

# WHAT ARE THE EFFECTS OF FISCAL POLICY SHOCKS? A VAR-BASED COMPARATIVE ANALYSIS\*

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## Abstract

In recent years VAR models have become the main econometric tool used to study the effects of fiscal policy shocks. Yet, the literature has so far failed to provide robust stylized facts and there is currently strong disagreement on even the qualitative response of key variables such as private consumption and employment to government spending shocks. We identify three aspects of existing empirical work which may be responsible for the absence of robust stylized facts: differences in specification of the reduced-form VAR model, differences in identification approaches and lack of comparability of the fiscal policy experiments considered in the literature. In order to assess the importance of each of these aspects we estimate a common reduced-form VAR model using data for the U.S. economy. Our main result is that specification issues and lack of comparability of policy experiments rather than differences in identification approaches explain the disagreement in the literature. In particular, all approaches yield the result that the response of private consumption to a spending shock follows a hump-shaped pattern and is significantly positive in the medium run. Moreover, the results suggest that a spending increase stimulates the economy in the medium run irrespective of whether it is deficit-financed or tax-financed. However, in the long run neither spending increases nor tax cuts have significant output effects.

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# 1 Introduction

In recent years vector autoregressive (VAR) models have become the main econometric tool used to study the effects of monetary and fiscal policy shocks. While there is a consensus on the effects of monetary policy shocks, the empirical literature has struggled so far to provide robust stylized facts on the effects of fiscal policy shocks. There is strong disagreement on even the qualitative response of key variables such as consumption, the real wage and employment to fiscal policy shocks. The aim of this paper is to investigate whether this lack of robust evidence is due to differences in specification of the reduced-form VAR models, differences in the policy experiments considered or differences in the identification approaches.

In order to assess the relative importance of these three aspects we estimate a common reduced-form VAR model for quarterly U.S. data for the period 1955-2004 and reports the results to government spending and government revenue shocks as well as for various policy experiments: a balanced-budget spending increase, a deficit-financed spending increase, a deficit-financed tax cut and a military buildup. These policy experiments are not only interesting from a theoretical and policymaking perspective but they are also necessary in order to make the results for different identification approaches truly comparable. We consider the four main identification approaches which have been proposed in the literature: the recursive approach applied by Fatas and Mihov (2001), the Blanchard and Perotti (2002) approach, the sign-restrictions approach introduced by Mountford and Uhlig (2005) as well as the fiscal dummy variable approach applied, e.g., by Edelberg et al. (1999). While the first three approaches solve the identification problem by transforming the reduced-form model into a structural model, the fiscal dummy variable approach looks for fiscal policy episodes which can be classified as exogenous with respect to the state of the economy. The other three approaches have in common that they look for ways to transform the reduced-form residuals such that the positive correlation between fiscal variables and output can be split into two components: the effects of automatic stabilizers on fiscal variables and the effects of discretionary fiscal policy on output. These approaches mainly differ in the way how they achieve this decomposition.

Our results suggest that specification issues and lack of comparability of policy experiments rather than differences in identification approaches explain the disagreement in the literature on the effects of government spending shocks. The results for all the methodologies considered in this paper suggest that following a pure spending shock private consumption, output and employment increase, while the real wage does not respond.

Interestingly, the output and consumption responses follow a hump-shaped pattern which is similar to the findings reported in the literature analyzing the effects of monetary policy shocks. As regards the effects of a pure revenue shock, the identification approaches considered in this paper do not agree. However, the results for the sign-restrictions approach suggesting that output, private consumption, nonresidential investment and employment fall in response to a pure revenue shock seem most plausible. In contrast, the recursive approach and the Blanchard-Perotti approach yield the puzzling result that macroeconomic variables do not react to such a shock. The results of a robustness analysis suggest that the reliability of the Blanchard-Perotti approach is impaired by the high sensitivity of the results to the value of the key parameter measuring the size of automatic stabilizers imposed in the estimation of the structural VAR model, while the recursive approach is too restrictive because it rules out any impact response of output to a revenue shock. Apart from providing results for pure government spending and revenue shocks, this paper also presents evidence for various policy experiments. In this respect, the results suggest that both a deficit-financed tax cut and a deficit-financed spending increase have expansionary effects in the short run, while a tax-financed spending increase depresses activity in the short run. A government spending increase stimulates the economy in the medium run irrespective of whether it is deficit-financed or tax-financed, whereas a deficit-financed tax cut has no output effects in the medium run. In the long run, neither spending increases nor deficit-financed tax cuts have significant output effects.

The remainder of this paper is organized as follows. Section 2 briefly reviews the literature with a focus on those aspects which are most relevant for our comparative analysis. Section 3 presents the econometric methodology, including a description of the data, the reduced-form VAR model and the alternative identification approaches. Section 4 presents the results for the pure government spending and revenue shocks. Section 5 presents the results for the four policy experiments mentioned above. Section 6 presents a sensitivity analysis with a special focus on the size of automatic stabilizers. Section 7 concludes.

## 2 Review of the Literature

This section reviews the empirical literature having applied VAR models to the study of the effects of fiscal policy shocks on the U.S. economy. More comprehensive surveys of the literature, including discussions of the effects of fiscal policy in traditional structural

macroeconometric models and dynamic general equilibrium models, have recently been provided by Perotti (2001) and Hemming et al. (2002). The focus of this section, instead, is on those aspects of existing research which are of particular relevance to our comparative analysis. This section first shows in which areas there is agreement in the literature and, more importantly, disagreement on the empirical effects of fiscal policy shocks and discusses how the absence of robust stylized facts on the empirical effects of fiscal policy shocks impairs theoretical research in this area. Against this background, this section subsequently reviews three aspects of existing empirical work which may be responsible for the absence of robust stylized facts: First, differences in specification of the reduced-form VAR model adopted in the literature; second, differences in identification approaches adopted in the literature, with a special emphasis on the distinction between the effects of automatic stabilizers on fiscal variables and the effects of discretionary fiscal policy on the macroeconomy; third, the lack of comparability of the fiscal policy experiments considered in the literature, a point which again impairs theoretical research in this area.

The following sentence taken from Perotti's (2001: 23) survey article nicely captures the lack of robust evidence on the effects of fiscal policy shocks: "*[...] despite some methodological advances, there is absolutely no consensus on even the basic effects of fiscal policy on the macroeconomy.*" While this statement is probably too strong as stated above, Perotti rightly drew attention to the fact that there is no agreement on the effects of fiscal policy on those macroeconomic variables which would be helpful to discriminate among competing theories. Table 1 shows for a selection of empirical papers that there is actually agreement on the short-run output effects of government spending shocks. However, at least for theory-building purposes this finding is not particularly helpful as both standard neoclassical models and Keynesian models can generate an increase in output in response to a spending shock. Much more interesting and controversial is the response of private consumption: While some parts of the literature report a statistically significant positive response of private consumption to a spending shock, other parts of the literature suggest that private consumption either does not react or even falls in response to a government spending shock. This is interesting insofar as the standard stochastic neoclassical growth model, analyzed in Baxter and King (1993) for example, predicts that private consumption falls in response to a spending shock due to the negative wealth effect associated with the spending increase. In a recent paper, Burnside et al. (2004) show that an estimated version of the standard neoclassical model can account for the qualitative effects of government spending shocks. Yet, this statement on the accuracy of the theoretical model critically hinges on the validity of the empirical evidence reported by these authors, suggesting that

a fall in private consumption is consistent with the data. At the same time, another part of the theoretical literature has searched for modifications of the standard neoclassical model which would make its predictions consistent with a rise in private consumption, taken to be a stylized fact because of the empirical results reported by Blanchard and Perotti (2002). For example, Galí et al. (2004) proposed a dynamic general equilibrium model introducing a number of frictions as well as rule-of-thumb consumers. They showed that in this setup it is possible to generate a rise in private consumption in response to a government spending shock. As regards the empirical effects of government revenue shocks on the U.S. economy, Table 1 shows that there is also disagreement in the literature. Blanchard and Perotti (2002) report significant negative effects of government revenue shocks on output and private consumption both in the short and in the long run, while Perotti (2005) reports a zero short-run response and Mountford and Uhlig (2005) report a zero long-run response. Against the background of the disagreement in the literature this paper explores whether it is possible to obtain more clear-cut evidence on the effects of fiscal policy shocks on key macroeconomic variables. To our eyes, the following three aspects handled differently in the empirical literature may potentially be responsible for the lack of clear-cut stylized facts.

First, there are *differences in the specification of the underlying reduced-form VAR models*. These differences concern the set of variables included in the analysis, the distinction between stochastic trends and deterministic trends in the variables, the choice of sample size as well as sample start and end dates, the inclusion of deterministic terms (constant, linear time trend, quadratic time trend, dummy variables) as well as the choice of lag length. As regards the set of variables, Blanchard and Perotti (2002) use the smallest model consisting of three variables only, while Mountford and Uhlig (2005) use the largest model consisting of ten variables. Unlike the other papers in this literature Mountford and Uhlig (2005) include monetary aggregates and commodity prices in the analysis in order to be able to identify a monetary policy shock. However, these authors report that the results for the fiscal shocks are not sensitive to the (non)identification of the monetary policy shock and that there is no evidence for sizeable monetary and fiscal policy interaction. As regards the treatment of stochastic versus deterministic trends, the literature in general uses the variables in levels without explicitly accounting for potential cointegration. A drawback of this procedure is that, while the model parameters can be estimated consistently (Sims et al. 1990), impulse responses based on the estimation of the model without cointegration restrictions may be inconsistent at long horizons (Phillips 1998). However, weighing this drawback against the consequences of imposing a wrong

cointegration rank, the literature estimates unrestricted VAR models instead of vector error correction models. As regards the choice of sample, Mountford and Uhlig (2005) and Blanchard and Perotti (2002) estimate their models on a sample starting in 1955 and 1960, respectively. With this choice they exclude the military buildup at the beginning of the 1950s in connection with the Korean war, which has been studied by, e.g., Edelberg et al. (1999). As shown by Perotti (2006) the spending increase associated with the Korean war has exceptional characteristics, which suggest that this episode may not be very informative for the effects of typical fiscal shocks. As regards the inclusion of deterministic terms, there are also large differences in the literature, with Mountford and Uhlig (2005) at one extreme including no deterministic terms at all and Blanchard and Perotti (2002) at the other extreme including a constant, linear and quadratic time trends, seasonal dummies, a dummy variable capturing the 1975 tax rebate and quarter-dependent coefficients. In the fiscal dummy variable approach applied, e.g., by Edelberg et al. (1999) one of the deterministic terms, i.e. the dummy variable capturing the onset of the Korean War, the Vietnam War and the Reagan military buildup, plays a key role in the identification of fiscal shocks. Finally, as regards the choice of lag length, the studies in this literature opt for either four or six lags of the endogenous variables.

Second, there are *differences in the identification of fiscal policy shocks*. As the unrestricted VAR models used at the estimation stage are reduced-form models they cannot directly be used for structural inference and policy analysis. An identification problem has to be solved such that the VAR model can be given a structural interpretation. The main challenge is to recover fiscal policy shocks which are orthogonal to the state of the economy. In practice, the residuals recovered from the estimation of the reduced-form VAR model are highly correlated. In particular, there is a strong positive correlation between the residuals of the output and government revenue equations. There are at least two potential interpretations: Either this positive correlation reflects the effects of automatic stabilizers on government revenue or it reflects the effects of discretionary tax changes on output. To most economists the first interpretation is probably more plausible than the second one as the latter implies that exogenous increases in taxes have a positive effect on output. In the literature three main identification approaches have been proposed to distinguish automatic stabilizers from discretionary policy. The simplest approach is the recursive approach introduced by Sims (1980) and applied to the study of fiscal policy by Fatas and Mihov (2001). The recursive approach implies a causal ordering of variables and imposes zero restrictions on the impact response of variables ordered before the variable that is hit by a shock. In our context, ordering output before government revenue implies

that the positive short-run comovement between these two variables is entirely attributed to the effects of automatic stabilizers, whereas revenue shocks have no effect on output on impact. The second approach is the structural VAR approach proposed by Blanchard and Perotti (2002) and extended by Perotti (2005) which exploits institutional information on the tax and transfer system in order to quantify the importance of automatic stabilizers. These authors follow a two-step approach. The first step mainly consists in the cyclical adjustment of government revenue, from which these authors obtain a value for the output elasticity of government revenue. In the second step, the value for this elasticity is used in the identification of the structural VAR model. This procedure allows these authors to leave the short-run response of output to government revenue shocks unrestricted, which can be seen as the main departure from the recursive approach. The third approach is the sign-restrictions approach introduced by Uhlig (2005) and applied to fiscal policy by Mountford and Uhlig (2005). Unlike the other two approaches this approach does not impose any zero restrictions on the impulse responses. Instead, it restricts the sign of the impulse responses for a number of quarters after a shock occurred. Mountford and Uhlig (2005) address the problem of the positive correlation of output and revenue residuals by first identifying a business cycle shock and by then requiring the government revenue shock to be orthogonal to the business cycle shock. An advantage of this approach is that unlike the recursive approach it does not impose a zero restriction on the impact output response to revenue shocks and that unlike the Blanchard-Perotti approach it does not require a two-step estimation procedure. However, a disadvantage of this approach is that by attributing the positive correlation of the output and revenue residuals entirely to the business cycle shock it rules out by construction non-Keynesian effects of fiscal policy (see, e.g., Giavazzi et al. 2000), i.e. it rules out that a revenue shock may have positive output effects for the first few quarters after the shock occurred. In this paper we apply all three identification approaches. In addition, we also provide results for the fiscal dummy variable approach introduced by Ramey and Shapiro (1998) and applied to VAR models by Edelberg et al. (1999) among others. The idea of the fiscal dummy variable approach is that the spending increases associated with the Korean War, the Vietnam War and the Reagan military buildup were exogenous to the state of the economy. Thus, there is no need to identify the structural form of the VAR model and the analysis can be based on the reduced-form VAR model, which for the implementation of this approach is augmented with a dummy variable capturing these three episodes.

