INCOMPLETE DRAFT: PLEASE DO NOT CITE WITHOUT PERMISSION

Tracking Monetary-Fiscal Interactions Across Time and Space[1]

Michal Franta	Jan Libich	Petr Stehlík
Czech National Bank	*La Trobe University*	*University of West Bohemia*

Abstract

The fiscal position of many countries is worrying - and getting worse primarily due to demographic trends of aging populations. Should formally independent central bankers be concerned that observed fiscal excesses spill over to monetary policy, and jeopardize inflation outcomes? To provide some insights this paper tracks the interactions between fiscal and monetary policies in the data across time and space. It makes three main contributions. The first one is methodological: we combine two recent econometric procedures - time varying parameter vector autoregression with sign restrictions identification - and discuss the advantages of this approach. The second contribution is positive: we show how the policy interactions and other macroeconomic variables such as fiscal multipliers have changed over time in six industrial countries. The third contribution is normative: the paper highlights the role of institutional design of each policy on the outcomes of *both* policies. Specifically, it offers some tentative evidence that a stronger commitment of monetary policy (to a legislated target for average inflation) may indirectly help improve fiscal outcomes towards sustainability and reduce the probability of unpleasant monetarist arithmetic. This is because an explicit long-term monetary commitment gives the central bank stronger ground for *not* accommodating debt-financed fiscal shocks, which improves the incentives of governments.

Keywords: Monetary-fiscal interactions, time-varying parameters VAR, sign restrictions, fiscal gap, unpleasant monetarist arithmetic. ***JEL classification:*** E61, C1

[1] Financial support from the Australian Research Council (DP0879638) and Czech Science Foundation (GA402/10/1046) is gratefully acknowledged.

1 Introduction

Many countries have been experiencing substantial fiscal stress. The responses to the global financial crisis combined with a large structural shortfall between government expenditures and revenues have lead to rapidly growing debt to GDP ratios. Importantly, demographic projections of significant increases in the old-age dependency ratios, see the discussion and Figure 8 in Appendix A, imply that the fiscal position of (virtually all advanced and many developing) countries is likely to deteriorate much further.[2]

These cyclical and structural fiscal policy developments have brought a new wave of discussions on whether such fiscal stress affects the conduct of monetary policy, and if so, how. Does it (eventually) spill over and lead to sub-optimally high inflation as many observers fear? Or is formal central bank independence sufficient to shelter monetary policy from such fiscal spillovers?

The fact that monetary and fiscal policies are inter-related is widely accepted. Both policies jointly affect a number of economic variables and private agents' expectations, and these in turn affect the payoffs of the central bankers and government officials. In addition to the obvious channels (such as debt-financed government spending in an expansion leading to inflationary pressures), the seminal work of Sargent and Wallace (1981) and Leeper (1991) identified two avenues through which fiscal excesses may spill over to monetary policy. When fiscal policymakers are unable or unwilling to balance their budgets both the unpleasant monetarist arithmetic and the fiscal theory of the price level eventually imply undesirable inflation outcomes. Their analyses point in the direction of *strategic* interactions between monetary and fiscal policy. 'Leadership' puts a policy into a dominant position in the interaction, giving it some leverage over the other policy. Our paper similarly highlights the important role of the institutional setup of the policies that determines the strength of policy leadership, and hence monetary and fiscal outcomes.

We examine fiscal-monetary interactions using data for six major countries in a novel empirical framework, and provide some answers to the above questions of if/when

[2] See for example IMF (2009) reporting the net present value of the impact of aging-related spending on fiscal deficits to be in the order of hundreds of percent for many advanced countries (and much higher than the effect of the global financial crisis). Specifically for the United States, Batini, Callegari, and Guerreiro (2011) provide a recent estimate of the 'fiscal gap' (unfunded liabilities) arguing that: 'a full elimination of the fiscal and generational imbalances would require *all* taxes to go up and *all* transfers to be cut immediately and permanently by 35 percent' (italics in the original).

fiscal-monetary spillovers are likely. Importantly, our analysis offers insights into the unexplored issue of whether there may be an effect in the opposite direction: from monetary to fiscal policy. In particular, we examine whether an appropriate design of monetary policy featuring strong commitment to a numerical inflation target may lead to an improved outcome of fiscal policy – by creating better incentives for governments to deal with the long-term driving forces of fiscal stress. We do so by contrasting the differences in monetary policy responses to fiscal shocks in three early inflation targeting countries (Canada, Australia, and the United Kingdom) prior and post adoption of the regime, and comparing them to those in countries without a legislated numerical inflation target (the United States, Japan, and Switzerland).

To see what macroeconomic data can tell us about the developments in monetary-fiscal interactions over time, this paper uses vector autoregressions (VARs) with time-varying parameters (TVP) as introduced in Primiceri (2005) and Cogley and Sargent (2005). The flexibility of such approach enables us to examine medium to long-term *changes* in policy behaviour over and above the short-run stabilization issues explored in fixed parameters VARs. Given the dire long-term fiscal projections, we believe that such broadened focus is warranted.[3]

In comparison with standard approaches featuring structural breaks, the TVP-VAR framework allows for structural policy changes to be gradual and differ in their timing across the two policies. As such the analysis based on TVP-VARs can be superior to the analysis based on data sub-samples.[4] On the other hand, the use of TVP-VARs requires a reduced number of endogenous variables and lags to keep the set of parameters manageable.

The methodological contribution of this paper, based on our companion work Franta (2011) and discussed in detail in the next section, is an extension of the TVP-VAR framework using an identification of fiscal shocks based on the combination of sign,

[3] This is analogous to the increased focus on the 'inflation bias' (i.e. levels) in the aftermath of the inflationary period of 1970s, and the move of focus onto the 'stabilization bias' (i.e. variances) in the mid-1990s. Nevertheless, the fact that the longer-term prospect of an unpleasant monetarist arithmetic is more pertinent than in the past does not mean that we should not pay attention to short-term stabilization issues. This is especially true given the weak recovery of most countries from the global financial crisis and the danger of deflation in the short-term.

[4] It is well established that many advanced countries have experienced structural breaks in monetary and fiscal policy with their policy regimes changing over time, see for example Davig and Leeper (2010), Clarida, Gali, and Gertler (1998). Fiscal policy analysis based on sub-samples can be found in Pappa (2010), Perotti (2007) or Blanchard and Perotti (2002).

magnitude and contemporaneous restrictions. First, we assume a positive response of output, government spending and government debt to an unexpected increase in debt-financed government spending. Next, to distinguish the spending shock from the effects of changing economic conditions we impose government spending not to be contemporaneously affected by output shocks. Finally, to be able to distinguish between spending shocks and shocks related to other components of the government budget constraint, magnitude restrictions are employed.

So far, only Kirchner et al. (2010) and Pereira and Lopes (2010) employed the TVP-VAR framework to assess the effect of fiscal policy shocks. Kirchner et al. (2010) focus on the Euro area using the traditional recursive assumption (e.g. as Fatás and Mihov, 2001) to identify government spending shocks. Pereira and Lopes (2010) examine the United States and identify the tax net transfers shock and spending shock along the lines of Blanchard and Perotti (2002) who exploit institutional information on taxes and transfers to distinguish between automatic movements of fiscal variables from fiscal shocks.

Their identification approach based on the assumption of lagged reactions among endogenous variables is however too restrictive as it implies either that the monetary authority does not react contemporaneously to fiscal shocks, or that the fiscal authority neglects contemporary movements in monetary policy. Intuitively, such specification implicitly imposes unrealistic timing assumptions about the interaction between the monetary and fiscal authorities. As the game theoretic examination of monetary-fiscal interactions in Libich and Stehlik (2011) under generalized timing of moves shows, the exact timing of policy moves is a crucial determinant of the outcomes of both policies. Therefore, an additional advantage of using the sign restrictions framework in the policy context is that no timing assumptions on the monetary-fiscal interaction need to be imposed, implying more adequate empirical results. On the other hand, sign restrictions are a weak identification approach in terms of there being many structural models that correspond to the estimated reduced form model and satisfy the signs imposed on the impulse responses (Fry and Pagan, 2011). We mitigate this potential problem by adding a set of contemporaneous and magnitude restrictions.

Our analysis offers several insights regarding the monetary-fiscal interaction: how it has changed over time, how it has differed across countries, and how institutional design of the policies may explain the changes and differences. In particular, it is shown that in the considered countries with a legislated numerical inflation target the degree of monetary policy accommodation of debt-financed fiscal shocks has decreased after adoption of the regime. In contrast, in the considered countries without a legislated inflation target the degree of accommodation over the same period has not changed much, or increased. This is in line with the game theoretic findings of Libich and Stehlik (2011): a legislated long-term inflation target acts as a monetary commitment, and partly shields the central bank from fiscal pressures.[5]

Our analysis offers additional results, most importantly regarding the size of output and consumption multipliers and how these evolved over time. Our impulse responses further show the zero lower bound on interest rates problem in Japan over the past two decades, the monetary-fiscal policy tug-of-war in the U.S. in the early 1980s etc.

2 Identification

Three approaches to the identification of fiscal policy shocks have been established in the literature. First, the event-study approach (Ramey and Shapiro, 1998) focuses on describing the effects of an unexpected increase in government defense spending. Second, the structural VAR approach (Blanchard and Perotti, 2002) draws on the assumption of a lagged reaction of fiscal variables to the changes in economic conditions. Third, the recent identification scheme based on sign restrictions developed originally for the analysis of the monetary policy shocks has been applied to fiscal policy analysis (Mountford and Uhlig, 2009, Pappa 2009, Canova and Pappa, 2007). Recently the sign restrictions identification approach has been enriched by additional identifying assumptions based on, for example, cointegration (Dungey and Fry, 2009) and magnitude restrictions (Hur, 2011).

