# Public Debt, Ricardian Fiscal Policy, and Time-Varying Government Spending Multipliers*

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**Abstract**

What determines government spending multipliers? While monetary policy and public debt have long been considered as important factors in determining the effects of fiscal policy, recent debate on multipliers in the post-war U.S. focuses on their state-dependent nature across the business cycle. This paper attempts to fill the gap by providing new empirical evidence from time-varying parameter vector autoregressive (TVP-VAR) model that includes monetary variables and public debt with sign restrictions. The results show that government spending multipliers declined substantially since the late 1970s. To examine the cause of the decline, government spending shocks in different scenarios are identified by imposing additional restrictions. The decline is also observed for those in recession and expansion scenarios. Contrary to conventional wisdom, monetary policy is shown to play little role in the decline. Applying the TVP-VAR technique for the testing of changes in fiscal policy stance, we find that the degree of Ricardian behavior of the government were strengthened over the period during which multipliers declined. Our results point to the importance of fiscal policy behavior that the public debt level may affect.

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# 1 Introduction

The economic impact of government spending is one of the classic theme in macroeconomics. While the size of the government spending multiplier has always been a central topic in the literature, the past several years have witnessed increased attention to its heterogeneity over time and across countries. As emphasized by Alesina and Giavazzi (2013), researchers in recent years generally agree with the view that "there is no such thing as a 'single' fiscal multiplier."[1] A growing body of literature has documented that the size of government spending multiplier may vary depending on the state and characteristics of the economy.

Recent debate on multipliers in the post-war U.S. tends to focus on their state-dependent nature across the business cycle. Table 1 gives a summary of studies that find nonlinear effects of government spending shocks in the U.S. Several studies provide evidences that the size of government spending multipliers is larger in recession than those in expansions (e.g., Auerbach and Gorodnichenko (2012); Bachmann and Sims (2012); Batini et al. (2012); Candelon and Lieb (2013); Caggiano et al. (2015)).[2] Similar results have also been reported in studies that consider data from OECD countries (e.g., Tagkalakis (2008); Baum et al. (2012); Auerbach and Gorodnichenko (2013); Dell'Erba et al. (2014); Riera-Crichton et al. (2014)). On the other hand, the relation between the size of government spending multipliers and characteristics of the economy has been studied mainly based on cross-country panel data. (e.g., Favero et al. (2011); Corsetti et al. (2012); Ilzetzki et al. (2013); Nickel and Tudyka (2014)). The notable common finding is that government spending multipliers are larger in the economies where debt-to-output ratio is low (e.g., Favero et al. (2011); Corsetti et al. (2012); Ilzetzki et al. (2013)). From the U.S. point of view, the role of public debt is worth examining because its debt-to-output ratio has been growing since the early 1980s. The relationship between public debt level and the effects of fiscal policy has also been investigated in the literature on non-Keynesian effects. Using a panel data from OECD countries, Perotti (1999) shows that government spending shocks have larger positive impact on private consumption at low levels of debt and negative one (i.e., non-Keynesian effects) in the opposite circumstances. The empirical evidences in the literature have been provided primarily based on cross-country panel data or specific episode in European countries. All in all, the role of public debt in the effects of government spending has not yet been examined based on the U.S. time series data.

In the context of the U.S. economy, a recent strand of the fiscal theory of the price level

[1] See also Parker (2011), Favero et al. (2011), and Corsetti et al. (2012). Batini et al. (2014) provide a comprehensive survey of the recent developments in the literature of fiscal multipliers.

[2] In contrast, Owyang et al. (2013) and Ramey and Zubairy (2014) argue that they do not find evidence that multipliers differ depending on the state of the U.S. economy based on the local projection method of Jordà (2005).

(FTPL) literature provide a new look at the importance of fiscal policy regime in determining the effects of government spending. Using a calibrated New Keynesian model augmented with estimated monetary and fiscal policy regimes on the U.S. data, Davig and Leeper (2011) demonstrate that output effects of government spending become smaller when monetary policy is active and fiscal policy is passive in the sense of Leeper (1991).[3] It is worth emphasizing that the active and passive policy are defined depending on its responsiveness to government debt, which gives rise to a potential role for the debt level in affecting changes in policy regimes.[4] Studies in this strand tend to find that fiscal policy has 'fluctuated' among active and passive rules. The results contrast with those based on linear models, which give support to Ricardian fiscal regime throughout the post-war period (e.g., Bohn (1998); Canzoneri et al. (2001); Canzoneri et al. (2010)).[5] Regarding the role of monetary policy, on the other hand, it has often been argued that multipliers became smaller because of the changes in the conduct of monetary policy after the appointment of Paul Volcker as Fed Chairman in 1979 (e.g., Perotti (2004); Bilbiie et al. (2008)).[6] Nevertheless, there is a considerable disagreement as to whether monetary policy has changed substantially or not.[7] Accordingly, little empirical evidence has been provided on the influence of monetary policy regime change on the effects of government spending.

Against this background, the present paper provides new evidence on the changes in the effects of government spending on output in the post-war U.S., by taking different approach. Instead of relying on sub-sample analysis or regime-switching models, we employ a time-varying parameter vector autoregressive (TVP-VAR) model with stochastic volatility, where both the autoregressive coefficients and the log of variances for structural shocks are assumed to follow random walk processes, because the evolution of government debt in the post-war U.S. are better described as permanent change rather than transitory change. The framework allows us to present time profile of the changes in government spending multipliers without any *a priori* knowledge of a certain timing of structural change or regimes that are characterized by certain policy rules.

There is a large strand of literature that documents time-varying effects of monetary policy within the TVP-VAR framework (e.g., Cogley and Sargent (2002); Primiceri (2005); Canova and

[3] Traum and Yang (2011) also examine the effects of government spending using New Keynesian models estimated over different sample periods with different priors centered at policy regimes of the period.

[4] Davig et al. (2010) develop a model in which probability of active fiscal policy rises with the level of public debt.

[5] By estimating Markov-switching model, Ito et al. (2011) conclude that the U.S. government follows a Ricardian fiscal policy throughout their entire sample period, 1940-2005.

[6] Canzoneri et al. (2012) develop a New Keynesian model in which the change in monetary policy can account for the reduction in the size of government spending multipliers.

[7] While the 'good policy' explanation of the Great Moderation has been suggested by several studies (e.g., Clarida et al. (2000); Lubik and Schorfheide (2004); Boivin and Giannoni (2006)), studies based on VAR models tend to find evidences in support of the 'good luck' hypothesis (e.g., Stock and Watson (2003); Cogley and Sargent (2005); Primiceri (2005); Sims and Zha (2006); Gambetti et al. (2008)).

Gambetti (2009); Baumeister and Benati (2013)), but only a few papers employ the methodology to investigate possible changes in the effects of fiscal policy. The notable exceptions are Pereira and Lopes (2014), Kirchner et al. (2010), and Rafiq (2012), which study the time variation in the effects of fiscal policy in the U.S., the euro area, and Japan, respectively.[8] They all report changes in the effects of fiscal policy, however, Kirchner et al. (2010) is the only study that performs exercises to investigate the driving forces behind the changes.[9] Conducting regression analysis using the estimated government spending multipliers calculated from their TVP-VAR and possible explanatory factors, they conclude that rising public debt is the main cause of the observed decline in multipliers in the euro area.

In the following, we estimate a TVP-VAR model with stochastic volatility along the lines of Primiceri (2005). In estimating the model, the Bayesian technique described in Nakajima et al. (2011) is exploited. Drawing on the findings of previous studies, monetary policy and public debt are considered as promising candidates for the possible driving forces behind the changes in the size of government spending multipliers. Therefore, we work with a medium scale TVP-VAR model that considers monetary variables and public debt. Differently from earlier TVP-VAR studies on fiscal policy, we achieve the identification of government spending shocks by means of sign restrictions in addition to the traditional recursive method. While applications of sign restrictions to TVP-VAR studies have been developed (e.g., Baumeister and Peersman (2013); Gambetti et al. (2008); Benati (2008)), this paper is the first work that applies the method to those on fiscal policy, to the best of our knowledge. The estimated results show that the government spending multipliers have declined substantially since the late 1970s. The medium scale TVP-VAR allows us to investigate the possible driving forces behind the changes in the effects of government spending with a help of sign restrictions identification. Considering that a growing body of literature focuses on the size of multipliers across different state of business cycles, we calculate those by imposing additional identification restrictions in the spirit of Canova and Pappa (2011). In line with existing studies, we obtain larger multipliers in a hypothetical recession scenario. We then explore the role of monetary policy with the addition of restrictions and show that it plays little role in the observed decline in multipliers. Finally, the prevalence of either Ricardian or non-Ricardian fiscal regimes is examined applying the methodology of Canzoneri et al. (2001) and Canzoneri et al. (2010) to our TVP-VAR framework. The results

[8] Rafiq (2012) use a TVP-FAVAR model that combines a TVP-VAR model and a factor-augmented VAR (FAVAR) approach, which extracts a few latent common factors from a large set of observed macroeconomic variables.

[9] Pereira and Lopes (2014) argue that the effectiveness of fiscal policy in the U.S. has declined over the period 1965-2009, while addressing that the decline is much more evident for net taxes than government spending. Kirchner et al. (2010) find a decline in government spending multipliers at a horizon of five years over the period 1980-2008 for the euro area. Rafiq (2012) find a decline in government investment multipliers in Japan since the 1980s, while reporting a rise in those of government consumption, particulary since the start of 2000s.

show that the degree of Ricardian behavior of the government has been strengthened since the late 1970s. The accumulation of government debt during the period is suggested to be the major driving force behind the decline in multipliers.

The remainder of this paper is organized as follows. Section 2 discusses the empirical methodology. Section 3 reports the results and examines the changes in the effects of government spending. Section 4 investigates the changes in the transmission of government spending shocks. Section 5 concludes.

# 2 Empirical Methodology

## 2.1 A VAR with Time-Varying Parameters and Stochastic Volatility

We consider the following VAR ($p$) model with time-varying parameters and stochastic volatility:

$$Y_t = B_{1,t}Y_{t-1} + \cdots + B_{p,t}Y_{t-p} + u_t, \tag{1}$$

where $Y_t$ is a $k \times 1$ vector of observed variables, and $B_{i,t}$, $i = 1, ...p$, are $k \times k$ matrices of time varying coefficients. The $u_t$ is a $k \times 1$ vector of heteroskedastic shocks that are assumed to be normally distributed with a zero mean and a time-varying covariance matrix, $\Omega_t$. Following established practice, we decompose $u_t$ as $u_t = A_t^{-1}\,\Sigma_t\varepsilon_t$, where

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ a_{21,t} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1,t} & \cdots & a_{kk-1,t} & 1 \end{bmatrix}, \tag{2}$$

$$\Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{k,t} \end{bmatrix}, \tag{3}$$

and $\varepsilon_t \sim N(0, I_k)$. It follows that $A_t\Omega_tA_t' = \Sigma_t\Sigma_t'$. Let $\beta_t$ be a stacked $k^2p \times 1$ vector of the elements in the rows of the $B_{1,t...p,t}$, and $a_t$ be the vector of nonzero and nonone elements of the $A_t$. Following Primiceri (2005), we assume that these vectors follow a random walk process as follows:

$$\beta_{t+1} = \beta_t + u_{\beta,t}, \tag{4}$$

$$a_{t+1} = a_t + u_{a,t}, \tag{5}$$

$$h_{t+1} = h_t + u_{h,t}, \tag{6}$$

$$\begin{bmatrix} \varepsilon_t \\ u_{\beta,t} \\ u_{a,t} \\ u_{h,t} \end{bmatrix} \sim N \left( 0, \begin{bmatrix} I & O & O & O \\ O & \Sigma_\beta & O & O \\ O & O & \Sigma_a & O \\ O & O & O & \Sigma_h \end{bmatrix} \right), \tag{7}$$

where $h_t = (h_{1,t}, \ldots, h_{k,t})'$ with $h_{j,t} = \ln \sigma_{j,t}^2$ for $j = 1, ..., k$, and $I$ is a $k$-dimensional identity matrix. As in Nakajima et al. (2011), we further assume for simplicity that $\Sigma_\beta$, $\Sigma_a$, and $\Sigma_h$ are all diagonal matrices.

Observe that the model allows the log of variance for the structural shocks to evolve over time as a random walk. The stochastic volatility assumption makes the likelihood function of the model to be hard to construct and requires Bayesian inference via Markov Chain Monte Carlo (MCMC) methods. In implementing the MCMC algorithm, we follow the procedure presented in Nakajima et al. (2011). Regarding the sampling of $\beta_t$ and $a_t$, the simulation smoother of de Jong and Shephard (1995) is used, because the model can be written as a linear Gaussian state space form conditional on the rest of the parameters.[10] In sampling $h_t$, on the other hand, we employ the multi-move sampler of Shephard and Pitt (1997) and Watanabe and Omori (2004) for nonlinear and non-Gaussian state space models. The methodological novelty of Nakajima et al. (2011) lies in their use of the sampler.[11] The multi-move sampler is known to be more efficient than the single-move sampler of Jacquier et al. (1994).[12] Furthermore, it enables us to draw sample from the exact conditional posterior density of the stochastic volatility, unlike the mixture sampler of Kim et al. (1998).