Third, there are *differences in the policy experiments considered*. All the empirical papers in this literature with the exception of Mountford and Uhlig (2005) report results

for what the last-mentioned authors call "pure" government spending and revenue shocks. The key issue is that to each of these shocks there will be a dynamic response of both government spending and government revenue. Consider the example of a government spending shock: Blanchard and Perotti (2002: 1348) show that in response to a spending shock government revenue increases, while Mountford and Uhlig (2005: 35) report that government revenue falls in response to a spending shock. Comparing the responses to a spending shock for these two studies is, thus, like comparing apples and oranges because in one case the policy experiment consists in a spending increase partly financed by an increase in government revenue whereas in the other case the spending increase is accompanied by a fall in government revenue. The solution to this problem is to estimate the responses to true policy experiments. As Mountford and Uhlig (2005) argue such policy experiments can easily be constructed by a linear combination of the pure spending and revenue shocks. They report results for three policy experiments: (i) a balanced-budget spending increase, (ii) a deficit-financed spending increase and (iii) a deficit-financed tax cut. Apart from ensuring the comparability of the results of the different VAR approaches, the consideration of policy experiments has the additional advantage that this is what is needed to guide theory building. In the standard neoclassical growth model analyzed by Baxter and King (1993) a government spending shock financed by distortionary taxes has a negative effect on output, while a spending shock financed by an increase in lump-sum taxes (which in this setting is equivalent to a deficit-financed spending shock) has a positive effect on output. In this paper we follow Mountford and Uhlig's (2005) approach and, in addition to showing results for the pure shocks, we report results for the three policy experiments mentioned above. This allows a meaningful comparison of the results for the various identification approaches. In addition, we also report results for the fiscal dummy variable approach for the military buildup episodes which can be seen as a fourth policy experiment.

Against this background, the remainder of this paper investigates which of these three issues may be responsible for the disagreement on the effects of fiscal policy shocks reported in the literature. The subsequent empirical analysis is based on a common VAR specification and identical policy experiments and is carried out for the four main identification approaches considered in the literature. The results suggest that specification issues and lack of comparability of policy experiments rather than differences in identification approaches explain the disagreement on the effects of government spending shocks. Controlling for specification and considering harmonized policy experiments allows us to obtain stylized facts on the effects of fiscal policy shocks.

### 3 Econometric Methodology

This section presents the vector autoregressive methodology used in the empirical application. It first presents the benchmark reduced-form VAR model and then discusses how we implement the various identification approaches. We estimate our model with quarterly data for the United States for the 1955-2004 period, which gives us a sample size of 200 observations.<sup>1</sup> Following Perotti (2005) our benchmark model is a five-variable VAR model including the log of real per capita output,  $y_t$ , the log of real per capita government spending (government consumption plus government investment),  $g_t$ , the log of government revenue (net of transfers),  $\tau_t$ , the GDP deflator inflation rate,  $\pi_t$ , and the 3-month Treasury Bill interest rate,  $r_t$ . In addition, we specify six-variable VAR models adding in turn the log of real per capita private consumption,  $c_t$ , the log of real per capita private nonresidential investment,  $i_t^{NR}$ , the log of real per capita private nonresidential investment,  $i_t^R$ , the log of total employment,  $n_t$ , and the log of the real wage,  $w_t$ , to the benchmark set of variables. Details on the sources of the variables used and on the construction of the government revenue series can be found in the Appendix. Collecting the endogenous variables in the  $k$ -dimensional vector  $X_t$  the reduced-form VAR model can be expressed as

$$X_t = \mu_0 + \mu_1 t + A(L)X_{t-1} + u_t, \quad (1)$$

where  $\mu_0$  is a constant,  $t$  is a linear time trend,  $A(L)$  is a 4th-order lag polynomial and  $u_t$  is a  $k$ -dimensional vector of reduced-form disturbances with  $E[u_t] = 0$ ,  $E[u_t u_t'] = \Sigma_u$  and  $E[u_t u_s'] = 0$  for  $s \neq t$ . We follow Blanchard and Perotti (2002) and choose a lag length of four quarters. This seems to be a natural choice in a model with quarterly data and, moreover, using a higher lag order like, e.g., Mountford and Uhlig (2005) does not affect the results. Deterministic terms other than the constant and the linear time trend like the quadratic time trend, the seasonal dummy variables and the quarter-dependent coefficients considered by Blanchard and Perotti (2002) turned out to be insignificant, thus we dropped them. For the policy experiment showing the effects of a military buildup for the fiscal dummy variable approach we augment our baseline VAR model with a dummy

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<sup>1</sup>With this choice we exclude the military buildup at the beginning of the 1950s in connection with the Korean War. The main reason is that as shown by Perotti (2006) the spending increase with the Korean War has exceptional characteristics, suggesting that this episode is not representative of a typical fiscal policy shock.

variable capturing the onset of the Vietnam war in 1965 and the onset of the Reagan military buildup in 1980 (see Section 5.4).

We follow Mountford and Uhlig (2005) and estimate the VAR model using Bayesian methods. The main advantage of the Bayesian approach is that it allows for a conceptually clean way of drawing error bands for impulse responses (see Sims and Zha 1999).<sup>2</sup> We use a Normal-Wishart prior for the coefficient matrices  $A(L)$  and  $\Sigma_u$ , implying that the posterior also belongs to the Normal-Wishart family. We take 500 draws from the posterior of the reduced-form VAR model and, for each draw of the posterior, identify the structural shocks for the three identification approaches discussed below. In Sections 4-6 we provide results in terms of impulse responses, reporting the median of the posterior distribution of the responses as well as error bands based on the 16% and 84% fractiles of the posterior distribution.<sup>3</sup>

As the reduced-form disturbances will in general be correlated it is necessary to transform the reduced-form model into a structural model. Premultiplying the above equation by the  $(k \times k)$  matrix  $A_0$  gives the structural form

$$A_0 X_t = A_0 \mu_0 + A_0 \mu_1 t + A_0 A(L) X_{t-1} + B e_t, \quad (2)$$

where  $B e_t = A_0 u_t$  describes the relation between the structural disturbances  $e_t$  and the reduced-form disturbances  $u_t$ . In the following, it is assumed that the structural disturbances  $e_t$  are uncorrelated with each other, i.e., the variance-covariance matrix of the structural disturbances  $\Sigma_e$  is diagonal. The matrix  $A_0$  describes the contemporaneous relation among the variables collected in the vector  $X_t$ . In the literature this representation of the structural form is often called the  $AB$  model (see, e.g., Lütkepohl 2005: 364). Without restrictions on the parameters in  $A_0$  and  $B$  the structural model is not identified. In the following we present the identification approaches used in the empirical application.

### 3.1 The recursive approach

The first approach we consider is the recursive approach which restricts  $B$  to a  $k$ -dimensional identity matrix and  $A_0$  to a lower triangular matrix with unit diagonal, which implies the

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<sup>2</sup>The main conclusions are not affected by the choice of a Bayesian approach rather than a classical approach. As regards the empirical results presented in this paper, the median impulse responses obtained using the Bayesian approach are nearly identical to the point estimate of the responses obtained using the classical approach.

<sup>3</sup>See Uhlig (2005: 409-410) for technical details on the estimation approach.

decomposition of the variance-covariance matrix  $\Sigma_u = A_0^{-1}\Sigma_e(A_0^{-1})'$ .<sup>4</sup> This decomposition is obtained from the Cholesky decomposition  $\Sigma_u = PP'$  by defining a diagonal matrix  $D$  which has the same main diagonal as  $P$  and by specifying  $A_0^{-1} = PD^{-1}$  and  $\Sigma_e = DD'$ , i.e. the elements on the main diagonal of  $D$  and  $P$  are equal to the standard deviation of the respective structural shock. The recursive approach implies a causal ordering of the model variables. Note that there are  $k!$  possible orderings in total. In this paper we order the variables as follows: government spending is ordered first, output is ordered second, inflation is ordered third, government revenue is ordered fourth and the interest rate is ordered last. This implies that the relation between the reduced-form disturbances  $u_t$  and the structural disturbances  $e_t$  takes the following form:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ -\alpha_{yg} & 1 & 0 & 0 & 0 \\ -\alpha_{\pi g} & -\alpha_{\pi y} & 1 & 0 & 0 \\ -\alpha_{\tau g} & -\alpha_{\tau y} & -\alpha_{\tau \pi} & 1 & 0 \\ -\alpha_{rg} & -\alpha_{ry} & -\alpha_{r\pi} & -\alpha_{r\tau} & 1 \end{bmatrix} \begin{bmatrix} u_t^g \\ u_t^y \\ u_t^\pi \\ u_t^\tau \\ u_t^r \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_t^g \\ e_t^y \\ e_t^\pi \\ e_t^\tau \\ e_t^r \end{bmatrix}. \quad (3)$$

This particular ordering of the variables has the following implications: (i) Government spending does not react contemporaneously to shocks to other variables in the system, (ii) output does not react contemporaneously to government revenue, inflation and interest rate shocks, but is affected contemporaneously by government spending shocks, (iii) inflation does not react contemporaneously to government revenue and interest rate shocks, but is affected contemporaneously by government spending and output shocks, (iv) government revenue does not react contemporaneously to interest rate shocks, but is affected contemporaneously by government spending, output and inflation shocks, and (v) the interest rate is affected contemporaneously by all shocks in the system. Note that after the initial period the variables in the system are allowed to interact freely, i.e., for example, government revenue shocks can affect output in all periods after the one in which the shock occurred.

The assumptions on the contemporaneous relations between the variables can be justified as follows: Movements in government spending, unlike movements in government revenue, are largely unrelated to the business cycle. Therefore, it seems plausible to assume that government spending is not affected contemporaneously by shocks originating in the private sector. Ordering output and inflation before government revenue can be justified on the grounds that shocks to these two variables have an immediate impact on

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<sup>4</sup>See, e.g., Lütkepohl (2005: 58).

the tax base and, thus, a contemporaneous effect on government revenue. This particular ordering of variables, thus, captures the effects of automatic stabilizers on government revenue, while it rules out (potentially important) contemporaneous effects of discretionary tax changes on output and inflation. Ordering the interest rate last can be justified (i) on the grounds of a central bank reaction function implying that the interest rate is set as a function of the output gap and inflation, and (ii) given that government spending and revenue as defined here (net of interest payments) are not sensitive to interest rate changes.

### 3.2 The Blanchard-Perotti approach

The identification approach due to Blanchard and Perotti (2002) relies on institutional information about tax and transfer systems and about the timing of tax collections in order to identify the automatic response of taxes and government spending to economic activity. This identification scheme relies on a two-step procedure: In a first step, the institutional information is used to estimate cyclically adjusted taxes and government expenditures. In a second step, estimates of fiscal policy shocks are obtained. Blanchard and Perotti (2002) and Perotti (2005) applied this approach to estimate the effects of tax and government spending shocks for the United States. This subsection relies on the identification scheme used by Perotti (2005) as he also used a five-variable VAR model while Blanchard and Perotti's (2002) analysis built on a three-variable system. Adapting Perotti's (2005) starting point to our context, the relationship between the reduced-form disturbances  $u_t$  and the structural disturbances  $e_t$  can be written as

$$u_t^g = \alpha_{gy}u_t^y + \alpha_{g\pi}u_t^\pi + \alpha_{gr}u_t^r + \beta_{g\tau}e_t^\tau + e_t^g, \quad (4)$$

$$u_t^\tau = \alpha_{\tau y}u_t^y + \alpha_{\tau\pi}u_t^\pi + \alpha_{\tau r}u_t^r + \beta_{\tau g}e_t^g + e_t^\tau, \quad (5)$$

$$u_t^y = \alpha_{yg}u_t^g + \alpha_{y\tau}u_t^\tau + e_t^y, \quad (6)$$

$$u_t^\pi = \alpha_{\pi g}u_t^g + \alpha_{\pi y}u_t^y + \alpha_{\pi\tau}u_t^\tau + e_t^\pi, \quad (7)$$

$$u_t^r = \alpha_{rg}u_t^g + \alpha_{ry}u_t^y + \alpha_{r\pi}u_t^\pi + \alpha_{r\tau}u_t^\tau + e_t^r, \quad (8)$$

