How Do Monetary and Fiscal Policy Shocks Explain US Macroeconomic Fluctuations? – A FAVAR Approach *

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Abstract
This paper analyses the role monetary and fiscal policy shocks play in explaining US macroeconomic fluctuations using a Factor Augmented Vector Autoregression framework. Identification is achieved via the sign restrictions methodology as in Dungey and Fry (2009) and Fry and Pagan (2011), with the federal funds rate ordered last. The impact of the government spending shock on output is longer lasting and explains more variability in macroeconomic variables compared to government taxation revenue or monetary policy shocks. There is some crowding-out effects, consistent with the Real Business Cycle-type models. The historical decomposition of GDP suggests that government expenditure shocks contribute positively to output in the Great Recession.

Keywords: Monetary policy, fiscal policy, stimulus package, factor augmented vector autoregression, sign restrictions

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I. Introduction

The subprime mortgage crisis in 2007 and the subsequent Great Recession in 2009 saw many advanced countries implement huge stimulus packages to boost economic growth. The enaction of these policies generally occurred simultaneously when policy interest rates in most advanced economies were at historically low levels and governments were trying to address underlying government debt problems. However, there are few empirical frameworks that examine the role of fiscal policy, in conjunction with monetary policy, in explaining macroeconomic fluctuations in the US economy. This paper seeks to investigate the joint behavior of monetary and fiscal authorities in the United States. Modelling fiscal and monetary policy reactions simultaneously allows for more precise determination of the effects of each policy and their reciprocal implications for each other and the macroeconomy. The paper extends the Factor Augmented VAR (FAVAR) framework approach developed by Bernanke et al. (2005) for a monetary policy setting to incorporate fiscal policy. The fiscal shocks are added to the FAVAR model, and are identified using the sign restriction framework used for fiscal policy as developed in Dungey and Fry (2009).

This paper finds that in comparing the effects of government expenditure, taxation and the federal funds rate shocks on output, it is government expenditure which has the longest impact compared to other policy levers. Second, this paper finds evidence that the government expenditure shock, explains more variability in macroeconomic variables than a monetary policy shock. Importantly, there is some evidence of the crowding-out effects of fiscal policy that is predicted by the Real Business Cycle (RBC) type-models, consistent with the existing empirical literature that often finds evidence in support of the RBC-type models or the Keynesian models. The historical decomposition of GDP suggests that government expenditure shocks contribute positively to output in the Great Recession. Finally, this paper finds evidence that monetary and fiscal policies are used as substitutes following a shock to one policy instrument, and hence emphasizes the importance of analyzing monetary and fiscal policies jointly.

The consensus view of the empirical effects of monetary policy shocks (e.g., Romer and Romer (1994), Christiano, Eichenbaum, and Evans (2000, 2005) and Bernanke et al. (2005)) is that following an increase in the short term interest rate, real activity measures and monetary aggregates such as the M1 money supply decline, prices eventually fall and in open economy models, the domestic currency appreciates. In contrast, the range of fiscal stimulus packages put together globally consist of different combinations of government spending, investment and tax cuts, highlighting the debate about the nature of fiscal policy and its ability to stimulate the economy through the different fiscal channels. Competing economic theories of fiscal policy provide different conclusions regarding its macroeconomic effects leading to no theoretical consensus. Similarly, from an empirical viewpoint, there is no consensus on the effects of fiscal policy shocks, partly because of difficulties in shock identification.

On the fiscal side, Ramey and Shapiro (1998), Fatás and Mihov (2001), Blanchard and Perotti (2002), Perotti (2004, 2007) and Galí et al. (2007) focus on government spending shocks. These papers agree that positive government spending shocks have persistent output effects, regardless of the chosen empirical methodology. A positive output response is consistent with both Keynesian and neoclassical theories.[2] However, there is no consensus on the effects of government spending shocks on macroeconomic variables. For example, Fatás and Mihov (2001), Blanchard and Perotti (2002) and Perotti (2004, 2007) report that private consumption significantly and persistently increases in response to a positive government spending shock. Edelberg et al. (1999) and Mountford and Uhlig (2009) provide evidence that the response of private consumption is close to zero and statistically insignificant over the entire impulse response horizon. Ramey (2011) finds that private consumption persistently and significantly falls over short and long horizons in response to a positive government spending shock.

[2] In the case of neoclassical theories, a positive output response occurs only if the increase in government spending is financed by non-distortionary taxes.

For the responses of the real wage and employment, Perotti (2007) finds that the real wage persistently and significantly increases while employment does not react, while Burnside et al. (2004) and Eichenbaum and Fisher (2005) show that the real wage and employment persistently and significantly falls and increases respectively.

Since both monetary and fiscal policy simultaneously affect fluctuations in macroeconomic variables, it is worthwhile to qualitatively and quantitatively evaluate their joint impact in explaining these macroeconomic fluctuations. Empirical analysis of fiscal and monetary policy interactions are limited. Examples for the US include Muscatelli et al. (2004), Mountford and Uhlig (2009) and Rossi and Zubairy (2011). In the former, the authors use sign restrictions in a VAR model to analyze the impact of fiscal policy shocks, while controlling for a business cycle and monetary policy shock. The latter two studies use VAR models to analyze the impact of fiscal policy shocks. Rossi and Zubairy (2011) use a VAR model to investigate the relative importance of fiscal and monetary policy shocks in explaining fluctuations in US macroeconomic variables by using historical counterfactual analyses. This involves looking at the impact on GDP if only fiscal or monetary policy shocks are present. Muscatelli et al. (2004) examine the interaction of fiscal and monetary policies by estimating a New-Keynesian Dynamic Stochastic General Equilibrium (DSGE) model and find that fiscal and monetary policies tend to work together in the case of output shocks, while they are substitutes following inflation shocks or shocks to either policy instrument. Mélitz (2002) uses pooled data for 15 members of the European Union and five other OECD countries to investigate the interaction between fiscal and monetary policies. The author finds that fiscal policy responds to the ratio of public debt to output in a stabilizing manner. Expansionary fiscal policy also appears to lead to a contractionary monetary policy, and vice versa.

A recent strand of the literature looks at the impact of fiscal policy on economic activity, accounting for the current state of the economy. The recent financial crisis has resulted in renewed interest in examining the Keynesian hypothesis that an increase in government spending has a greater impact on the economy in recessions than in expansions. For example, Auerbach and Gorodnichenko (2012) estimate a Smooth Transition Vector Autoregression (STVAR) model to analyze the impact of expansionary fiscal policy on output, allowing for smooth transition between recessions and expansions. The key findings provide evidence in support of the Keynesian hypothesis that government spending multipliers are larger in recessions than in expansions. Fazzari et al. (2013) also examine the effects of government spending on US economic activity, depending on the state of the economy. The authors estimate a nonlinear structural Threshold Vector Autoregression model that allows parameters to switch depending on the economic slack variable. The authors find that the effects of a government spending shock on output are larger and more persistent when the economy is in recession with a high degree of underutilized resources than when the economy is in expansion and close to capacity. Overall, the empirical findings of this paper find state-dependent effects of fiscal policy.

Another strand of work incorporate debt as a variable in order to account for budget deficits when estimating the effects of fiscal policy on economic activity. For example, Favero and Giavazzi (2007) include a feedback loop from government debt, allowing taxes, spending and interest rates to respond to the level of debt over time. Fiscal authorities with Ricardian behavior care about the stabilization of debt. Hence, feedback from debt to government revenue and spending is expected. The authors find that the fiscal policy is stabilizing in the early 1980s but not in the 1960s and 1970s. Chung and Leeper (2007) also include government debt into a conventional fiscal VAR, confirming the results of Favero and Giavazzi (2007). In particular, the paper provides evidence that the primary surplus plays a stabilizing role following shocks to taxes and transfers. Afonso and Sousa (2009) estimate the macroeconomic effects of fiscal policy for the US, UK, Germany and Italy using a Bayesian SVAR approach, including debt dynamics. They show that government spending shocks, in general, have a small effect on GDP, and leads to crowding-out effects.

The remainder of the paper is organized as follows. Section II. presents the FAVAR model for analyzing monetary and fiscal policy shocks, discusses the identification of the model, identification of the factors, outlines the estimation methodology and describes the wide set of US macroeconomic variables used in the empirical investigation. Section III. presents the empirical results of shocks to the policy variables of the federal funds rate, government expenditure, taxation revenue, and the debt to GDP ratio. This is followed by the analysis of variance decompositions and historical decompositions of output in particular. Section VI. concludes.

II. FAVAR model of fiscal and monetary policy

To analyze monetary and fiscal policy interactions and their effects on the macroeconomy, the monetary policy FAVAR style of model first developed by Bernanke et al. (2005) is extended to include a fiscal sector. The factors included in the VAR are extracted from a large panel of US informational variables to capture as much information about the dynamics of the economy as possible. The addition of fiscal policy to SVAR models is a challenging area in terms of identification. The sign restriction approach is adopted to identify fiscal shocks here similar to Dungey and Fry (2009) which avoids the need to choose an ordering of the variables, allowing for simultaneous responses to cross-policy shocks by using sign restrictions on the impulse responses to identify fiscal policy shocks.[3] The rest of the macroeconomy is identified using recursive techniques as in Bernanke et al. (2005). Although wider in terms of economic system modeled, the goal of this paper is to identify shocks to the short term interest rate, government expenditure, taxation revenue and the debt-to-GDP ratio and so is

[3]Examples include Faust (1998) and Uhlig (2005) for monetary policy, and Mountford and Uhlig (2009) and Dungey and Fry (2009) for fiscal policy. For a review of the capabilities of this method of identification, see Fry and Pagan (2011).

focused accordingly.

FAVAR model

The FAVAR model of fiscal and monetary policy is described as follows. Let Y_t denote a vector of $M \times 1$ observable macroeconomic variables and X_t denote a $N \times 1$ vector of 113 economic time series that describes the US economy. Define $\tilde{F}_t$ as a $k \times 1$ vector of unobserved factors that summarizes the information contained in X_t, with possible contemporaneous effects from variables ordered after the factors removed as is explained in Section II.. The observable variables, Y_t, include the fiscal policy variables of total government expenditure (G_t) and total government taxation revenue (T_t), the monetary policy instrument of the federal funds rate (R_t), as well as the key macroeconomic variables of real domestic absorption (GNE_t), the ratio of debt held by the public to GDP ($debt_t$), real GDP (GDP_t) and CPI inflation (inf_t).