## 2.2 Data and Identification Strategies

We use the quarterly data from the U.S. for the period 1952:Q1-2013:Q4. Although our sample period contain the period of zero interest-rate policy, we do not incorporate the zero lower bound constraint in light of the findings of Nakajima (2011).[13] The observed variables include

[10] We employ the simulation smoother of de Jong and Shephard (1995) instead of the multi-state sampler of Carter and Kohn (1994), which is widely used in previous TVP-VAR studies (e.g., Primiceri (2005); Canova and Gambetti (2009); Baumeister and Benati (2013)). The multi-state sampler generates the whole of the state vector at once and therefore converges more quickly than the single-state sampler that yields a strong correlation among the samples. However, the method is prone to a problem of degeneracies because the whole of the state vector is constructed recursively. The simulation smoother of de Jong and Shephard (1995) avoids the problem by drawing disturbances rather than states.

[11] The Ox and MATLAB codes to implement the MCMC algorithm incorporated with the multi-move sampler of Shephard and Pitt (1997) and Watanabe and Omori (2004) are available at Jouchi Nakajima's Web site ( https://sites.google.com/site/jnakajimaweb/tvpvar).

[12] The shortcoming of using the single-move sampler is that it leads to slow convergence when state variables are highly autocorrelated. The multi-move sampler reduces the inefficiency by generating randomly selected blocks of disturbances rather than the states one at a time.

[13] Nakajima (2011) provides evidence that a TVP-VAR model with stochastic volatility can produce almost the same result as that explicitly considers the zero lower bound based on the Japanese data from 1977 to 2010. The

government spending (consumption expenditures and gross investment), gross domestic product (GDP), personal consumption expenditures, debt-to-output ratio,[14] GDP deflator, and nominal interest rate. Because the level of public debt and the conduct of monetary policy are often suggested as candidates that affect the size of multipliers, we include debt-to-output ratio and monetary variables, such as price level and interest rate, in the TVP-VAR. The importance of including public debt in a VAR model is suggested by Favero and Giavazzi (2012) and Chung and Leeper (2007) who argue that the effects of its dynamics on other variables should not be overlooked. While they impose equations assuming a feedback from the level of public debt to fiscal instruments, we include debt-to-output ratio without imposing any restrictions as in Corsetti et al. (2013) because we consider plausibility of non-Ricardian behavior of the government. For the very same reason, we are interested in a price level adjustment and hence include price level rather than inflation rate in our system.[15] The first three variables are expressed in real per capita terms. We use the logarithm for all variables except the nominal interest rate and debt-to-output ratio. All variables are detrended with a linear and quadratic trend, and are seasonally adjusted except for the interest rate. The lag length is set to $p = 4$ following Blanchard and Perotti (2002). We postulate an inverse-Gamma distribution for the $i$-th diagonal elements of the covariance matrices. The prior densities are specified as $(\Sigma_\beta)_i^2 \sim IG\left(20, 10^{-4}\right)$, $(\Sigma_a)_i^2 \sim IG\left(4, 10^{-4}\right)$, and $(\Sigma_h)_i^2 \sim IG\left(4, 10^{-4}\right)$. The initial states of the time-varying parameters are set as $\beta_0 \sim N(0, 10I)$, $a_0 \sim N(0, 10I)$, and $h_0 \sim N(0, 50I)$.

The identification of structural shocks are achieved via both traditional recursive approach and sign restrictions approach for robustness reasons. We follow Corsetti and Müller (2006) in ordering real variables before monetary variables in the Cholesky decomposition. Ordering government spending first is in line with the assumption proposed by Blanchard and Perotti (2002). In implementing the sign restrictions approach within the TVP-VAR framework, we exploit the algorithm proposed by Rubio-Ramírez et al. (2010) (RWZ algorithm, hereafter), as in Benati (2008) and Baumeister and Peersman (2013). To calculate the sign-restricted impulse responses, we proceed as follows. We draw an independent standard normal $k \times k$ matrix $X_j$ for period $j$. $QR$ decomposition of $X_j$ gives an orthogonal matrix $P_j$ that satisfies $P_j P_j' = I$ and an upper triangular matrix $R$. Using $A_j^{-1} \Sigma_j P_j$, impulse responses are generated for each MCMC replication, and if the impulse response satisfies the restrictions, we keep the draw, and otherwise we discard it. The combination of $P_j'$ and $\varepsilon_t$, $\varepsilon_t^* = P_j' \varepsilon_t$ is now regarded as a new set of structural shocks, which has the same covariance matrix as the original shock $\varepsilon_t$. Because $P_j$

role of stochastic volatility in obtaining the similar impulse responses is suggested.

[14] The U.S. public debt is the sum of federal, state, and local government liabilities.

[15] The following results does not change much if we use inflation rate instead of price level. The use of GDP deflator in estimating VARs can be found in Uhlig (2005), Sims and Zha (2006), and Mountford and Uhlig (2009).

is orthogonal, the new shocks are orthogonal to each other by design.

The sign restrictions we employed are presented in Table 2. As argued by Canova and Pappa (2011), existing theories do not provide definitive answers to the short-run dynamics after a government spending shock. Furthermore, it is computationally burdensome to estimate impulse responses from a TVP-VAR model imposing sign restrictions for several periods. Therefore, we impose a minimum set of contemporaneous restrictions to make our identification as agnostic as possible.[16] We do not impose restrictions on output responses to fiscal and monetary policy shocks, as in Mountford and Uhlig (2009) and Uhlig (2005). The restriction that an increase in government spending has a positive impact on debt-to-output ratio is the key identifying restriction that distinguishes government spending shocks from other shocks. We also require government spending shocks to be orthogonal to monetary policy and business cycle shocks following Mountford and Uhlig (2009). The restrictions to identify the 'monetary policy shock' and the 'business cycle shock' are imposed borrowing their definition. The RWZ algorithm allows us to impose orthogonality conditions only by identifying other uncorrelated shocks. The algorithm is particularly appealing in identifying several shocks within our highly parameterized medium-scale TVP-VAR, because it is computationally efficient as addressed by Fry and Pagan (2011).

# 3 Evidence on Time Variation

## 3.1 Basic Results

We executed 30,000 MCMC replications and discarded the first 5,000 draws to estimate the TVP-VAR model described in the previous section. Table 3 reports the posterior means, the standard errors and 95% credible intervals for selected parameters. The $p$-values associated with the convergence diagnostic (CD) of Geweke (1992) and the inefficiency factors are also reported. The $p$-values for the CD statistics are at least 0.05 for each parameter. The efficiency factors are less than 200, which indicates that we drew enough number of uncorrelated samples. Figure 1 presents the estimated stochastic volatility of the structural shocks, $\varepsilon_t$, identified by the recursive ordering. The time variation in the volatility estimates of monetary policy shocks and the residuals of price and output equations are largely consistent with those reported in previous studies (e.g., Mumtaz and Zanetti (2013); Koop et al. (2009); Primiceri (2005); Cogley and Sargent (2005)). The volatility of monetary policy shocks increased substantially around the time when Paul Volcker was appointed as Fed Chairman in 1979 and showed a large decline

[16] The choice of time periods for which the responses are restricted does not change the basic results of this paper. Similar patterns of time-variation in government spending multipliers are found when we estimated the model imposing sign restrictions for a year after a shock.

during the early 1980s. The residual of price equation reached its highest peak during the Great Inflation of mid-1970s. The smoother variation in the volatility of price level compared to that of inflation rate reported in previous studies can be attributed to the difference in variables. The volatility of output fell sharply in the early 1980s, showing a similar pattern to that of unemployment reported in Cogley and Sargent (2005). The observed reduction in volatility of government spending also can be found in Justiniano and Primiceri (2008). We notice that there have been marked increases in the volatility of debt-to-out put ratio at the beginning of 2000s and after the Lehman shock. It is worth noting that the volatility of monetary policy shocks dropped significantly during the period of zero interest-rate policy, especially since after QE2 and QE3 were announced.[17] This is in line with Nakajima (2011), who find effectively low level of stochastic volatility for the monetary policy shocks during the zero interest-rate period in Japan. The results lead us to conjecture that the effects of zero lower bound may be negligible in our TVP-VAR framework with a help of stochastic volatility. Overall, the results show that stochastic volatility model well capture the changes in volatilities and that its inclusion to the TVP-VAR model is important to detect the structural changes in the transmission of government spending shocks.

Figures 2-5 present impulse responses of output and price to government spending and monetary policy shocks for the two alternative identification schemes. The impulse response at time $t$ is computed for each MCMC replication based on the estimated time-varying parameters at time $t$.[18] The shapes of the responses of output and price to government spending shocks are similar across the different identification schemes, although their quantitative differences are evident. Both responses vary over time and their time profiles exhibit similar patterns regardless of the identification schemes. In contrast, the responses of output and price to monetary policy shocks exhibit different shapes across the different identification as documented by Uhlig (2005). Whereas contractionary effects on output and the 'price puzzle' raised by Sims (1992) are observed for recursive identification, it is shown that monetary policy shocks identified via sign restrictions have no clear effect on output and is followed by a slow decline in price. Furthermore, little time variation is found in the responses of output and price, which is in line with the finding of Primiceri (2005).

[17] The Federal Reserve's second round of quantitative easing (QE2) and the third one (QE3) were announced in November 2010 and September 2012, respectively.

[18] Koop (1996) and Koop et al. (1996) propose a method to calculate impulse response taking into account the history of the observations that affects impulse responses in non-linear models. However, because the method can be computational demanding and a slight difference is expected from the use of the method as addressed by Koop et al. (2009), we follow the simple computational procedure used in Primiceri (2005), Koop et al. (2009), and Nakajima et al. (2011).

### 3.2 Time-Varying Government Spending Multipliers

Figure 6 compares point estimates (posterior means) of impulse responses of output and consumption to government spending shocks for the two alternative identification schemes, at the dates, 1970:Q1, 1990:Q1, and 2010:Q1. The responses are scaled so that they show output and consumption increases to a $1 increase in government spending. We divide the responses by sample average ratio of respective variables and government spending as in Auerbach and Gorodnichenko (2012).[19] Because of the transformation, the responses are interpreted as output and consumption multipliers. The expansionary output effects become smaller over the period. The shapes and magnitudes of the output responses for recursive identification are similar to those in Blanchard and Perotti (2002). The changing patterns of the output and consumption multipliers are largely the same across the alternative identification schemes and specifications, although there are some differences in their magnitude. The initial output multipliers to government spending shocks are larger for recursive identification than those for sign restrictions, while subsequent increases in output are larger for the latter. A similar but smaller discrepancy between the multipliers identified by those two approaches can be found in Caldara and Kamps (2008).[20]

Regardless of the identification schemes, the output multipliers are in between -1.0 and 1.5 on impact across the different dates of the sample. After almost one year of decline, the output multipliers increase and reach the highest peak four years after the shock. The peak multipliers range from 1 to 1.9 and from 0.4 to 2.2 for recursive and sign restrictions identification, respectively. The consumption multipliers display similar shapes and time variation to those of output described above. Whereas existing empirical studies that consider linear time series models typically find a crowding-in of consumption, the consumption multipliers calculated from the posterior mean responses suggest that the crowding-in effects become smaller for the both identification scheme. Figure 7 takes up the question whether a crowding-in of consumption in response to a government spending shock is observed in a statistically significant way. The figure displays posterior means of consumption multipliers along with 16th and 84th percentile error bands. The upper row panels indicate that the observed increase in consumption in 1980s becomes smaller, and that the increase is not statistically larger than zero in the 2010s for

[19] Ramey and Zubairy (2014) point out a potential problem that arise from the use of sample average ratio in calculating multipliers. Nevertheless, we stick to use the average ratio because we are interested in the causes of the changes in multipliers rather than their sizes. Furthermore, the ratios of output and consumption to government spending do not vary much in our sample period.

[20] Note that Caldara and Kamps (2008) employ the penalty function approach of Mountford and Uhlig (2009), whereas we rely on pure sign restrictions approach exploiting the RWZ algorithm in line with Arias et al. (2014). Arias et al. (2014) address that the penalty function approach undermines the agnosticism of sign restrictions by introducing additional restrictions that create bias in impulse responses and artificially narrow confidence intervals. Kilian and Murphy (2012) and Fry and Pagan (2011), on the other hand, suggest that imposing sign restrictions alone is insufficient and that additional parametric restrictions are necessary.

recursive identification. On the other hand, the lower row panels show that the crowding-in of consumption cannot be observed in a statistically significant way throughout the estimation period for sign restrictions identification. Taken together, we can safely argue that the crowding-in effects of government spending on consumption disappears by the 2010s.