Note that the above system of equations is not identified. The variance-covariance matrix of the reduced-form disturbances has ten distinct elements whereas the above system of equations has 17 free parameters. Unlike the recursive approach the Blanchard-Perotti approach does not involve imposing (only) zero restrictions on seven parameters in order to achieve identification. The first step of the estimation strategy consists in an adjustment of government spending and revenue for the automatic response of these variables to the business cycle and inflation. For this purpose, Perotti (2005) regresses individual revenue items on their respective tax base, obtaining an aggregate value for the output elasticity of government revenue ( $\alpha_{\tau y}$ ) of 1.85 and an aggregate value for the inflation elasticity of government revenue ( $\alpha_{\tau\pi}$ ) of 1.25. Since government spending is defined net of transfers and, thus, acyclical, Perotti (2005) sets the output elasticity of government spending ( $\alpha_{gy}$ ) equal to zero. He sets the inflation elasticity of government spending ( $\alpha_{g\pi}$ ) equal to -0.5, arguing that nominal wages of government employees, which account for a large part of government consumption, do not react contemporaneously to changes in inflation implying that the government wage bill declines in real terms if there is an unanticipated increase in inflation. In addition, he sets the interest rate elasticities of government spending ( $\alpha_{gi}$ ) and net taxes ( $\alpha_{\tau i}$ ) equal to zero, respectively, because interest payments paid and received by the government are excluded from the definition of spending and net taxes. Finally, he sets the parameter  $\beta_{g\tau}$  equal to zero, which is equivalent to saying that government decisions on government are taken before decisions on revenue. Imposing these restrictions on the parameter values the relation between the reduced-form and the structural disturbances can be written in matrix form as<sup>5</sup>

$$\begin{bmatrix} 1 & 0 & 0.5 & 0 & 0 \\ -\alpha_{yg} & 1 & 0 & -\alpha_{y\tau} & 0 \\ -\alpha_{\pi g} & -\alpha_{\pi y} & 1 & -\alpha_{\pi\tau} & 0 \\ 0 & -1.85 & -1.25 & 1 & 0 \\ -\alpha_{rg} & -\alpha_{ry} & -\alpha_{r\pi} & -\alpha_{r\tau} & 1 \end{bmatrix} \begin{bmatrix} u_t^g \\ u_t^y \\ u_t^\pi \\ u_t^\tau \\ u_t^r \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ \beta_{\tau g} & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_t^g \\ e_t^y \\ e_t^\pi \\ e_t^\tau \\ e_t^r \end{bmatrix}. \quad (9)$$

Comparing this system of equations with the system for the recursive approach reveals

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<sup>5</sup>Since the structural parameters collected in  $A_0$  and  $B$  are nonlinearly related to the reduced-form parameters, a closed form of the maximum likelihood estimates does not exist, necessitating the use of an iterative optimizing algorithm to compute the estimates. We use the Broyden-Fletcher-Goldfarb-Shanno algorithm implemented in RATS (see Doan 2004).

the following differences between the two identification approaches: Whereas in the recursive approach all elements of  $A_0$  above the principal diagonal are restricted to zero, there are three exceptions in Perotti's identification approach. These exceptions are potentially important when the responses to a government revenue shock are considered. By fixing the size of automatic stabilizers Perotti (2005) is able to freely estimate the contemporaneous effect of government revenue on output and inflation whereas the recursive approach freely estimates the size of automatic stabilizers while imposing a zero restriction on the contemporaneous effect of government revenue on output and inflation. Surprisingly, the empirical analysis suggests that the conceptual differences between the recursive approach and the Blanchard-Perotti approach have little effect on the results—for the benchmark value of the output elasticity of net taxes imposed for the Blanchard-Perotti approach.

### 3.3 The sign-restrictions approach

The third approach identifies fiscal policy shocks via sign restrictions on the impulse responses. Unlike the recursive approach and the Blanchard-Perotti approach, the sign-restrictions approach does not require the number of shocks to be equal to the number of variables and it does not impose linear restrictions on the contemporaneous relation between reduced-form and structural disturbances. Rather, Mountford and Uhlig (2005) impose restrictions directly on the shape of the impulse responses and identify four shocks: a business cycle shock, a monetary policy shock, a government spending shock and a government revenue shock. In our application we identify a business cycle shock, a government spending shock and a government revenue shock. We disregard the monetary policy shock because it is not the focus of this paper and because the results are not sensitive to the (non)identification of this shock. We impose the following sign restrictions on the impulse responses: The business cycle shock is identified by the requirement that the impulse responses of output and government revenue are positive for at least the four quarters following the shock. This turns out to be the crucial identifying assumption, having implications also for the identification of the fiscal policy shocks. This assumption implies that whenever government revenue and output move in the same direction, this must be due to a change in the business cycle. It rules out that an increase (fall) in government revenue can generate an increase (fall) in output and, thus, rules out such phenomena as "expansionary fiscal contractions" that have received a lot of attention in the recent literature on the effects of fiscal policy (see, e.g., Giavazzi et al. 2000). As a consequence, it might be that the sign-restrictions overstates the (negative) output effects of a revenue

shock. The government revenue shock is identified by the requirements that the impulse responses of government revenue are positive for at least the four quarters following the shock, while the government spending shock is identified by the requirements that the impulse responses of government spending are positive for at least the four quarters following the shock. In addition, both shocks are required to be orthogonal to the business cycle shock identified in the first step.

Following Uhlig (2005) we write the relationship between the reduced-form disturbances  $u_t$  and the structural shocks  $e_t$  as  $u_t = Be_t$ , with  $E[u_t u_t'] = \Sigma_u$  and  $E[e_t e_t'] = I$ . Note that  $e_t$  is a  $m$ -dimensional vector with  $m \leq k$ , i.e. unlike in the two approaches discussed above it is not necessary to identify as many shocks as there are variables. In our setup, for example, we identify three shocks using the sign-restrictions approach while there are five or six variables in the estimated VAR models. For the implementation of the sign-restrictions approach Mountford and Uhlig (2005) decompose the matrix  $B$  into two components,  $B = PQ$ , where  $P$  is the lower triangular Cholesky factor of  $\Sigma_u$  and  $Q$  is an orthonormal matrix with  $QQ' = I$ . Note that the matrix  $P$ , which serves to identify the structural shocks in the recursive approach, here merely serves a useful computational tool without affecting the results. Instead, the matrix  $Q$  plays the crucial role in the sign-restrictions approach because it collects the identifying weights with each column of  $Q$  corresponding to a particular structural shock. We use the penalty function approach described in detail in Mountford and Uhlig (2005: Appendix A) to compute the individual elements of  $Q$ . The penalty function approach consists in minimizing a criterion function, which penalizes impulse responses violating the sign restrictions, with respect to the identifying weights. As for the other identification approaches we take 500 draws from the posterior of the VAR coefficients and the variance-covariance matrix of the reduced-form residuals. For each draw we identify the three structural shocks.

## 4 Results For the Pure Fiscal Shocks

This section presents empirical results for pure government spending and government revenue shocks. The impulse responses are scaled as follows: As regards the responses of output and its components as well as the fiscal variables, the original impulse responses are transformed such as to give the dollar response of each variable to a dollar shock in one of the fiscal variables. For this purpose we follow the procedure of Blanchard and Perotti (2002) and first divide the original impulse responses by the standard deviation

of the respective fiscal shock in order to have shocks of size one percent. These impulse responses are then divided by the ratio of the respective variable and the shocked fiscal variable, where the ratio is evaluated at the sample mean. The major advantage of this transformation is that the responses of output to the fiscal shocks can be interpreted as (non-accumulated) multipliers. As regards the responses of inflation, wages and employment, they give the percentage change of each variable in response to a one-percent fiscal shock. Finally, the responses of the interest rate are expressed as change in percentage points for a one-percent fiscal shock. For each variable we report the median as well as the 16% and 84% fractiles of the posterior distribution of the impulse responses.

Most papers in the literature report the effects of pure fiscal shocks only. However, as Mountford and Uhlig (2005) have recently pointed out, pure fiscal shocks are not connected to the policy experiments considered in the theoretical literature or by policymakers. The reason is that pure fiscal shocks do not restrict the time paths of both fiscal variables. As a consequence it is not possible to answer questions such as "What are the effects of a tax-financed compared to a deficit-financed spending increase?" on the basis of the results for the pure spending shock because the identification of this shock does not restrict the response of government revenue. Yet, there is an easy way to construct meaningful policy experiments on the basis of the results for pure spending and revenue shocks. Following Mountford and Uhlig (2005) such policy experiments can be constructed as linear combinations of the two pure fiscal shocks. Section 5 presents the results for four policy experiments, while this section shows results for the pure fiscal shocks which are directly comparable to what has typically been reported in the literature.

#### **4.1 The Pure Spending Shock**

The impulse responses for a pure spending shock are shown in Figure 1 for the recursive approach, in Figure 2 for the Blanchard-Perotti approach and in Figure 3 for the sign-restrictions approach. A number of interesting findings emerge: First, the pure spending shock has highly persistent but not permanent effects on government spending and output. Second, the responses of government revenue differ across identification approaches. While government revenue increases by around 50 cents on impact according to the results for the recursive approach and the Blanchard-Perotti approach, it decreases by around 20 cents on impact according to the results for the sign-restrictions approach. This difference in the revenue response limits the comparability of the results across approaches. Section 5 provides comparable results controlling for the revenue response to a spending shock.

Third, even though the revenue responses differ across approaches there is a remarkable agreement on the effects of pure spending shocks on output and its components. According to all approaches the responses of output and private consumption are positive and follow a hump-shaped pattern, with the peak effect arising after around three years. The latter finding is interesting insofar as the empirical literature studying the effects of monetary policy shocks cites as one of the key stylized facts that the responses to monetary policy shocks are hump-shaped. According to the recursive approach and the Blanchard-Perotti approach the output and consumption responses are significantly positive both in the short run and the medium run, while according to the results for the sign-restrictions approach they are insignificant in the short run. The results further indicate that there are no sizeable effects of spending shocks on private investment. Fourth, and in line with the results reported in the related literature, the inflation response to a pure spending shock is negative in the short run which is somewhat puzzling. Yet, according to our results this "price puzzle" is limited to the short run and, thus, much less pronounced as, e.g., the one documented in Mountford and Uhlig (2005).<sup>6</sup> As could be expected the responses of the nominal interest rate follow the same pattern as the inflation responses. Fifth, employment does not react on impact to a pure spending shock but shows a positive response in the medium run, whereas the real wage does not respond to spending shocks at any horizon. Sixth, the responses for the recursive approach and the Blanchard-Perotti approach are virtually identical. This is not surprising given that concerning the spending shock the identification assumptions in the Blanchard-Perotti approach are nearly the same as in the recursive approach (compare the first row of  $A$  in Equations (3) and (9)).

## 4.2 The Pure Revenue Shock

The impulse responses for a pure revenue shock are shown in Figure 4 for the recursive approach, in Figure 5 for the Blanchard-Perotti approach and in Figure 6 for the sign-restrictions approach. The results show that the effects of a pure revenue shock are less persistent than the effects of a pure spending shock, with the response of government revenue dying out after around three years. Apart from a small decline in the short run government spending does not react to a revenue shock, implying that the revenue

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<sup>6</sup>In the literature studying the effects of monetary policy shocks the "price puzzle" refers to the empirical result obtained by many studies using VAR models that prices increase following a contractionary monetary policy shock (see, e.g., Uhlig 2005 for a discussion). One way to solve this price puzzle is to include a commodity price index among the set of variables. In our context, however, this does not help to resolve the price puzzle (see Mountford and Uhlig 2005).

shock can be interpreted as a "deficit-reducing tax increase" policy experiment. As regards the responses of the non-fiscal variables to a pure revenue shock, the results for the sign-restrictions approach seem most plausible. Whereas the results for the other two approaches suggest that a pure revenue shock does not have any sizeable effect on most variables, the results for the sign-restrictions approach suggest that output, private consumption, nonresidential investment, employment and inflation strongly decline in the short and medium run. The results further suggest that the interest rate declines in the medium run after a small increase on impact, while the real wage (which is not measured net of taxes) slightly increases.

A surprising finding is that the results for the recursive approach and the Blanchard-Perotti approach are nearly identical also for the pure revenue shock. A priori, it could be expected that the results for these approaches differ because the recursive approach restricts the short-run output effect of a pure revenue shock to be zero while the Blanchard-Perotti approach does not. Our benchmark results suggest that this conceptual difference does not matter much given that the impact response of output is close to zero for the Blanchard-Perotti approach. This result is in line with the results reported by Perotti (2005: Figure 3) but stands in contrast to the results of Blanchard and Perotti (2002: Figure III) who report that output decreases by around 70 cents in response to a pure revenue shock. The results of a robustness analysis presented in Section 6 suggest that the results for the Blanchard-Perotti approach are very sensitive to the value of the output elasticity of net taxes ( $\alpha_{ty}$ ) imposed in the estimation of the structural VAR model. The results of the sensitivity analysis suggest that the larger the output elasticity of net taxes, i.e. the larger the size of automatic stabilizers, the stronger is the (negative) impact response of output to a pure revenue shock and the more the results for the Blanchard-Perotti approach resemble those for the sign-restrictions approach.

## 5 Results for the Policy Experiments

This section presents empirical results for four alternative policy experiments: (i) a deficit-financed spending increase, (ii) a deficit-financed tax cut, (iii) a balanced-budget spending increase, and (iv) a military buildup. As in Mountford and Uhlig (2005) the first three policy experiments are based on linear combinations of the pure fiscal policy shocks identified in the previous section. In order to save space this section does not present any results for the Blanchard-Perotti approach as the results of the policy experiments for this

approach are virtually identical to those of the recursive approach. The next section shows that the equivalence between the recursive approach and the Blanchard-Perotti approach breaks down if the output elasticity of net taxes is freely estimated rather than fixed at the benchmark value suggested by Perotti (2005). This section also shows results for a fourth policy experiment: a military buildup. For this purpose we augment our baseline VAR model with a dummy variable capturing the Ramey and Shapiro (1998) episodes (excluding the Korean War) and estimate the responses of the endogenous variables to an exogenous increase in this dummy variable.