The joint dynamics of $\tilde{F}_t$ and Y_t evolve according to the general transition equation 1

$$\begin{bmatrix} Y_t \\ \tilde{F}_t \end{bmatrix} = B(L) \begin{bmatrix} Y_{t-1} \\ \tilde{F}_{t-1} \end{bmatrix} + u_t, \tag{1}$$

where $B(L)$ is a conformable lag polynomial of finite order p, and u_t is an error term with mean zero and a covariance matrix Ω. Equation 1 is a standard VAR except that $\tilde{F}_t$ is an estimate of the unobserved factors from X_t. Structural identification of the model, estimates of the relevant structural shocks $\widehat{\varepsilon}_t$ and calculation of impulse responses then proceeds as normal using any of the standard structural VAR identification methods. Further details on the structure of the FAVAR and the identification of the factors and of are provided in Section II. and Section II. respectively.

Identification of the FAVAR

The structural elements of the model are identified in two parts. First, the variables in the transition equation 1 are ordered as G_t, T_t, GNE_t, $debt_t$, GDP_t, $\widetilde{F}_t$, inf_t and R_t and the VAR estimated using a Cholesky Decomposition. Second, to properly identify fiscal policy shocks, this paper incorporates the sign restrictions methodology as in Dungey and Fry (2009) to the impulses of the government expenditure and taxation shocks, with the remaining shocks, including the monetary policy shock identified using the recursive scheme. The advantage is that it is possible to have a contemporaneous taxation increase in response to a government expenditure shock, and a contemporaneous government expenditure increase in response to a taxation shock while still uniquely identifying both shocks.

Existing models investigating fiscal policy shocks using small-scale VAR or structural VAR models without the factor augmentation use various approaches to identify shocks. The first is an 'event-based' approach introduced by Ramey and Shapiro (1998) where dummy variables capture the effects of large unexpected increases in government spending. For example, one can use a dummy variable to trace the impact of the Reagan fiscal expansion period on output. This approach is not feasible if the fiscal policy shocks are anticipated or influenced by other shocks occurring at the same time. More recently, Romer and Romer (2010) use a narrative approach to estimate the effects of tax changes on the US economy and find that the impact of tax increases on output are highly contractionary and significant, and much larger than those obtained using broader measures of tax changes. Cloyne (2011) finds similar results for the UK. The second approach takes into account the long decision and implementation lags in fiscal policy and information about the elasticity of fiscal variables to economic activity (see Blanchard and Perotti (2002); Chung and Leeper (2007); Favero and Giavazzi (2007) for the US). Perotti (2004) extends this type of model to investigate the impact of fiscal policy shocks on inflation and interest rates in OECD countries. The third approach relies on recursive ordering to identify fiscal or monetary policy shocks. In Fatás and Mihov (2001), government spending is ordered first on the assumption that other variables such as output cannot affect government spending contemporaneously. In Favero (2002), government spending is ordered last on the assumption that government spending can affect output contemporaneously.

The fourth approach is the sign restrictions approach combined with a recursive ordering adopted in this paper. Recent literature on this area looks at combining sign restrictions with zero restrictions in the short and long run impact matrices using the Givens rotation matrices or the Householder transformation. Brave and Butters (2012) impose one zero restriction in combination with sign restrictions using Givens rotation matrices to identify a short term interest rate shock in their paper. Benati and Lubik (2012, 2013) and Benati (2013a, 2013b) combine zero restrictions on the long run impact matrix with sign restrictions using the Householder transformation. More recently, Binning (2013) show how zero short and long run restrictions can be combined with sign restrictions in any combination, extending the algorithm in Rubio-Ramírez et al. (2010). In another application, Bjørnland and Halvorsen combine sign and short term zero restrictions to investigate the response of monetary policy to movements in exchange rate in six open economies, focusing on the contemporaneous interactions between monetary policy and the exchange rate.

For the sign restrictions component, the reduced form errors can be written as a function of an impact matrix of shocks T coming from the estimated structure and standard deviations, and the estimated shocks with unit variance η_t

$$\widehat{u}_t = T\eta_t. \tag{2}$$

This impulse responses is redefined using a Givens rotation matrix Q which is an orthogonal matrix with the property $Q'Q = QQ' = I$

$$\begin{aligned} \widehat{u}_t &= TQ'Q\eta_t \\ &= T^*\eta_t^*. \end{aligned} \tag{3}$$

The inclusion of Q recombines (rotates) the original shocks to present a new set of estimated shocks η_t^* which given the properties of Q, has the same covariance matrix of η_t, but with different impact on each variable in the VAR through their impulse responses I_j.

Following Dungey and Fry (2009), the Q is

$$\begin{bmatrix} \cos\theta & -\sin\theta & \cdots & 0 \\ \sin\theta & \cos\theta & \cdots & 0 \\ \vdots & \vdots & 1 & \vdots \\ & \cdots & \ddots & 0 \\ & & & 1 \end{bmatrix}. \tag{4}$$

where θ is chosen randomly from a uniform distribution and takes on a value between 0 and π. This choice of Q implies that only the impulse responses from the shocks corresponding to government expenditure (G_t) and government taxation revenue (T_t) in the system are rotated.

As there are an infinite number of possibilities for Q, the sign restrictions approach is implemented by drawing a value of θ until $1,000$ impulse response functions satisfying a predetermined set of sign patterns in the impulse response functions are drawn. The median of a set of impulse responses following Fry and Pagan (2011) are then reported as the impulse responses for the government expenditure and taxation shocks.

To disentangle the impulse responses to the two fiscal shocks, three levels of criteria are examined. Denoting the government expenditure and government taxation revenue impulses respectively as $\tau = 1$ and $\tau = 2$. The first criterion is purely based on the sign of the impulse responses. The sign restrictions are summarized in Table 1.

TABLE 1
First criterion: pure sign restrictions

	G shock	*T shock*
G	+	
T		+
GDP	+	
GNE		-

For a positive government expenditure shock (G shock), both government expenditure and GDP respond positively for the first period following the shock. For a positive taxation revenue shock (T shock), taxation revenue increases and domestic absorption falls in the first period following the shock.[4] There are no restrictions on the signs of the remaining variables in both set of impulse responses. After using the first criterion, it is possible to have some draws that remain entangled. For example, in the case where a T shock is identified, it is possible to observe a positive response for government expenditure and GDP as well. In this case, the T shock could be labelled as a G shock as well. Hence, to further disentangle the impulse responses, the second criterion, a magnitude restriction, is implemented on these draws.

In each set of impulses, if the magnitude of the response of government expenditure is greater than the magnitude of the response of taxation, then the shock is a G shock. However, if in a set of impulses, the magnitude of government expenditure is less than the magnitude of the response of taxation, then the set of impulses is considered a T shock.

In the case where both set of impulse responses appear to be both G or both T shocks, this paper imposes criterion 3. This criterion examines the ratio of the absolute

[4] Given the US is not a small open economy, the GDP and GNE data series are not very different. Hence, this paper also initially attempted to identify a taxation shock via a decline in GDP for one period following the shock. However, no taxation shocks could be found in any iterations. Hence, this implies that the US external sector remains important when it comes to identifying taxation shocks.

value of the response of government expenditure to the response of taxation in period one for both set of impulse responses. The absolute value of the impulse responses for the G and T shocks in the first period following the shock can be denoted as $\left|\left(\frac{I^G_{G,1}}{I^G_{T,1}}\right)\right|$ and $\left|\left(\frac{I^T_{G,1}}{I^T_{T,1}}\right)\right|$ respectively, where the superscripts refer to the shocks and the subscripts refer to the responses. Hence, comparing the ratios in the G shock impulses, if $\left|\left(\frac{I^G_{G,1}}{I^G_{T,1}}\right)\right|$ $\geq \left|\left(\frac{I^T_{G,1}}{I^T_{T,1}}\right)\right|$, then this implies that the G shock impulses is a G shock, while the T shock impulses is a T shock. Comparing the ratios in the T shock impulses, if $\left|\left(\frac{I^G_{G,1}}{I^G_{T,1}}\right)\right|$ $\geq \left|\left(\frac{I^T_{G,1}}{I^T_{T,1}}\right)\right|$,then the T shock impulses is a T shock, and the G shock impulses is a G shock.

Identification of the factors

The relation between the set of economic time series that describe the economy, X_t, the observed variables Y_t and the factors $\tilde{F}_t$ are summarized in the observation equation 5

$$X_t = \Lambda^f \tilde{F}_t + \Lambda^y Y_t + v_t, \tag{5}$$

where Λ^F and Λ^Y are $N \times K$ and $N \times M$ matrices of factor loadings, and the disturbance term v_t is a $N \times 1$ vector of idiosyncratic error terms with zero mean and a covariance matrix σ^2. The estimation of the FAVAR given by equation 1 requires that the unobserved factors $\tilde{F}_t$ be estimated first. The dynamics of the US economy are captured by k factors, $\tilde{F}_t = (\tilde{F}_{1,t}, ..., \tilde{F}_{k,t})$, extracted from the panel of US economic time series with possible contemporaneous effects from inf_t and R_t removed. In this paper and consistent with Bernanke et al. (2005), k is chosen to be 3. These US factors do not have a specific economic interpretation, but serve as a parsimonious control for elements in the US economy that contributes towards movements in Y_t. The dynamics of each US variable is a linear combination of the US factors which are determined by the factor loadings, and which are linked to the observable variables via the transition equation 1. This implies that the response of any underlying US variable in X_t to a shock in the transition equation 1 can be calculated using the estimated factor loadings and equation 3.

The methodology adopted in this paper to obtain $\tilde{F}_t$ is set out as follows. First, three common factors are extracted from the panel of US economic series using the principal components method, and are denoted as $F_t = (F_{1,t},\ F_{2,t},\ F_{3,t})$. Within the panel of US economic time series, 46 time series are fast moving variables and 67 series are slow moving. With about 40% of the variables in X_t as fast moving variables implies that F_t can potentially respond contemporaneously to variables in Y_t to inf_t and R_t. Hence, it is not appropriate to estimate a VAR with inf_t and R_t ordered after F_t, without first removing the effects of inf_t and R_t on F_t.