To investigate changes in the transmission of government spending shocks, we compute the cumulative output and consumption multipliers evaluated at horizon 20. The cumulative output and consumption multipliers are defined as the ratio of the sum of output and consumption responses to the sum of government spending path.[21] Figure 8 plots the time profiles of point estimates (posterior means) of the cumulative multipliers for the two alternative identification schemes. The size of the cumulative multipliers differ to some extent according to the identification schemes employed. The cumulative output multipliers for recursive identification are between 0.8 and 1.5, while those for sign restrictions are between -1.7 and 1.5. The figure suggests that the nonlinearities in the responses of output and consumption to government spending shocks are particularly pronounced when sign restrictions identification is employed. Figure 8 also illustrates the similarity between the patterns of time variation in cumulative output and consumption multipliers. They both decline substantially since the late 1970s regardless of the identification schemes. Their co-movement indicates that the time variation in the effects of government spending on output is mostly led by that on consumption.

# 4 Investigating the Changes in the Transmission of Government Spending

In this section, we examine the cause of the decline in government spending multipliers starting in the late 1970s. While we have already seen that the time variation in government spending multipliers does not show cyclical movements, we begin by studying the size of multipliers for different economic scenarios because recent debate on multipliers in the post-war U.S. focuses on their state-dependent nature across the business cycle. Although our TVP-VAR framework is not suited to capture the difference in the size of multipliers across the extreme states of business cycles, we attempt to fill the gap by conducting hypothetical exercise with the addition of identification restrictions in the spirit of Canova and Pappa (2011). We then explore the role of monetary policy and public debt, our main suspects for the cause of the observed decline in multipliers.

[21] To be precise, the cumulative output and consumption multipliers evaluated at horizon $k$ are calculated as: $\frac{\sum_{s=0}^{k} \Delta y_{t+s}}{\sum_{s=0}^{k} \Delta g_{t+s}} \frac{Y}{G}$, $\frac{\sum_{s=0}^{k} \Delta c_{t+s}}{\sum_{s=0}^{k} \Delta g_{t+s}} \frac{C}{G}$, where $y = \ln Y$, $c = \ln C$, and $g = \ln G$. $Y$, $C$, and $G$ represent output, consumption, and government spending, respectively.

## 4.1 Calculating Multipliers for Different Economic Scenarios

In contrast with the existing studies, the result in the previous section indicates that the state of the business cycle does not play a major role in determining the size of multipliers. A possible explanation for the different results can be attributed to the difference in methodologies. As we have seen in Table 1, those studies that focus on state-dependent nature of multipliers typically rely on regime switching models that allow discrete change in parameters in a deterministic manner. These methodologies require some measures to differentiate the state of economic slack. The multipliers in each state are calculated primarily reflecting information set within the state, which is differentiated by the measure. Because the information set does not contain that of transitory phase, the estimated multipliers using these methodologies can be viewed as those in extreme states of the business cycle which are independent from the history.

The TVP-VAR framework, on the other hand, allows parameters to vary continuously over time in a stochastic manner and is hence not suited to capture those under extreme states. Nevertheless, it is possible to replicate the multipliers in the extreme states within the TVP-VAR framework, by conducting scenario analysis based on sign restrictions approach.[22] As shown in Canova and Pappa (2011), government spending shocks during certain economic states can be identified by imposing additional sign restrictions. It is important to notice that these multipliers are essentially hypothetical in our TVP-VAR framework, because the shocks under certain states are identified in each period through the same sign restrictions regardless of the actual state of business cycles. The calculated multipliers thus replicate those under the extreme states that are hypothetically assumed to last throughout the estimation period. It is worth noting that the implicit assumption in calculating multipliers here is similar to that in Auerbach and Gorodnichenko (2012), who argue that their regime-based multipliers should be interpreted as bounds from polar settings and more realistic ones should fall between the extremes.

Table 4 presents additional restrictions for different economic scenarios. As in Canova and Pappa (2011), we identify government spending shocks that take place in recession as those accompanied by a simultaneous fall in price.[23] Analogously, those during expansions are assumed to be accompanied by a price rise. Figure 9 presents point estimates of output multipliers in 'recession' and 'expansion' scenarios at the same selected dates as those in Figure 6. The multipliers are calculated based on the subset of parameters that are chosen from those for the basic scenario by the additional sign restrictions. The multipliers during 'recession' reach values of over 3 after three years at either date. During 'expansion,' on the other hand, multipliers take

[22] Mountford and Uhlig (2009) first apply sign restrcitions approach to analyze different fiscal policy scenario by calculating linear combination of basic fiscal shocks.

[23] Although Canova and Pappa (2011) assume that a government spending shock has a positive impact on output, we do not impose restriction on output following Mountford and Uhlig (2009).

negative values throughout the estimation period. Although our agnostic sign restrictions yield relatively wide credible intervals, the negative impact on output is statistically significant in the 2000s and 2010s, which can be interpreted as an evidence in support of non-Keynesian effects.[24] Figure 10 depicts the time profiles of point estimates of the cumulative output multipliers at horizon 20 for different economic states. As expected, the cumulative multipliers in the basic scenario fall between those in 'recession' and 'expansion.' Consistent with existing studies, we find larger multipliers in 'recession' and smaller ones in 'expansion.' While the exercise here aims to replicate the multipliers in the extreme states within the TVP-VAR framework, the figure also tells us that cumulative multipliers in 'recession' and 'expansion' both exhibit decline since the late 1970s as those observed in the basic scenario. It follows that the state of the business cycle matters in determining the size of multipliers, however, it does not play a role in the observed decline of multipliers.

### 4.2 Role of Monetary Policy

We next consider contractionary and expansionary monetary policy scenarios. Table 4 reports the additional sign restrictions imposed for these scenarios. As in the case of the state of the business cycle, restriction on output is imposed in neither scenario, because we do not impose restriction on output for basic shocks to government spending and monetary policy.

Figure 11 presents point estimates of output multipliers under different monetary policy scenario at the three dates. As expected, multipliers are larger if it is accompanied by expansionary monetary policy. After a government spending shock, output shows a hump-shaped pattern of increase. On the other hand, output declines immediately after a government spending shock if it is accompanied by contractionary monetary policy. The similarity between the shapes of output responses to government spending shocks in expansionary monetary policy scenario and those in basic scenario suggest that most of the government spending shocks during the estimation period are accompanied by expansionary monetary policy. Note that the decline in output multipliers can still be observed in both scenarios.

Because output responses to government spending shocks accompanied by contractionary and expansionary monetary policy show very similar patterns to those in expansion and recession scenarios, respectively, we further examine the role of monetary policy in determining the size of multipliers across different states of business cycles. Figure 12 presents point estimates of output multipliers during 'recession' accompanied by contractionary monetary policy, and those

[24] Giavazzi and Pagano (1990) find non-Keynesian effects from the Irish debt stabilization experience of 1987-89 and standard contractionary effects from that of 1982-84. The eased credit conditions in the late 1980s are suggested as the cause of the non-Keynesian effects. In this regard, it is worth mentioning that credit conditions tend to be tightened during recession (e.g., Bacchetta and Gerlach (1997)).

during ‘expansion’ accompanied by expansionary monetary policy. Contractionary monetary policy delays the output increase in response to government spending shock during ‘recession,’ while expansionary monetary policy mitigates the crowding-out effect. However, those monetary policy effects are not strong enough to change the output response drastically. The results here indicate that monetary policy plays a role in determining the shapes of output response, however, it does not play a major role in determining the size of multipliers in different states of business cycles. The result here leads us to conclude that the state of business cycle itself matters for the effectiveness of expansionary government spending. To put it differently, a government spending shock accompanied by expansionary monetary policy does not seem to have a positive impact on output during when the economy is in the midst of a boom.

Figure 13 displays point estimates of cumulative responses of price and interest rate to government spending shocks evaluated at horizon 20 for different monetary policy scenario. The cumulative responses are computed as the cumulative percent change in price level and interest rate divided by the cumulative percent change in the government spending after 20 quarters. In both scenarios, cumulative response of price bottomed out in the late 1970s and has risen sharply since then. In contrast, cumulative response of interest rate shows very different pattern across the state of the economy. While the time profile of interest rate response to government spending shocks and that of price level show similar pattern in contractionary monetary policy scenario, they move in the opposite direction in the expansionary monetary policy scenario. In the former scenario, monetary policy is assumed to be conducted in an uncoordinated manner with the expansionary fiscal policy. The Federal Reserve raises interest rate in response to an increase in government spending followed by heightened inflationary pressure. Therefore, interest rate response to a government spending shock shows largely correlated movement with that of price level until the aftermath of financial crisis of 2007, when interest rates are kept at a low level. The latter scenario, on the other hand, assumes that monetary policy is well-coordinated with the expansionary fiscal policy. While an increase in government spending heightens inflationary pressure, interest rate response moves in the opposite direction from that of price level because monetary policy is conducted in an expansionary manner as well. In either scenario, there seems to be a stable relationship between the interest rate response and price level response to a government spending shock, which suggests that monetary policy response to government spending shocks does not change much throughout the estimation period. Based on this finding together with the result shown in Figure 12, we can conclude that monetary policy does not explain the decline in government spending multipliers.

Why then does government spending become more inflationary, as government debt accumulates? From a viewpoint of the FTPL, Sims (2011) documents that the high inflation of the mid-1970s and 1980s can be attributed to the rapidly increased debt-to-output ratio during the period. According to Cochrane (1999), the analytical content of FTPL is summarized to the following version of intertemporal budget constraint of the government:

$$\frac{\text{nominal debt}}{\text{price level}} = \text{present value of real surpluses.} \tag{8}$$

The FTPL states that the price level is determined so that the real value of nominal debt equal to present value of real surpluses, taking an exogenous sequence of surpluses and nominal debt as given. Rearranging the equation (8), we get:

$$\text{price level} = \text{nominal debt} \times \frac{1}{\text{present value of real surpluses}}. \tag{9}$$

The intertemporal budget constraint of the government suggests that the price level goes up after a government spending shock as long as the shock has a negative impact on present value of real surpluses. The FTPL states that the price level is determined so that the real value of nominal debt equal to present value of real surpluses, taking an exogenous sequence of surpluses and nominal debt as given. Suppose that an increase in government spending has a negative impact on present value of real surpluses. The equation (9) then indicates that the price level goes up in response to government spending shocks. Furthermore, the effects of government spending shocks on the price level become larger, as the nominal debt of the economy accumulates. The important presumption is that the sequence of surpluses reacts to neither price nor debt level. We note here that this channel works even if the additional government spending is partially offset by additional taxation. As argued by Sims (2011), "when rational, forward-looking agents believe that newly issued nominal government debt is only partially backed by future taxes, debt issue is inflationary." Figure 14 presents evidence underlining the empirical relevance of the above argument. The figure shows a scatter plot of the point estimates of cumulative responses of price to government spending shocks in the basic scenario against historical data on debt-to-output ratio. There appears to be a strong positive correlation between them, which suggests that the accumulation of government debt makes government spending shocks inflationary.

### 4.3 Time-Variation in Fiscal Policy

We now turn to the role of fiscal policy regimes, which are typically defined depending on their responsiveness to public debt. The U.S. public debt as a share of GDP has consistently increased since the early 1980s, which largely corresponds to the period of decline in government spending multipliers. As argued by Perotti (1999), government spending multipliers become smaller as higher future tax is expected. Therefore, the accumulation of public debt that induces necessity of future tax burden and subsequent corrective action of the government to repay the debt are possible causes of the decline in multipliers.

Nevertheless, we find that government spending becomes more inflationary in accordance with public debt accumulation in the previous section. This may give the impression that public debt is backed only partially by future tax and that a Ricardian fiscal regime is not in place.[25] However, we cannot conclude about the prevalence of either Ricardian or non-Ricardian fiscal regimes from the observed inflationary effects of government spending. Canzoneri et al. (2001) and Canzoneri et al. (2010) demonstrate theoretical plausibility of Ricardian regime by showing that a wide class of fiscal feedback rule from debt level to surplus leads to Ricardian regime. They argue that debt-stabilizing fiscal policy need not be in effect each period to meet the requirements for a Ricardian regime. Furthermore, Davig and Leeper (2007) and Chung et al. (2007) suggest that the FTPL is always operative as long as there is a positive probability of moving to a regime with active fiscal policy in a regime-switching environment. Their argument also applies to our TVP-VAR framework, because it allows continuous and stochastic change in parameters.