### **5.1 The deficit-financed spending increase**

The deficit-financed spending increase is defined as an increase in government spending by 1\$ for four quarters while government revenue remains unchanged. This policy experiment is obtained by the linear combination of the sequence of the two pure fiscal policy shocks that causes these responses in the two fiscal variables. The impulse responses for this policy experiment are shown in Figure 7 for the recursive approach and in Figure 8 for the sign-restrictions approach. In both cases the responses of the endogenous variables are very similar to those depicted in Figures 1 and 3 for the pure spending shock. A deficit-financed spending shock has a significant positive effect on output and private consumption, with the response of consumption having a pronounced hump-shaped pattern. The recursive approach and the sign-restrictions approach differ mainly regarding the impact response of output and private consumption. While the results for the recursive approach suggest a significant positive short-run response, the results for the sign-restrictions approach suggest that the response of these two variables in the first year after the deficit-financed spending shock is not significantly different from zero. Other differences between the two approaches concern the responses of private investment and employment. While the results for the recursive approach suggest that the short-run response of investment and employment is insignificant, the results for the sign-restrictions approach suggest that there is a significant negative short-run response of nonresidential investment and employment. Both approaches agree that the deficit-financed spending increase has only a temporary effect on fiscal and other macroeconomic variables, with the effects dying out approximately ten years after the shock occurred.

## 5.2 The deficit-financed tax cut

The deficit-financed tax cut is defined as a fall in government revenue by 1\$ for four quarters while government spending remains unchanged. The impulse responses for this policy experiment are shown in Figure 9 for the recursive approach and in Figure 10 for the sign-restrictions approach. In both cases the responses of the endogenous variables are the mirror image of the responses depicted in Figures 4 and 6, respectively, for the pure revenue shock. The main reason for this similarity is that government spending does not respond very strongly to a pure revenue shock, implying that the pure revenue shock analyzed in the previous section can be interpreted as a deficit-reducing tax increase. In the case of the recursive approach, most impulse responses to a deficit-financed tax cut are statistically insignificant and in those cases where the responses are significant they are rather implausible. For example, the results suggest that nonresidential investment, employment and the real wage decline in the short run in response to a deficit-financed tax cut. In the case of the sign-restrictions approach, the evidence is more clear-cut. In response to a deficit-financed tax cut output, consumption, investment and employment increase in the short to medium run, entailing an increase in both inflation and the interest rate. The deficit-financed tax cut has only a temporary effect on fiscal and macroeconomic variables, with the effects on the latter dying out approximately three to five years after the shock occurred.

## 5.3 The balanced-budget spending increase

The balanced-budget spending increase is defined as an increase in both government spending and government revenue by 1\$ for four quarters. The impulse responses for this policy experiment are shown in Figure 11 for the recursive approach and in Figure 12 for the sign-restrictions approach. As regards the recursive approach, the results for the balanced-budget spending increase are very similar to those reported in Figure 1 for the pure spending shock and those reported in Figure 7 for the deficit-financed spending increase. The reason for this surprising similarity is that almost all responses to a pure revenue shock are statistically insignificant in the case of the recursive approach (see Figure 4). This implies that it makes very little difference whether a spending increase is financed with an increase in the budget deficit or an increase in government revenue. As regards the sign-restrictions approach, the results for the balanced-budget spending increase are markedly different from those reported in Figure 8 for the deficit-financed

spending increase. In the short run output, consumption, investment and employment fall in response to a balanced-budget spending increase, while they rise in response to a deficit-financed spending increase. One possible interpretation of this finding is that the rise in distortionary taxes necessary to match the spending increase has strong disincentive effects which entail a decline in output. Indeed, the standard neoclassical growth model analyzed by Baxter and King (1993) predicts that output and employment increase if a spending increase is financed with lump-sum taxes (which is equivalent to deficit-finance in their model) while they decrease if a spending increase is financed with distortionary taxes. However, the responses of consumption and investment still represent a challenge for the neoclassical growth model, which predicts that consumption and investment fall irrespective of the financing alternative. Moreover, the results for the balanced-budget spending increase suggest that the responses of output and consumption switch sign in the medium run, whereas the neoclassical growth model predicts that the responses of output and consumption remain negative in the medium run. Finally, the results show that similar to the other policy experiments the budget-balanced spending increase has only a temporary effect on fiscal and macroeconomic variables, with the effects dying out approximately six to eight years after the shock occurred.

#### 5.4 The military buildup

In this subsection we present results for a policy experiment which is different in nature to the experiments considered so far. Following the work of Ramey and Shapiro (1998) parts of the literature have tried to avoid the identification problem inherent in structural VAR analysis and have instead looked for fiscal episodes which can be seen as exogenous with respect to the state of the economy. Ramey and Shapiro (1998) have argued that the large increases in military spending associated with the onset of the Korean war, the Vietnam war and the Reagan military buildup can be seen as such exogenous events. For this policy experiment we follow the literature and define a dummy variable,  $D_t$ , which takes on the value of 1 in the first quarter of 1965, i.e. at the onset of the Vietnam war, and in the first quarter of 1980, i.e. at the onset of the Reagan military buildup. Including this dummy variable in the empirical model, our baseline reduced-form VAR model given by equation (1) is replaced by the following reduced form:

$$X_t = \mu_0 + \mu_1 t + A(L)X_{t-1} + \Phi(L) D_t + u_t, \quad (10)$$

where  $\Phi(L)$  is the 4th-order lag polynomial associated with the fiscal dummy variable. The impulse responses to a military buildup obtained by computing the responses of the endogenous variables to an exogenous unit increase in the dummy variable are shown in Figure 13. Note that for this particular policy experiment the responses are not reported in \$ changes but in percentage changes. Figure 13 shows that during a military buildup both government spending and revenue react with a delay of about one year but after that strongly rise. The responses of output, consumption, nonresidential investment and employment have a hump-shaped pattern, with the response being insignificant in the first year after the shock occurred, becoming strongly positive in the second to fourth year and dying out quickly thereafter. A remarkable result of this policy experiment is that the fiscal dummy variable approach does not lead to conclusions very different from the other approaches, in particular concerning the response of private consumption. All the approaches yield the interesting result that the response of private consumption to an increase in government spending follows a hump-shaped pattern and is positive in the medium run.

## 6 Robustness

This section presents the results of various sensitivity analyses regarding the specification of the reduced-form VAR model and the sensitivity of the Blanchard-Perotti approach to the value of a key parameter, the output elasticity of net taxes, imposed in the estimation of the structural VAR model. As concerns the specification of the reduced-form VAR model, the results presented for the benchmark specification are robust to the following alternative specifications:<sup>7</sup> (i) use of a 6-th order lag polynomial instead of a 4-th order lag polynomial, (ii) inclusion of a quadratic time trend among the deterministic terms, (iii) inclusion of a dummy variable capturing the Ramey and Shapiro (1998) episodes, (iv) inclusion of a dummy variable capturing the tax rebate in the second quarter of 1975, as in Blanchard and Perotti (2002), and (v) use of an earlier starting date of the sample (1947:1), as in Eichenbaum and Fisher (2005).<sup>8</sup>

<sup>7</sup>Detailed results are available on request.

<sup>8</sup>If, in addition to extending the sample by including the period 1947-1954, we redefine the dummy variable capturing the military buildup episodes by setting it to 1 also in the third quarter of 1950 (onset of the Korean War), the results for the fiscal dummy variable approach are affected. In particular, the response of private consumption is not statistically significant except on impact where it is significantly positive.

As described in Section 4, for the Blanchard-Perotti approach the response of GDP to a pure revenue shock is puzzling because the results suggest that GDP responds positively to a tax increase in the short run. One possible explanation is related to the estimation of the output elasticity of net taxes ( $\alpha_{\tau y}$ ).<sup>9</sup> In this paper we use the estimate provided in Perotti (2005) and set this elasticity equal to 1.85. In the latter paper, as well as in Blanchard and Perotti (2002), the value for the output elasticity of net taxes ranges between 1.75 and 2.2, depending on the sample size and on the starting and ending years of the sample. Figure 14 shows the impact response of GDP to a pure revenue shock for alternative values of the output elasticity. As can be seen the results are highly sensitive to the value of the output elasticity of net taxes imposed in the estimation of the structural VAR model. Remember that in the recursive approach the output elasticity of net taxes is treated as free parameter in the estimation. We obtain a point estimate of 1.93, which is nearly identical to the value imposed for the Blanchard-Perotti approach. This also explains the striking similarity of the results for these two approaches.

In fact, it is possible to estimate rather than to impose the output elasticity of net taxes also for the Blanchard-Perotti approach. For this purpose it is necessary to restrict another parameter in the estimation and we choose to set  $\beta_{\tau g}$  equal to zero in order to ensure identification.<sup>10</sup> If the output elasticity of net taxes is freely estimated in the Blanchard-Perotti approach a point estimate of 2.98 obtains, which translates into a negative impact response of GDP to a revenue shock of almost 50 cents.<sup>11</sup> Using this value for the output elasticity of net taxes the results provided by the Blanchard-Perotti approach would, thus, appear not to differ significantly from those obtained for the sign-restrictions approach for the pure revenue shock and, consequently, for the policy experiments. Moreover, the results for the sign-restrictions approach suggest that a value for the output elasticity of net taxes of 2.98 is not implausibly large. Figure 15 shows the responses of GDP and

<sup>9</sup>Another possible explanation regards the definition of the net tax series. As mentioned in the data description, we define the net tax series as in Mountford and Uhlig (2005). These authors construct the aggregate net tax series using individual tax series taken from the National Income and Product Accounts (NIPA). Blanchard and Perotti (2002) also rely on NIPA data with one exception: corporate profit taxes for which they take cash data from the Quarterly Treasury Bulletin. As it turns out this small difference has a large impact on the results. Using the net tax series of Blanchard and Perotti (2002) the impact response of GDP to a pure revenue shock is negative. In a more recent paper, however, Perotti (2005: 10) argued that it is preferable to use corporate profit taxes on an accrual basis as reported in the NIPA. This is the approach we follow in this paper.

<sup>10</sup>Setting this parameter to zero does not affect the results. This statement is based on the benchmark Blanchard-Perotti structural VAR model where setting this parameter to zero gives an overidentifying restriction which can be tested and in our context cannot be rejected.

<sup>11</sup>The standard deviation of the estimate of  $\alpha_{\tau y}$  is 1.01, revealing that the uncertainty surrounding this parameter is quite large.

government revenue for the business cycle shock scaled such that the impact response of GDP is equal to 1 percent. The impact response of government revenue to the business cycle shock can be interpreted as measuring the size of automatic stabilizers and is, thus, comparable to the output elasticity of net taxes in the Blanchard-Perotti approach. The results suggest that government revenue increases by 3.49 percent on impact in response to the business cycle shock, with a 68% confidence band ranging from around 2.97 to 3.90.

However, it would be premature to conclude that once the key model parameter in the Blanchard-Perotti approach is freely estimated the results are the same as those for the sign-restrictions approach. An important issue, not addressed by Blanchard and Perotti (2002) and Perotti (2005), is that it is not innocuous to treat the output elasticity of net taxes as fixed in the estimation of the structural VAR model. Recall that these authors follow a two-step estimation approach. In the first step the output elasticity of net taxes is estimated using a method of cyclical adjustment similar to the ones used by international organizations. The output of the cyclical adjustment is a point estimate of the output elasticity of net taxes and (not reported by Blanchard and Perotti (2002)) the standard error of this estimate. In the second step Blanchard and Perotti (2002) use the point estimate of the output elasticity of net taxes and impose it in the estimation of the structural VAR model, thereby neglecting the uncertainty surrounding the point estimate. An implication of this procedure is that the confidence bands shown in Blanchard and Perotti (2002) for the responses to a government revenue shock are artificially small. Figure 16 shows this for our benchmark VAR model. The left-hand subplot reports the output response to a pure revenue shock for a specification of the structural VAR model in which the output elasticity of net taxes is fixed at the value of the point estimate (2.98), whereas the right-hand subplot shows it for a specification of the model in which this elasticity is freely estimated for each draw of the Monte-Carlo simulation. While the median response is almost the same in both cases, the confidence band is much wider in the second case.<sup>12</sup> The results shown in the right-hand subplot suggest that, accounting for the fact that  $\alpha_{\tau y}$  is random, the output response is not significant, while the results shown in the left-hand subplot suggest that, incorrectly treating  $\alpha_{\tau y}$  as fixed, the output response is significantly negative.

We interpret this evidence as suggesting that as regards the effects of government

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<sup>12</sup>The finding that the median response is nearly identical in both cases reflects the fact that two-step procedures yield consistent estimates of second-stage parameters under fairly general conditions (see, e.g., Murphy and Topel 1985). However, second-step estimated standard errors are incorrect, which in our context implies that the confidence bands are too narrow if the output elasticity of net taxes is treated as known in the second step.

revenue shocks the results both for the recursive approach and for the Blanchard-Perotti approach should be taken with a pinch of salt. While the recursive approach is too restrictive by ruling out any impact response of output to a revenue shock, the results for the Blanchard-Perotti approach are sensitive to the treatment and the value of the key parameter, the output elasticity of net taxes, imposed in the estimation of the structural VAR model.

## 7 Conclusions

This paper presents an extensive comparative study on the empirical literature assessing the effects of fiscal policy shocks using VAR models. The starting point of our analysis is that there is strong disagreement on even the qualitative effects of fiscal policy shocks on key macroeconomic variables. Our results suggest that specification issues and lack of comparability of policy experiments rather than differences in identification approaches explain the disagreement in the literature on the effects of government spending shocks. The results for all the methodologies considered in this paper suggest that following a pure spending shock private consumption, output and employment increase, while the real wage does not respond. Interestingly, the output and consumption responses follow a hump-shaped pattern which is similar to the findings reported in the literature analyzing the effects of monetary policy shocks.