Our identification procedure draws on recent research regarding identification of fiscal shocks and combines sign, magnitude and contemporanous restrictions. The focus is on the identification of a debt-financed government spending shock. Similarly to Canova and Pappa (2007), Pappa (2009) and Dungey and Fry (2009) we assume that a positive debt-financed government spending shock increases: (i) government spending for four

[5] It should however be stressed that since the target is specified as a long-term objective achievable on average over the business cycle, it does not seem to reduce policy short-run stabilization flexibility: for recent evidence see e.g. Kuttner and Posen (2011), and for theoretic modeling see Libich (2011).

quarters, (ii) and government debt for four quarters, and (iii) output for two quarters. The length of the imposed sign restrictions is related to some aspects of the data which we discuss in Section 5. As shown in Pappa (2009) such restrictions, at least on impact, are consistent with standard structural models of both the Real Business Cycles (RBC) and the New-Keynesian tradition, and they do not result from productivity, labor supply or monetary shocks.[6]

Rise in output and government debt can, however, be also brought about by a tax cut and/or an increase in transfers. Therefore, to filter out the effects of the government transfer and tax shocks, we impose a magnitude restriction that an identified debt-financed spending shock does not increase government debt more than the amount of government spending.[7] The situation where tax cuts imply increase of tax revenues cannot be distinguished from the government spending shock within our identification framework.

Next, to capture the fact that government purchases do not react much to the business cycle, we impose a zero contemporaneous restriction on the effect of a business cycle shock on government spending. This is reminiscent of the recursive identification of shocks when government spending is ordered before GDP. Nevertheless, we do not restrict the contemporaneous effects between government debt and output to allow for the effect of automatic stabilizers on the fiscal variables (taxes/debt). The contemporanous restriction on the relationship between output and government spending enables us to distinguish between a generic business cycle shock (Mountford and Uhlig, 2009) and fiscal shocks. As shown by Wouters (2005) a higher number of identified shocks implies greater reliability of the sign identification procedure.

[6] Leeper et al. (2010) show within a neoclassical growth model fit to U.S. postwar data that implementation delays of government investment can even lead to a slight decline of output in the short run. Anticipation effects are not, however, taken into account in this paper. For an empirical justification of such approach for the U.S. data see Mertens and Ravn (2010).

[7] The aim of the paper is the reaction of a central bank on a debt-financed spending shock. The reason we need to distinguish the shock from a tax cut shock and government transfers shock is that the real economy behaves differently after different types of fiscal shocks. For example, private investment is usually crowded out in the case of excessive government spending, but not in the case of a tax cut, and hence the central bank would react differently. To distinguish between spending and tax cut shock, Pappa (2010) assumes a zero or small correlation of the identified shock and tax revenues. The difference of our identification approach is driven by our set of the endogenous variables that includes government debt instead of tax revenues.

Finally, let us stress that we do not impose any restriction on the interest rate because it is the variable of our main interest summarizing the responses of monetary policy to a debt-financed spending shock. Furthermore, no restriction on private consumption is imposed because of the opposite predictions of the traditional Keynesian and RBC models: the former predicts an increase whereas the latter predicts a decrease in private consumption following a debt-financed fiscal policy shock.

3 The Econometric Model

The reduced form TVP-VAR follows Cogley and Sargent (2005) and Primiceri (2005):

$$y_t = X_t \beta_t + A_t^{-1} \Sigma_t \varepsilon_t \qquad t = p+1, \ldots, T, \tag{1}$$

where y_t is an $M \times 1$ vector of endogenous variables, $X_t = I_M \otimes (1, y'_{t-1}, \ldots, y'_{t-p})$ is a Kronecker product of the identity matrix with a constant and lagged vectors of endogenous variables, and ε_t denotes the vector of i.i.d. structural shocks. An $M(Mp+1) \times 1$ vector γ stacks reduced form coefficients, the matrix A_t is a lower triangular matrix capturing contemporaneous relations:

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ \alpha_{21,t} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{M1,t} & \cdots & \alpha_{M,M-1,t} & 1 \end{bmatrix},$$

and the matrix of standard deviations of structural shocks, Σ_t, is diagonal:

$$\Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{M,t} \end{bmatrix}.$$

The TVPs follow random walks and a geometric random walk:

$$\beta_{i,t} = \beta_{i,t-1} + u_t^i \qquad i = 1, \ldots, M^2 p + M, \tag{2}$$

$$\alpha_{i,t} = \alpha_{i,t-1} + v_t^i \qquad i = 1, \ldots, (M^2 - M)/2, \tag{3}$$

$$\log(\sigma_{i,t}) = \log(\sigma_{i,t-1}) + w_t^i \qquad i = 1, \ldots, M. \tag{4}$$

Model innovations are assumed to be jointly normally distributed:

$$\begin{bmatrix} \varepsilon_t \\ u_t \\ v_t \\ w_t \end{bmatrix} \sim N\left(0, \begin{bmatrix} I_M & 0 & 0 & 0 \\ 0 & U & 0 & 0 \\ 0 & 0 & V & 0 \\ 0 & 0 & 0 & W \end{bmatrix}\right), \tag{5}$$

where the vectors u_t, v_t and w_t consists of innovations as introduced in (2)–(4). The matrices *U, V* and *W* are positive definite. Moreover, *V* is assumed to be a block diagonal matrix, with blocks constituted by the coefficient innovations from a particular equation, i.e. we assume that innovations to contemporaneous effects are uncorrelated across equations. Finally, we follow Cogley and Sargent (2005) and assume the matrix *W* to be diagonal. As noted in Kirchner et al. (2010) the reason is that fiscal TVP-VARs usually consists of more variables than VARs for monetary policy analysis and thus we need to reduce the number of parameters. The simulation of the system (2)-(5) employs a Gibbs sampler. A sample from the joint posterior distribution of the parameter set is obtained from blocks that provide samples from conditional distributions. Thus, draws from VAR coefficients $\beta_{i,t}$, contemporaneous relations $\alpha_{i,t}$, volatility states $\sigma_{i,t}$, and hyperparameters *U, V* and *W* are produced by the sampler in turn. A detailed description of the sampler and priors used can be found in Appendix B. The Gibbs sampler generates 30,000 draws after a burn-in period of 30,000. Only every fifth draw is kept to avoid the autocorrelation of draws. Convergence diagnostics are presented in Appendix C.

The identification of structural shocks boils down to finding a linear combination of structural shocks ε_t that yields reduced form residuals z_t. The relationship between the two is modeled in (1) as follows:

$$z_t = A_t^{-1}\Sigma_t\varepsilon_t .$$

Our identification approach draws on the fact that for any orthonormal matrix Q, i.e. the matrix such that $Q'Q = I_M$, holds:

$$z_t = A_t^{-1}\Sigma_t Q' Q\varepsilon_t .$$

In such way the new set of uncorrelated structural shocks, $\tilde{\varepsilon}_t = Q\varepsilon_t$, is produced and the new linear combination, $z_t = A_t^{-1}\Sigma_t\tilde{\varepsilon}_t$, no longer determines the system of structural shocks recursively. However, the covariance matrix of the reduced form residuals does not change.

As noted in Primiceri (2005), the draws of the covariance matrix of the reduced form residuals are dependent on the ordering of the variables.[8]

The implementation of the identification restrictions is based on Givens rotations i.e. orthonormal matrices of the form:

$$Q_{ij}(\theta)=\begin{pmatrix} 1 & \cdots & 0 & \cdots & 0 & \cdots & 0 \\ \vdots & \ddots & \vdots & & \vdots & & \vdots \\ 0 & \cdots & \cos(\theta) & \cdots & \sin(\theta) & \cdots & 0 \\ \vdots & & \vdots & \ddots & \vdots & & \vdots \\ 0 & \cdots & \sin(\theta) & \cdots & \cos(\theta) & \cdots & 0 \\ \vdots & & \vdots & & \vdots & \ddots & \vdots \\ 0 & \cdots & 0 & \cdots & 0 & \cdots & 1 \end{pmatrix},$$

where the rotation angle $\theta \in [0, \pi]$ and respective goniometric functions occupy the i-th and j-th columns and the i-th and j-th rows of the matrix. For 5x5 matrices, any rotation can be constructed as a product of 10 possible Givens rotations:

$$Q(\theta)=\prod_{\substack{i,j=1 \\ i<j}}^{5} Q_{ij}(\theta).$$

In order to impose no impact of output on government spending in a given period, we use only nine Givens rotations to guarantee zero at a respective position (the first row and second column) in the matrix *Q*. So,

$$Q(\theta)=Q_{24}(\theta)Q_{23}(\theta)Q_{14}(\theta)Q_{35}(\theta)Q_{34}(\theta)Q_{25}(\theta)Q_{45}(\theta)Q_{15}(\theta)Q_{13}(\theta).$$

For each rotation we check the sign and magnitude restrictions. The sign restrictions are described in the first row of Table 1. Pappa (2009) shows that a crucial feature of the spending shock identification - distinguishing it from other types of shocks - is that unexpected spending raises output and government deficit on impact. In terms of our framework it means that a government debt-financed spending shock increases output and government debt. In addition, in the second and third row Table 1 presents

[8] In contrast to Kirchner et al. (2010) and Pereira and Lopes (2010), the identification is not an integral part of the estimation procedure. In their case, the estimated matrices of the contemporaneous effects already embed the identification scheme.

reactions of endogenous variables to a generic business cycle shock (e.g. technology shock, labour supply shock) and a monetary policy shock. The important feature of the shocks is that either they do not affect government spending contemporaneously, or they affect output and government debt in opposite directions.

Table 1. Sign Restrictions

	Output		Private consumption		Interest rate		Government spending		Government debt	
	impact	2 lags	impact	lag	impact	lag	impact	4 lags	impact	4 lags
Debt-financed gov. spending shock	+	+	none	none	none	none	+	+	+	+
Monetary policy shock	0	-	0	-	+	+	0	+/-	+	+
Generic business cycle shock	+/-	+/-	+/-	+/-	+/-	+/-	0	+/-	-	-

In addition, magnitude restrictions are imposed such that the effect of a shock on government spending is not lower than the effect of the shock on government debt in the next four quarters. If it is lower it means that other components of the government budget constraint must be affected by the shock (e.g. lower tax revenues). Note that the magnitude restrictions are applied on a particular draw of the rotation matrix, i.e. on a particular structural model. For a given draw of the model parameters at most forty rotations are tested to find the ones that satisfy the sign and magnitude restrictions.

4 Data

An analysis of this type is constrained by unavailability of fiscal data affecting decisions on variables and countries included. Our set of endogenous variables y_t consists of output, private consumption, the short term interest rate, government spending (consumption and investment), and government debt.[9] All variables except the interest rate are in real per capita terms. The data are quarterly except for the data on government debt that are yearly. Using a simple univariate interpolation method we disaggregated the yearly debt data into quarters.[10] Following the existing two papers on

[9] Note that Kirchner et al. (2010) use government spending, output, private consumption and the short term interest rate in their benchmark model. Pereira and Lopes (2010) use government spending, output, short term interest rates and taxes net of transfers.