The VAR-based methodology of Canzoneri et al. (2001) and Canzoneri et al. (2010) allows us to examine the prevalence of either Ricardian or non-Ricardian fiscal regimes without assuming any particular type of policy rules. They estimate a bivariate VAR in surplus/GDP and liabilities/GDP on the post-war U.S. data, and document that a Ricardian fiscal regime is more plausible. Their methodology is attractive because it is VAR-based and hence can easily be extended to our TVP-VAR framework with stochastic volatility. We estimate a bivariate TVP-VAR with two lags in surplus/GDP and liabilities/GDP for the period 1952:Q1-2013:Q4 in the same manner presented in section 2. Same data is used for the debt-to-output ratio described in Section 2 and the liabilities/GDP here, but we call it liabilities/GDP following the notation used in Canzoneri et al. (2010). The prior densities are specified as $(\Sigma_\beta)_i^2 \sim IG\left(40, 10^{-4}\right)$, $(\Sigma_a)_i^2 \sim IG\left(5, 10^{-3}\right)$, and $(\Sigma_h)_i^2 \sim IG\left(5, 10^{-3}\right)$, and the initial states of the time-varying parameters are set as $\beta_0 \sim N(0, 10I)$, $a_0 \sim N(0, 10I)$, and $h_0 \sim N(0, 50I)$. We executed 30,000 MCMC replications and discarded the first 5,000 draws. The posterior estimates for stochastic volatilities are presented in Figure 15. As expected, similar result is obtained for the volatility of a liabilities/GDP shock to that in Figure 1. The overall results for the volatility of surplus/GDP shocks well capture the fiscal events showing similar pattern to those of estimated tax shocks reported in Gonzalez-Astudillo (2013). The stochastic volatility of surplus/GDP shocks height-

[25] Woodford (1995) defines a Ricardian regime as the case in which fiscal policy fail to play any role in price-level determination and emphasizes a non-Ricardian regime, suggesting that a Ricardian regime represents a highly special case. Aiyagari and Gertler (1985) consider fiscal regimes in a more flexible way. They define 'polar' Ricardian and non-Ricardian fiscal regimes as the cases in which the fiscal and monetary authorities provide full backing for the debt, respectively. A continuum of fiscal regimes is assumed to lie in between the polar cases.

ened most around the time of Tax Reduction Act of 1975. It also shows increase in times of tax reform and measures, such as the Reagan Tax Reform of 1981 and 1986, the Bush Tax Cuts of 2001 and 2003, and the American Recovery and Reinvestment Act of 2009. Figure 16 compares point estimates of impulse responses to a one percentage point increase in liabilities/GDP and surplus/GDP at the dates, 1970:Q1, 1990:Q1, and 2010:Q1. The surplus/GDP is ordered first in the top panels and the liabilities/GDP is ordered first in the bottom panel. The former ordering is consistent with a non-Ricardian regime and the latter makes more sense in a Ricardian regime. Regardless of the ordering used, liabilities/GDP declines for several years in response to a surplus/GDP shock across the different dates of the sample. The degree of the decline is smaller for the case in which liabilities/GDP is ordered first. The results are very much similar to those obtained by Canzoneri et al. (2001) and Canzoneri et al. (2010), which suggest that the U.S. government follows a Ricardian fiscal regime throughout the post-war period. As addressed in Canzoneri et al. (2001) and Canzoneri et al. (2010), non-Ricardian explanation is implausible because it requires a negative correlation between present surpluses and future surpluses, which cannot be observed. Furthermore, our application of their VAR-based methodology to the TVP-VAR reveals that the degree of Ricardian behavior of the government has been strengthened.

Figure 17 depicts point estimates of cumulative responses of liabilities to a surplus shock together with historical data on debt-to-output ratio. The degree of Ricardian behavior has been strengthened since the late 1970s, showing some weakening in the early 1990s, the early 2000s, and the late 2000s.[26] A corroborative evidence is provided by Sala (2004), who suggests that the U.S. fiscal policy can be characterized as non-Ricardian before 1979, while it is truly Ricardian since the 1990s. It is also worth noting that the periods when weakening of Ricardian behavior is observed largely coincide with the timings often suggested as the periods of FTPL regime (e.g., Davig and Leeper (2011); Gonzalez-Astudillo (2014)). Figure 17 also indicates that the cumulative response of liabilities and the debt-to-output ratio largely move in opposite directions, suggesting that the corrective action of the U.S. government becomes stronger in the presence of higher indebtedness. If the government moves toward more Ricardian fiscal policy in response to the increase in public debt, expectation on future tax burden increases, thereby leading to smaller multipliers. This interpretation shares views on the relationship between debt and multipliers with various strands of literature. The nonlinear relationship between the

[26] While the early 2000s and the late 2000s are the periods during which large-scale stimulus packages are implemented, the early 1990 features steady fiscal consolidation efforts. In response to the accelerated deterioration of the budget due to a recession that began in July 1990, the Budget Enforcement Act that creates caps for discretionary spending and "pay-as-you-go" (PAYGO) rules had been adopted in 1990. However, debt-to-output did not decline until the Omnibus Budget Reconciliation Act of 1993 that brings tax increase came into effect in 1994.

corrective action of the government and the level of public debt is already pointed out by Bohn (1998) who provides evidence that the marginal response of the U.S. surplus to changes in debt is an increasing function of the debt level. Combining the Ricardian explanation presented above and the findings of Bohn (1998), we conjecture that the accumulation of public debt since the early 1980s plays an important role in changing the fiscal policy stance, and thus serves as the major driving force for the observed decline in government spending multipliers. It should be noted that the changes in fiscal policy stance occurs soon after the passage of the Congressional Budget and Impoundment Act of 1974 that establishes the Congressional Budget Office. Congress has introduced a variety of budget rules since then in attempting to impose a fiscal discipline on the budgetary process. By examining the effects of budget rules, Auerbach (2008) concludes that those rules appear to have had some success at deficit control.

## 5 Conclusions

In this paper, we have provided new empirical evidence on the evolution of government spending multipliers in the post-war U.S. From a methodological point of view, we present time profile of the changes in multipliers by exploiting a TVP-VAR framework, instead of relying on sub-sample analysis and regime switching models. The identification of government spending shocks are achieved by means of sign restrictions in addition to the traditional recursive method. Irrespective of the use of alternative identification schemes, the results document that government spending multipliers have declined substantially since the late 1970s. Furthermore, time profiles of output and consumption responses suggest that the decline in output multiplier is mostly led by that in consumption multiplier.

Our medium-scale TVP-VAR that includes monetary variables and public debt together with sign restrictions allows us to examine the cause of the decline by conducting scenario analysis. With the addition of restrictions, we can study government spending multipliers under different state of business cycle. Although these multipliers are essentially hypothetical in the TVP-VAR framework, we find larger multipliers in recession and smaller ones in expansion in line with existing literature. The time profiles of output responses in recession and expansion indicate that those can be viewed as extreme bounds, and that the state of business cycle plays little role in the time-variation in government spending multipliers. Calculating the time profiles of price level and interest rate responses to government spending shocks under different monetary policy scenario, on the other hand, we find a stable relationship between them, which indicates that monetary policy response to government spending shocks does not change much throughout the estimation period. It is also shown that the inflationary effects of government spending shocks become larger since the late 1970s in accordance with the accumulation of public debt.

Applying the TVP-VAR technique for the testing of changes in fiscal policy regime, we further find that the degree of Ricardian behavior of the government were strengthened since the late 1970s, which corresponds to the period when government spending multipliers declined. The results lead us to conjecture that the accumulation of government debt during the period may play an important role in changing the fiscal policy stance, and thus serve as the major driving force for the observed decline in government spending multipliers. While empirical evidence on the negative correlation between debt and multipliers has been established for cross-country data, this paper provides it by analyzing the U.S. time series data.

Much work still need to be done. Although our atheoretical VAR-based approach is a flexible way to model the evolution of time series data, it has limitations in explaining the underlying mechanism. It would be worth exploring to develop a theoretical model that account for the relation between the time-variation in multipliers and fiscal policy behavior provided in this paper.

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Table 1. Empirical studies: The nonlinear effects of government spending shocks in the U.S.

| Study | Sample | Method | Results |
|---|---|---|---|
| *(1) State-dependent* | | | |
| Auerbach and Gorodnichenko (2012) | 1947:Q1-2008:Q4 | Smooth transition VAR (STVAR) (Measure of slack: moving average of GDP growth rate), Blanchard and Perotti (2002) | Cumulative multipliers (5yrs): 2.24 (recessions), -0.33 (expansions) |
| Bachmann and Sims (2012) | 1960:Q1-2011:Q1 | Smooth transition VAR (STVAR) (Measure of slack: moving average of GDP growth rate), Recursive | Cumulative multipliers (5yrs): 2.16 (recessions), 0.15 (expansions) |
| Batini et al. (2012) | 1975:Q1-2010:Q2 | Threshold VAR (TVAR) (Measure of slack: GDP growth rate), Recursive | Cumulative multipliers (2yrs): 2.17 (recessions), 0.49 (expansions) |
| Candelon and Lieb (2013) | 1968:Q1-2010:Q4 | Short-run threshold VECM (SR-TVECM) (Measure of slack: Chicago Fed National Activity Index), Sign restrcitions | Impact multipliers: around 2.4 at the highest (recessions), between 1 and 0 (expansions) |
| Caggiano et al. (2015) | 1981:Q3-2013:Q1 | Smooth transition VAR (STVAR) (Measure of slack: moving average of GDP growth rate), Recursive | Cumulative multipliers (5yrs): 1.09 (deep recessions), -3.28 (strong expansions), 0.83 (mild recessions), -2.37 (weak expansions) |
| Owyang et al. (2013) | 1890:Q1-2010:Q1 | Jordà's (2005) local projection method (Measure of slack: unemployment rate), Narrative | Cumulative multipliers (4yrs): 0.78 (high unemployment), 0.88 (low unemployment) |
| Ramey and Zubairy (2014) | 1890:Q1-2013:Q4 | Jordà's (2005) local projection method (Measure of slack: unemployment rate), Narrative | Cumulative multipliers (4yrs): 0.76 (high unemployment), 0.96 (low unemployment) |
| *(2) Time-dependent* | | | |
| Bilbiie et al. (2008) | 1957:Q1-1979:Q2 (S1), 1983:Q1-2004:Q4 (S2) | Sub-sample analysis based on VAR, Recursive | Cumulative multipliers (5yrs): 0.42 (S1), 0.35 (S2) |
| Cimadomo and Benassy-Quere (2012) | 1971:Q1-2009:Q4 | Rolling window analysis based on Factor-augmented VAR (FAVAR), Blanchard and Perotti (2002) | Impact multipliers: relatively stable (at around 1.3), Multipliers at two year horizon: declines to negative value in the 1980s and 1990s |
| Pereira and Lopes (2014) | 1965:Q2- 2009:Q2 | TVP-VAR, Blanchard and Perotti (2002) | Multipliers at one year horizon and longer: relatively stable (at around 0.75-0.5) after the late 1970s |
| Perotti (2004) | 1960:Q1-1979:Q4 (S1), 1980:Q1-2001:Q4 (S2) | Sub-sample analysis based on VAR, Blanchard and Perotti (2002) | Annualized cumulative responses of GDP (3yrs): 2.23 (S1), 1.48 (S2) |

Notes: The cumulative multipliers of Bilbiie et al. (2008) presented above are calculated using cumulative responses of government spending and output reported in their study.

Table 2. Contemporaneous identifying restrictions

| | Government spending | Monetary policy | Business cycle |
|---|---|---|---|
| Gov. spending | + | ? | ? |
| Output | ? | ? | + |
| Consumption | ? | ? | ? |
| Price | ? | − | ? |
| Interest rate | ? | + | ? |
| Public debt | + | ? | − |

Notes: This table reports signs imposed on the impulse responses of the variables to an expansionary government spending shock, a contractionary monetary policy shock, and a positive business cycle shock. The question mark indicates that the responses of the variables are unrestricted. A positive sign [negative sign] indicates the response of the variables are restricted to be positive [negative] on impact.