To obtain $\tilde{F}_t$ with the effects of inf_t and R_t removed, a multiple regression approach is adopted. First, three slow moving factors, $F_t^{slow} = (F_{1,t}^{slow},\ F_{2,t}^{slow},\ F_{3,t}^{slow})$ are extracted from the panel of 67 slow moving variables, a subset of X_t. The following regression in equation 6 is then estimated,

$$F_t = \beta_1 inf_t + \beta_2 R_t + \beta_3 F_{1,t}^{slow} + \beta_4 F_{2,t}^{slow} + \beta_5 F_{3,t}^{slow} + e_t, \tag{6}$$

where e_t captures the residual effects of the 46 fast moving variables, with the contemporaneous effects of inf_t and R_t removed.

Next, the estimated factor $\tilde{F}_t$ is calculated as the differences between F_t and the product of the observed factors, R_t, $inf_t$and its estimated β_i coefficients, as outlined in equation 7,

$$\tilde{F}_t = F_t - \beta_1 inf_t - \beta_2 R_t = \beta_3 F_{1,t}^{slow} + \beta_4 F_{2,t}^{slow} + \beta_5 F_{3,t}^{slow} + e_t, \tag{7}$$

removing contemporaneous effects of inf_t and R_t.

Estimation

This paper uses the two-step procedure as in Bernanke et al. (2005) and Mumtaz and Surico (2009) to estimate the parameters of the model. In the first step, the unobserved factors and loadings are estimated via the principal components estimator. In the second step, the FAVAR model in equation 1 is estimated as a standard VAR via Bayesian methods. This two-step approach is chosen for computational convenience. A one-step procedure that simultaneously estimates the unobserved factors, the factor loadings and the VAR coefficients is computationally intensive.[5] Details of the prior and the estimation procedure are given in Appendix A.

Before estimating the FAVAR, it is also necessary to consider the number of factors that explain the dynamics of the US economy, allowing for proper modelling of the simultaneous effects of monetary and fiscal policy. Bai and Ng (2002) provide a criterion to determine the number of factors present in the data set X_t. However, as pointed out by Bernanke et al. (2005), the use of this criterion does not address the question of how many factors should be included in the VAR. Hence, three unobserved factors are included in the model, consistent with Bernanke et al. (2005). This choice implies that the second step in the estimation procedure involves the estimation of a standard VAR with ten endogenous variables. The VAR assumes a lag structure of $p = 1$. The choice of one lag is based on the Schwarz Criterion (SC). Estimating a VAR system with one lag implies a fairly large number of free parameters in the VAR system to be estimated using 154 observations.

Data

The data set is quarterly from 1972Q1 to 2010Q4. The VAR system uses the natural logarithm first difference for all variables except the CPI inflation rate and interest rate

[5] Another method in estimating the FAVAR is to use a single-step Bayesian likelihood approach. This approach estimates the factors, factor loadings and parameters of the FAVAR simultaneously. Bernanke, Boivin, and Eliasz (2005) show that both approaches produce qualitatively similar results.

which are in percentages. The two fiscal variables in the VAR are defined in the same way as in Blanchard and Perotti (2002). Thus, total government expenditure (G_t) is total government consumption plus total government investment and total government taxation revenue (T_t) is total government revenues minus transfers. The debt-to-GDP ratio ($debt_t$) is constructed based on the definition outlined in Favero and Giavazzi (2007). All data series are transformed to ensure stationarity and are standardized. The dataset for X_t consist of 113 series, and is a combination of the datasets used in Bernanke et al. (2005) and Koop and Korobilis (2009). A more detailed description of the dataset can be found in Table 3 in Appendix B.

III. Empirical results

This paper considers the following types of shocks in the FAVAR model: shocks to monetary policy, real government expenditure, real government taxation revenue and debt-to-GDP ratio. This section presents the impulse responses for one standard deviation shock to the errors. All responses are cumulated except for CPI inflation, new orders, civilian unemployment rate, six-month treasury bill rate and Aaa corporate bond yield. For each shock, the mean, 10th and 90th percentile of the posterior distribution of the impulse responses are plotted in the Figures 1 to 4.[6] All impulse responses for the variables in the VAR component of the model are presented excluding those for the factors. Selected impulse response functions are also calculated for the variables contained in X_t.

Monetary policy shock

In this paper, the monetary policy shocks are defined as temporary shocks in the short term interest rate, such as the federal funds rate for the US. The responses of

[6] In practice, the number of gibbs sampling iterations chosen is usually a large number, as in this paper, 10,000 replications. Empirically, the mean and median will be the same.

the model in Figure 1 generally have the expected signs and magnitude. The federal funds rate increases with the shock, coming back to its initial value after 30 quarters. Government expenditure increases and tax revenue declines, implying that fiscal policy is expansionary and acts as a substitute to the contractionary monetary policy in place. Muscatelli et al. (2004) obtain similar results for the US and find that fiscal and monetary policies often behave as substitutes following inflation shocks or shocks to either fiscal or monetary policy. The combination of an increase in government expenditure and a decline in tax revenue results in a budget deficit. GDP declines for 15 quarters before increasing, consistent with the contractionary monetary policy. The debt-to-GDP ratio increases briefly at the start due to the budget deficit, but declines after 17 quarters, helped by the increase in GDP after 15 quarters.

CPI inflation and PPI inflation declines as expected with contractionary monetary policy. The price puzzle usually observed in VAR models disappears in this FAVAR model. This suggests that the additional information on the US economy, summarized in the form of three common factors, adequately captures the large information set the US Federal Reserve observes before deciding on monetary policy. The increase in the federal funds rate implies that there are greater returns on the US currency. In turn, there is an increase in demand for US currency, resulting in the appreciation of the exchange rate.

The impact of the contractionary monetary policy shock on real activity measures are mostly contractionary, resulting in an initial decline in GDP, domestic absorption and industrial production. Fixed private investment also falls, as borrowing becomes more expensive with the increase in the federal fund rate. Consumption declines briefly for 10 quarters before increasing. The appreciation of the exchange rate results in a deterioration of exports. Imports fall for 16 quarters as a result of the fall in consumption. The unemployment rate responds to the deterioration in real activity with a lag, falling for three quarters before increasing. Real compensation declines for six quarters before increasing.

Movements in the short term and long term interest rates are within expectations. With the increase in the federal funds rate, the monetary base and M1 decline, while the 6 month treasury bill rate increases. Longer term bonds such as the Moody's Seasoned Aaa corporate bond is often seen as an alternative option to the federal ten-year treasury bill.[7] Hence, the movement in the Moody's Seasoned Aaa corporate bond yield can be anticipatory in nature, and may move in the same or opposite direction as the federal funds rate. For example, if investors believe that the Federal Reserve has tightened monetary policy too much resulting in slower economic growth and eventually leading to a lower federal funds rate, the anticipatory attitude of investors will be reflected in the lower bond yields. Hence, the increase in the Aaa corporate bond yield suggests that investors generally agree with the monetary policy stance.

Government expenditure shock

Figure 2 displays the responses of the selected macroeconomic variables to a shock in government expenditure. The increase in government expenditure is short-lived, increasing in the first quarter before declining. The level of government expenditure stays positive for two quarters, declines for the next three quarters and remain relatively unchanged. Taxation revenue increases simultaneously, in contrast to the results Favero and Giavazzi (2007) find. The combination of the brief increase in government expenditure and the increase in taxation revenue is a budget surplus. The budget surplus implies that the government is funding its own expenditure, which also leads to the fall in the debt-to-GDP ratio. GDP increases for ten quarters, partly due to

[7] To construct the Moody's Seasonal Aaa corporate bond yield, Moody's tries to include bonds with remaining maturities as close as possible to 30 years. Several cases where bonds are dropped include: i) bonds with a remaining lifetime falling below 20 years; ii) likely redemption of a bond; and iii) rating changes.

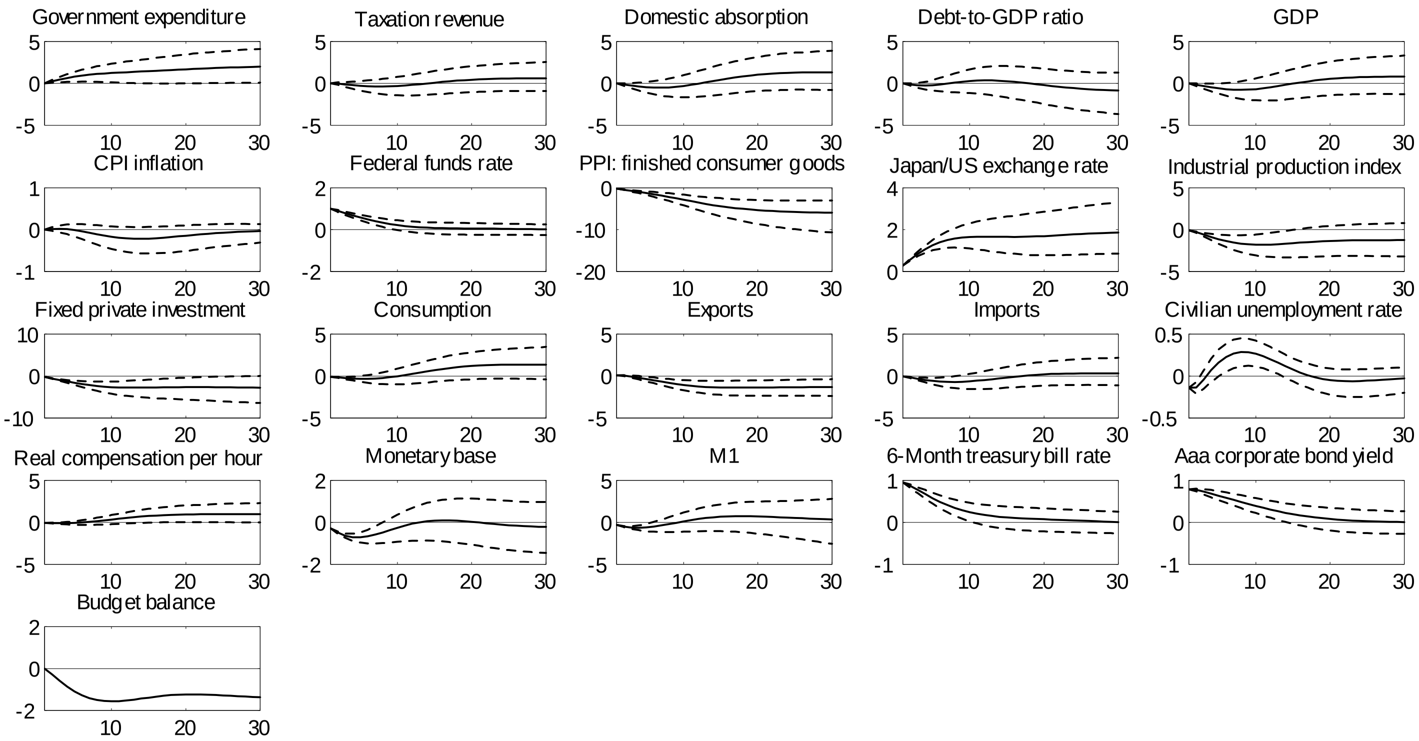

FIGURE 1A 1 standard deviation shock in the federal funds rate.

