1</td>
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Table 3: Admissible Ranges for Various Elasticities Augmented on the Sign Identified Models to Identify a Set of Government Spending Shocks.

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<th>Estimated Parameters</th>
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<td>Co-movement between capital and consumption taxes</td>
<td>$\phi_{kc}$</td>
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<tr>
<td>Co-movement between labor and consumption taxes</td>
<td>$\phi_{lc}$</td>
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Table 4: Additional Estimated Parameters for the Fiscal Policy Specifications of the DSGE Model in (26)-(30) Drawn from Leeper, Plante, and Traum (2010).
### Table 5: Dollar-valued Output, Consumption, and Investment Multipliers for Government Spending Shocks Identified by Sign and Elasticity Bound Restrictions.

<table>
<thead>
<tr>
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<th>8 qtrs</th>
<th>12 qtrs</th>
<th>20 qtrs</th>
<th>40 qtrs</th>
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<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>1.84</td>
<td>1.35</td>
<td>0.79</td>
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<td>0.41</td>
<td>0.65</td>
<td>1.04</td>
<td>1.36</td>
<td>0.97</td>
<td>0.40</td>
</tr>
<tr>
<td>16th Percentile</td>
<td>0.02</td>
<td>−0.02</td>
<td>0.63</td>
<td>0.94</td>
<td>0.64</td>
<td>0.06</td>
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<td>0.61</td>
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<td>0.79</td>
<td>0.33</td>
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<td>−0.51</td>
<td>0.19</td>
<td>0.27</td>
<td>−0.11</td>
<td>0.08</td>
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<td>−0.83</td>
<td>0.03</td>
<td>0.21</td>
<td>−0.14</td>
<td>0.02</td>
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</table>

### Table 6: Dollar-valued Output, Consumption, and Investment Multipliers for Government Spending Shocks with Tax or Transfer Adjustment Anticipation.

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<td>0.02</td>
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<table>
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### Panel A: Anticipated Tax Adjustment

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<th>100 qtrs</th>
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### Panel B: Anticipated Transfer Adjustment

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<td>1.57*</td>
<td>1.49*</td>
<td>1.86*</td>
<td>1.29*</td>
<td>0.76</td>
<td>1.99*(10 qtr)</td>
<td></td>
</tr>
<tr>
<td>Consumption</td>
<td>0.25*</td>
<td>0.44*</td>
<td>1.08*</td>
<td>1.16*</td>
<td>0.97*</td>
<td>0.58</td>
<td>1.25*(10 qtr)</td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>0.01</td>
<td>−0.07</td>
<td>0.32</td>
<td>0.37</td>
<td>−0.13</td>
<td>0.13</td>
<td>0.59*(10 qtr)</td>
<td></td>
</tr>
</tbody>
</table>

**Table 7:** Dollar-valued Output, Consumption, and Investment Multipliers for Government Spending Shocks with Tax or Transfer Adjustment Anticipation from Structural Models Evaluated at Median Elasticities. An asterisk indicates zero is outside of the region between the two one-standard deviation bands.

### Panel A: Anticipated Tax Adjustment

<table>
<thead>
<tr>
<th></th>
<th>1 qtr</th>
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<th>12 qtrs</th>
<th>20 qtrs</th>
<th>40 qtrs</th>
<th>100 qtrs</th>
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</tr>
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<tbody>
<tr>
<td>Output</td>
<td>0.23</td>
<td>0.28</td>
<td>0.56</td>
<td>1.25</td>
<td>2.08</td>
<td>3.45</td>
<td>3.67</td>
<td>9.08</td>
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<tr>
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<td>−0.05</td>
<td>−0.01</td>
<td>0.44</td>
<td>0.96</td>
<td>1.58</td>
<td>2.92</td>
<td>2.06</td>
<td>5.70</td>
</tr>
<tr>
<td>Investment</td>
<td>−0.40</td>
<td>−0.58</td>
<td>−0.59</td>
<td>−0.32</td>
<td>−0.27</td>
<td>−0.50</td>
<td>0.37</td>
<td>1.38</td>
</tr>
</tbody>
</table>

### Panel B: Anticipated Transfer Adjustment

<table>
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<th>8 qtrs</th>
<th>12 qtrs</th>
<th>20 qtrs</th>
<th>40 qtrs</th>
<th>100 qtrs</th>
<th>1000 qtrs</th>
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</thead>
<tbody>
<tr>
<td>Output</td>
<td>0.91</td>
<td>1.27</td>
<td>1.50</td>
<td>2.24</td>
<td>2.96</td>
<td>5.10</td>
<td>5.97</td>
<td>10.53</td>
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<tr>
<td>Consumption</td>
<td>0.26</td>
<td>0.28</td>
<td>0.68</td>
<td>1.18</td>
<td>1.69</td>
<td>3.43</td>
<td>3.44</td>
<td>6.67</td>
</tr>
<tr>
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<td>0.04</td>
<td>−0.01</td>
<td>0.25</td>
<td>0.22</td>
<td>0.19</td>
<td>0.92</td>
<td>1.71</td>
</tr>
</tbody>
</table>