Table 3. Estimation results for selected parameters

| | Parameter | Mean | St. dev. | 95% interval | | CD | Inefficiency |
|---|---|---|---|---|---|---|---|
| Recursive | $(\Sigma_\beta)_1$ | 0.0003 | 0.0001 | [0.0003 | 0.0004] | 0.880 | 29.78 |
| | $(\Sigma_\beta)_{40}$ | 0.0003 | 0.0001 | [0.0003 | 0.0004] | 0.697 | 21.46 |
| | $(\Sigma_\beta)_{80}$ | 0.0003 | 0.0001 | [0.0003 | 0.0004] | 0.461 | 21.44 |
| | $(\Sigma_\beta)_{120}$ | 0.0003 | 0.0001 | [0.0003 | 0.0004] | 0.499 | 27.45 |
| | $(\Sigma_a)_1$ | 0.0144 | 0.0032 | [0.0109 | 0.0186] | 0.619 | 41.10 |
| | $(\Sigma_a)_6$ | 0.0156 | 0.0043 | [0.0113 | 0.0210] | 0.506 | 69.25 |
| | $(\Sigma_a)_{12}$ | 0.0139 | 0.0030 | [0.0105 | 0.0177] | 0.506 | 38.67 |
| | $(\Sigma_h)_1$ | 0.0520 | 0.0166 | [0.0337 | 0.0748] | 0.051 | 120.21 |
| | $(\Sigma_h)_3$ | 0.0254 | 0.0095 | [0.0156 | 0.0381] | 0.163 | 138.22 |
| | $(\Sigma_h)_6$ | 0.4274 | 0.0818 | [0.3286 | 0.5359] | 0.877 | 50.27 |
| Sign restrictions | $(\Sigma_\beta)_1$ | 0.0003 | 0.0001 | [0.0003 | 0.0004] | 0.371 | 26.24 |
| | $(\Sigma_\beta)_{40}$ | 0.0003 | 0.0001 | [0.0003 | 0.0004] | 0.089 | 33.79 |
| | $(\Sigma_\beta)_{80}$ | 0.0003 | 0.0001 | [0.0003 | 0.0004] | 0.135 | 32.46 |
| | $(\Sigma_\beta)_{120}$ | 0.0003 | 0.0001 | [0.0003 | 0.0004] | 0.254 | 23.69 |
| | $(\Sigma_a)_1$ | 0.0148 | 0.0036 | [0.0109 | 0.0195] | 0.609 | 35.86 |
| | $(\Sigma_a)_6$ | 0.0157 | 0.0039 | [0.0114 | 0.0208] | 0.209 | 54.90 |
| | $(\Sigma_a)_{12}$ | 0.0141 | 0.0031 | [0.0106 | 0.0181] | 0.343 | 40.56 |
| | $(\Sigma_h)_1$ | 0.0505 | 0.0160 | [0.0339 | 0.0697] | 0.821 | 113.93 |
| | $(\Sigma_h)_3$ | 0.0264 | 0.0109 | [0.0151 | 0.0407] | 0.802 | 157.36 |
| | $(\Sigma_h)_6$ | 0.4317 | 0.0821 | [0.3299 | 0.5392] | 0.457 | 34.30 |

Notes: The parameters, $(\Sigma_j)_i$, stand for the square roots of the $i$-th diagonals of covariance matrices, $\Sigma_j$, where $j = \beta, a, h$. CD refers to the $p$-value associated with the convergence diagnostic of Geweke (1992).

Table 4. Restrictions to identify government spending shocks in different scenarios

| | Recession | Expansion | Monetary contraction | Monetary expansion |
|---|---|---|---|---|
| Gov. spending | + | + | + | + |
| Output | ? | ? | ? | ? |
| Consumption | ? | ? | ? | ? |
| Price | − | + | ? | ? |
| Interest rate | ? | ? | + | − |
| Public debt | + | + | + | + |

Notes: This table reports signs imposed on the impulse responses of the variables to an expansionary government spending shock in different scenarios. The question mark indicates that the responses of the variables are unrestricted. A positive sign [negative sign] indicates the response of the variables are restricted to be positive [negative] on impact.

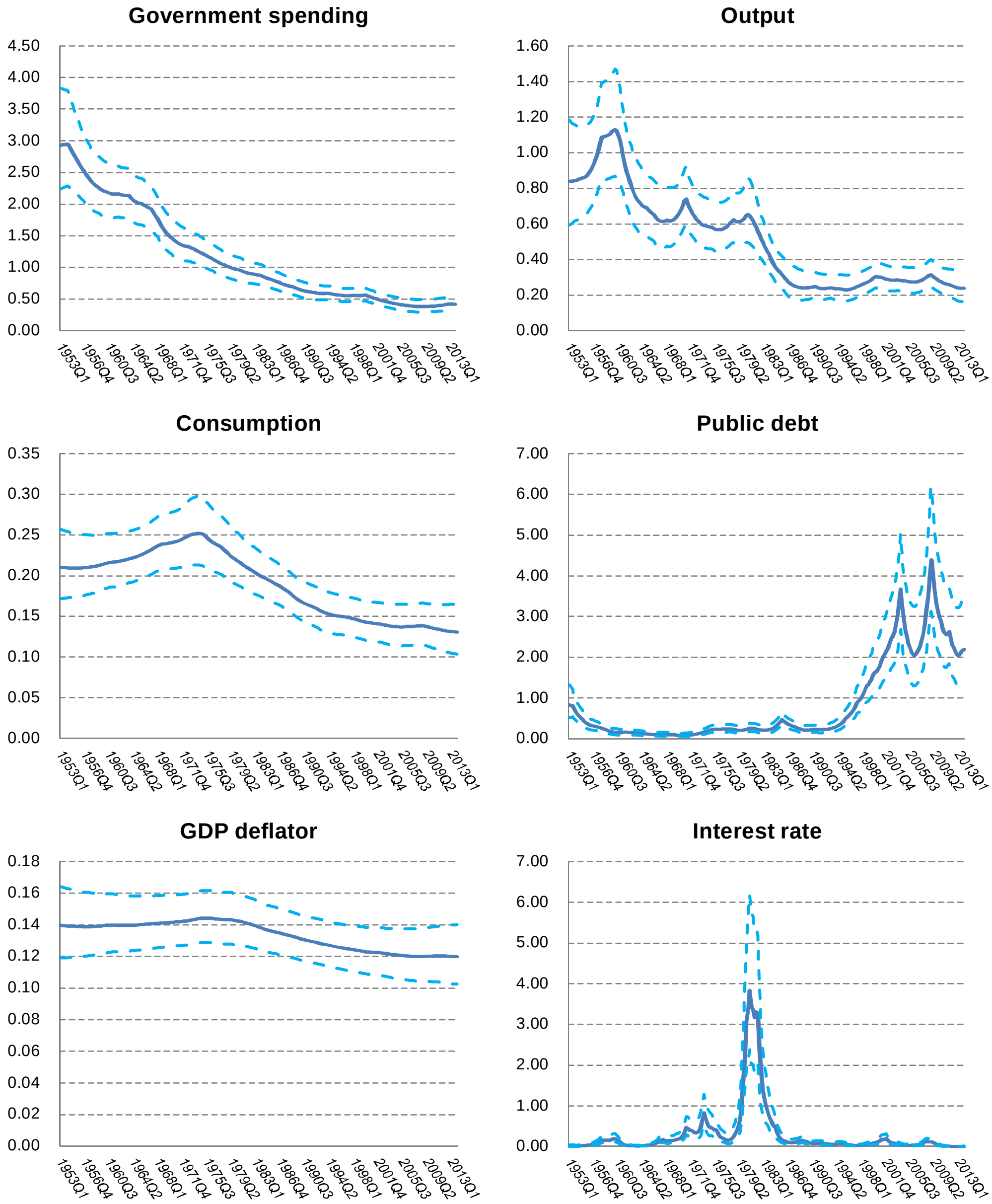
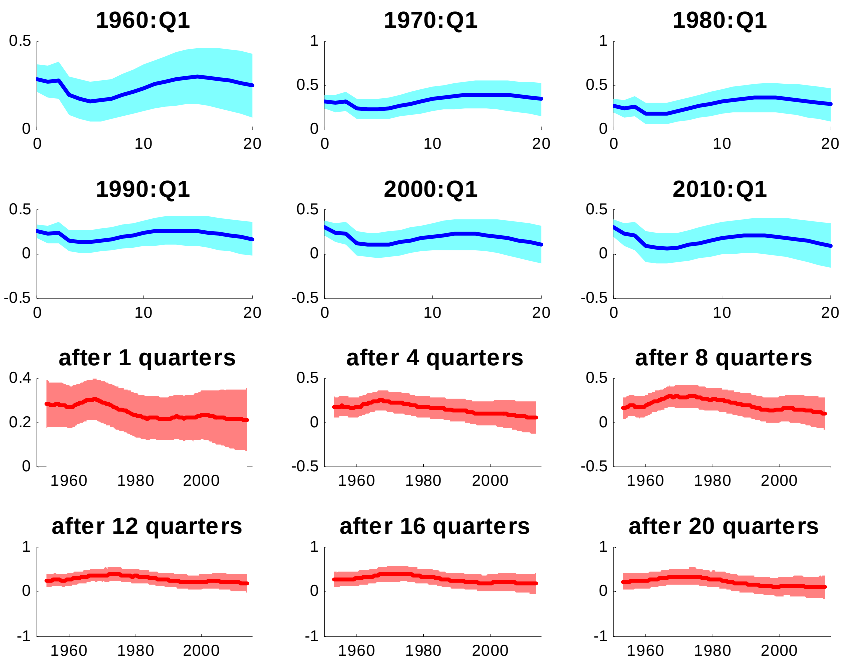
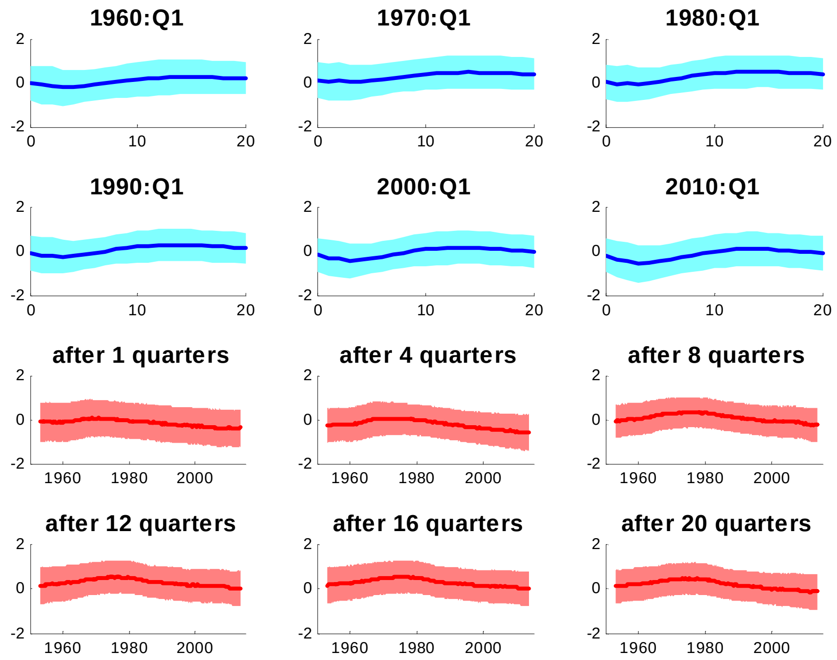



Fig. 1. Posterior estimates for stochastic volatility of structural shocks (Recursive)

Notes: Solid lines: posterior mean, dashed lines: 16th and 84th percentiles.



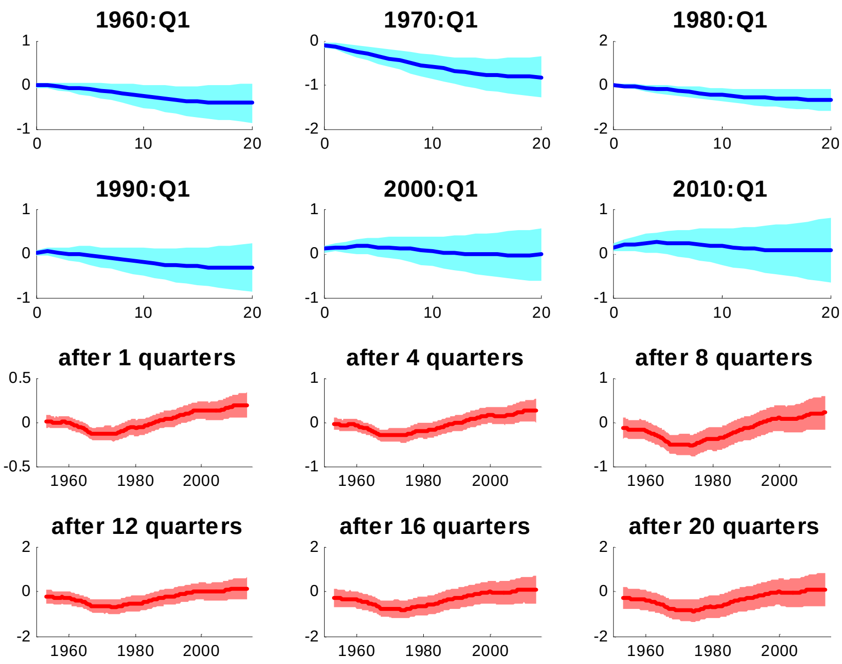

(a) Recursive



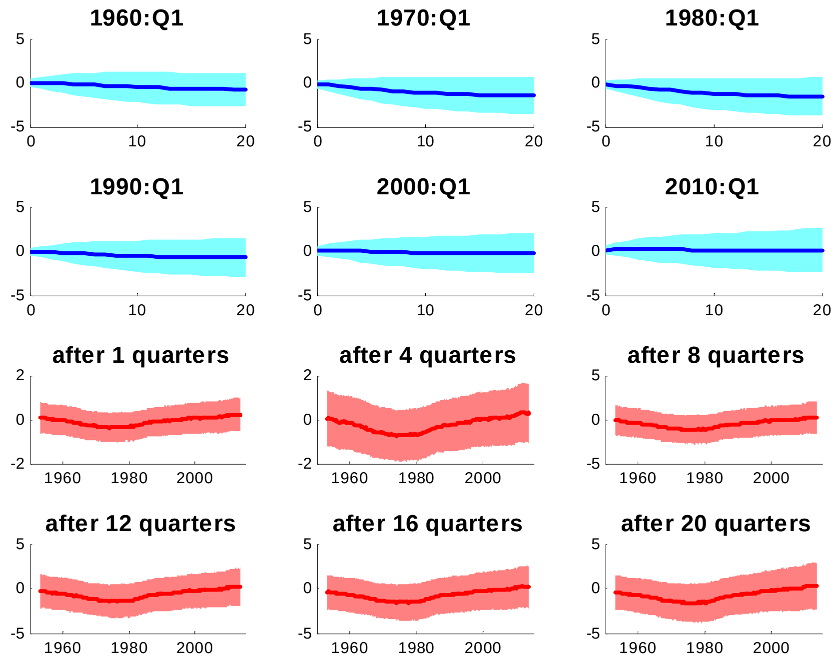

(b) Sign restrictions

Fig. 2. Responses of real GDP to an expansionary government spending shock

Notes: The figures show the responses to a one percentage point increase in government spending. The solid lines and the shaded areas represent posterior means and the 16-84 percent credible bands.