As regards the effects of a pure revenue shock, the identification approaches considered in this paper do not agree. However, the results for the sign-restrictions approach suggesting that output, private consumption, nonresidential investment and employment fall in response to a pure revenue shock seem most plausible. In contrast, the recursive approach and the Blanchard-Perotti approach yield the puzzling result that macroeconomic variables do not react to such a shock. The results of a robustness analysis suggest that the reliability of the Blanchard-Perotti approach is impaired by the high sensitivity of the results to the value of the key parameter measuring the size of automatic stabilizers imposed in the estimation of the structural VAR model, while the recursive approach is too restrictive because it rules out any impact response of output to a revenue shock.

Apart from providing results for pure government spending and revenue shocks, this paper also presents evidence for various policy experiments. In this respect, the results suggest that both a deficit-financed tax cut and a deficit-financed spending increase have expansionary effects in the short run, while a tax-financed spending increase depresses

activity in the short run. A government spending increase stimulates the economy in the medium run irrespective of whether it is deficit-financed or tax-financed, whereas a deficit-financed tax cut has no output effects in the medium run. Neither spending increases nor deficit-financed tax cuts have significant output effects in the long-run.

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## Data Appendix

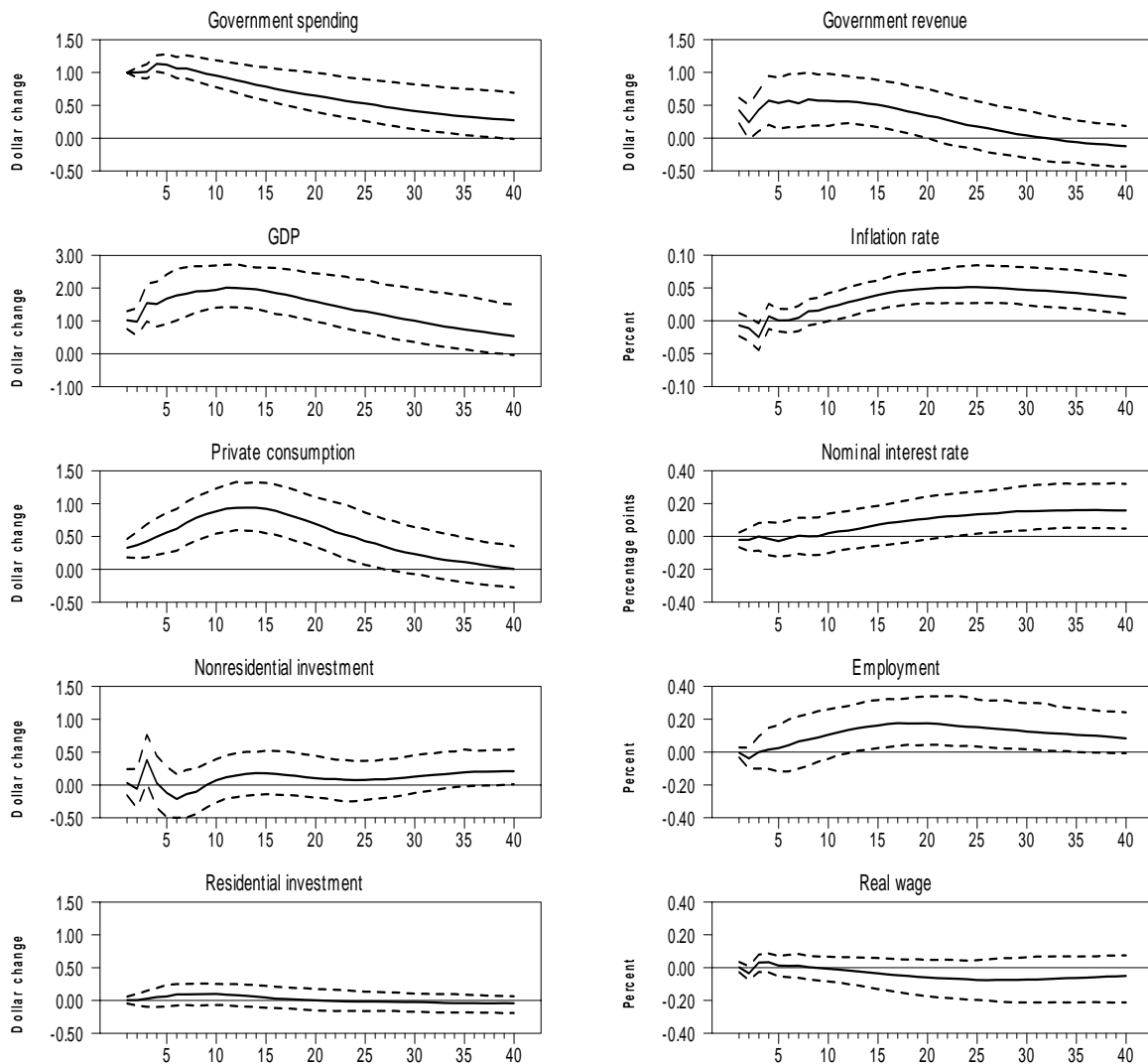
Regarding the definition of variables we closely follow Perotti (2005) and Mountford and Uhlig (2005). The wage and employment series are defined as in Edelberg et al. (1999). All the components of national income are in real per capita terms and are transformed from their nominal values by dividing them by the GDP deflator (NIPA Table 1.1.4 Row 1) and the population measure (NIPA Table 2.1 Row 38). The series are seasonally adjusted by the source. The Table and Row numbers refer to the organization of the data by the Bureau of Economic Analysis (BEA). We use the vintage of data published by the BEA on 30 March 2005. The interest rate was taken from the Federal Reserve Bank of St. Louis' FRED database, data on wages and employment were downloaded from the website of the Bureau of Labor Statistics (BLS). The data used in this paper are available on request.

- GDP: This is NIPA Table 1.1.5 Row 1.
- Private Consumption: This is NIPA Table 1.1.5 Row 2.
- Total Government Expenditure: Government consumption expenditures and gross investment, NIPA Table 3.9.5 Row 1.
- Total Government Revenue: This is 'Government Current Receipts', NIPA Table 3.1 Row 1, minus 'Current Transfers Payments', NIPA Table 3.1 Row 17, and 'Interest payments', NIPA Table 3.1 Row 22.
- Private Investment: This is 'Gross Private Domestic Investment', NIPA Table 1.1.5 Row 6.
- Private Residential Investment: This is 'Gross Private Domestic Investment - Residential', NIPA table 1.1.5 Row 11.
- Private Non-Residential Investment: This is 'Gross Private Domestic Investment', NIPA table 1.1.5 Row 6, minus 'Gross Private Domestic Investment - Residential', NIPA table 1.1.5 Row 11.
- Interest Rate: 3-month Treasury Bill secondary market rate (TB3MS); Federal Reserve Bank of St. Louis. We took the arithmetic average of the monthly figures to get a quarterly figure.
- The GDP Deflator: This is NIPA Table 1.1.4 Row 1.
- Wages: Manufacturing sector- Average hourly earnings of production workers - dollars per hour (Series Id: CES3000000006); Bureau of Labor Statistics (BLS). We took the arithmetic average of the monthly figures to get a quarterly figure.
- Total Private Employment: Total Private Employment, Quarterly Averages (Series Id: CES0500000081); Bureau of Labor Statistics (BLS).

<b>Table 1. Comparison of results reported by the literature for selected variables</b>										
Response to a Pure Spending Shock										
	GDP		C		R.I.		W		N	
	S	M/L	S	M/L	S	M/L	S	M/L	S	M/L
<i>Fatas/Mihov (2001)</i>	+	+	+	+			0	0	+	0
<i>Blanchard/Perotti (2002)</i>	+	+	+	+	-*	0*	n.a.	n.a.	n.a.	n.a.
<i>Perotti (2005)</i>	+	+	+	+	0*	-*	n.a.	n.a.	n.a.	n.a.
<i>Mountford/Uhlig (2005)</i>	+	0	-	0	-	-	n.a.	n.a.	n.a.	n.a.
<i>Edelberg et al (1999)</i>	+	0	0	0	0	0	0	0	+	0
Response to a Pure Revenue Shock										
<i>Fatas/Mihov (2001)</i>	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
<i>Blanchard/Perotti (2002)</i>	-	-	-	-	-*	+	n.a.	n.a.	n.a.	n.a.
<i>Perotti (2005)</i>	0	-	+/-	+/-	+/-	+/-	n.a.	n.a.	n.a.	n.a.
<i>Mountford/Uhlig (2005)</i>	-	0	-	0	0	+	n.a.	n.a.	n.a.	n.a.
<i>Edelberg et al (1999)</i>	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

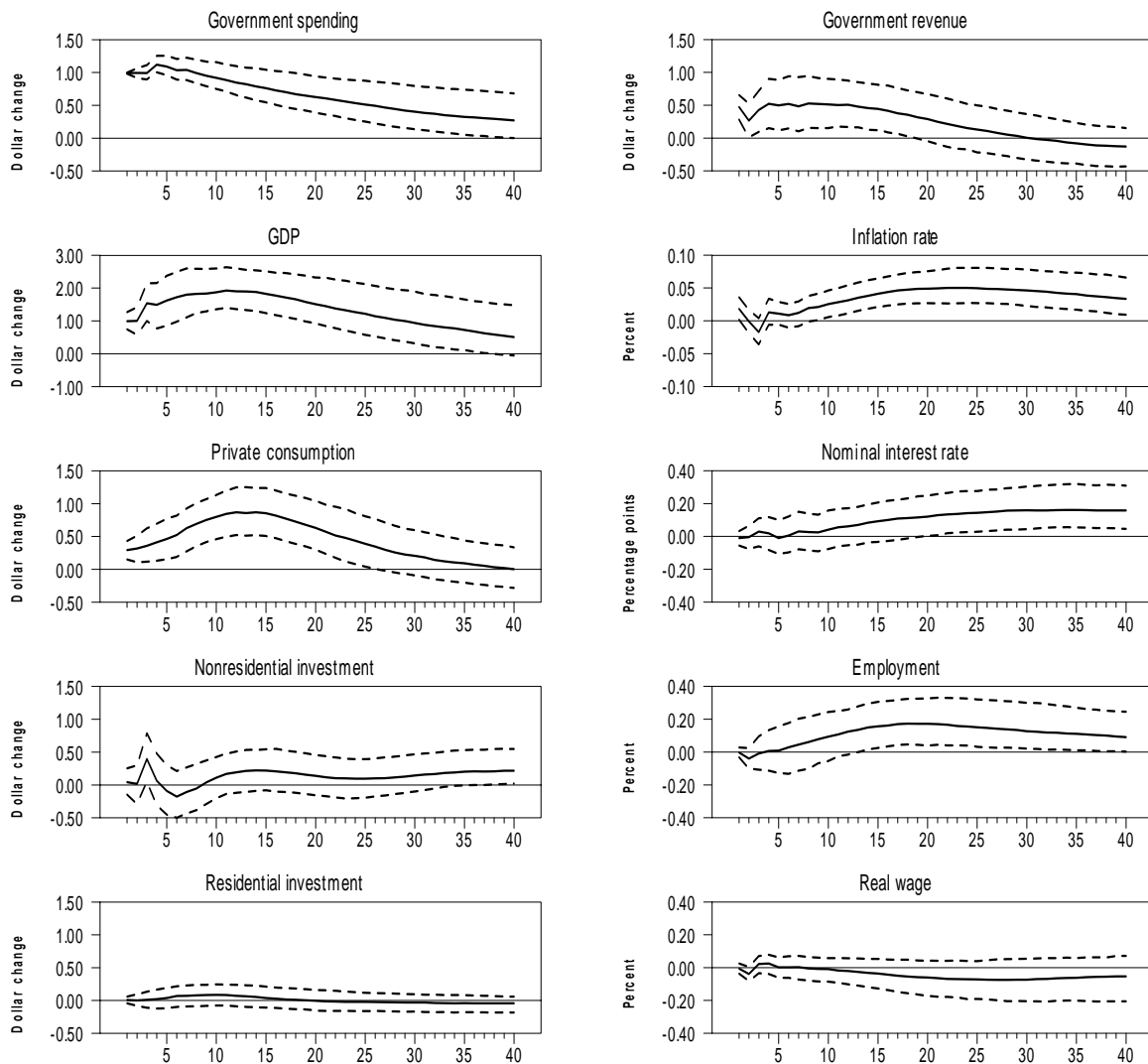
Note: C: Total Consumption; R.I.: Residential Investment; W: Real Wage; N: Total Employment; S: Short Run; M/L: Medium Long Run; "+": Positive response; "-": Negative response; \*: Total Investment; n.a.: not available.