[10] This is the reason for imposing sign restrictions on the response of debt to four quarters: a change in government debt that occurs anytime during the year is reflected by the debt data in all four quarters. Similarly this is true for the magnitude restrictions.

fiscal TVP-VARs we set the lag length equal to two. Data sources are described in Appendix G.

We estimate the model for Australia (1980Q1-2008Q4), Canada (1981Q1-2008Q4), Japan (1980Q1-2008Q4), Switzerland (1980Q1-2008Q4), the UK (1980Q1-2008Q4) and the U.S. (1980Q1-2008Q4). Our country sample choice is driven by our interest in comparing countries with and without a legislated inflation target. As there are only three advanced countries in the latter category (Japan, Switzerland, and the U.S.), we pick an equal number of early targeters. Their choice follows the justification of Dotsey (2006), most importantly the fact that 'their inflation rates were fairly well contained before they adopted inflation targeting'. The reason we do not include the data during the global financial crisis in our benchmark VAR estimates is to focus on changes to medium-long-term interactions free from cyclical considerations.[11]

5 Results

We are primarily interested in the interactions of monetary and fiscal policies, and how these have changed over time. Our examination attempts to learn from the past to provide some clues about possible outcomes of both policies in the future. Specifically, it is of high importance to anticipate to what extent the observed and predicted fiscal shortfalls may threaten the outcomes of monetary policy, and whether some institutional arrangements may play a positive role in this respect.

Such interest drives our empirical analysis. We estimate impulse response functions of endogenous variables to a positive debt-financed government spending shock. The shock is normalized in the dimension of government spending (note that the considered fiscal shock is a linear combination of government spending and government debt). In order to get the interpretation of responses as multipliers, the size of the shock equals to one percent of GDP and all endogenous variables except the interest rate are expressed also in the percentage of GDP. The interest rate is considered in percentage points.

To maintain focus we will in the main text only report a selection of the results. Specifically, the next section examines the impulse responses of the interest rate to the fiscal shock, whereas the following section discusses the estimated output and

[11] Recall that our priors are based on OLS estimates of the model on the whole sample so extreme observations can alter the estimates in a way unrepresentative of the medium to long term developments.

consumption multipliers. For an illustration of the rest of the results the responses on impact and in the 3rd quarter are available in Appendix E for all variables and countries.

5.1 Fiscal-Monetary Interactions

Our game theoretic work Libich and Stehlik (2011) implies two testable hypotheses that provide guidance in interpreting our results regarding monetary-fiscal interactions (Appendix D sketches the theory and intuition behind these hypotheses):

Hypothesis 1: A central bank with an explicit target for average inflation is less prone to accommodate a debt-financed government spending shock than a central bank without such an explicit long-term monetary commitment.

Hypothesis 2: The change in the responses of a central bank explicitly committed to targeting medium-run inflation alters the incentives of governments by reducing their payoff from debt-financed spending, and therefore leads to an improvement in the fiscal balance.

Our TVP-VAR estimates relate to both hypotheses. If Hypothesis 1 is correct, we should see a decrease in monetary accommodation of fiscal shocks after legislating a numerical inflation target, or an increase in the central bank's offsetting such shocks by raising interest rates. In contrast, Hypothesis 1 predicts no change or possibly even more monetary accommodation in countries without a legislated inflation objective.

Figure 1 reports the estimated responses of the interest rate instrument of monetary policy to the fiscal shock for all considered countries. It plots the medians of the posterior distributions. Figure 2 presents the *average responses* for two sub-samples (pre inflation targeting period and post inflation targeting period) in order to better contrast monetary policy behavior before and after the introduction of an explicit numerical inflation target.[12]

[12] Note that for the countries without a legislated inflation target the switch period for the computation of average responses is set to 1992/1993 following Dotsey (2006).

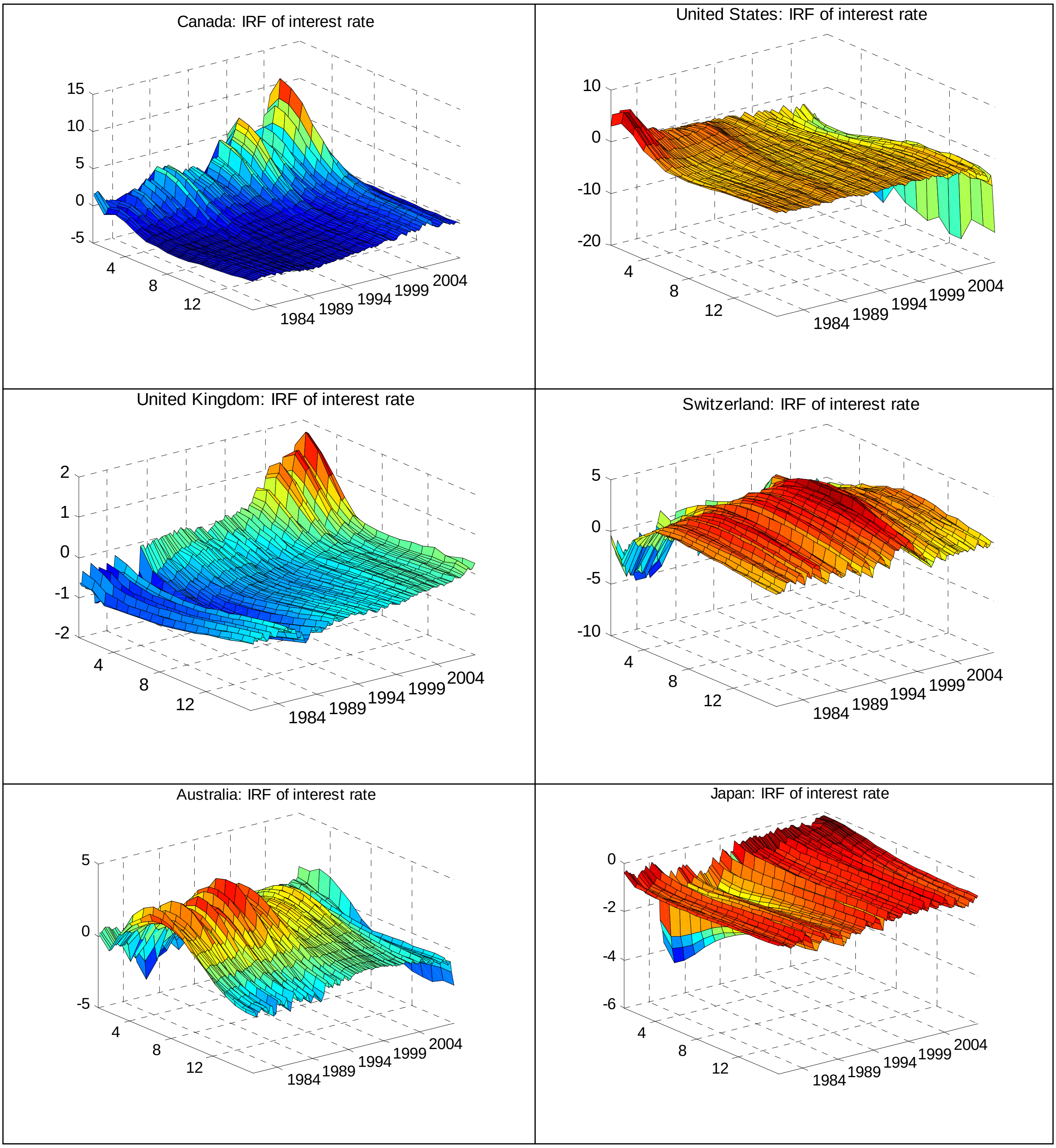


Figure 1: IRF of the interest rate for explicit inflation targeters (the left column) and non-targeters (the right column)

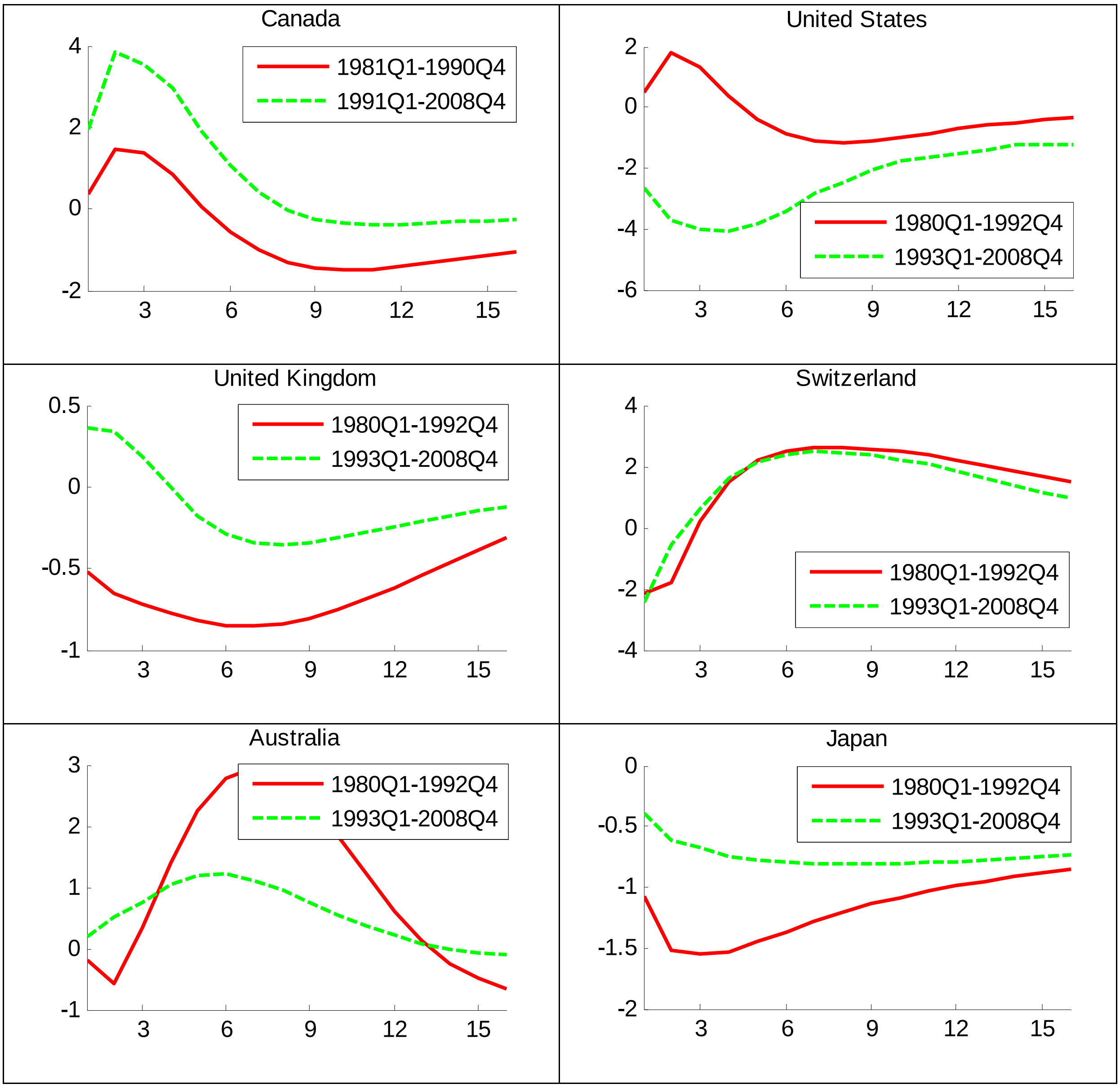


Figure 2: Average IRFs of the interest rate for a horizon of 16 quarters.