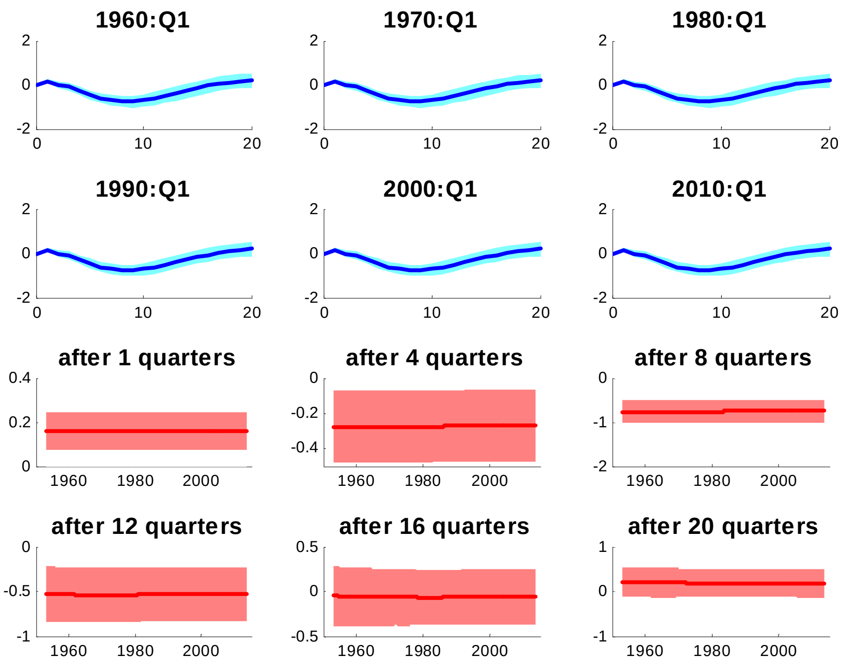

(a) Recursive



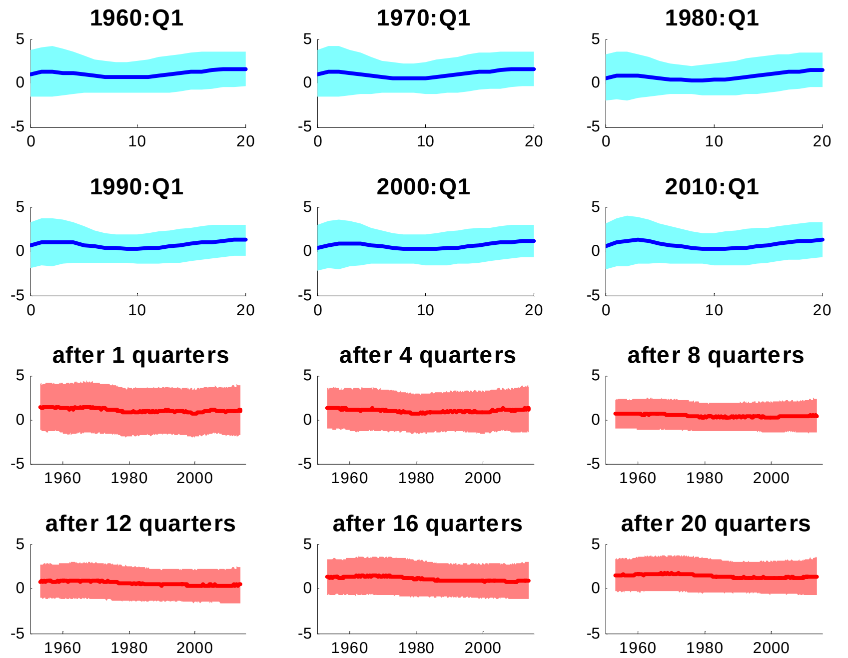

(b) Sign restrictions

Fig. 3. Responses of GDP deflator to an expansionary government spending shock

Notes: The figures show the responses to a one percentage point increase in government spending. The solid lines and the shaded areas represent posterior means and the 16-84 percent credible bands.



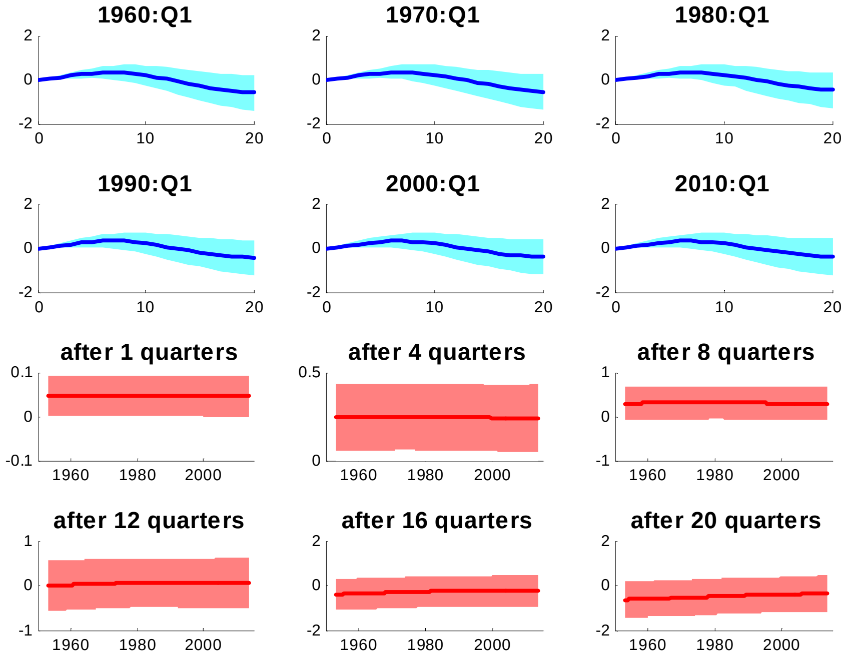

(a) Recursive



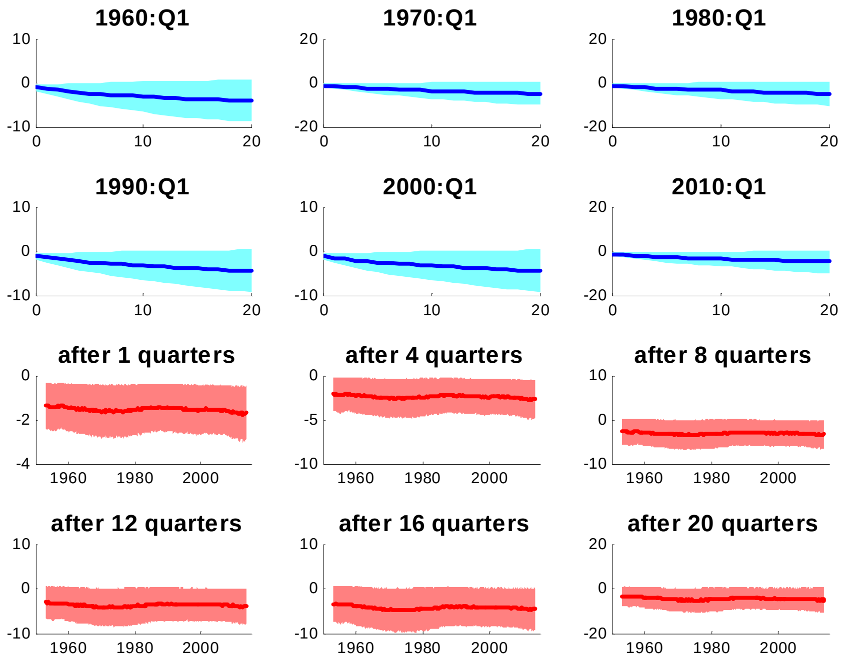

(b) Sign restrictions

Fig. 4. Responses of real GDP to a contractionary monetary policy shock

Notes: The figures show the responses to a one percentage point increase in interest rate. The solid lines and the shaded areas represent posterior means and the 16-84 percent credible bands.




(a) Recursive




(b) Sign restrictions

Fig. 5. Responses of GDP deflator to a contractionary monetary policy shock

Notes: The figures show the responses to a one percentage point increase in interest rate. The solid lines and the shaded areas represent posterior means and the 16-84 percent credible bands.

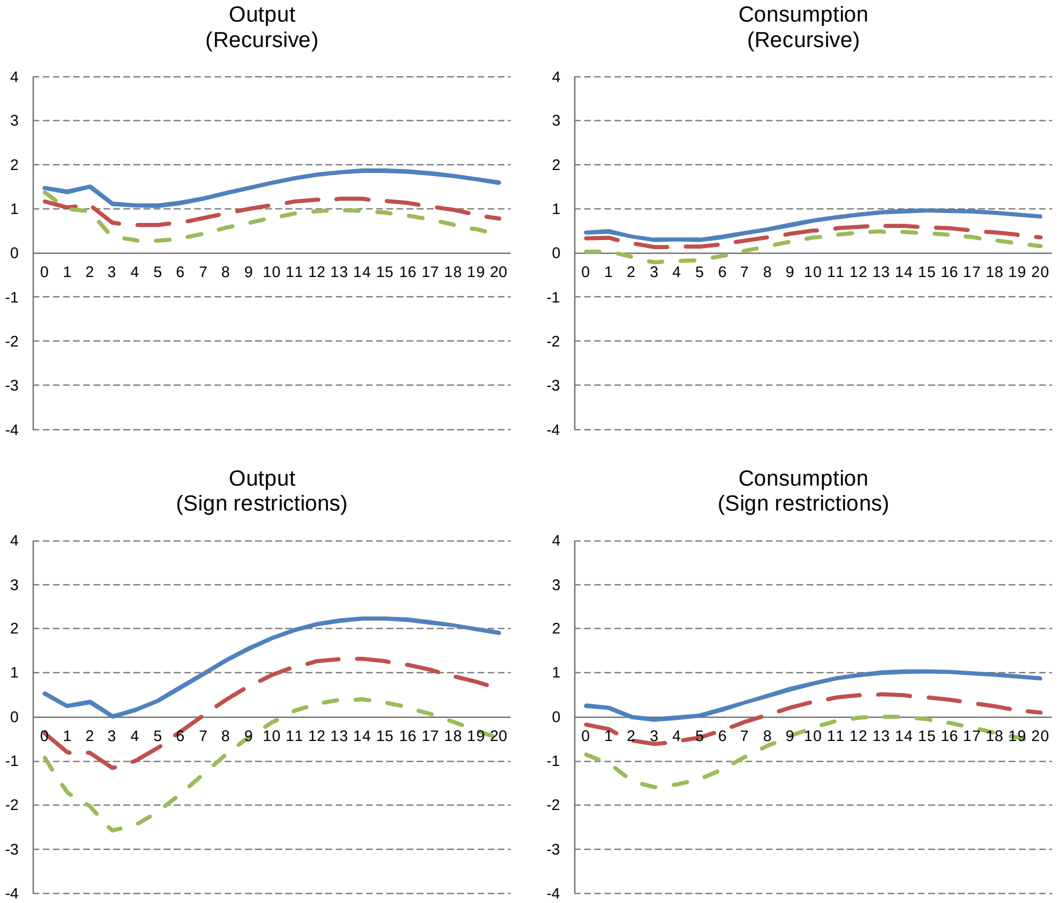



Fig. 6. Government spending multipliers

Notes: The figures show posterior means of the responses to a one dollar increase in government spending. Solid lines: 1970:Q1, dashed lines: 1990:Q1, dotted lines: 2010Q1.