Figure 1: Responses to a pure spending shock – Recursive approach



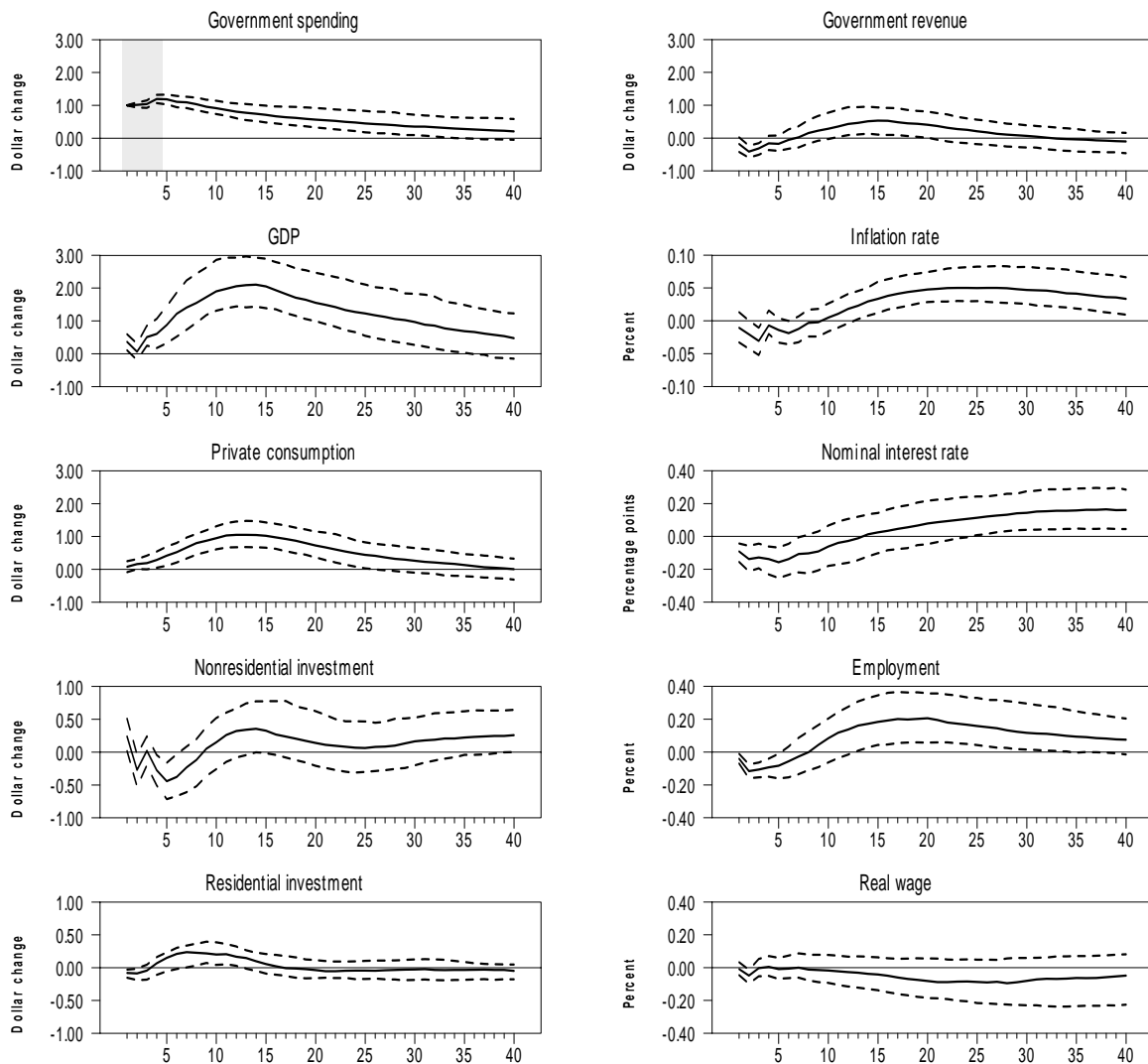
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the recursive identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. For GDP, its components and the fiscal variables, the responses are scaled such that they depict the dollar change in these variables in response to a pure government spending shock of size one dollar. For the other variables, they are scaled such that they depict the percentage change in response to a pure government spending shock of size one percent.

Figure 2: Responses to a pure spending shock – Blanchard-Perotti approach



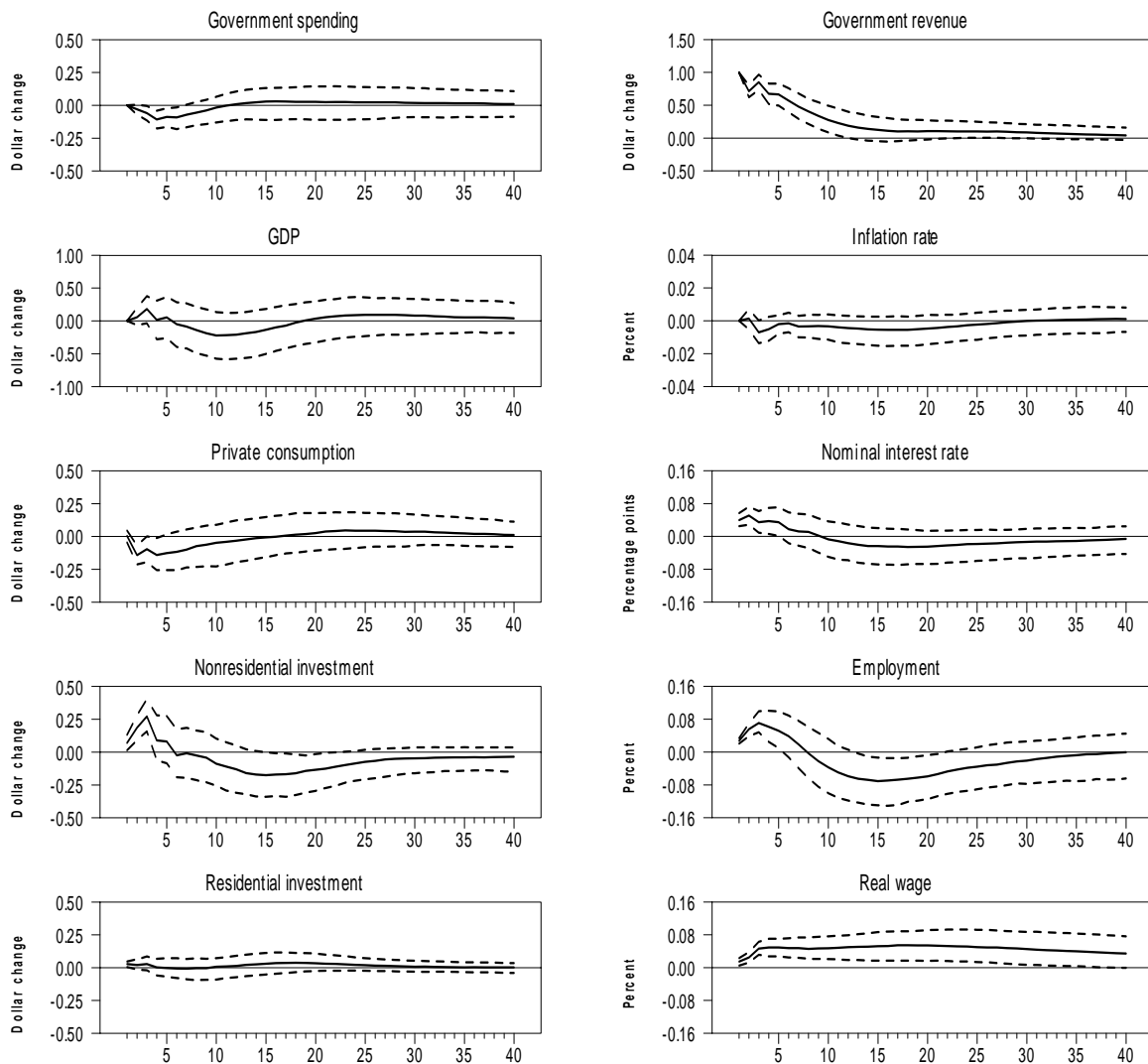
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the Blanchard-Perotti identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. For GDP, its components and the fiscal variables, the responses are scaled such that they depict the dollar change in these variables in response to a pure government spending shock of size one dollar. For the other variables, they are scaled such that they depict the percentage change in response to a pure government spending shock of size one percent.

Figure 3: Responses to a pure spending shock – Sign-restrictions approach



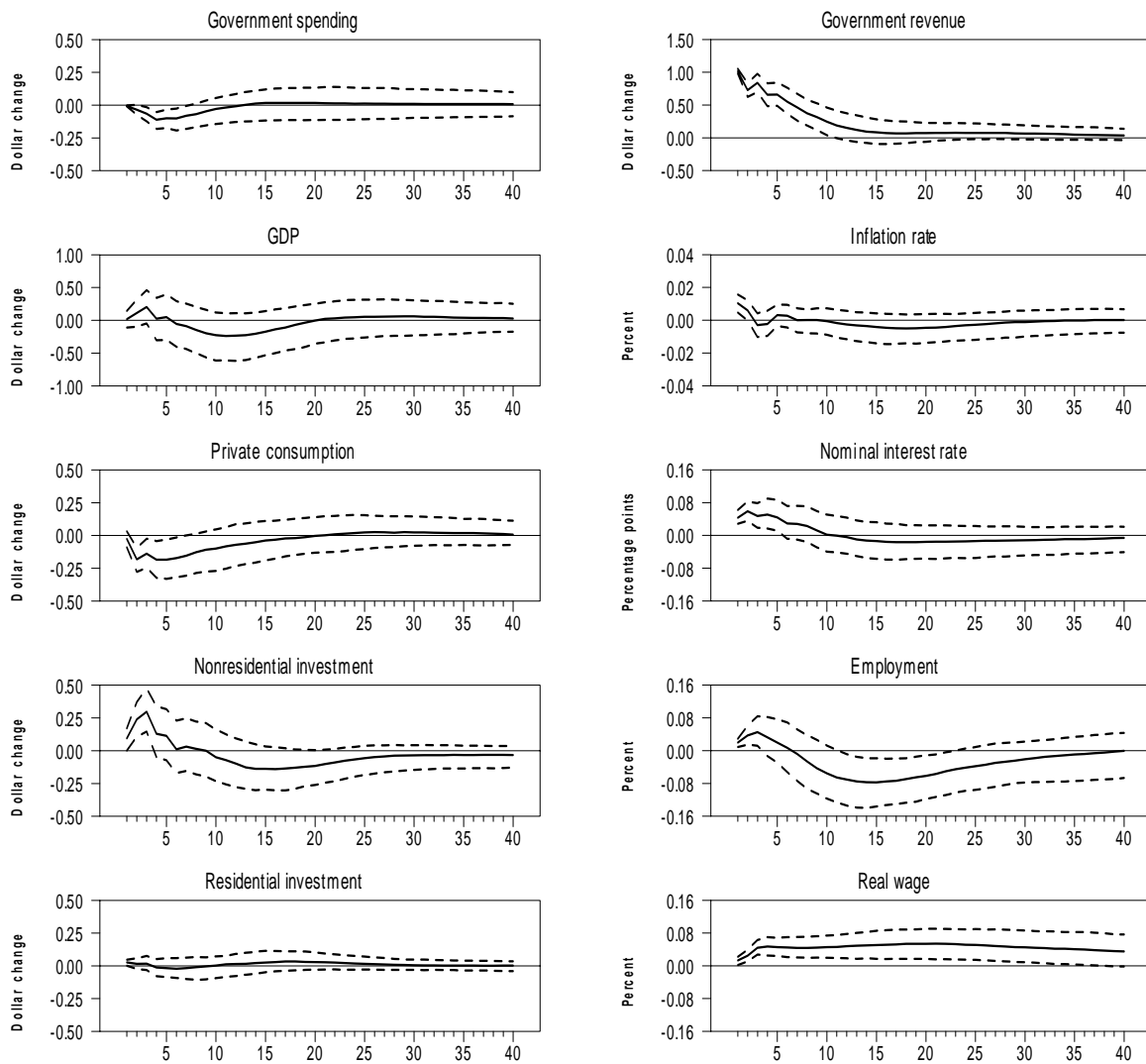
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the sign-restrictions identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. For GDP, its components and the fiscal variables, the responses are scaled such that they depict the dollar change in these variables in response to a pure government spending shock of size one dollar. For the other variables, they are scaled such that they depict the percentage change in response to a pure government spending shock of size one percent. The sign restrictions on the impulse responses are indicated by the shaded area.

Figure 4: Responses to a pure revenue shock – Recursive approach



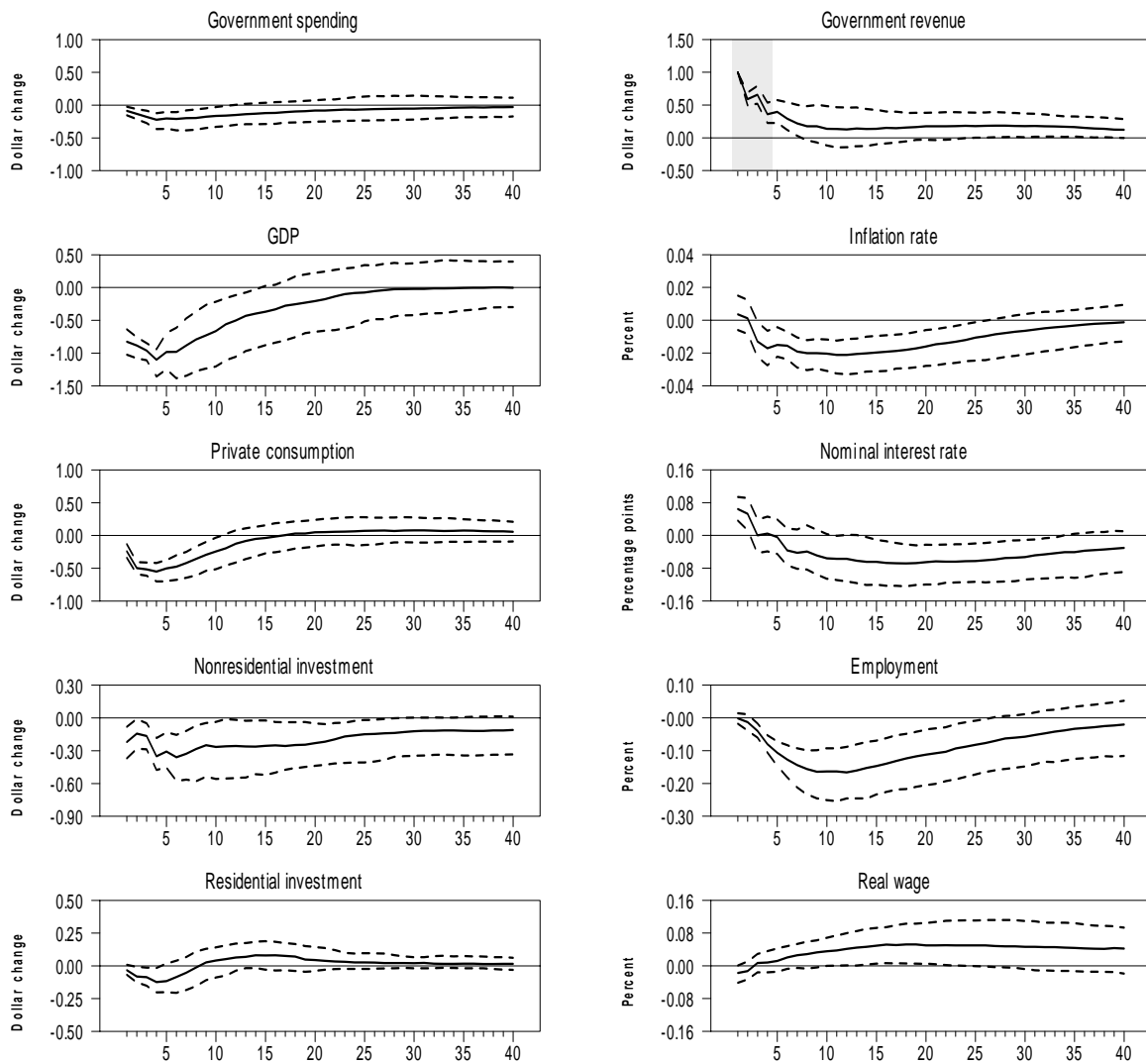
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the recursive identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. For GDP, its components and the fiscal variables, the responses are scaled such that they depict the dollar change in these variables in response to a pure government revenue shock of size one dollar. For the other variables, they are scaled such that they depict the percentage change in response to a pure government revenue shock of size one percent.