Note: All responses are cumulated except for CPI inflation, new orders, civilian unemployment rate, 6-month treasury bill rate and Aaa corporate bond yield.

the increase in government expenditure, before declining. The increase in GDP also contributes to the fall in the debt-to-GDP ratio. Domestic absorption follows the path of GDP, increasing for eight quarters before declining.

Due to the short-lived nature of the government expenditure shock, most real activity measures increase for a few quarters before falling. Fixed private investment increases, while consumption increases for eight quarters before deteriorating. The eventual fall in consumption and GDP provide evidence of the crowding-out effects of fiscal policy, consistent with the Real Business Cycle (RBC)-type models. Theoretical predictions of the RBC type-models predict a decline in private consumption and an increase in private investment in response to a rise in government spending. Keynesian type-models predict an increase in consumption and a decline in investment in response to a government spending shock. The existing empirical literature on the crowding-out effects of fiscal policy is mixed, often finding evidence in support of one theory or the other. For example, Perotti (2007) and Canova and Paustian (2011) find evidence of crowding out of private consumption in some model specifications. Blanchard and Perotti (2002) find that an increase in government spending leads to an increase in private consumption and a decline in private investment, consistent with the Keynesian approach.

Industrial production and new orders increase for a few quarters before returning to baseline. The exchange rate appreciates, consistent with the increase in the federal funds rate. The improvement in real activity also leads to a decline in the unemployment rate for eight quarters, putting downward pressure on real compensation. Exports and imports increase. However, the increase in imports only last for nine quarters before declining, similar to the path of domestic absorption.

The increase in real activity contributes to the increase in CPI and PPI inflation. This result is in contrast to the negative relationship between prices and government spending that has been noted in several US based studies of Chung and Leeper (2007), Mountford and Uhlig (2009) and the majority of Favero and Giavazzi (2007) results. With an increase in inflation, the Federal Reserve responds by increasing the federal funds rate to help bring down inflation. The increase in the federal funds rate in response to the government expenditure shock also suggests that the contractionary monetary policy acts as a substitute to the expansionary fiscal policy. Within expectations, the monetary base and M1 decline, moving in the opposite direction of the federal funds rate. The six-month treasury bill rate and Aaa corporate bond yield increase, consistent with the increase in the federal funds rate.

Taxation revenue shock

Figure 3 displays the responses of the selected macroeconomic variables to a shock in government taxation revenue. The shock to taxation revenue is short-lived but lasts for a longer time than the shock to government expenditure. Taxation revenue increases for four quarters before declining. The level of taxation revenue however remains positive. At the same time, government expenditure declines. The combination of an increase in taxation revenue and a decline in government expenditure is a budget surplus, resulting in a fall in the debt-to-GDP ratio. This observation suggests that fiscal policy is stabilizing in this model. This is similar to what Favero and Giavazzi (2007) find in their paper, where debt stabilization appears to be a concern for the US fiscal authorities in the second part of the sample (after 1980).

The impact of the increase in government revenue on GDP has the expected contractionary impact. GDP increases very briefly for three quarters before deteriorating as it takes time for the impact of a tax increase to feedback to GDP. Romer and Romer (2010) investigate the impact of tax changes on economic activity for the case of US and similarly find that tax increases have large contractionary impact on output. The initial increase in GDP contributes to the decline in the debt-to-GDP ratio. Domestic absorption falls on impact as a result of the sign restrictions, and follows a similar path

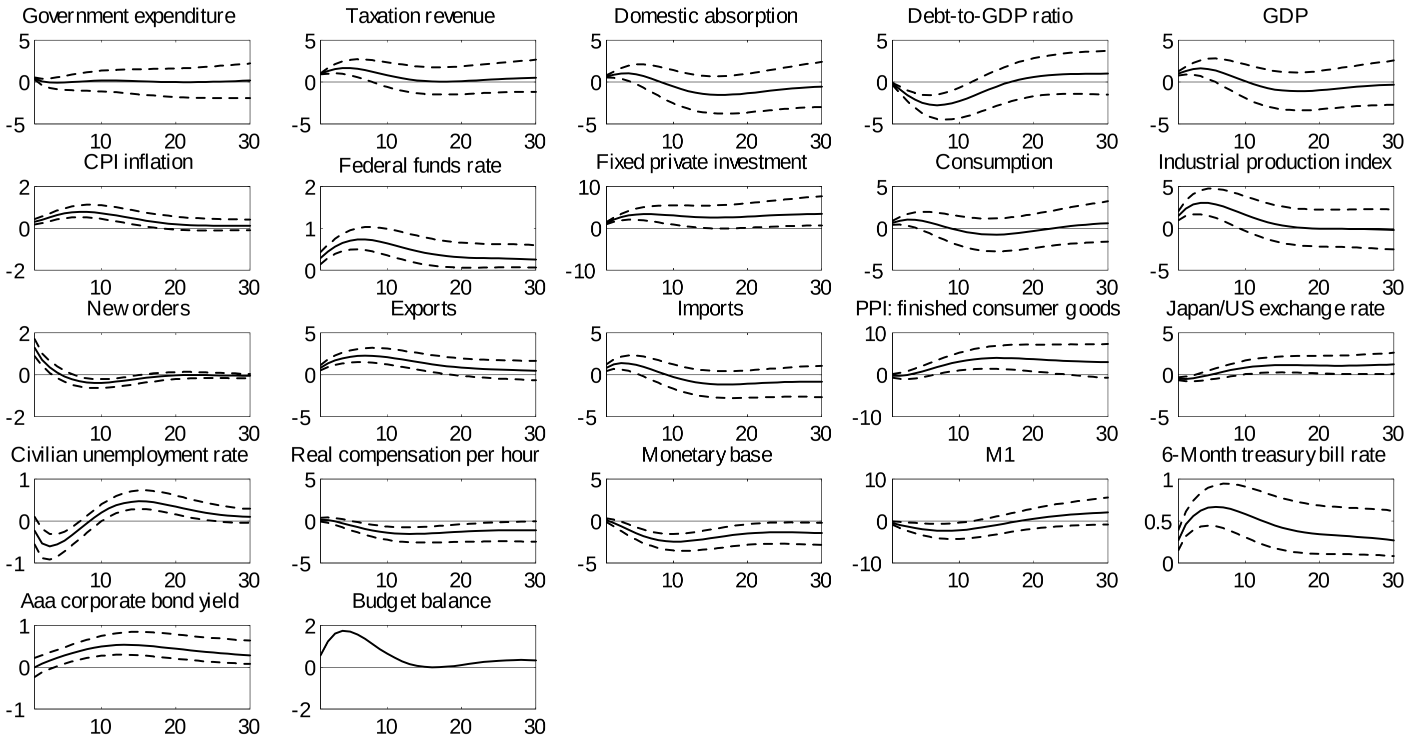

FIGURE 2A 1 standard deviation shock in government expenditure.

Note: All responses are cumulated except for CPI inflation, new orders, civilian unemployment rate, 6-month treasury bill rate and Aaa corporate bond yield.

to GDP.

Most real activity measures show signs of decline after a few quarters, contributing to the deterioration in GDP and domestic absorption. Consumption, fixed private investment, new private housing units and imports increase briefly for a few quarters before declining. The movements of industrial production and exports are similar, with both variables increasing, showing no signs of decline.

The behavior of CPI inflation following the shock to taxation revenue is less intuitive. The initial increase in real activity leads to an increase in CPI inflation for a few quarters before returning to its initial value. Mountford and Uhlig (2009) also find an increase in prices for the case of the US after a taxation shock. On the other hand, Favero and Giavazzi (2007) find that inflation declines after a taxation shock, with the interest rate falling as a result.

The Federal Reserve responds to the increase in CPI inflation accordingly by tightening monetary policy. The exchange rate appreciates, which also aids the increase in imports. With real activity declining after a few quarters, the unemployment rate increases after seven quarters. The movements in the monetary variables are consistent with the increase in the federal funds rate. The monetary base and M1 decline, while the six-month treasury bill rate and the Aaa corporate bond yield increase.

Debt-to-GDP ratio shock

The responses of the selected macroeconomic variables to a shock to the debt-to-GDP ratio is reflected in Figure 4. The change in debt-to-GDP ratio is positive for four quarters before turning negative. Government expenditure increases minimally. The increase in taxation revenue is greater than the increase in government expenditure, resulting in a budget surplus. The increase in government expenditure contributes to the increase in GDP and domestic absorption. The budget surplus and increase in GDP combine to help to bring the debt-to-GDP ratio back to its initial value. The

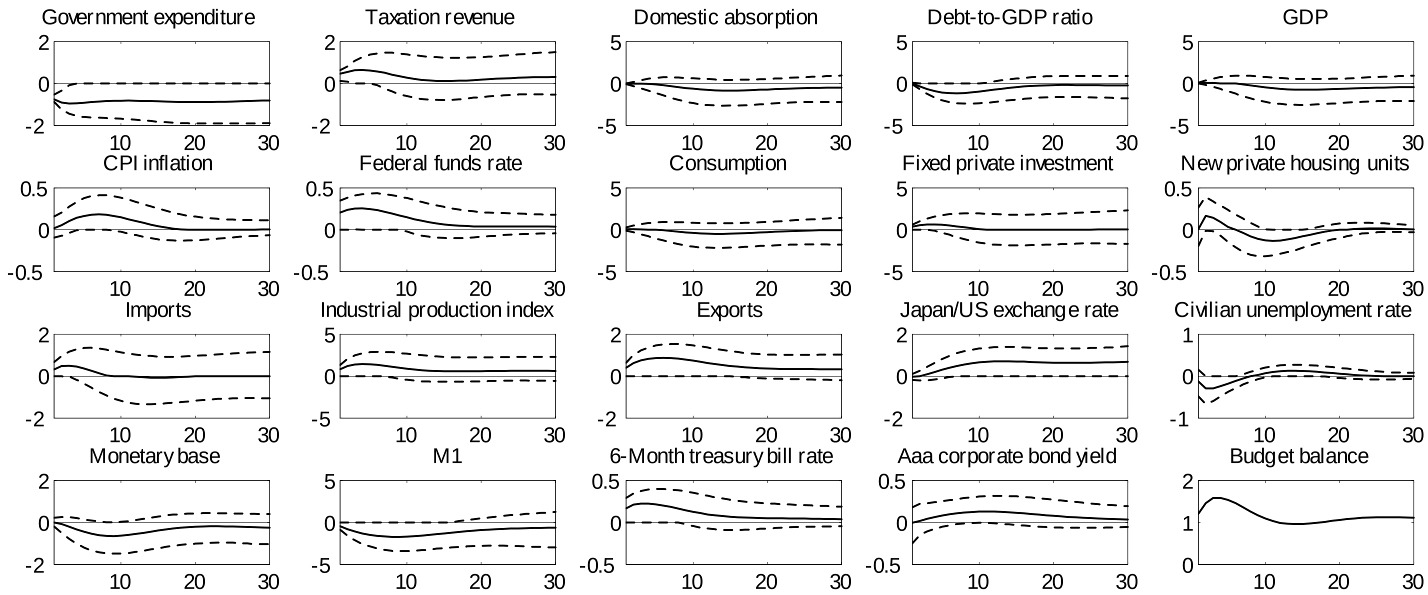

FIGURE 3A 1 standard deviation shock in government taxation revenue.