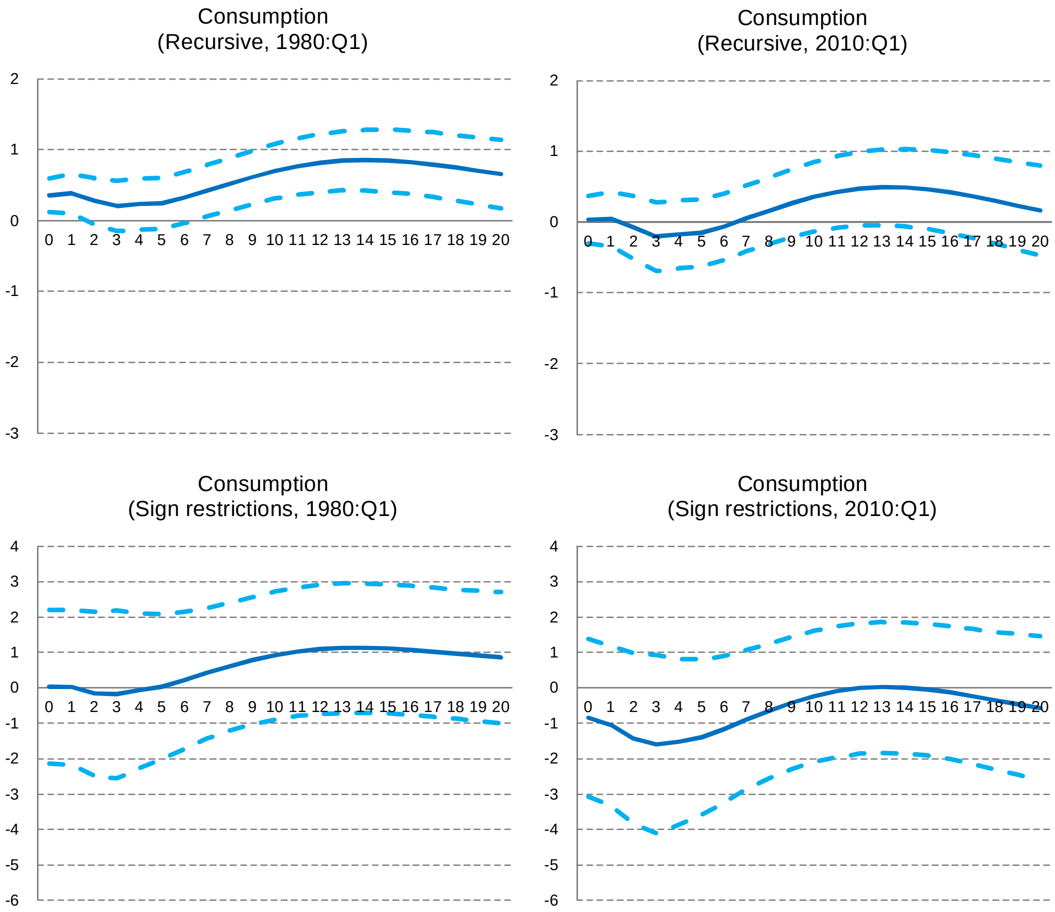



Fig. 7. Consumption multipliers

Notes: The figures show the responses to a one dollar increase in government spending. Solid lines: posterior mean, dashed lines: 16th and 84th percentiles.

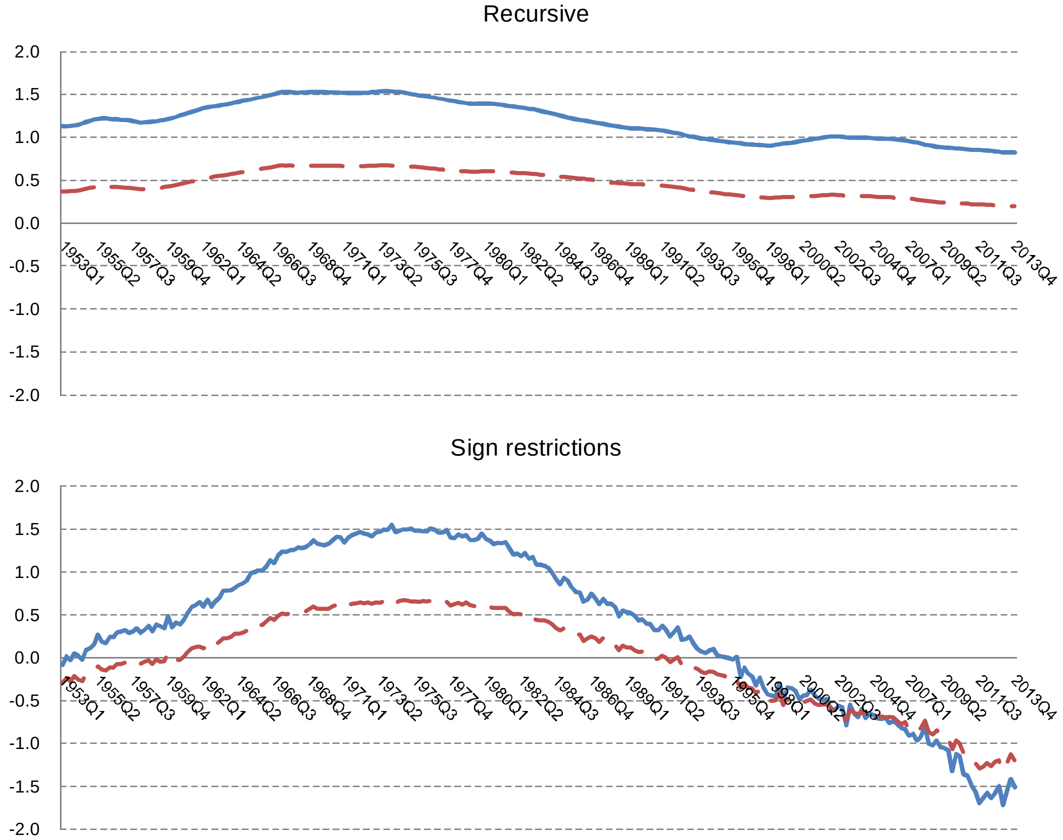



Fig. 8. Cumulative government spending multipliers

Notes: The figures show posterior means of the cumulative responses of output (solid lines) and consumption (dashed lines) to a one dollar government spending increase evaluated at horizon 20.

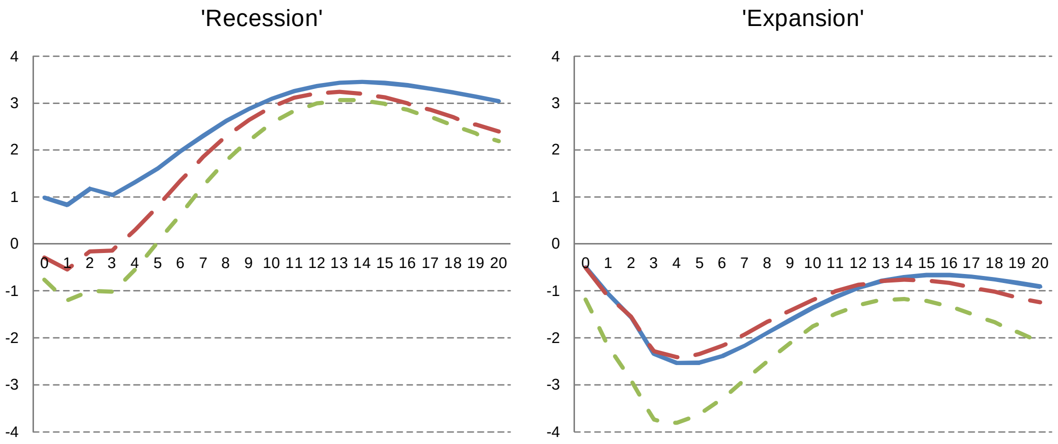



Fig. 9. Government spending multipliers in different business cycle scenarios

Notes: The figures show posterior means of the responses of output to a one dollar increase in government spending. Solid lines: 1970:Q1, dashed lines: 1990:Q1, dotted lines: 2010Q1.

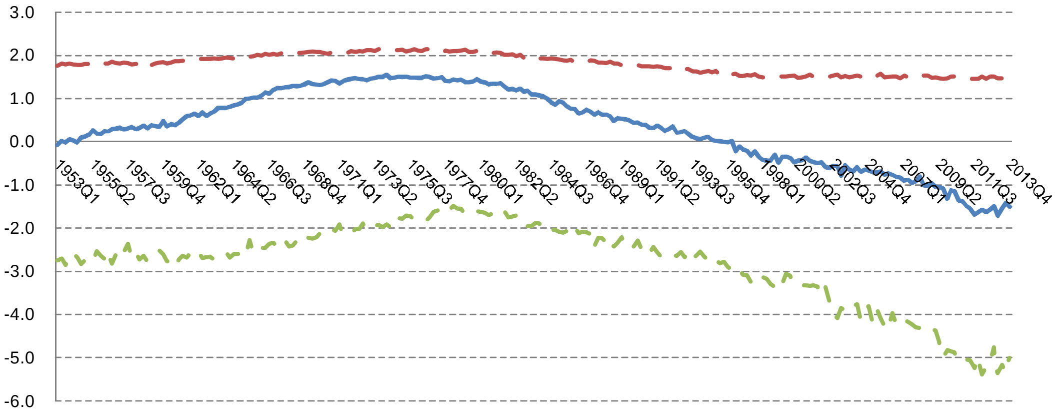



Fig. 10. Cumulative government spending multipliers in different business cycle scenarios

Notes: The figure shows posterior means of the cumulative output multipliers evaluated at horizon 20. Solid lines: basic, dashed lines: recession, dotted lines: expansion.

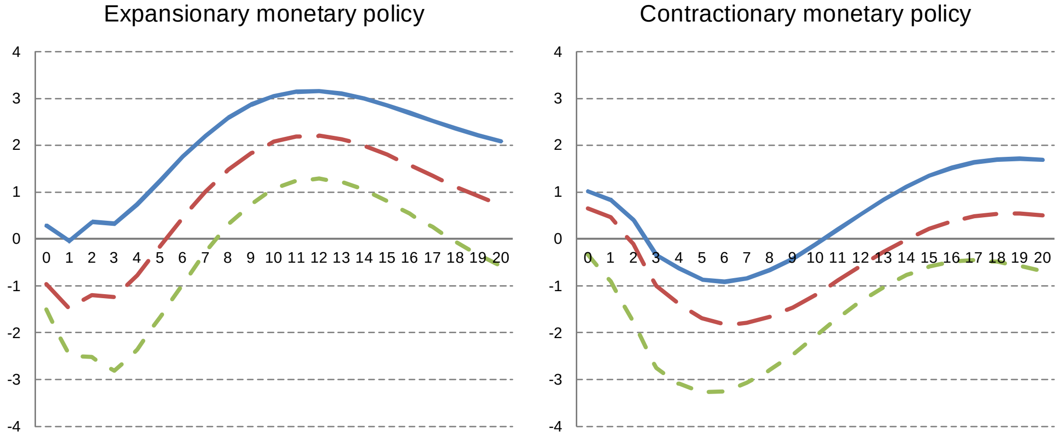



Fig. 11. Government spending multipliers in different monetary policy scenarios

Notes: The figures show posterior means of the responses of output to a one dollar increase in government spending. Solid lines: 1970:Q1, dashed lines: 1990:Q1, dotted lines: 2010Q1.

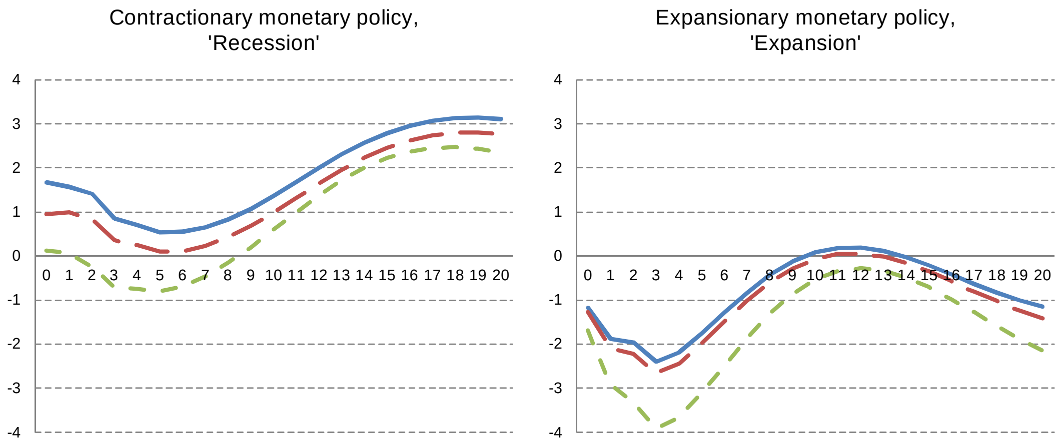



Fig. 12. Government spending multipliers in different business cycle and monetary policy scenarios

Notes: The figures show posterior means of the responses of output to a one dollar increase in government spending. Solid lines: 1970:Q1, dashed lines: 1990:Q1, dotted lines: 2010Q1.