The reported results in Figures 1-2 are largely consistent with Hypothesis 1. The estimates suggest that after legislating a numerical inflation target the central banks' response to unexpected debt-financed government spending has changed in all three considered countries. The left column of Figure 1 shows the following changes post formal adoption of the inflation targeting regime: (i) The Bank of Canada tends to offset fiscal shocks more aggressively on impact, and over longer horizons it switched from accommodating to no reaction. (ii) The degree of fiscal shocks accommodation by the

Bank of England has decreased substantially. (iii) The Reserve Bank of Australia no longer accommodates fiscal shocks on impact.[13]

In contrast, central banks in the three considered countries without a legislated inflation commitment accommodated on impact both prior to and post 1992 (the right column of Figure 1). They have either not changed their responses to debt-financed spending shocks in a major way (Switzerland and Japan), or their policy response have become more accommodative (the United States).[14]

It is interesting to note the strong monetary offset of debt-financed fiscal shocks in the United States in the early 1980s. This reflects the tug-of-war between Chairman Volcker's disinflation efforts, and the expansionary policies of the Reagan administration. Such finding is in line with the estimates of Leeper a David (2010) who identify this period as the (active fiscal, active monetary) regime in which debt is on an explosive path. Our estimated U.S. monetary policy responses for other periods also seem to match Leeper a David (2010), for example the period from early 2000s can be characterized as passive monetary policy.

Importantly, the presented results should not be over interpreted. As already mentioned, the TVP-VARs contains a large number of parameters and an additional piece of information in the form of priors need not necessarily lead to a substantial decrease in uncertainty. Moreover, the identification based on sign restrictions adds uncertainty related to the structural model underlying the reduced form VAR. For illustration, Figures 14 and 15 in Appendix F present effects of a debt-financed spending shock on impact together with centered 68 percents of posterior distribution of the response.

In terms of Hypothesis 2, if correct the estimated standard deviations of the spending shock should decrease after a numerical inflation target is legislated. The fact that government spending does not react contemporaneously to the business cycle shocks in

[13] The behavior of the Reserve Bank of Australia pre-targeting is of interest. It tended to accommodate on fiscal shocks on impact and then, after about one year (arguably when the inflationary effects became apparent), the bank reverse this accommodation by tightening monetary policy. Such (non-forward-looking) responses have lead to a much greater volatility of the interest rate instrument, and are inconsistent with the notion of interest rate smoothing (Woodford, 1999).

[14] In case of Japan the magnitude of monetary policy accommodation since the early 1990s has been constrained by the zero lower bound on the interest rate. Note that this is reflected in our results even though we haven't explicitly accounted for the zero lower bound.

our identification approach is an advantage here as it means that the reduced form residuals in the equation for government spending do *not* capture immediate reactions of government spending to the state of the economy. Nevertheless, they can represent not only an unexpected fiscal shock but also a reaction to an unexpected monetary policy shock. Therefore, a decrease in the standard deviation of the reduced form residuals could be caused not only by a reduction in the frequency/size of debt-financed government spending shocks, but also by a reduction in the response of the fiscal authority to monetary policy actions.

Figure 3 shows the standard deviation of reduced form residuals for spending with the red line indicating an average of the standard deviations median for the two sub-periods. The periods the average is computed for correspond to the period average impulse responses are computed. The figure shows – in line with Hypothesis 2 - that the standard deviation of the reduced form residuals for spending has decreased post adoption of formal inflation targeting. Nevertheless, reductions in the volatility of spending are present for non-targeters as well.

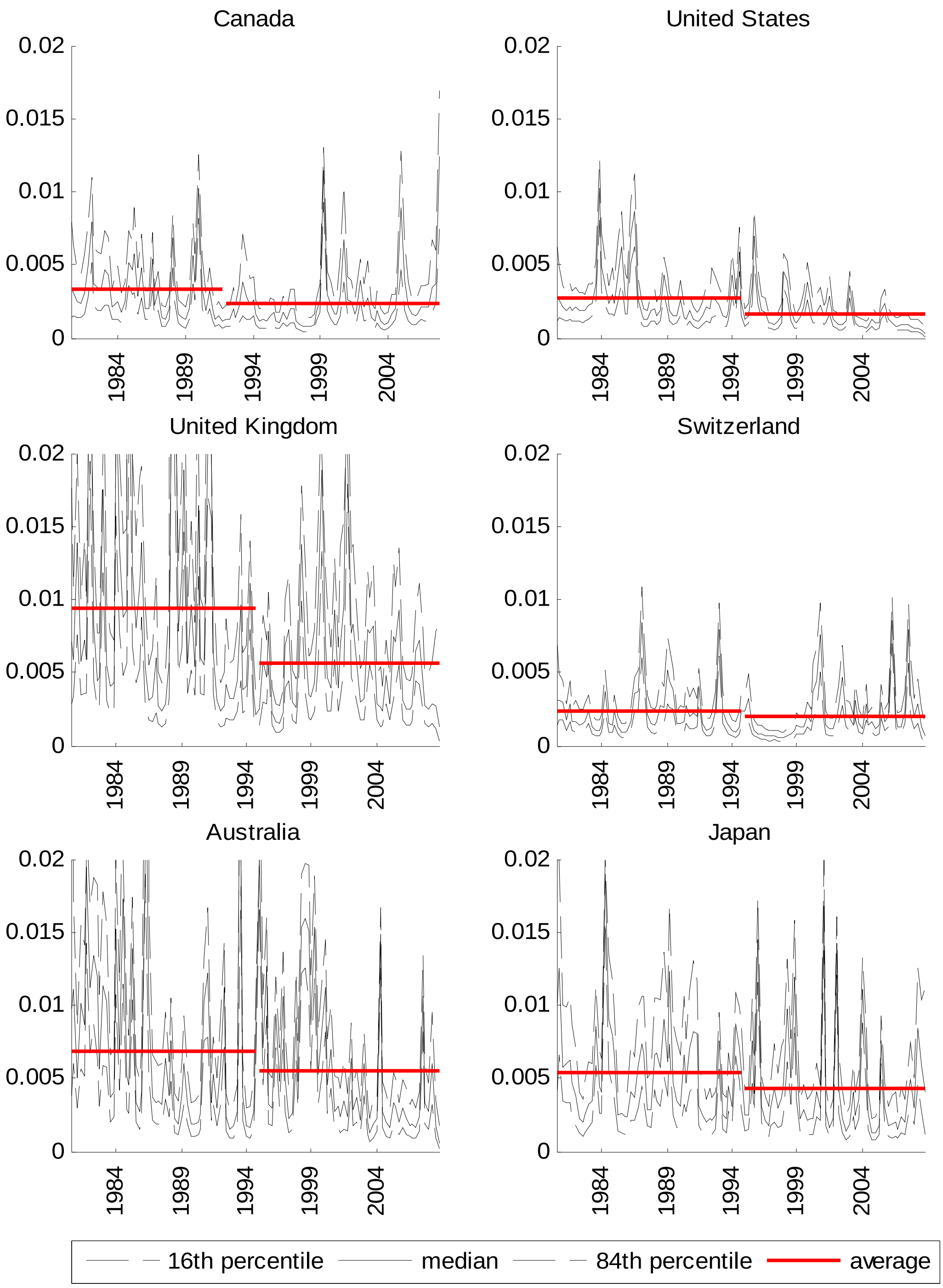


Figure 3: Estimated standard deviations of the reduced form residuals for government spending

Therefore, in order to get an indication of whether the reductions in volatility may be linked to inflation targeting, Figure 4 plots the central government debt to GDP ratio separately for five early inflation targeters and non-targeters (to better see the trends the series are de-meaned). In all five early targeters, we can see a decrease in government debt starting about 1-3 years after the formal adoption of an explicit inflation target (in the case of the UK after the subsequent granting of central bank instrument independence, which is a prerequisite of the regime). These improvements are sustained at least until the global financial crisis. In contrast, such improvements in the fiscal balance are not present for the non-targeters. It should however be emphasized that this does not in any way constitute evidence of causality.