Note: All responses are cumulated except for CPI inflation, civilian unemployment rate, 6-month treasury bill rate and Aaa corporate bond yield.

initial increase in GDP also suggests that the increase in the debt-to-GDP ratio is likely due to debt increasing more than GDP. Dungey and Fry (2009) similarly find that the debt-to-GDP ratio returns to its initial value after a few quarters through a decline in government expenditure and a delayed increase in taxation revenue.

Real activity measures such as consumption, fixed private investment and industrial production increase, which should lead to an increase in CPI inflation. Hence, the decline in CPI inflation is less intuitive. The federal funds rate responds with a lag, increasing after seven quarters of decline.

The initial decline in the federal funds rate leads to a depreciation of the exchange rate. The depreciation of the exchange rate results in more expensive imports. Intuitively, imports are expected to decline. However, imports increase, likely with the help of the increase in consumption. The increase in imports is likely to be funded by the increase in debt and borrowing.

The increase in the monetary base is consistent with the initial decline in the federal funds rate. The 6-month treasury bill rate mimics the path of the federal funds rate. On the other hand, the Aaa corporate bond yield increases, moving in the opposite direction of the federal funds rate. This outcome is possible if investors believe that the Federal Reserve has kept the federal funds rate too low, and are factoring an increase in the future.

IV. Forecast error variance decomposition

This paper performs a forecast error variance decomposition exercise to determine the fraction of the forecast error of a variable that is due to a particular shock at a given horizon. The variance decomposition of each of the observed variable in Y_t, denoted as $V_{Y,it}$, that is due to a particular shock, say η_t^*, can be expressed as

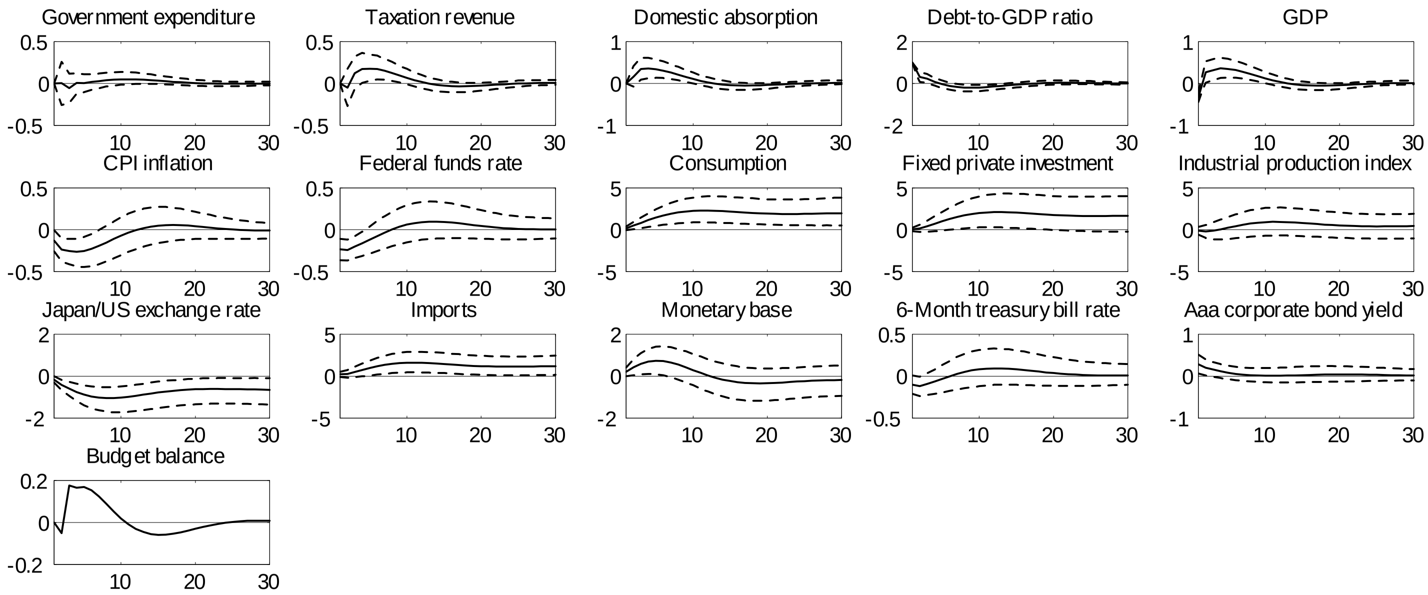

FIGURE 4A one standard deviation shock in debt-to-GDP ratio.

Note: All responses are cumulated except for CPI inflation, 6-month treasury bill rate and Aaa corporate bond yield.

$$V_{Y,it} = \frac{var(Y_{it+k} - \hat{Y}_{it+k|t}|\eta_t^*)}{var(Y_{it+k} - \hat{Y}_{it+k|t})} \quad (8)$$

To compute the variance decomposition for the 113 macroeconomic time series in X_t, the relative importance of a structural shock is assessed only to the portion of the variable explained by the common factors. The variance decomposition of each of the 113 macroeconomic time series in X_t, denoted as $V_{x,it}$, that is due to a particular shock, say η_t^*, can be expressed as

$$V_{x,it} = \frac{\Lambda_i var(X_{it+k} - \hat{X}_{it+k|t}|\eta_t^*)\Lambda_i'}{\Lambda_i var(X_{it+k} - \hat{X}_{it+k}|t)\Lambda_i'}, \quad (9)$$

where Λ_i is the i^{th} line of Λ and $\frac{var(X_{t+k} - \hat{X}_{t+k|t}|\eta_t^*)}{var(X_{t+k} - \hat{X}_{t+k|t})}$ is the standard VAR variance decomposition based on equation 1.

Focusing on the forecast error variance decomposition of output in Table 2, three main messages become apparent.

Table 2

Contribution of shocks to variance of output (percent)

Shocks	*1 quarter ahead*	*4 quarters ahead*	*30 quarters ahead*
GDP	21.463	11.837	7.307
GNE	53.966	22.920	11.774
Government expenditure	22.238	9.445	6.136
Taxation revenue	0.061	0.024	0.298
Debt-to-GDP-ratio	2.272	2.263	3.100
Fiscal policy (government expenditure plus taxation revenue)	22.299	9.470	6.434
Monetary policy	0.000	0.395	0.984
CPI inflation	0.7222	0.227	2.686

First, as reflected in Table 2, domestic absorption explains the majority of the variance of output, while the contribution of an output shock to its own variable is around 21%. Second, government expenditure shock explains a reasonable fraction of output variability. Third, the government expenditure shock also has more impact on the selected US macroeconomic variables, compared to the taxation revenue, debt-to-GDP ratio and monetary policy shocks, as seen in Tables 4-7 in Appendix C. The contribution of the monetary policy shocks to the selected macroeconomic variables is mostly under five%, apart from monetary variables such as the 6-month treasury bill rate. In contrast, Bernanke et al. (2005) and Soares (2013) assess monetary policy in the US and the euro area respectively using FAVAR models and find a greater contribution of the monetary policy shock to the variance of the forecast error of the variables in their models. Tables A.2–A.5 in Appendix C report the results of the variance decomposition exercise for the selected macroeconomic variables.

V. Historical decompositions

This section presents the historical decompositions of US GDP, the federal funds rate and inflation over the sample period 1996Q1 and 2010Q4. The period covers the last two recessions in the US economy – the dot-com recession from 2001Q1 to 2001Q3, and the great recession from 2008Q1 to 2009Q2.[8]

To calculate the historical decomposition for any of the variables, the reduced form FAVAR in equation 1 is first transformed into the moving average representation by multiplying both sides of equation 1 by $B(L)^{-1}$,

$$Z_t = C(L)u_t = \Sigma_{i=0}^{\infty} C_i u_{t-i}, \tag{10}$$

where $Z_t = [Y_t', \tilde{F}_t']', C(L) = B(L)^{-1}$, and C_i are the impulse responses at each quarter. Consider T as some base period in the sample (1972Q3 to 2010Q4). For any $j = 1, 2,$

[8] The dates of the dot-com recession and the Great Recession are obtained from the National Bureau of Economic Research (NBER) website. The recession dates are determined based on the decisions of the Business Cycle Dating Committee of the NBER ((Source: NBER, http://www.nber.org/cycles/cyclesmain.html (accessed 7 July, 2013)).

..., where $T + j$ is less than or equal to the last period in the sample, the vector time series Z_t can be expressed as

$$Z_{T+j} = \Sigma_{i=0}^{j-1} C_i u_{T+j-i} + \Sigma_{i=0}^{\infty} C_i u_{T+j-i}. \tag{11}$$

based on the reorganization of the moving average representation and written as the sum of two components. The first component represents the part of the historical time series attributable to innovations since T, and can be further examined to establish the role of the innovations of each variable separately. The second component is the 'base projection' of Z_{T+j}, and is formed solely from information available at time T.