Figure 5: Responses to a pure revenue shock – Blanchard-Perotti approach



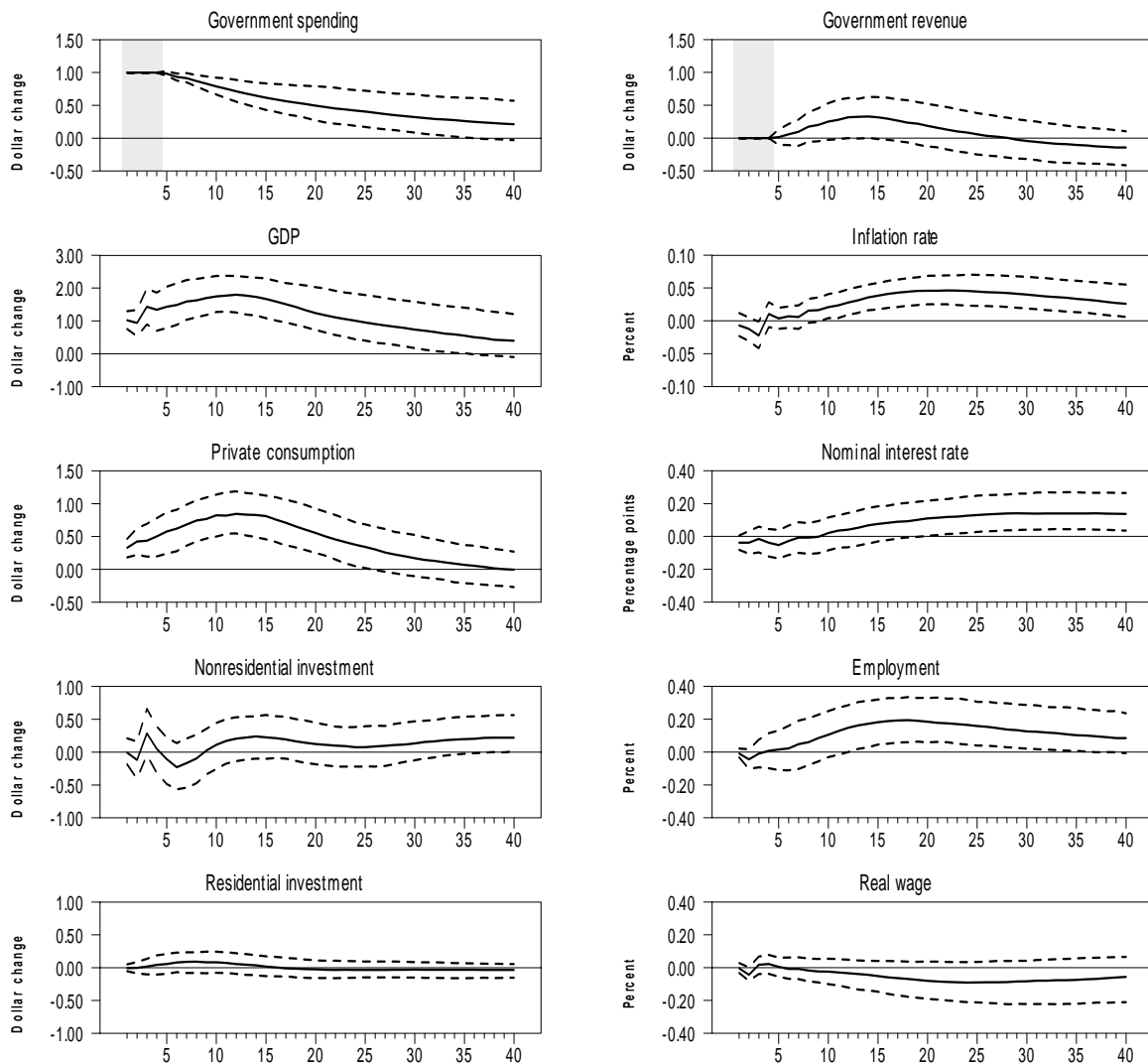
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the Blanchard-Perotti identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. For GDP, its components and the fiscal variables, the responses are scaled such that they depict the dollar change in these variables in response to a pure government revenue shock of size one dollar. For the other variables, they are scaled such that they depict the percentage change in response to a pure government revenue shock of size one percent.

Figure 6: Responses to a pure revenue shock – Sign-restrictions approach



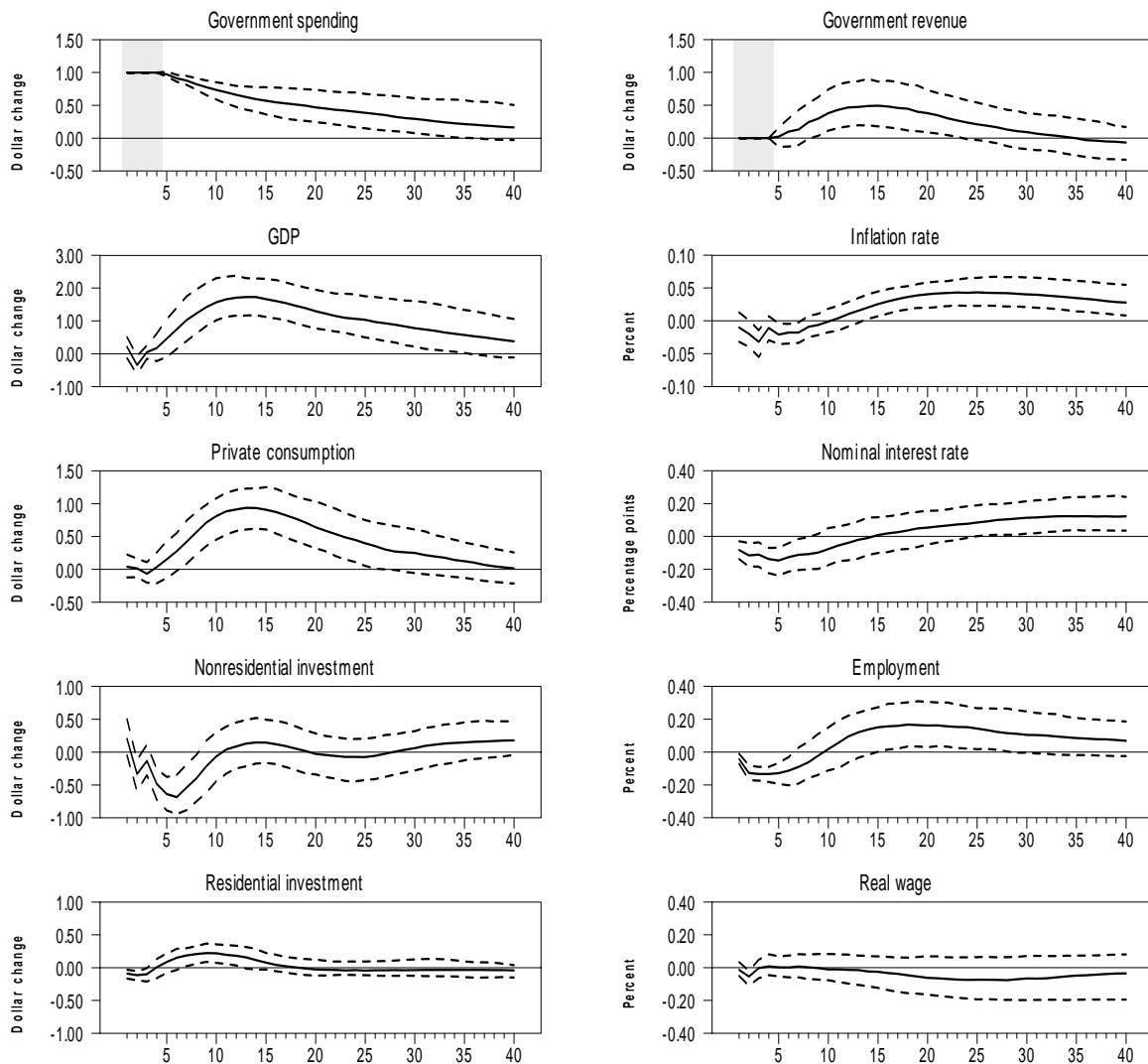
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the sign-restrictions identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. For GDP, its components and the fiscal variables, the responses are scaled such that they depict the dollar change in these variables in response to a pure government revenue shock of size one dollar. For the other variables, they are scaled such that they depict the percentage change in response to a pure government revenue shock of size one percent. The sign restrictions on the impulse responses are indicated by the shaded area.

Figure 7: Responses to a deficit-financed spending increase – Recursive approach



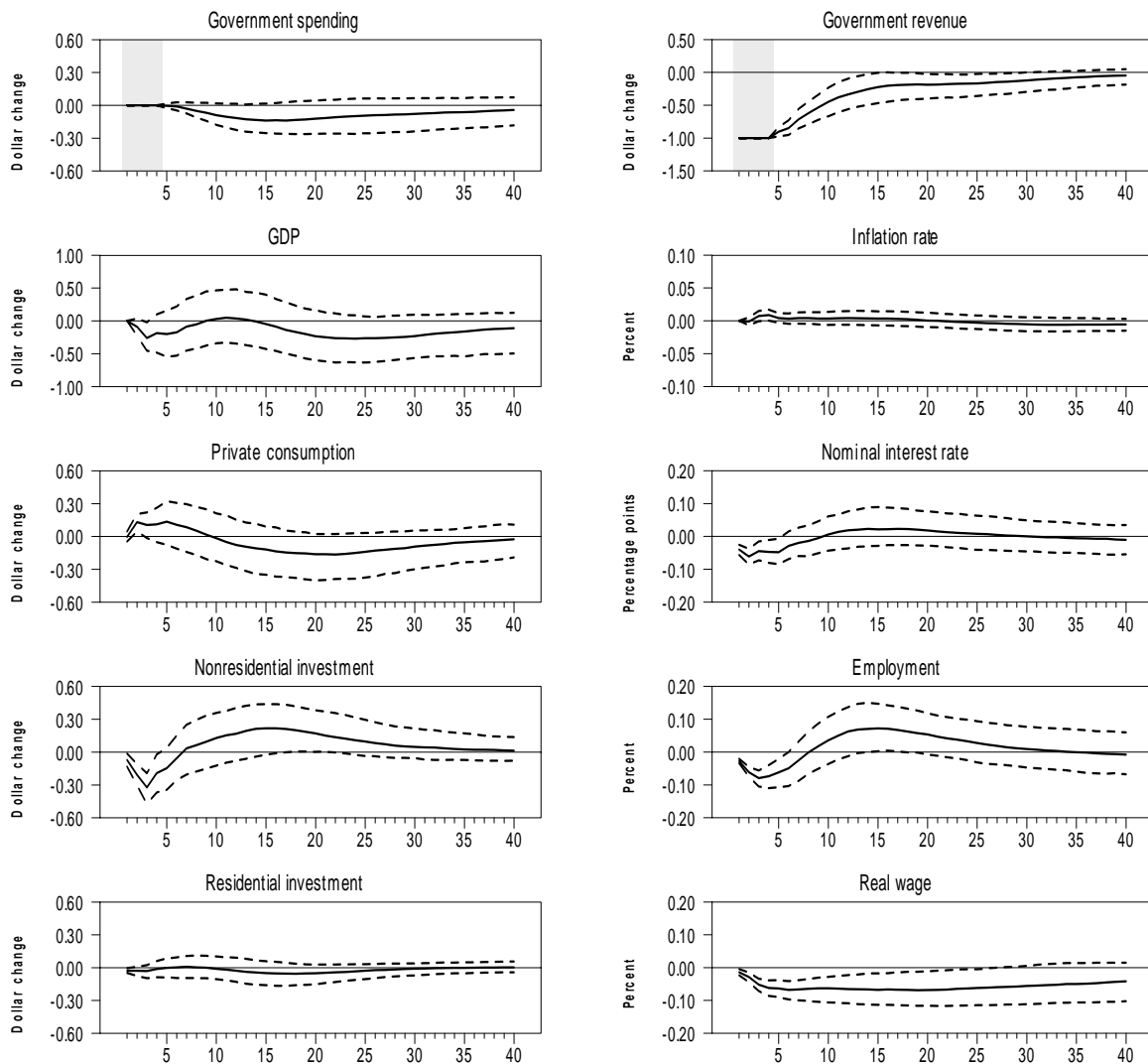
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the recursive identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. This policy experiment is defined as follows: The pure spending and revenue shocks are linearly combined such that the response of government spending is equal to one dollar for four quarters while government revenue remains unchanged. For GDP, its components and the fiscal variables the responses are shown in dollar changes, for the other variables they are shown in percentage changes. The restrictions on the impulse responses are indicated by the shaded areas.