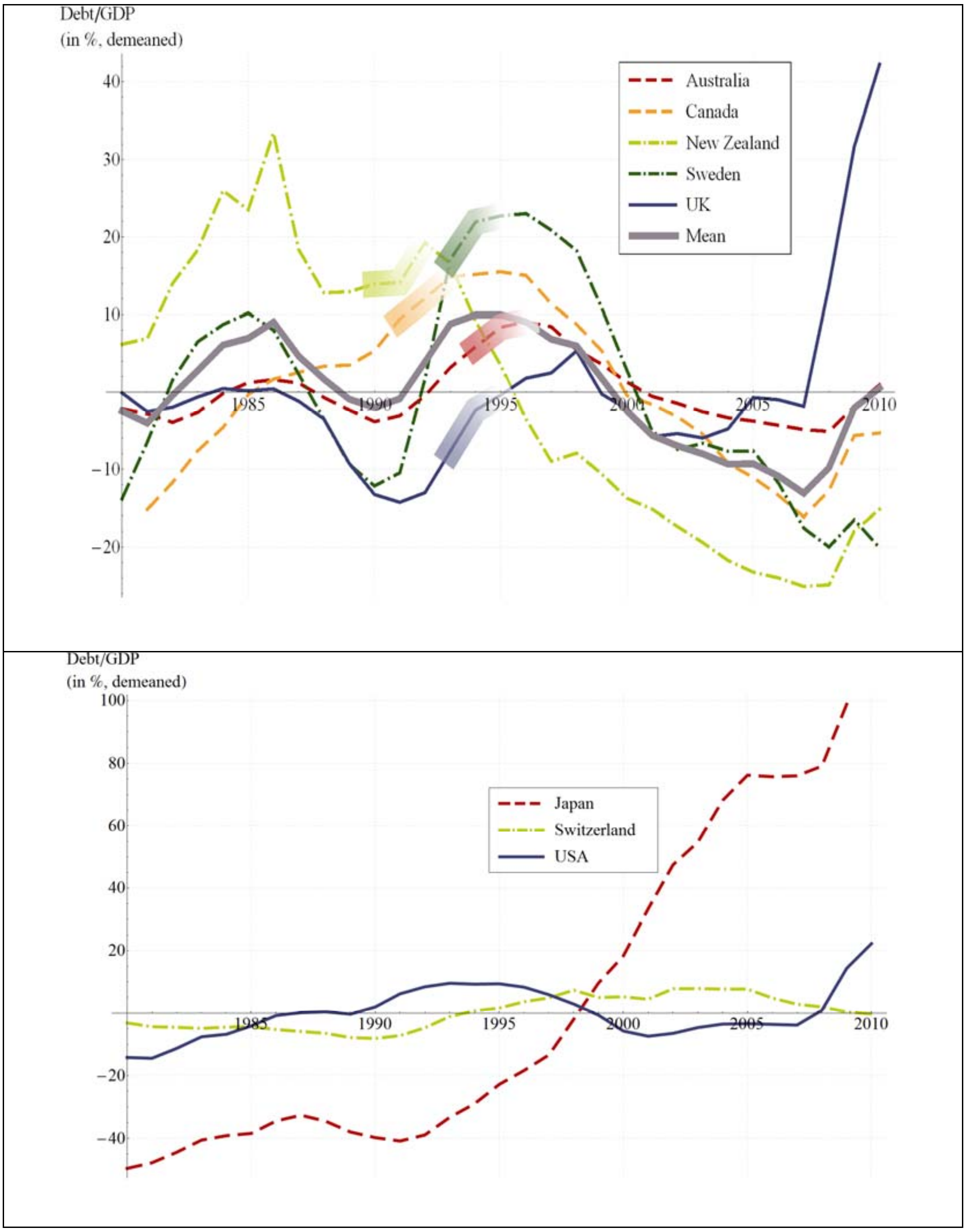


Figure 4: Central government debt to GDP ratio (de-meaned) for explicit inflation targeters (the top panel where the start of the regime is indicated by the shaded region) and non-targeters (the bottom panel).

5.2 Output and Private Consumption Multipliers

Figures 5 and 6 report output and private consumption multipliers, respectively, for the six considered countries (an illustrative depiction of the impact and 3rd quarter multipliers can be found in Figures 8-13). As there does not appear to be a major difference between inflation targeters and non-targeters, we discuss all countries together.

In terms of the output multipliers, the general pattern is similar for all countries. The multiplier for each time horizon is relatively stable over time. On impact, it exceeds one, with the 1980-2008 average impact multiplier being between 1.4 and 3 for all countries (except Switzerland where it is higher). In all countries the size of the output multiplier decreases monotonically over longer horizons (except for Australia where the peak can be observed approximately after a year). Specifically, Figures 8-13 show that the 3rd quarter multiplier is roughly 0.4-0.5 lower than the impact multiplier. The expansionary effect is close to zero after three years for most (but not all) periods/countries.

Our estimated output multipliers can be easily compared with those reported in the fiscal VAR literature because our setup features similar types of fiscal shocks and the same normalization. In comparison with other studies based on (constant parameter) VARs – see Table 2 in Hall (2009) – our estimated multipliers are relatively high. It is however important to note that Hall (2009) surveys effects of shocks to general government purchases while we focus on a subset of such shocks: those financed by debt. Government spending financed by higher taxes potentially affects output and private consumption in a different way than spending financed by debt, depending on whether the assumptions underlying Ricardian equivalence hold. In particular, if economic agents are myopic and/or credit constrained debt-financed spending has a larger stimulatory effect than tax financed spending.

Keeping this caveat in mind, at face value, our results are closest to Perotti (2008) who estimates multipliers achieving one after a year. Nevertheless, the profile of Perotti's estimated output multipliers differs from ours as they are higher over a longer horizon whereas ours are highest on impact. Regarding fiscal TVP-VARs, Pereira and Lopes (2010) found for the U.S. that the median response of output to a general spending shock exceeds unity after a year.

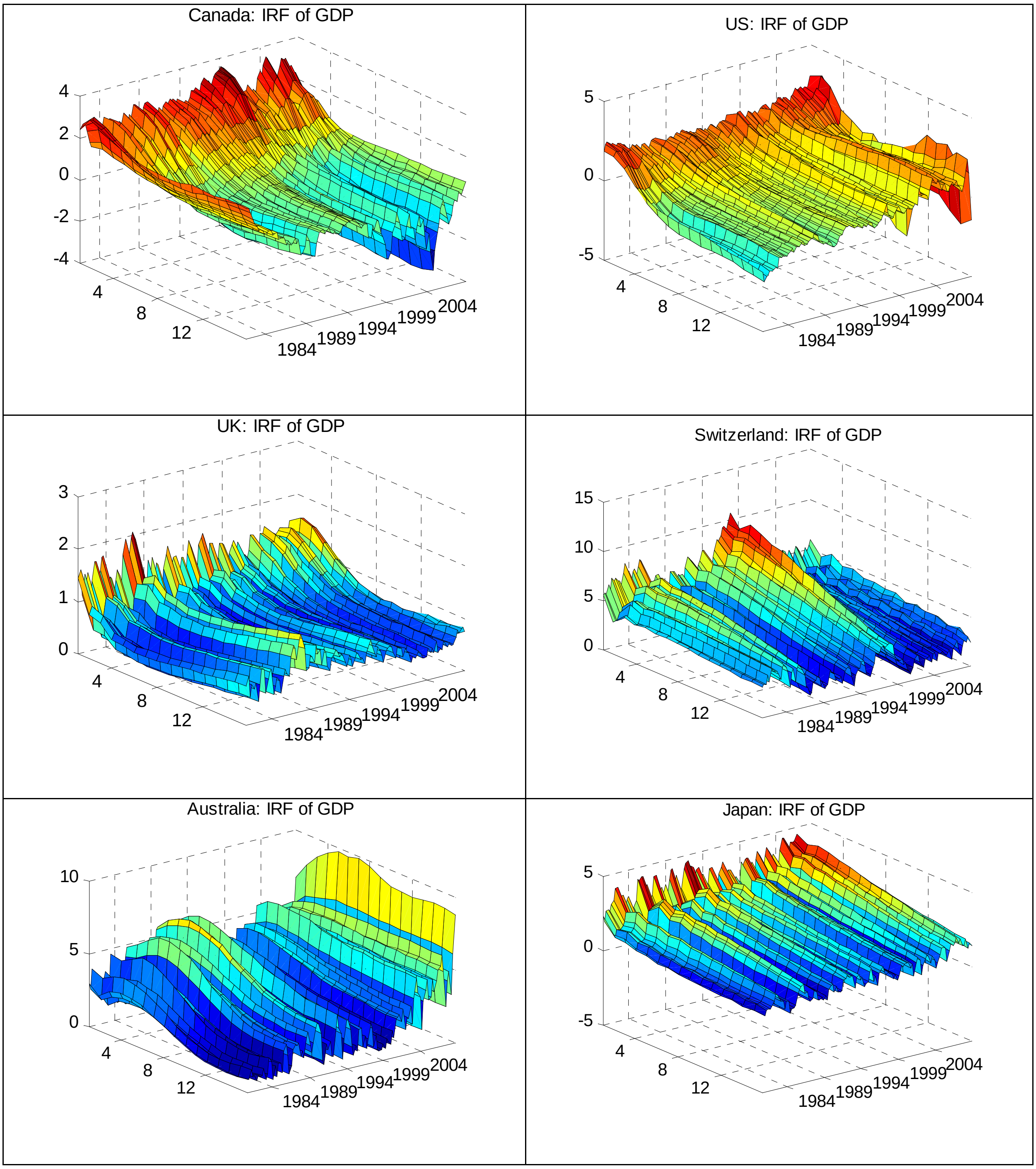
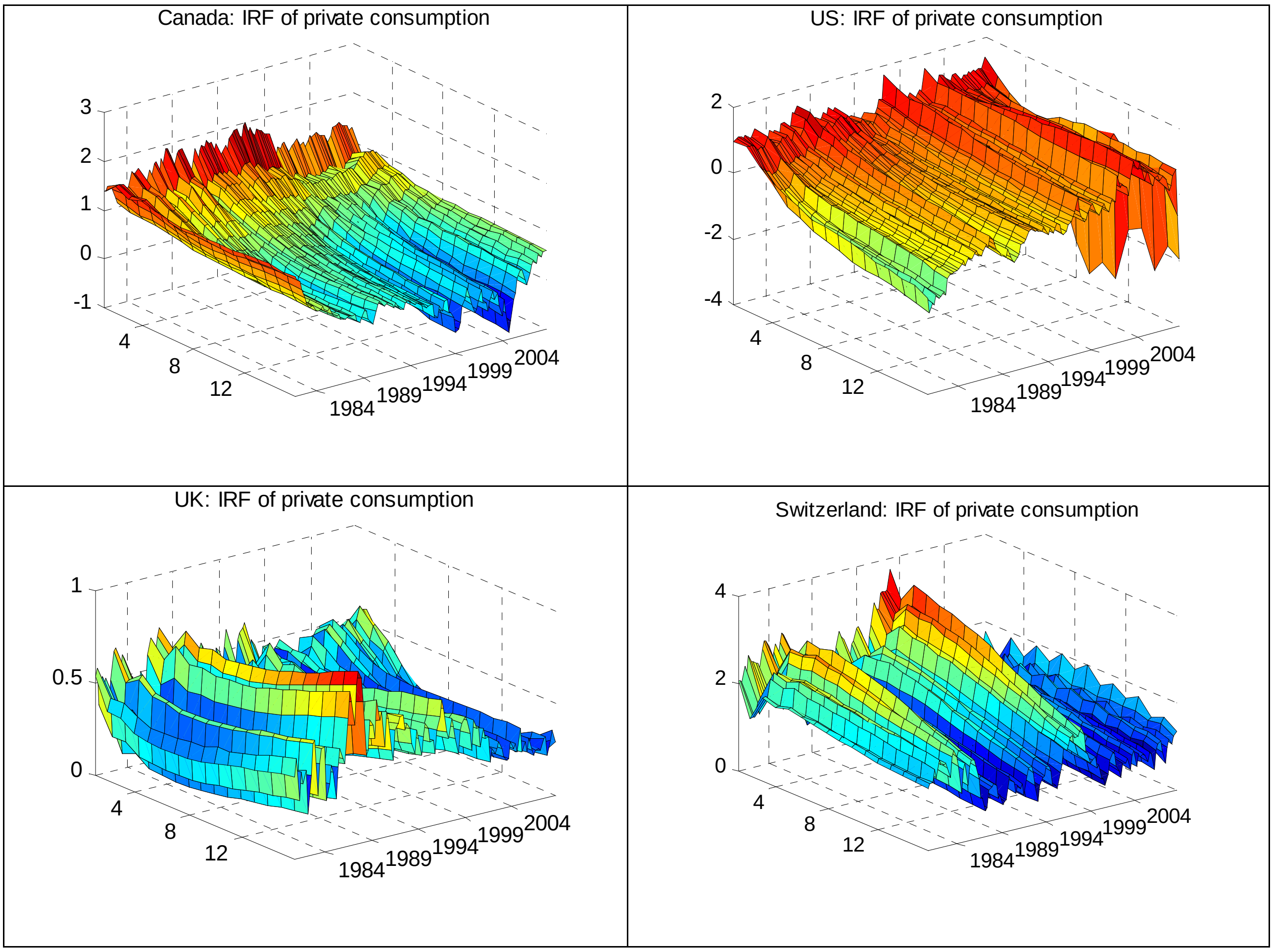