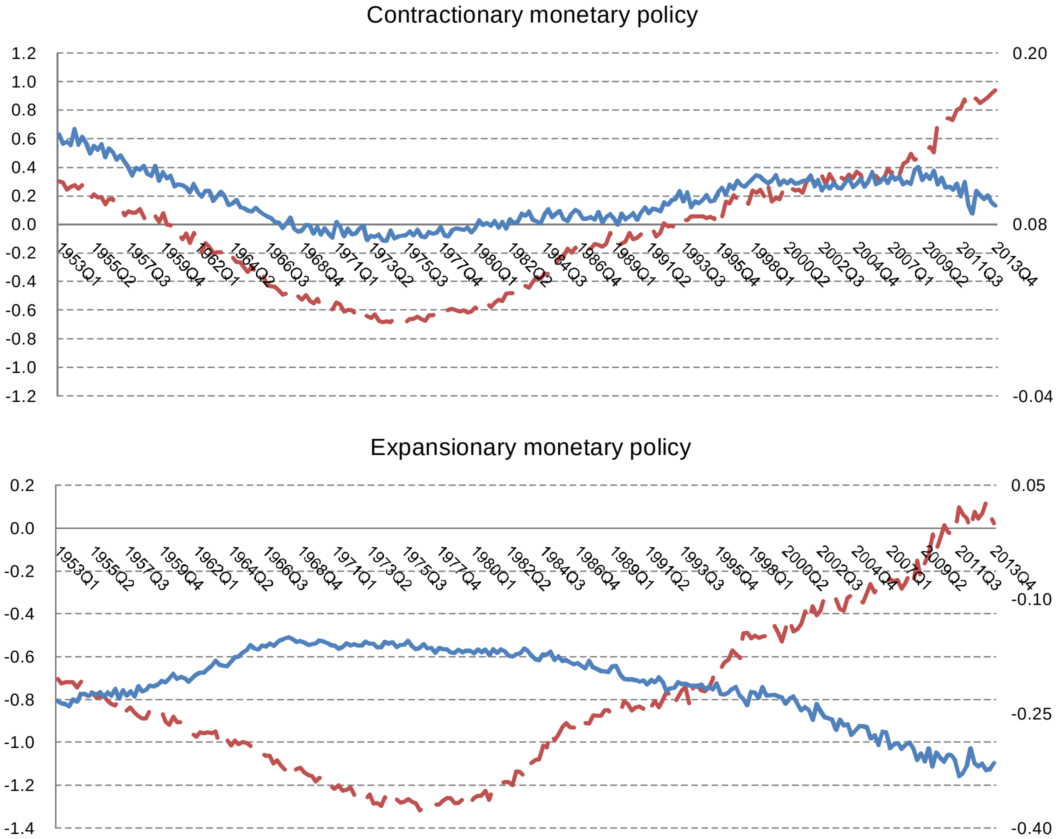



Fig. 13. Cumulative responses of price and interest rate in different monetary policy scenarios

Notes: The figures show posterior means of the cumulative percent change in price level (dashed lines, left axis) and interest rate (solid lines, right axis) divided by the cumulative percent change in the government spending after 20 quarters.

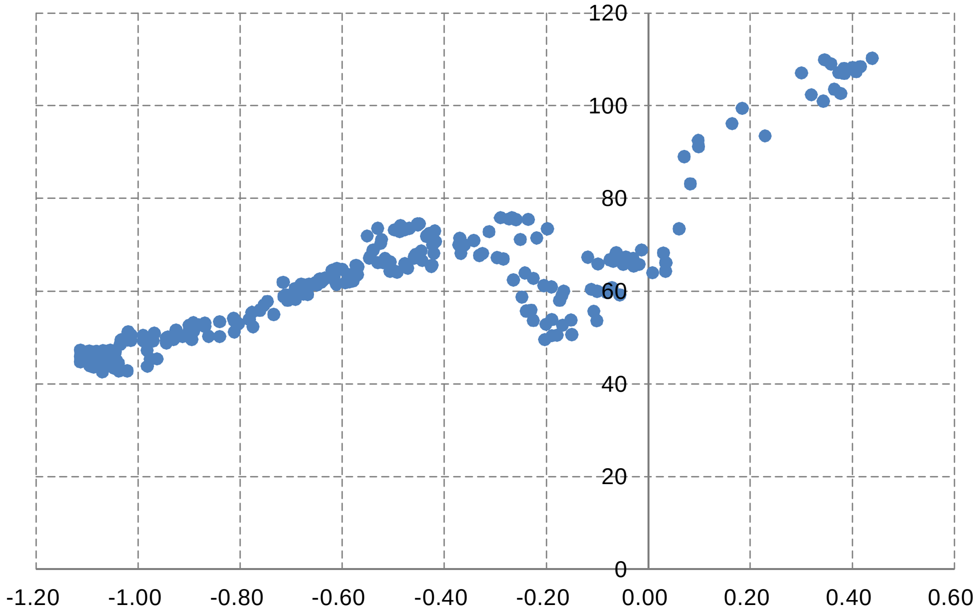



Fig. 14. Inflationary effects of government spending and debt-to-GDP ratio

Notes: The figure plots posterior means of the cumulative responses of price level to government spending shocks evaluated at horizon 20 (horizontal axis) in the basic scenario and historical data on debt-to-GDP (vertical axis).

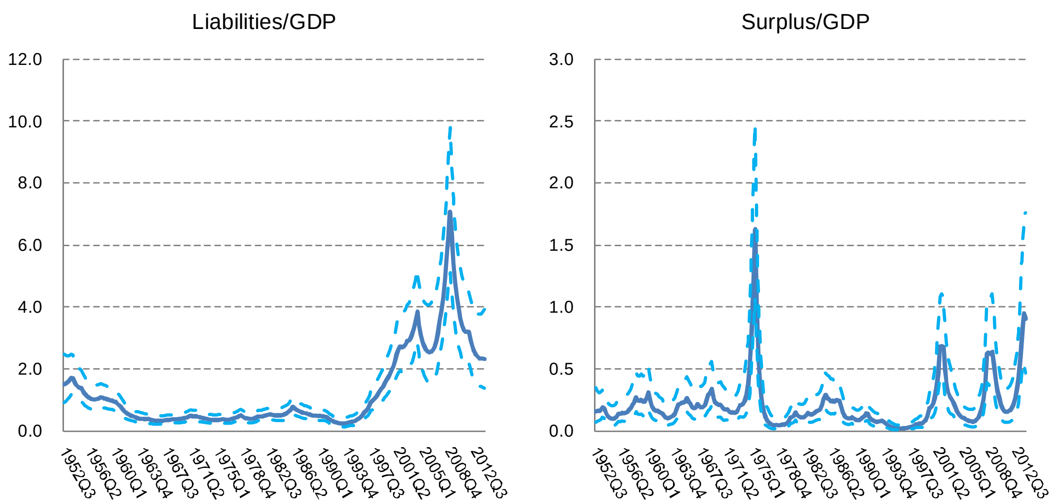



Fig. 15. Posterior estimates for stochastic volatility of structural shocks

Notes: Solid lines: posterior mean, dashed lines: 16th and 84th percentiles.

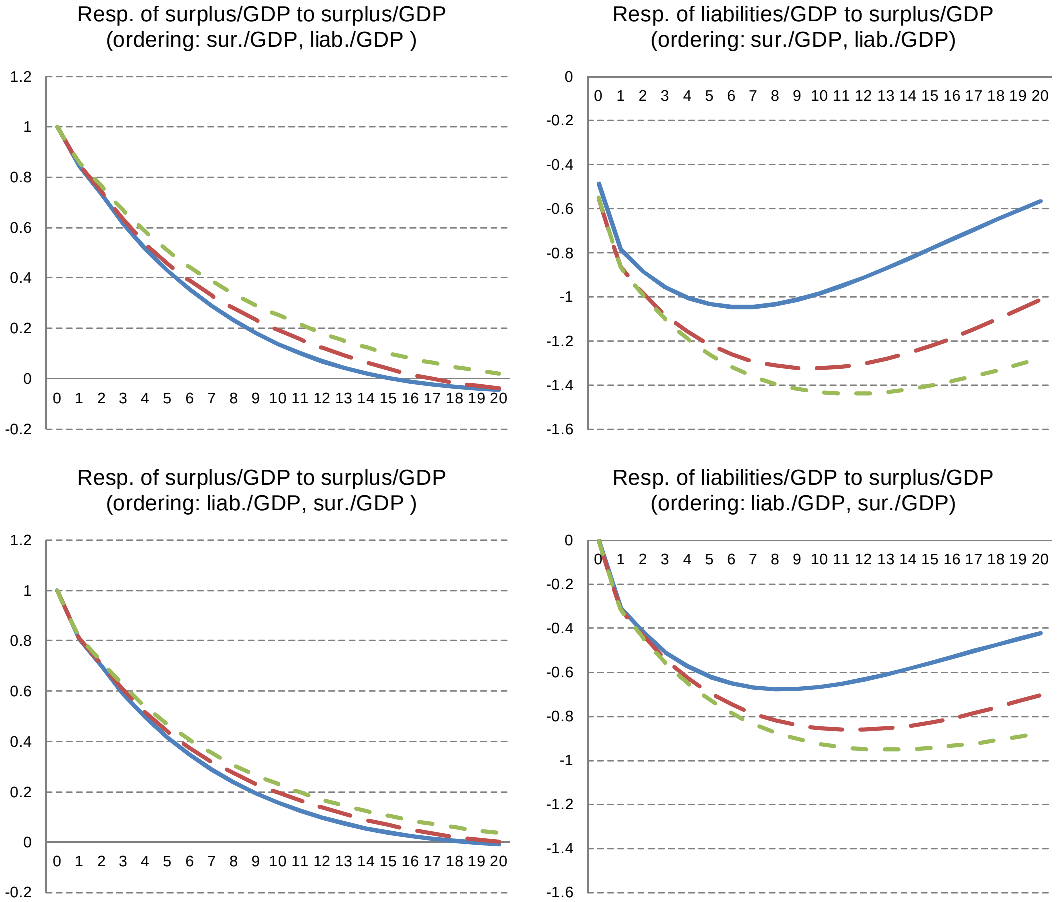



Fig. 16. Surplus and debt dynamics

Notes: The figures show posterior means of the responses to a one percentage point increase in surplus/GDP. Solid lines: 1970:Q1, dashed lines: 1990:Q1, dotted lines: 2010Q1.

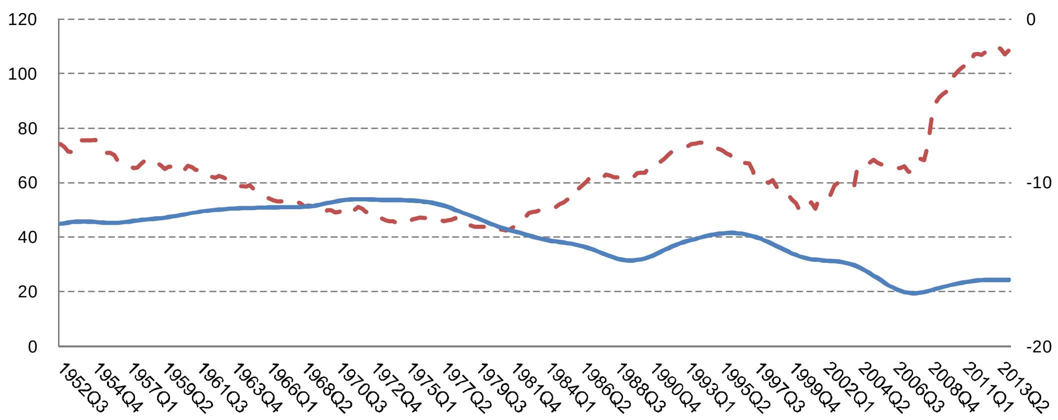


Fig. 17. Cumulative response of liabilities/GDP to surplus/GDP

Notes: The figure shows posterior means of the cumulative response of liabilities/GDP to a one percentage point increase in surplus/GDP evaluated at horizon 20 (solid line, right axis) and historical data on debt-to-GDP ratio (dashed line, left axis).