Historical decomposition of US GDP

Figure 5 presents the historical decomposition of GDP. The major contributors to GDP, apart from its own shocks, are domestic absorption and government expenditure shocks. The GDP shock plays a relatively larger role in the Great Recession than in the dot-com recession, which is within expectations given the severity of the Great Recession. The government expenditure shocks make slightly negative contributions to GDP in the dot-com recession, and positive contributions to GDP during the Great Recession. In the aftermath of the Great Recession from 2009Q4, the contribution of the government expenditure shocks turns negative. This suggests that government expenditure shocks play an important role in supporting the US economy in the recent Great Recession, consistent with the views of Benati and Lubik (2013) and Christiano et al. (2011). Both papers argue that the government spending multiplier is larger in the recent crisis, given that the nominal interest rate is at the zero lower bound. The contributions of the taxation revenue shocks and the federal funds rate shocks to GDP over the sample are small, supporting the result from the previous section that finds that monetary policy shocks do not explain much of the variability in output.

Debt-to-GDP ratio shocks play a contractionary role during the Great Recession, but makes a marginal positive contribution towards GDP in the aftermath of the Great Recession.

Historical decomposition of the federal funds rate

The historical decomposition of the federal funds rate in Figure 6 suggests that the major contributor to federal funds rate does not come from its own innovations, but from the shocks of the first two factors describing the US economy and shocks of GDP, particularly in the great recession. This suggests that the Federal Reserve monitors and responds to a large panel of variables and indicators beyond inflation, further justifying the use of a FAVAR approach. Government expenditure plays more of a role in influencing the federal funds rate than taxation revenue does, particularly in the period following the dot-com crisis. The debt-to-GDP ratio contributes by dampening the federal funds rate.

Historical decomposition of US CPI inflation

The historical decomposition of US CPI inflation is shown in Figure 7. The major contributors to inflation are shocks of factor 1 that describe the US economy and shocks to GDP. The contributions of factor 1 and GDP to inflation during the Great Recession period is positive, only falling after 2009Q2 as it takes time for the negative impact on the US economy to influence inflation. Shocks to government expenditure also makes a positive contribution to inflation towards the end of both recessions as the expansionary effects from government expenditure takes time to affect the US economy and inflation.

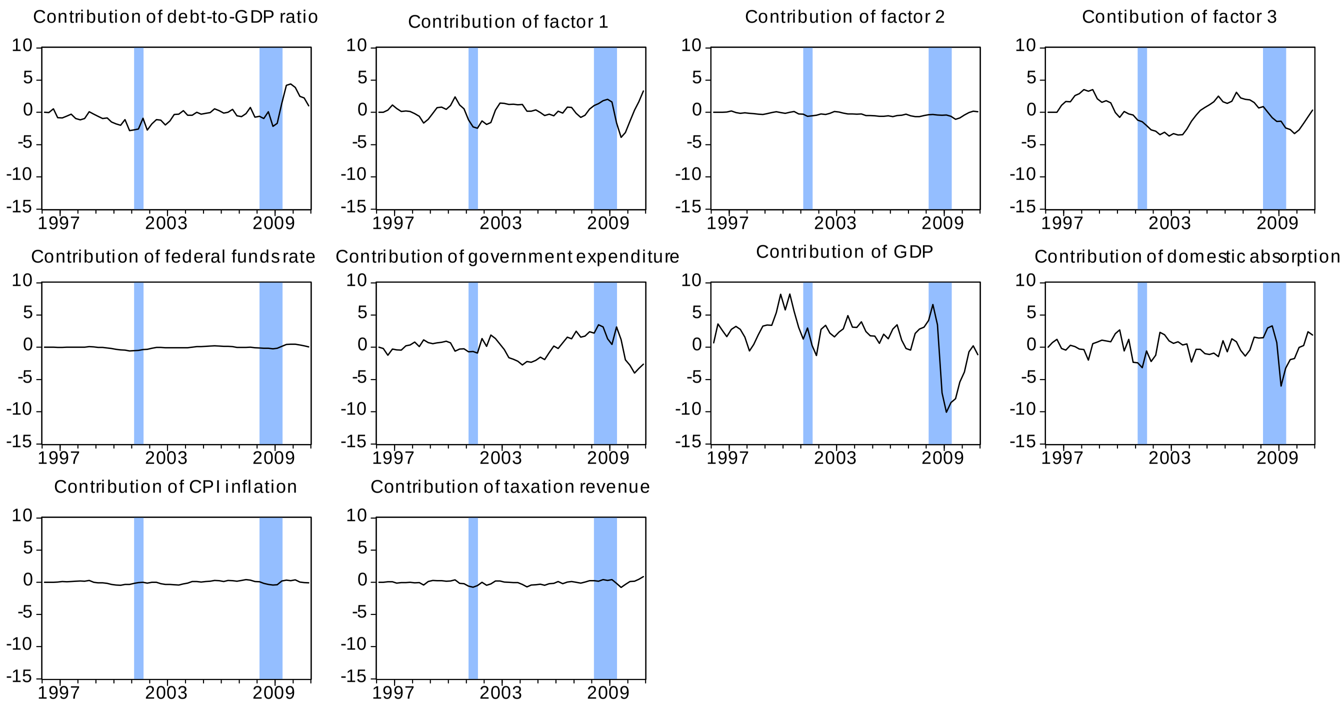

Figure 5Historical decomposition of GDP.

Note: The shaded areas refer to the dot-com recession from 2001Q1 to 2001Q3 and the Greal Recession from 2008Q1 to 2009Q2..

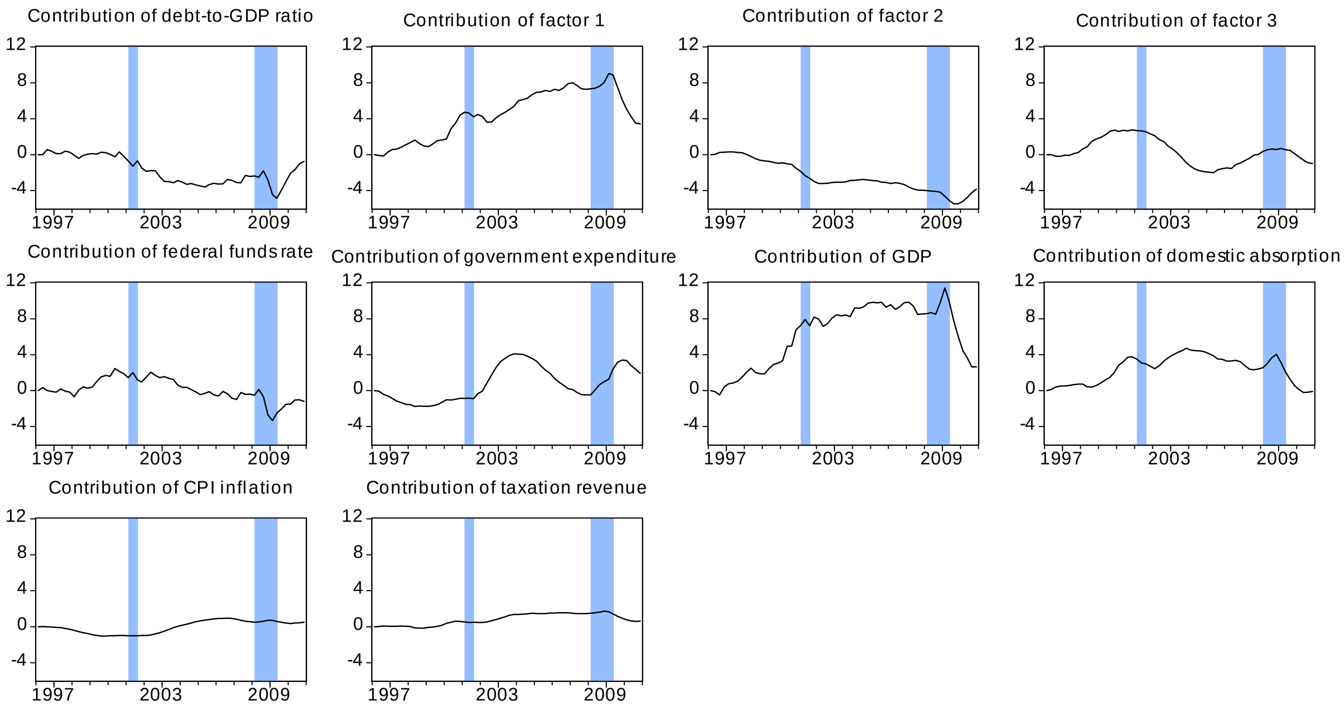

FIGURE 6Historical decomposition of the federal funds rate.

Note: The shaded areas refer to the dot-com recession from 2001Q1 to 2001Q3 and the Greal Recession from 2008Q1 to 2009Q2..

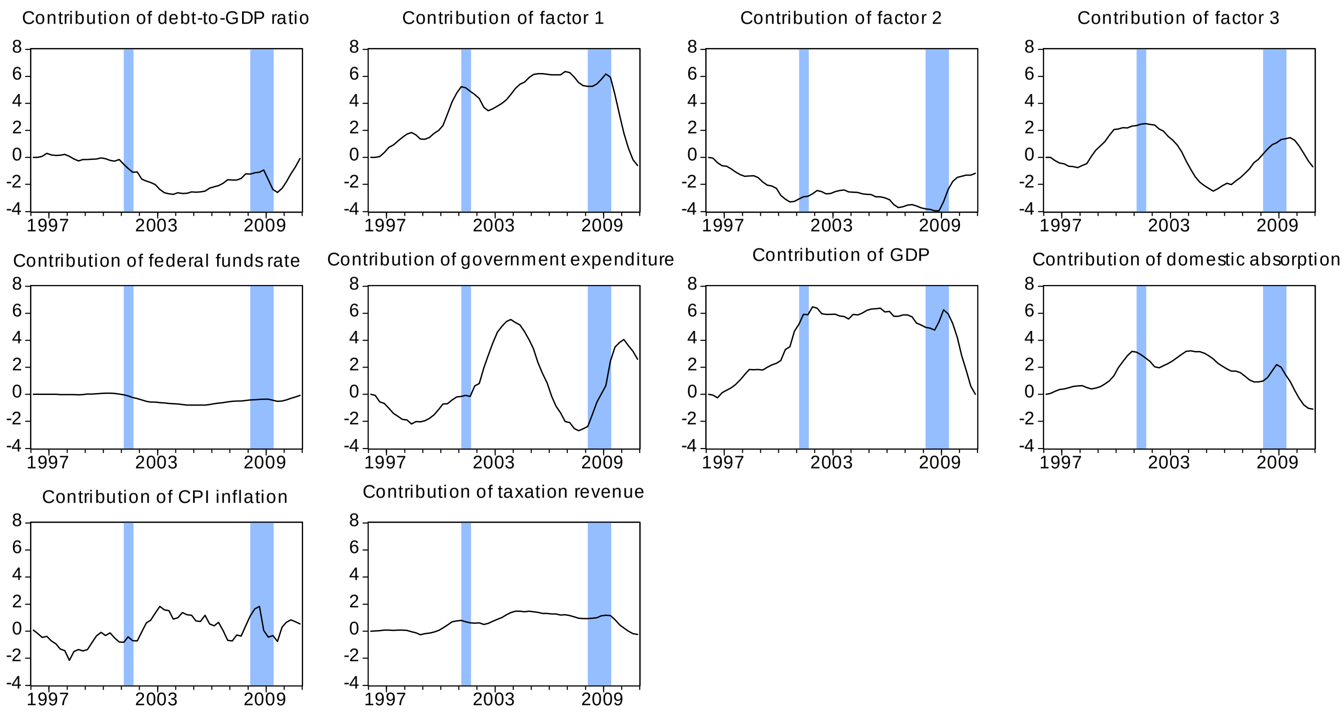

FIGURE 7Historical decomposition of CPI inflation.