Figure 5: IRF of GDP to a debt-financed government spending shock.

Regarding the multiplier on private consumption, they are lower than output multipliers in all horizons - similarly to the literature. Nevertheless, on impact they still exceed unity for most countries and quarters. The average size of the impact multiplier is between 1 and 1.7 (except for the UK where it is lower and Switzerland where it is higher). The 3rd quarter consumption multipliers are slightly lower for all countries except Australia. Interestingly, a decline in the longer horizons consumption multiplier can be observed for Canada, UK and Switzerland in the 2000s.

The private consumption multipliers surveyed in Hall (2009) are also positive but very close to zero on impact. The difference in the considered type of spending shock discussed above is likely to be partly responsible for our higher estimates. Another difference is the multiplier profile: the majority of the papers surveyed in Hall (2009) find a growing size of the multiplier over longer horizons, the opposite of what we find (which is in line with Kirchner et al. (2010) who find declining multipliers in the Euro area).



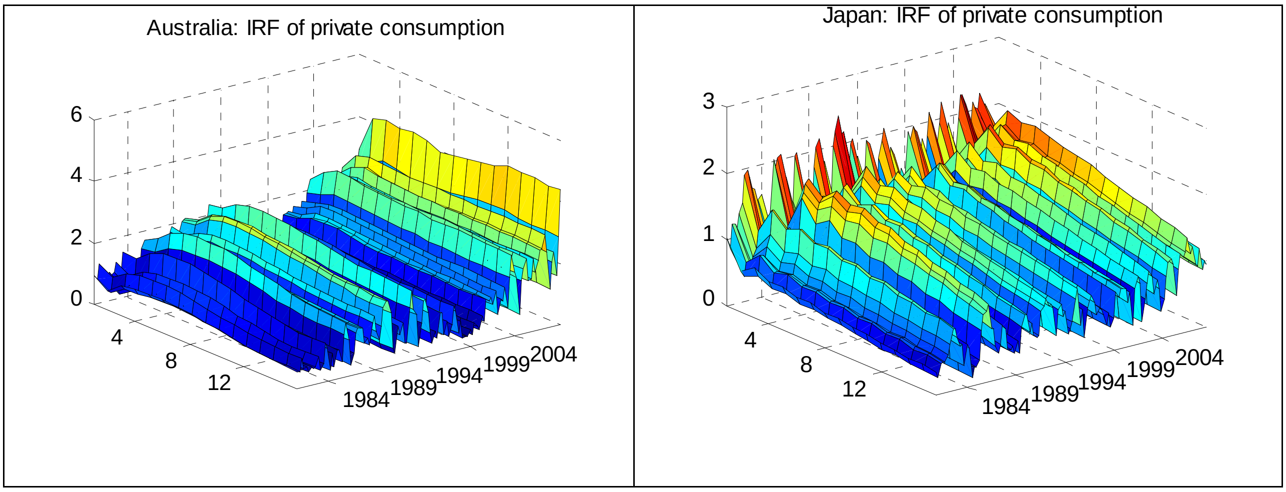


Figure 6: IRF of GDP to a debt-financed government spending shock

6 Robustness (yet to be finalized)

6.1 Sensitivity of Estimates to the Parameters of Prior Distributions

6.2 Robustness to Changing the Order of Endogenous Variables

7 Summary and Conclusions

It is uncontroversial that monetary and fiscal policies are inter-related even if the central bank is formally independent of the government. This is because the actions of each policy affect many important economic variables (including private expectations of the future), and these variables in turn affect the optimal responses of both policies in achieving their objectives. The fact that the institutional design of each policy affects incentives and outcomes of that policy is also uncontroversial. But could it be that the design affects the behavior and outcomes of the *other* policy in a major way? If so, how?

The paper attempts to track monetary-fiscal interactions over time and across several advanced countries in order to contribute to our understanding of the inter-relation of the two policies, and offer some tentative answers to these questions. It does so using a novel empirical framework that combines time varying parameter vector autoregression with the sign restrictions identification procedure.

Having first discussed the advantages of this framework vis-à-vis the standard fixed parameter VARs and/or the recursive identification method, we then report how monetary policy responses to debt-financed government spending shocks have changed in countries that had legislated an inflation target. Specifically, inflation targeting central banks generally stopped accommodative monetary policy and started offsetting such fiscal shocks by raising interest rates. No such change can be found in the non-targeters.

Interestingly, the beneficial effects of a stronger monetary commitment seem to have spilled over to fiscal policy too. The changed behavior of inflation targeting central banks is associated with a decrease in the variability of fiscal shocks as well, and a general improvement in the fiscal balance towards sustainability. Intuitively, this could be because the government's payoff decrease when engaged in a tug-of-war with the committed central bank, and its incentives to pursue excessive fiscal policy diminish.

While these results should only be taken as suggestive rather than conclusive, they suggest that an institutional reform of each policy may have positive effects on the outcomes of both policies. More research is required to shed light on the robustness of our findings, and the specific channels through which monetary and fiscal policies affect each other. This is of particular importance in the current situation of high economic uncertainty, and large fiscal gap facing advanced countries.

8 References

Batini, N., G. Callegari and J. Guerreiro (2011). An Analysis of U.S. Fiscal and Generational Imbalances: Who Will Pay and How? IMF WP/11/72.

Blanchard, O.J. and R. Perotti (2002). An empirical investigation of the dynamics effects of changes in government spending and taxes on output. *Quarterly Journal of Economics*, 117(4), 1329-68.

Bongaarts, J. (2004). Population Aging and the Rising Cost of Public Pensions. *Population and Development Review* 30(1): 1-23.

Canova. F. and E. Pappa (2007). Price differentials in monetary unions: The role of fiscal shocks, *The Economic Journal*, 117, 713-737.

Carter, C.K. and R. Kohn (1994). On Gibbs Sampling for State Space Models. *Biometrika*, 81, 541-553.

Clarida, R., J. Gali and M. Gertler (1998). Monetary Policy Rules in Practice: Some International Evidence. *European Economic Review* 42 6: 1033-67.

Cogley, T. and T.J. Sargent (2005). Drift and volatilities: Monetary policies and outcomes on the post WWII U.S.. *Review of Economic Studies*, 8, 262–302.

Dotsey, M. (2006). A review of inflation targeting in developed countries. *Federal Reserve Bank of Philadelphia Business Review* Q3.

Dungey, M. and R. Fry (2009). The identification of fiscal and monetary policy in a structural VAR. *Economic Modelling*, 26, 1147-1160.

Fatás, A. and I. Mihov, 2001. The effects of fiscal policy on consumption and employment: Theory and evidence, CEPR Discussion Paper 2760.

Favero, C. and F. Giavazzi (2007). Debt and the Effects of Fiscal Policy, NBER Working Paper, 12822.

Franta, M. (2011). Identification of Monetary Policy Shocks in Japan Using Sign Restrictions within the TVP-VAR Framework. IMES Discussion Paper, 2011-E-13, Bank of Japan.

Fry, R. and A.R. Pagan (2011). Sign Restrictions in Structural Vector Autoregressions: A Critical Review. *Journal of Economic Literature* (forthcoming).

Hur, J. (2011). Anticipated Fiscal Adjustment and Identification of Vector Autoregressions, mimeo, Indiana University.

Jacquier, E., N.G. Polson, and P.E. Rossi (1994). Bayesian analysis of stochastic volatility models. *Journal of Business and Economic Statistics*, 12, 371-389.

Kirchner, M., Cimadomo, J. and S. Hauptmeier (2010). Transmission of government spending shocks in the euro area: Tome variation and driving forces, ECB Working Paper, 1219.

Kuttner K. N. and A. S. Posen (2011). How flexible can inflation targeting be and still work? Bank of England (External MPC Unit) Discussion Paper No. 34.

Libich, J. (2011). Inflation Nutters? Modelling the Flexibility of Inflation Targeting. *The B.E. Journal of Macroeconomics (Topics)* 11(1), Article 17.

Libich, J. and P. Stehlík (2012). Monetary Policy Facing Fiscal Indiscipline Under Generalized Timing of Actions. *Journal of Institutional and Theoretical Economics*, in press.

Leeper, E.M., Walker, T.B., and S.S. Yang (2010). Government investment and fiscal stimulus. *Journal of Monetary Economics*, 57, 1000-1012.