**Table 8:** Present-Value Output, Consumption, and Investment Multipliers for Government Spending Shocks with Tax or Transfer Adjustment Anticipation from Structural Models Evaluated at Median Elasticities.
Panel A: Anticipated Tax Adjustment

<table>
<thead>
<tr>
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<th>4 qtrs</th>
<th>8 qtrs</th>
<th>12 qtrs</th>
<th>16 qtrs</th>
<th>20 qtrs</th>
<th>24 qtrs</th>
<th>30 qtrs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td>84th Percentile</td>
<td>0.80</td>
<td>0.47</td>
<td>0.11</td>
<td>-0.07</td>
<td>-0.09</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>50th Percentile</td>
<td>0.57</td>
<td>0.22</td>
<td>-0.07</td>
<td>-0.22</td>
<td>-0.24</td>
<td>-0.14</td>
</tr>
<tr>
<td></td>
<td>16th Percentile</td>
<td>0.39</td>
<td>0.03</td>
<td>-0.25</td>
<td>-0.35</td>
<td>-0.36</td>
<td>-0.30</td>
</tr>
<tr>
<td><strong>Consumption</strong></td>
<td>84th Percentile</td>
<td>0.17</td>
<td>0.05</td>
<td>-0.07</td>
<td>-0.13</td>
<td>-0.14</td>
<td>-0.10</td>
</tr>
<tr>
<td></td>
<td>50th Percentile</td>
<td>0.07</td>
<td>-0.06</td>
<td>-0.15</td>
<td>-0.20</td>
<td>-0.20</td>
<td>-0.17</td>
</tr>
<tr>
<td></td>
<td>16th Percentile</td>
<td>-0.03</td>
<td>-0.14</td>
<td>-0.23</td>
<td>-0.26</td>
<td>-0.26</td>
<td>-0.24</td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td>84th Percentile</td>
<td>0.00</td>
<td>-0.23</td>
<td>-0.48</td>
<td>-0.62</td>
<td>-0.62</td>
<td>-0.53</td>
</tr>
<tr>
<td></td>
<td>50th Percentile</td>
<td>-0.14</td>
<td>-0.38</td>
<td>-0.59</td>
<td>-0.70</td>
<td>-0.70</td>
<td>-0.64</td>
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<tr>
<td></td>
<td>16th Percentile</td>
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<td>-0.52</td>
<td>-0.71</td>
<td>-0.77</td>
<td>-0.77</td>
<td>-0.75</td>
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</table>

Panel B: Anticipated Transfer Adjustment

<table>
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<th>8 qtrs</th>
<th>12 qtrs</th>
<th>16 qtrs</th>
<th>20 qtrs</th>
<th>24 qtrs</th>
<th>30 qtrs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output</strong></td>
<td>84th Percentile</td>
<td>1.12</td>
<td>1.08</td>
<td>0.94</td>
<td>0.93</td>
<td>0.95</td>
<td>0.92</td>
</tr>
<tr>
<td></td>
<td>50th Percentile</td>
<td>0.84</td>
<td>0.79</td>
<td>0.60</td>
<td>0.53</td>
<td>0.55</td>
<td>0.58</td>
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<tr>
<td></td>
<td>16th Percentile</td>
<td>0.58</td>
<td>0.53</td>
<td>0.27</td>
<td>0.13</td>
<td>0.17</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>Consumption</strong></td>
<td>84th Percentile</td>
<td>0.36</td>
<td>0.36</td>
<td>0.30</td>
<td>0.31</td>
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<td>0.31</td>
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<td>50th Percentile</td>
<td>0.26</td>
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<td>0.15</td>
<td>0.16</td>
</tr>
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<td>16th Percentile</td>
<td>0.14</td>
<td>0.11</td>
<td>0.02</td>
<td>-0.02</td>
<td>-0.01</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td>84th Percentile</td>
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<td>0.13</td>
<td>0.04</td>
<td>0.03</td>
<td>0.05</td>
<td>0.04</td>
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<tr>
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<td>50th Percentile</td>
<td>-0.02</td>
<td>-0.07</td>
<td>-0.20</td>
<td>-0.24</td>
<td>-0.23</td>
<td>-0.21</td>
</tr>
<tr>
<td></td>
<td>16th Percentile</td>
<td>-0.20</td>
<td>-0.24</td>
<td>-0.42</td>
<td>-0.52</td>
<td>-0.48</td>
<td>-0.45</td>
</tr>
</tbody>
</table>