Note: The shaded areas refer to the dot-com recession from 2001Q1 to 2001Q3 and the Greal Recession from 2008Q1 to 2009Q2..

VI. Conclusion

This paper investigates the behavior of monetary and fiscal authorities in the US by using a new approach. The paper uses a FAVAR framework to analyze the effects of fiscal policy, in conjunction with monetary policy, on US macroeconomic variables. Identification of fiscal policy is achieved via the signs restriction methodology as in Dungey and Fry (2009) and Fry and Pagan (2011). Several important findings emerge from this study.

First, the impact of shocks in government spending on output appears to be longer lasting than the impact of shocks in taxes and federal funds rate. Second, this paper finds evidence that a government expenditure shock explains more variability in macroeconomic variables than a monetary policy shock. Third, there is some evidence of the crowding-out effects of fiscal policy, consistent with the Real Business Cycle (RBC)-type models. The existing empirical literature often find evidence in support of crowding-out effects that is predicted by the RBC type-models or the Keynesian type-models. The historical decomposition exercise on GDP suggests that government expenditure shocks contribute positively to output in the Great Recession. Last, this paper finds evidence that monetary and fiscal policies move in opposite directions following a shock to either the fiscal or monetary policy instrument. Therefore, an expansionary fiscal policy is likely to be counteracted by a contractionary monetary policy, limiting the full potential effects that an expansionary fiscal policy can have on the US economy. Hence, this finding emphasizes the need for better coordination between the government and monetary authorities in designing optimal fiscal and monetary policies that are complementary and the importance of analyzing monetary and fiscal policies jointly.

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Appendices

A Estimation methodology

This Appendix details the two-step procedure used to estimate the model in the paper. In the first step, the unobserved factors and factor loadings are estimated via the principal components estimator. In the second step, the estimated factors along with the observed factors are used to estimate the FAVAR model via Bayesian methods. Gibbs sampling is used to approximate the posterior distribution in the model. The parameters in the VAR model are sampled conditional on the final estimate of the factors obtained via the principal components estimator (just as if the factors were observed data). The paper uses 10,000 Gibbs replications, and discard the first 2,000 replications as the burn-in sample.

The procedure used in this paper closely follows Bernanke et al. (2005) in using a diffuse conjugate Normal-Wishart prior (a non-informative version of the natural conjugate prior) to estimate the FAVAR model. The use of the non-informative prior leads to a posterior distribution and predictive results based on familiar Ordinary Least Squares quantities. In other words, the results from estimating a Bayesian FAVAR using a non-informative prior will be largely similar to a FAVAR estimated by the frequentist method. The drawback of the non-informative prior is that it does not do any shrinkage which can be important for VAR modelling. Shrinkage is found to be of great benefit in reducing the over parameterization problem VAR frameworks face. This paper addresses the issue of the high dimensionality problem that VAR models face by using a FAVAR framework. This paper uses a non-informative prior and Bayesian estimation methods for the FAVAR over a frequentist approach as their interpretations differ even though the results are going to be very similar.[9] The steps followed in this paper to estimate the model are:

- **Step 1 - Sample $\tilde{B}$.** Draw B_i from f(B|$\tilde{\Omega}$,y$_i$)~N(μ,σ^2).
- **Step 2 - Sample $\tilde{\Omega}$.** Draw Ω_i from f(Ω|y$_i$)~IW(σ,T-K), where $T-K$ is the degrees of freedom. T is the total number of time series observations $T = 154$, and K is the dimensionality of this FAVAR $K = 10$.
- **Step 3 - Return to Step 1.**

B The data

This section provides information on the datasets Y_t and $X_{\mathbf{t}}$ used in this paper.

[9] For example, using the frequentist approach, a 95% confidence interval implies the notion of repeating an experiment many times and being able to capture the true parameter 95% of the times. On the other hand, using the bayesian approach, a 95% credible (confidence) interval implies there is a 95% chance that the interval captures the true value.

Variables in Y_t

The data in Y_t is collected from several sources. The data on components of US national income are taken from the National Income and Product Accounts (NIPA), which are made publicly available by the Bureau of Economic Analysis on their website.[10] The remaining data are taken from the Federal Reserve Economic Data (FRED) database of the Federal Reserve Board of St Louis website [11] and Thomson Reuters Datastream.

Definitions of variables in Y_t

All the components of national income are in real terms and are transformed from their nominal values by dividing them by the GDP deflator (GDPDEF) from the FRED. The table and row numbers refer to the organization of the data by the Bureau of Economic Analysis. The definitions of Total Government Expenditure and Total Government Revenue follow Mountford and Uhlig (2009).

Total Government Expenditure: This refers to 'Federal Defense Consumption Expenditures', NIPA Table 3.9.5 row 12, plus 'Federal Non Defense Consumption Expenditures', NIPA Table 3.9.5 row 17, plus 'State and Local Consumption Expenditures', NIPA Table 3.9.5 row 22, plus 'Federal Defense Gross Investment', NIPA Table 3.9.5 row 13, plus 'Federal Non Defense Gross Investment', NIPA Table 3.9.5 row 18, plus 'State and Local Gross Investment', NIPA Table 3.9.5 row 23.

Total Government Revenue:[12] This is 'Total Government Receipts', NIPA Table 3.1 row 1, minus 'Net Transfer Payments', NIPA Table 3.1 row 17, and 'Net Interest

[10] Source: Bureau of Economic Analysis, http://www.bea.gov/iTable/index_nipa.cfm (accessed 7 July, 2013).

[11] Source: Federal Reserve Board of St Louis, http://research.stlouisfed.org/fred2 (accessed 7 July, 2013).

[12] This definition follows Blanchard and Perotti (2002) and Mountford and Uhlig (2009) regarding transfer payments as negative taxes.

Paid', NIPA Table 3.1 row 22.

Gross National Expenditure: This is 'Personal Consumption Expenditures', plus 'Gross Private Domestic Investment', plus 'Government Consumption Expenditures & Gross Investment'.

Debt-to-GDP ratio: The definition of Debt-to-GDP ratio follows Favero and Giavazzi (2007). This is 'Federal Debt Held by the Public' (FYGFDPUN in FRED) divided by GDP. When the government spending exceeds its taxation revenue, it borrows to finance the debt. Hence, the federal debt held by the public represents the value of all federal securities sold to the public. The public includes a wide range of investors outside of the federal government, including international and domestic private investors, the Federal Reserve, and state and local governments.

Real GDP: This is 'Real Gross Domestic Product, 3 decimal' (GDPC96) taken from the FRED.

CPI Inflation–All Items: This is the change in 'Consumer Price Index for All Urban Consumers: All Items' (CPIAUCSL) taken from the FRED.

Federal Funds Rate: This is the 'Effective Federal Funds Rate' (FEDFUNDS) taken from the FRED.

Variables in X_t

Table 3 lists the 113 variables in X_t used to extract the three unobserved US factors for use in the FAVAR. The following transformation codes have been applied: 1 – Level; 4 – Log-level; 5 – Log-First Difference.

TABLE 3

Variables in X_t

No.	Series ID	Description	Transformation
US activity			
1	FINSLC96	Real Final Sales of Domestic Product, 3 Decimal	5
2	CP	Corporate Profits After Tax	5
3	CNCF	Corporate Net Cash Flow	5
4	FPI	Fixed Private Investment	5
5	GSAVE	Gross Saving	5
6	PRFI	Private Residential Fixed Investment	5
7	NAPM	ISM Manufacturing: PMI Composite Index	1
8	HOUST	Housing Starts: Total: New Privately Owned Housing Units Started	4
9	HOUSTNE	Housing Starts in Northeast Census Region	4
10	HOUSTMW	Housing Starts in Midwest Census Region	4
11	HOUSTS	Housing Starts in South Census Region	4
12	HOUSTW	Housing Starts in West Census Region	4
13	HOUST1F	Privately Owned Housing Starts: 1-Unit Structures	4
14	PERMIT	New Private Housing Units Authorized by Building Permit	4
15	EXPGSC96	Real Exports of Goods & Services, 3 Decimal	5
16	IMPGSC96	Real Imports of Goods & Services, 3 Decimal	5
17	PMNO	NAPM New Orders Index (Percent)	1
18	INDPRO	Industrial Production Index	5
19	IPBUSEQ	Industrial Production: Business Equipment	5
20	IPCONGD	Industrial Production: Consumer Goods	5
21	IPDCONGD	Industrial Production: Durable Consumer Goods	5
22	IPDMAN	Industrial Production: Durable Manufacturing (NAICS)	5
23	IPDMAT	Industrial Production: Durable Materials	5
24	IPFINAL	Industrial Production: Final Products (Market Group)	5
25	IPMAN	Industrial Production: Manufacturing (NAICS)	5