Mertens, K. and M.O. Ravn (2010). Measuring the Impact of Fiscal Policy in the Face of Anticipation: A Structural VAR Approach. *The Economic Journal*, 120, 393-413.

Pappa, E. (2010). Government spending multipliers: An international comparison. Mimeo.

Pappa, E. (2009). The effects of fiscal shocks on the real wage and employment, International Economic Review, 50, 217-244.

Pereira, M.C. and A.S. Lopes (2011). Time varying fiscal policy in the U.S.. CEMAPRE Working Paper 1004.

Perotti, R. (2007). In search of the transmission mechanism of fiscal policy. NBER Macroeconomic Annual, Vol. 22, 169-249.

Primiceri, G.E. (2005). Time varying structural vector autoregressions and monetary policy. *Review of Economic Studies*, 72, 821–852.

Woodford, M. (1999). Optimal Monetary Policy Inertia. *Manchester School* 67 0: 1-35.

Wouters, R. (2005). Discussion of Scholl and Uhlig. Conference Macroeconomics and Reality 25 Years Later, Universitat Pompau Fabra.

Appendix A – Aging Populations

Figure 7 shows the old-age dependency ratios, defined as the proportion of the population aged at least 65 years old over the population aged 15-64.

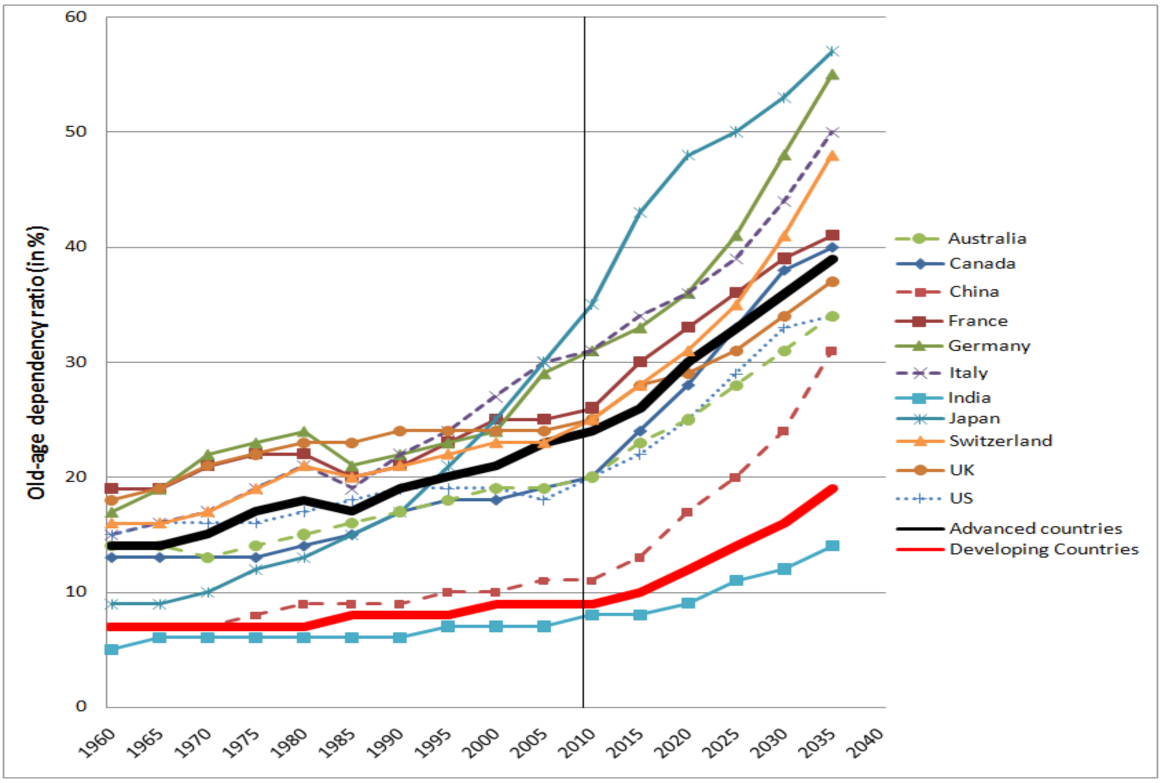


Figure 7: Old-age dependency ratios for selected countries (United Nations 2010 data)

The figure highlights the fact that populations (of virtually all industrial and many developing countries) are growing older due to lower population growth and increased life expectancy. In fact, the increases in Figure 7 do not reveal the full extent of the demographic shift in the labour market: Bongaarts (2004) reports the actual pensioner per worker ratio in advanced economies to be commonly 50-100% higher than the old-age dependency ratio.

A number of papers have analyzed the 'problematic' fiscal consequences of such demographic trends, see for example IMF (2009) or Batini et al (2011). The implications of excessive fiscal policy for monetary policy outcomes have been analyzed by Sargent and Wallace (1981) and the subsequent literature to which our paper attempts to contribute.

Appendix B – Gibbs sampler

The specification of the sampling algorithm and parameters of prior distributions mostly follows Primiceri (2005), Cogley and Sargent (2005), Kirchner et al. (2010) and Pereira and Lopes (2010).

B1. Priors

The prior distribution of the initial states ($\alpha_{i,0}$, $\beta_{i,0}$, $\log(\sigma_{i,0})$) is normal with means given by corresponding OLS estimates on the whole data sample. Assumed prior variances are proportional to estimated OLS variances for coefficients and to the identity matrix for the volatility states:

$$\beta_{i,0} \sim N\left(\beta_{i,0}^{OLS}, 4Var\left(\beta_i^{OLS}\right)\right)$$

$$\alpha_{i,0} \sim N\left(\alpha_{i,0}^{OLS}, 4Var\left(\alpha_i^{OLS}\right)\right)$$

$$\log\left(\sigma_{i,0}\right) \sim N\left(\log\left(\sigma_i^{OLS}\right), 10I_5\right).$$

The hyperparameter *U* and blocks of *V* are distributed as inverse-Wishart distribution:

$$U \sim IW\left(k_Q^2 \tau Var\left(\beta^{OLS}\right), \tau\right)$$

$$V_{bl} \sim IW\left(k_V^2\left(1+\dim\left(V_{bl}\right)\right)Var\left(A_{bl}^{OLS}\right), 1+\dim\left(V_{bl}\right)\right) \quad bl = 1, \ldots, 4$$

where $k_Q = 0.01$ and $k_V = 0.1$. The two parameters represent our prior belief on the proportion of uncertainty of the OLS estimate attributed to time-variation of VAR coefficients and elements of the matrix *A*. The degrees of freedom parameter τ equals 50 and we discuss the sensitivity of this parameter in Section 7.

Diagonal elements of the hyperparameter *W* are distributed as inverse-Gamma (Kirchner et al., 2010):

$$W_i = IG\left(\frac{k_w^2}{2}, \frac{1}{2}\right),$$

where $k_W = 0.01$.

B2. Estimation procedure

The Gibbs sampler exploits the fact that draws from the conditional distributions of subsets of model parameters (given the rest of the parameter set) represent a sample from the joint posterior distribution. So, the sampler can be described in several steps:

1) The vector of coefficient states β is estimated using the Carter and Kohn (1994) algorithm. For a given data and the history of the covariance and volatility states, equation (1) and (2) represent a linear Gaussian system with a known covariance matrix.

2) Covariance states stacked in the matrix A_t are also estimated employing the algorithm of Carter and Kohn (1994). Equation (1) implies that

$$\hat{y}_t = A_t\left(y_t - X_t\beta_t\right) = \Sigma_t\varepsilon_t, \qquad \text{(A1)}$$

i.e. given data and the history of coefficient and volatility states we again obtain a linear Gaussian system. The algorithm is applied equation by equation i.e. it yields draws of the covariance states stacked below the diagonal of A_t in turns.

3) To draw volatility states we follow Cogley and Sargent (2005). Given data and the history of coefficient and covariance states, the RHS of (A1) is observable. Assuming diagonality of the hyperparameter *W*, volatility states can be drawn as in Jacquier et al. (1994), i.e. a univariate algorithm is applied on the orthogonalized residuals element by element. Jacquier et al. (1994) describe a Metropolis step that produces a draw (if accepted) from the conditional posterior distribution for a volatility state.

4) Finally, given the data, coefficient states and covariance and volatility states, the innovations in (2)-(4) are observable. Priors on hyperparameters are distributed as inverse-Wishart (inverse-Gamma), thus posterior distributions take the same type of distribution and drawing of the hyperparameters is straightforward.

Appendix C – Convergence diagnostics (yet to be finalized)

Appendix D – The Theory Behind Strategic Monetary-Fiscal Interactions

Using game theoretic methods, the gist of the Sargent and Wallace (1981) and Leeper (1991) analyses can be presented in the following payoff matrix.

		Fiscal policymaker	
		Debt-financed Spending (active)	Tax-financed Spending (passive)
Monetary policymaker	Not Accommodate (active)	*a, w*	*b, x*
	Accommodate (passive)	*c, y*	*d, z*

The variables *{a, b, c, d, w, x, y, z}* denote the policymakers' payoffs that are functions of the structure of the economy, behavior of expectations, policy preference etc. Let us stress again that this represents a structural (i.e. cycle-free) situation: the economy is performing at potential, it is *not* at a cyclical swing that would require some specific (stimulatory) actions. Roughly speaking, Leeper's (1991) passive policies adjust to balance the intertemporal budget constraint of the government. Specifically, an increase in government spending is accompanied by an increase in (current or future taxes) under passive fiscal policy, and higher (current or future) inflation (via lower interest rates and debt monetization) under passive monetary policy. In contrast, active policies largely ignore the budget constraint: spending is financed by debt creation under active fiscal policy with active monetary policy not accommodating such actions due to its focus on achieving low inflation.

How can we relate this payoff matrix, which summarizes medium-long-term policy options free of cyclical considerations, to the estimates from the VAR framework commonly used for analyzing short-term policy responses to cyclical movements? When estimating the impulse responses of the interest rate to a debt-financed shock in a VAR framework, the exercise focuses - implicitly imposes - active fiscal policy. The exercise looks at the reactions of the central bank, i.e. roughly speaking asks whether monetary policy is active or passive.