Table 9: Dollar-valued Output, Consumption, and Investment Multipliers for Government Spending Shocks with Tax or Transfer Adjustment Anticipation across Various Fiscal Foresight Horizons.
FIGURE 1: Response of a 1% increase in government spending. The solid line corresponds to the impulse response with foresight neither on taxes nor on transfers. The other two lines correspond to agents having tax foresight (heavy dashed line) and transfer foresight (dotted-dashed line). The x-axis measures quarters.
Figure 2: Venn diagram summarizing the identification procedure of this work. Government spending shocks are identified by sign and elasticity bound restrictions. The anticipated fiscal adjustment restrictions classify the identified shocks into tax or transfer anticipation cases.
Figure 3: Average annual marginal federal individual income tax rates in Barro and Redlick (2011) (solid line with the left y-axis) and one-year lagged annualized municipal-treasury bond spreads (dashed line with the right y-axis), 1955-2006.

Figure 4: Estimated median responses of taxes to tax shocks (solid line with the left y-axis) and two-quarter lagged median responses of taxes to spread shocks (dashed lines with the right y-axis). These fiscal shocks are identified by sign restrictions combined with elasticity bound restrictions. The x-axis measures quarters.
Figure 5: Estimated average spectral densities of the simulated equilibrium data from the DSGE model in Leeper, Plante, and Traum (2010): Monte-Carlo simulations of 1,000 iterations are used to simulate the equilibrium data. The spectral density estimation uses Parzen window with the truncation number to be 12. Each column corresponds to the shock that perturbs the equilibrium system—a technological shock, a government spending shock, and a transfer shock, respectively.
Figure 6: Estimated average spectral densities of the simulated equilibrium data from the DSGE model in Leeper, Plante, and Traum (2010): Monte-Carlo simulations of 1,000 iterations are used to simulate the equilibrium data. The spectral density estimation uses Parzen window with the truncation number to be 12. Each column corresponds to the shock that perturbs the equilibrium system—a capital tax shock, a labor tax shock, and a consumption tax shock, respectively.
Figure 7: Frequency domain decomposition of fiscal variable impulse responses. The left three figures (figure 7a-7c) use the Hodrick-Prescott filter as in Hodrick and Prescott (1997) whereas the right three figures (figure 7d-7f) use the bandpass filter by Christiano and Fitzgerald (2002). The solid line corresponds to the original impulse response from the 12-variable VAR model identified by sign and elasticity restrictions combined while the other two lines correspond to its high- and low-frequency components, the low-frequency component (heavy dashed line) and the high-frequency component (dotted-dashed line). The x-axis measures quarters.
Figure 8: Estimated 84th and 16th percentile bands of dollar-valued impulse responses to government spending shocks identified by sign and elasticity bound restrictions. The x-axis measures quarters.
Figure 9: Estimated median responses with 84th and 16th percentile bands of dollar-valued impulse responses to government spending shocks under the two anticipation scenarios—tax and transfer adjustments. The heavy dashed line corresponds to the median responses of anticipated tax adjustment case and the light shade area displays its 84th and 16th percentile bands. And the solid line corresponds to the median responses of anticipated transfer adjustment case and the dense shade area displays its 84th and 16th percentile bands.
Figure 10: Comparison between median responses (the solid lines) and responses from the structural models evaluated at median elasticities (the dashed lines), both are measured in dollar. The left three figures (figure 10a-10c) and the right three figures (figure 10d-10f) correspond to the dollar-valued impulse responses of anticipated tax and transfer adjustment cases, respectively. The x-axis measures quarters.
Figure 11: Estimated dollar-valued responses for the structural model of anticipated tax adjustment with one-standard-deviation bands. The confidence intervals are obtained from 5,000 draws of a Monte Carlo simulation, using the OLS VAR point estimates as a data-generating process. The x-axis measures quarters.

Figure 12: Estimated dollar-valued responses for the structural model of anticipated transfer adjustment with one-standard-deviation bands. The confidence intervals are obtained from 5,000 draws of a Monte Carlo simulation, using the OLS VAR point estimates as a data-generating process. The x-axis measures quarters.
Figure 13: Estimated dollar-valued responses at impact across various fiscal foresight horizons of agents. The dotted dashed line corresponds to the median responses of anticipated tax adjustment case with its 84th and 16th percentile bands. And the squared solid line corresponds to the median responses of anticipated transfer adjustment case with its 84th and 16th percentile bands. The x-axis measures quarters.
**Figure 14:** Frequency domain decomposition of government spending, output, and consumption responses. The left three figures (figure 14a-14c) and the right three figures (figure 14d-14f) correspond to anticipated tax and transfer adjustment cases, respectively. The frequency domain decomposition in these figures uses the Hodrick-Prescott filter as in *Hodrick and Prescott (1997)*. The solid line corresponds to the original impulse response from the 12-variable VAR model while the other two lines correspond to its high-frequency (dotted-dashed line) and low-frequency (heavy dashed line) components. The shaded area displays horizons over which spending reversal is observed. The x-axis measures quarters.
References