No.	Series ID	Description	Transformation
US Activity			
26	IPMAT	Industrial Production: Materials	5
27	IPMINE	Industrial Production: Mining	5
28	IPNCONGD	Industrial Production: Nondurable Consumer Goods	5
29	IPNMAN	Industiral Production: Nondurable Manufacturing (NAICS)	5
30	IPNMAT	Industrial Production: Nondurable Materials	5
31	IPUTIP	Industrial Production: Electric and Gas Utilities	5
32	PCECC96	Real Personal Consumption Expenditure	5
US Employment Situation			
33	UNRATE	Civilian Unemployment Rate	1
34	UEMPLT5	Civilians Unemployed – Less than 5 weeks	5
35	UEMP5TO14	Civilians Unemployed for 5 – 14 weeks	5
36	UEMP15OV	Civilians Unemployed - 15 Weeks & Over	5
37	UEMP15T26	Civilians Unemployed for 15-26 Weeks	5
38	UEMP27OV	Civilians Unemployed for 27 Weeks and Over	5
39	NDMANEMP	All Employees: Nondurable Goods Manufacturing	5
40	MANEMP	Employees on Nonfarm Payrolls: Manufacturing	5
41	SRVPRD	All Employees: Service-Providing Industries	5
42	USTPU	All Employees: Trade, Transportation & Utilities	5
43	USWTRADE	All Employees: Wholesale Trade	5
44	USTRADE	All Employees: Retail Trade	5
45	USFIRE	All Employees: Financial Activities	5
46	USEHS	All Employees: Education & Health Services	5
47	USPBS	All Employees: Professional & Business Services	5
48	USINFO	All Employees: Information Services	5
49	USSERV	All Employees: Other Services	5

No.	Series ID	Description	Transformation
US Employment Situation			
50	USPRIV	All Employees: Total Private Industries	5
51	USGOVT	All Employees: Government	5
52	USLAH	All Employees: Leisure & Hospitality	5
53	AWHMAN	Average Weekly Hours: Manufacturing	1
54	AWOTMAN	Average Weekly Hours: Overtime: Manufacturing	1
55	HOABS	Business Sector: Hours of All Persons	5
56	HOANBS	Nonfarm Business Sector: Hours of All Persons	5
US Price Indices			
57	OILPRICE	Spot Oil Price: West Texas Intermediate	5
58	PPIACOINF	Producer Price Index: All Commodities	5
59	PPICRMINF	Producer Price Index: Crude Materials for Further Processing	5
60	PPIFCFINF	Producer Price Index: Finished Consumer Foods	5
61	PPIFCGINF	Producer Price Index: Finished Consumer Goods	5
62	PFCGEFINF	Producer Price Index: Finished Consumer Goods Excluding Foods	5
63	PPIFGSINF	Producer Price Index: Finished Goods	5
64	PPICPEINF	Producer Price Index Finished Goods: Capital Equipment	5
65	PPIENGINF	Producer Price Index: Fuels & Related Products & Power	5
66	PPIIDCINF	Producer Price Index: Industrial Commodities	5
67	PPIITMINF	Producer Price Index: Intermediate Materials: Supplies & Components	5
68	AHECONS	Average Hourly Earnings: Construction	5
69	AHEMAN	Average Hourly Earnings: Manufacturing	5
70	AHETPI	Average Hourly Earnings: Total Private Industries	5
71	ULCBS	Business Sector: Unit Labor Cost	5
72	ULCNFB	Nonfarm Business Sector: Unit Labor Cost	5
73	RCPHBS	Business Sector: Real Compensation Per Hour	5
74	COMPRNFB	Nonfarm Business Sector: Real Compensation Per Hour	5

No.	Series ID	Description	Transformation
US Credit			
75	CMDEBT	Household Sector: Liabilites: Household Credit Market Debt Outstanding	5
76	TOTALSL	Total Consumer Credit Outstanding	5
77	NONREVSL	Total Nonrevolving Credit Outstanding, Seasonally adjusted, Billions of Dollars	5
78	USGSEC	US Government Securities at All Commercial Banks	5
79	OTHSEC	Other Securities at All Commercial Banks	5
80	BUSLOANS	Commercial and Industrial Loans at All Commercial Banks	5
81	CONSUMER	Consumer (Individual) Loans at All Commercial Banks	5
82	LOANS	Total Loans and Leases at Commercial Banks	5
83	LOANINV	Total Loans and Investments at All Commercial Banks	5
84	INVEST	Total Investments at All Commercial Banks	5
85	REALLN	Real Estate Loans at All Commercial Banks	5
US Money			
86	BOGAMBSL	Board of Governors Monetary Base, Adjusted for Changes in Reserve Requirements	5
87	TRARR	Board of Governors Total Reserves, Adjusted for Changes in Reserve Requirements	5
88	NFORBRES	Net Free or Borrowed Reserves of Depository Institutions	1
89	M1SL	M1 Money Stock	5
90	CURRSL	Currency Component of M1	5
91	CURRDD	Currency Component of M1 Plus Demand Deposits	5
92	DEMDEPSL	Demand Deposits at Commercial Banks	5
93	TCDSL	Total Checkable Deposits	5
US Interest Rates			
94	TB3MS	3-Month Treasury Bill: Secondary Market Rate	1
95	TB6MS	6-Month Treasury Bill: Secondary Market Rate	1
96	GS1	1-Year Treasury Constant Maturity Rate	1
97	GS3	3-Year Treasury Constant Maturity Rate	1

No.	Series ID	Description	Transformation
US Interest Rates (continued)			
98	GS5	5-Year Treasury Constant Maturity Rate	1
99	GS10	10-Year Treasury Constant Maturity Rate	1
100	MPRIME	Bank Prime Loan Rate	1
101	AAA	Moody's Seasoned Aaa Corporate Bond Yield	1
102	BAA	Moody's Seasoned Baa Corporate Bond Yield	1
103	STB3MS	TB3MS - FEDFUNDS	1
104	STB6MS	TB6MS - FEDFUNDS	1
105	SGS1	GS1 - FEDFUNDS	1
106	SGS3	GS3 - FEDFUNDS	1
107	SGS5	GS5 - FEDFUNDS	1
108	SGS10	GS10 - FEDFUNDS	1
109	SMPRIME	MPRIME - FEDFUNDS	1
110	SAAA	Aaa - FEDFUNDS	1
111	SBAA	Baa - FEDFUNDS	1
US Exchange Rates			
112	EXSZUS	Switzerland/US Foreign Exchange Rate	5
113	EXJPUS	Japan/US Foreign Exchange Rate	5

C Additional forecast error variance decompositions

Tables A2 – A5 provide the forecast error variance decompositions due to shocks in the federal funds rate, government expenditure, government taxation revenue and debt-to-GDP ratio.

TABLE 4

Forecast error variance decomposition due to the federal funds rate shock

	4 quarters ahead	*30 quarters ahead*
Government Expenditure	1.934	3.529
Government Revenue	0.166	0.753
Gross National Expenditure	0.336	1.063
Debt-to-GDP ratio	0.346	0.865
GDP	0.395	0.984
CPI inflation: All Items	0.011	1.467
Federal Funds Rate	53.604	9.212
Fixed Private Investment	1.756	3.549
Real Compensation Per Hour	0.085	3.228
Civilian Unemployment Rate	0.186	1.587
New Private Housing Units	0.153	1.453
Monetary Base	1.922	0.484
M1	0.607	0.192
6-month Treasury Bill Rate	58.206	9.068
Aaa Corporate Bond Yield	19.339	9.573
Japan/US Exchange Rate	6.575	23.159
PPI: Finished Consumer Goods	0.664	10.536
New orders	3.226	4.373
Exports	0.046	6.042
Imports	0.173	0.258
Industrial Production Index	0.228	1.400
Consumption	0.136	0.674

Table 5

Forecast error variance decomposition due to government expenditure shock

	4 quarters ahead	*30 quarters ahead*
Government Expenditure	6.327	5.552
Government Revenue	18.226	11.557
Gross National Expenditure	13.664	11.322
Debt-to-GDP ratio	2.570	4.620
GDP	9.445	6.136
CPI inflation: All Items	13.124	19.026
Federal Funds Rate	13.311	15.417
Fixed Private Investment	3.364	0.051
Real Compensation Per Hour	2.236	0.818
Civilian Unemployment Rate	0.356	0.841
New Private Housing Units	14.732	7.853
Monetary Base	1.860	0.204
M1	0.270	0.022
6-month Treasury Bill Rate	13.754	14.014
Aaa Corporate Bond Yield	0.201	10.143
Japan/US Exchange Rate	1.793	0.556
PPI: Finished Consumer Goods	0.062	0.026
New orders	8.750	6.169
Exports	2.158	0.234
Imports	2.431	0.133
Industrial Production Index	2.013	0.112
Consumption	1.616	0.195

TABLE 6

Forecast error variance decomposition due to government taxation revenue shock

	4 quarters ahead	*30 quarters ahead*
Government Expenditure	10.713	8.874
Government Revenue	3.584	2.002
Gross National Expenditure	0.015	0.284
Debt-to-GDP ratio	2.789	1.820
GDP	0.024	0.298
CPI inflation: All Items	0.294	0.716
Federal Funds Rate	3.637	1.284
Fixed Private Investment	1.209	0.043
Real Compensation Per Hour	0.008	0.221
Civilian Unemployment Rate	0.843	1.115
New Private Housing Units	0.522	0.573
Monetary Base	0.116	0.633
M1	1.717	0.928
6-month Treasury Bill Rate	3.158	1.006
Aaa Corporate Bond Yield	0.026	0.512
Japan/US Exchange Rate	0.056	3.259
PPI: Finished Consumer Goods	0.096	0.005
New orders	0.841	0.901
Exports	2.718	1.535
Imports	0.838	0.057
Industrial Production Index	2.181	0.573
Consumption	0.012	0.067

TABLE 7

Forecast error variance decomposition due to debt-to-GDP ratio shock

	4 quarters ahead	*30 quarters ahead*
Government Expenditure	0.056	0.322
Government Revenue	0.269	1.368
Gross National Expenditure	1.479	2.682
Debt-GDP ratio	14.545	6.976
GDP	2.263	3.100
CPI inflation: All Items	2.900	1.198
Federal Funds Rate	3.363	0.632
Fixed Private Investment	0.296	1.666
Real Compensation Per Hour	1.685	2.190
Civilian Unemployment Rate	5.404	3.976
New Private Housing Units	0.302	2.579
Monetary Base	1.564	0.666
M1	4.532	2.751
6-month Treasury Bill Rate	0.868	0.264
Aaa Corporate Bond Yield	1.636	0.435
Japan/US Exchange Rate	3.212	5.392
PPI: Finished Consumer Goods	0.411	1.004
New orders	0.627	1.584
Exports	1.619	0.333
Imports	0.569	2.402
Industrial Production Index	0.039	0.256
Consumption	1.725	3.009