The payoff matrix makes it transparent that, unless $a=c$, the central bank's (intended/actual) responses affect the payoffs of the government, and hence potentially its decision regarding a medium-run fiscal stance. Nevertheless, it should be pointed out that the TVP-VAR exercise cannot directly identify from the data which type of fiscal policy the government tended to pursue over time. As discussed in the main text, indirect evidence on this issue is provided by (i) the evolution of public debt over time, or by (ii) the estimated standard deviation of an unexpected change in government spending in the case of a debt-financed spending shock.

A number of papers starting Sargent and Wallace (1981) imply that in the presence of a fiscal gap the policy interaction can best be modeled as the Game of Chicken, whereby the above payoffs satisfy: $a>d>b>c$ and $z>w>x>y$. [15] In such case the game has two pure strategy Nash equilibria: (active monetary, passive fiscal) and (passive monetary, active fiscal). The fact that the former is preferred by the central bank, and the latter by the government implies that there is a policy conflict. In addition, the fact that both pure Nash equilibria are Pareto superior to the mixed Nash implies also a coordination problem between the policies.

Given that neither standard nor evolutionary game theory cannot select between the pure Nash equilibria, researchers have commonly applied Stackelberg leadership to the game. The leader in the game (the dominant policy) ensures its preferred pure Nash by being able to force the follower to coordinate. In the real world, leadership/dominance can be achieved by firm commitment of the policy to its preferred stance. Arguably, legislating a long-term numerical inflation target for the central bank may play a role of such commitment, giving it more ammunition to fight excessive fiscal policy. This would, in turn, ensure the (active monetary, passive fiscal) regime and an improvement in the fiscal balance compared to the other two equilibria. This is the underlying logic behind Hypotheses 1-2 of the main text.[16]

[15] Let us stress again that the payoffs relationships, and hence the class of game, would be different in a cyclical downturn such as the global financial crisis in which stimulatory actions (passive monetary and or active fiscal policy) are likely to be required.

[16] Libich and Stehlik (2011) generalize the timing of the policy moves to allow for arbitrary (stochastic or deterministic) policy revisions. Effectively, their framework converts the standard Stackelberg leadership concept from static to dynamic. The analysis refines the standard conclusion that the leader in the game always insures its preferred Nash equilibrium by showing that this depends on a number of economic and policy variables. Nevertheless, the fact that under reasonable circumstances the central bank's

Appendix E – IRFs to a Debt-financed Government Spending Shock for All Countries and Variables at Two Horizons

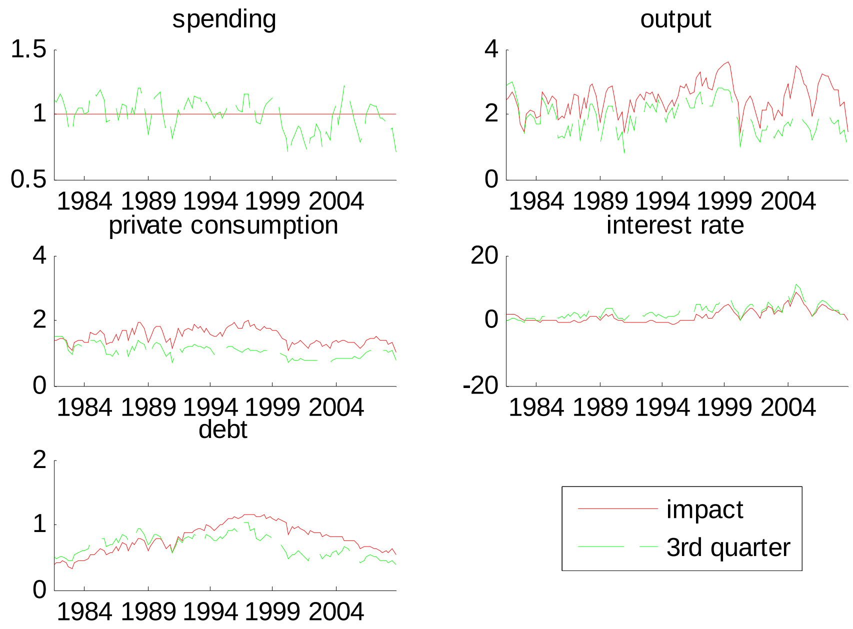


Figure 8: Canada: IRF on impact and in the 3rd quarter.

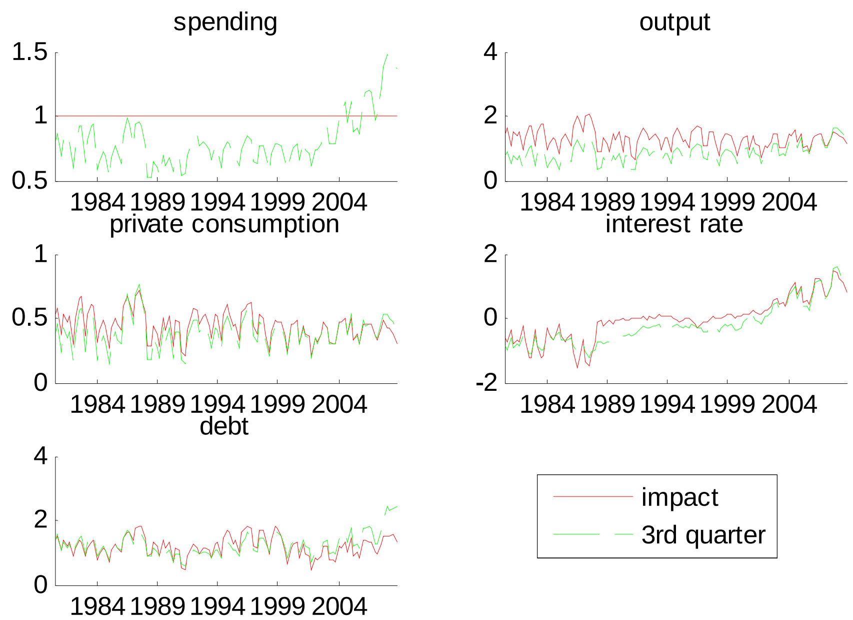


Figure 9: the UK: IRF on impact and in the 3rd quarter.

---

commitment reduces monetary accommodation of fiscal shocks and improves the government's incentives still obtains.

Figure 10: Australia: IRF on impact and in the 3rd quarter.

Figure 11: the U.S.: IRF on impact and in the 3rd quarter.

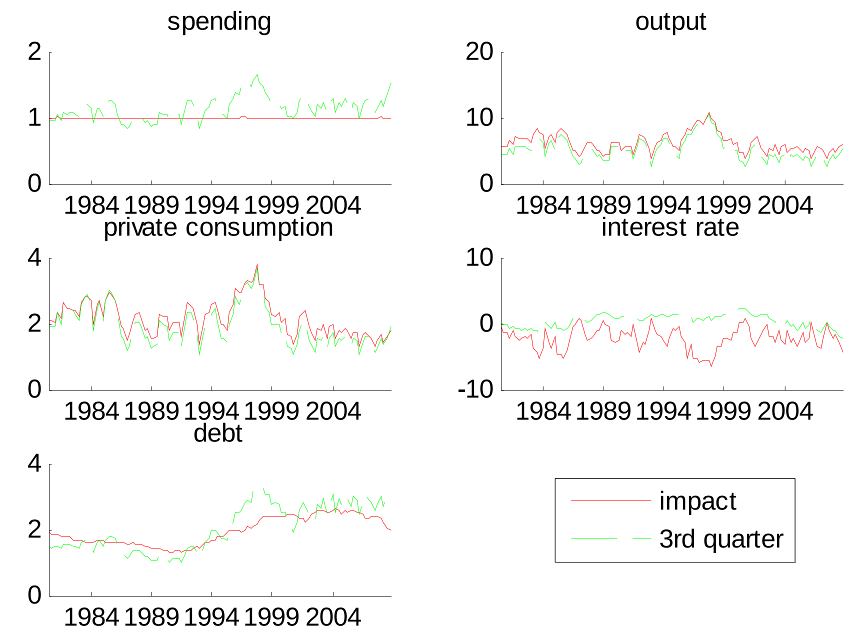


Figure 12: Switzerland: IRF on impact and in the 3rd quarter.

Figure 13: Japan: IRF on impact and in the 3rd quarter.

Appendix F – Illustration of the Estimates 'Uncertainty'

Figure 14: Canada: Impulse response functions on impact with centered 68 percents of posterior distribution.

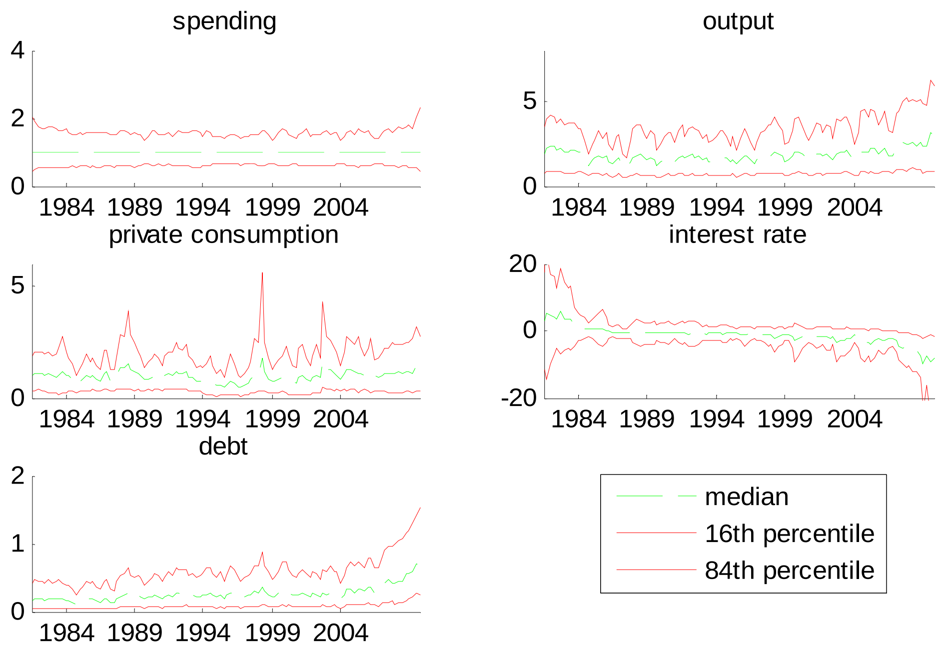


Figure 15: the U.S.: Impulse response functions on impact with centered 68 percents of posterior distribution.

Appendix G – Data sources (yet to be finalized)