Figure 8: Responses to a deficit-financed spending increase – Sign-restrictions approach



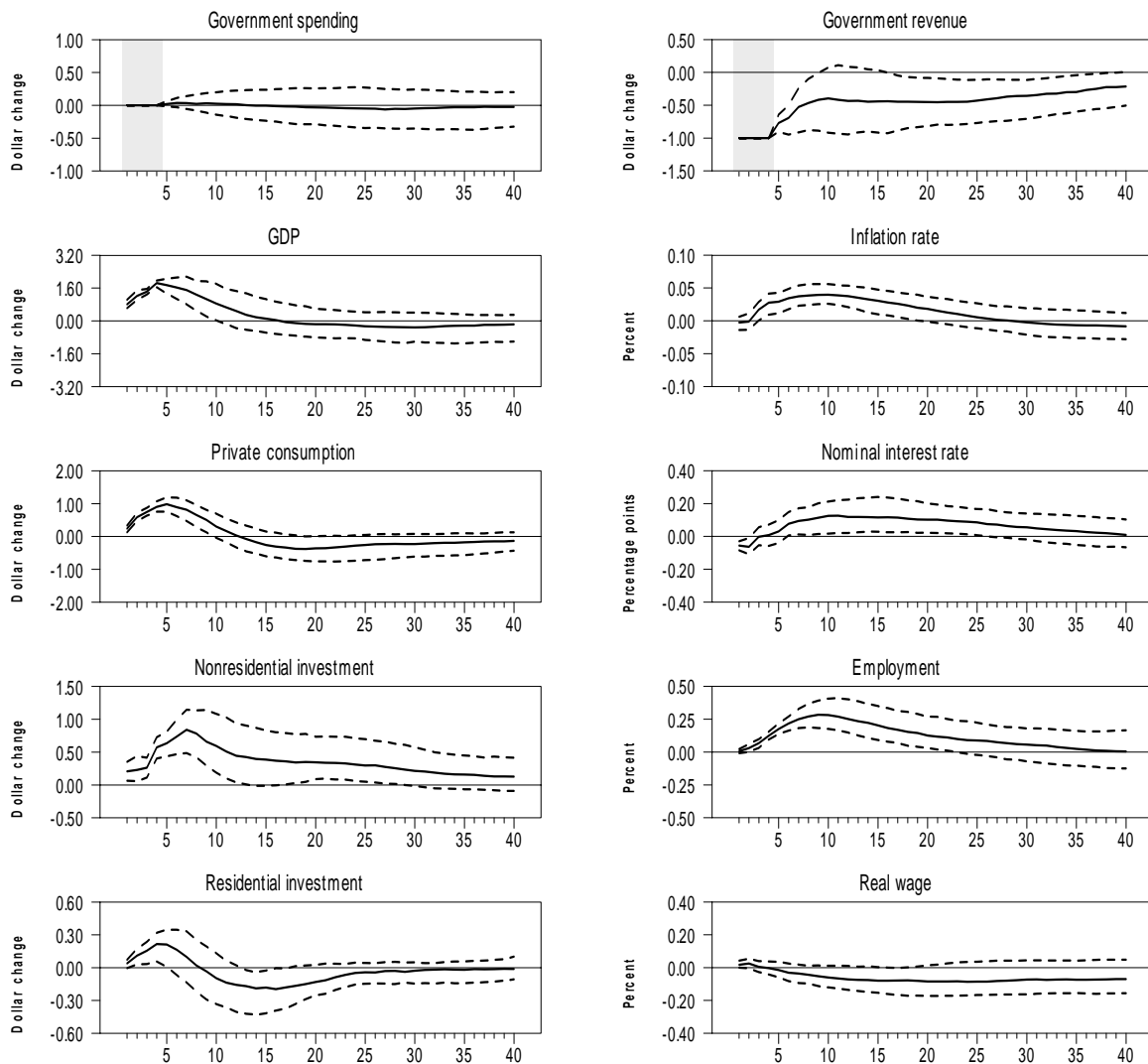
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the sign-restrictions identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. This policy experiment is defined as follows: The pure spending and revenue shocks are linearly combined such that the response of government spending is equal to one dollar for four quarters while government revenue remains unchanged. For GDP, its components and the fiscal variables the responses are shown in dollar changes, for the other variables they are shown in percentage changes. The restrictions on the impulse responses are indicated by the shaded areas.

Figure 9: Responses to a deficit-financed tax cut – Recursive approach



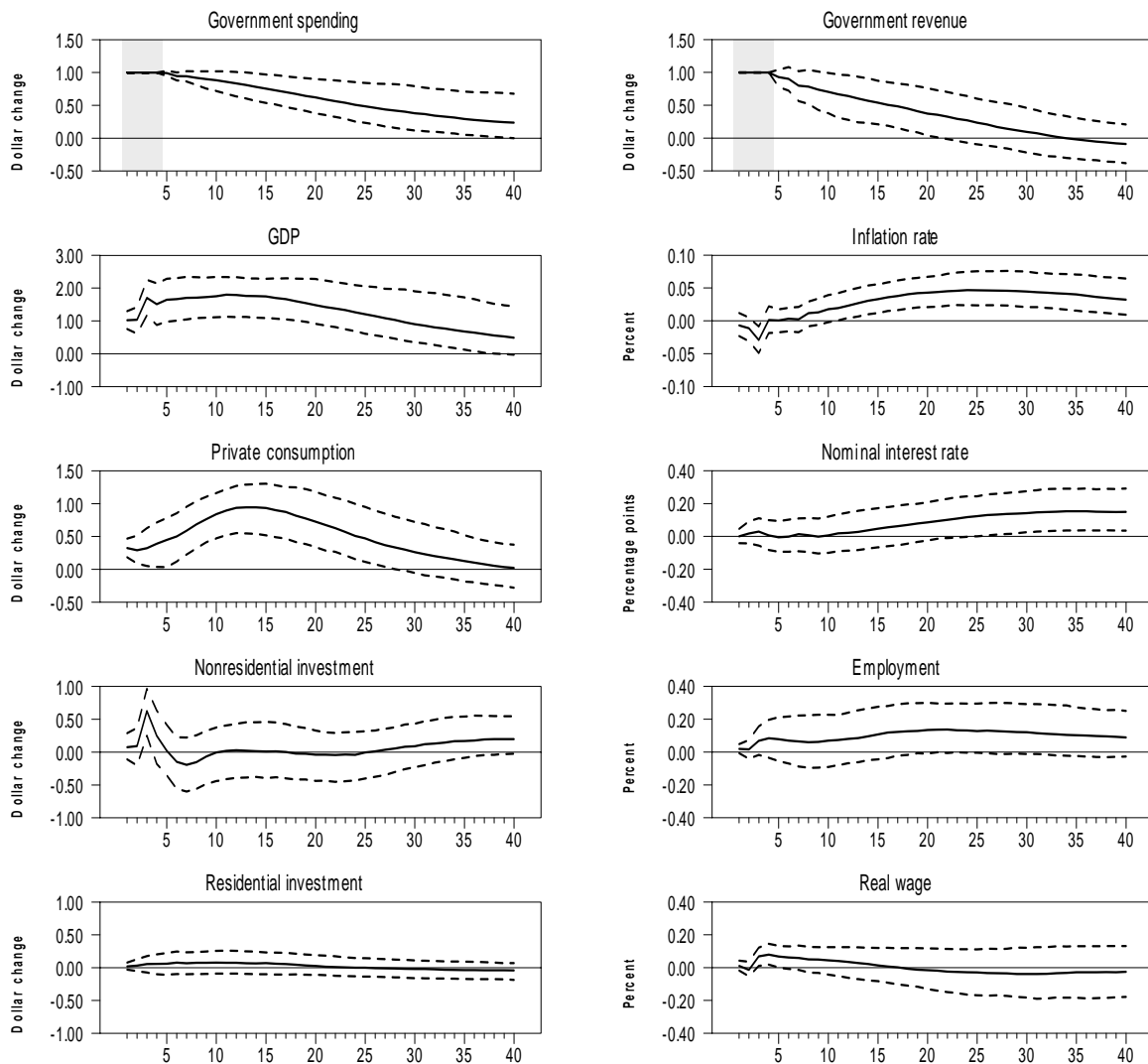
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the recursive identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. This policy experiment is defined as follows: The pure spending and revenue shocks are linearly combined such that the response of government revenue is equal to minus one dollar for four quarters while government spending remains unchanged. For GDP, its components and the fiscal variables the responses are shown in dollar changes, for the other variables they are shown in percentage changes. The restrictions on the impulse responses are indicated by the shaded areas.

Figure 10: Responses to a deficit-financed tax cut – Sign-restrictions approach



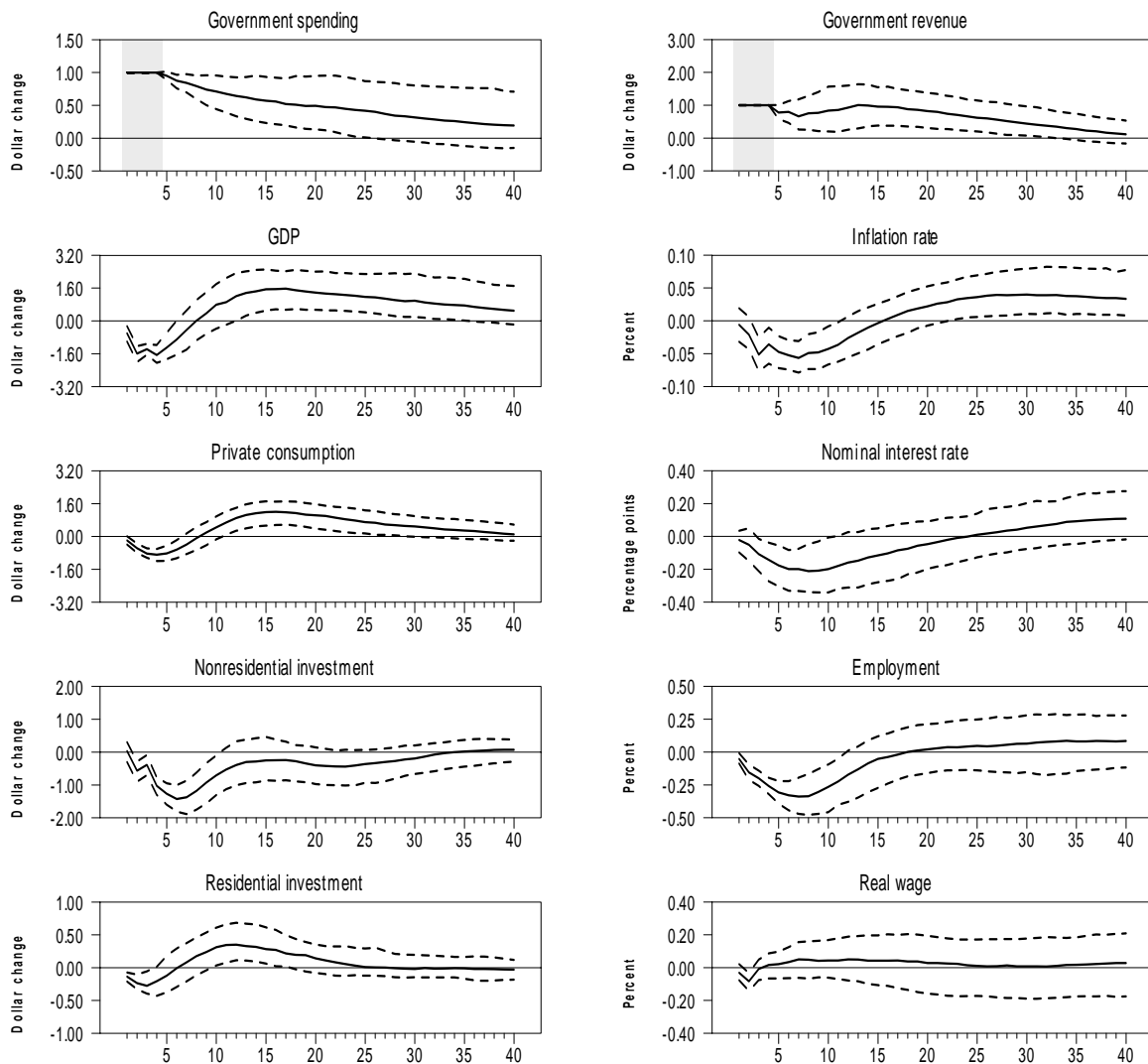
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the sign-restrictions identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. This policy experiment is defined as follows: The pure spending and revenue shocks are linearly combined such that the response of government revenue is equal to minus one dollar for four quarters while government spending remains unchanged. For GDP, its components and the fiscal variables the responses are shown in dollar changes, for the other variables they are shown in percentage changes. The restrictions on the impulse responses are indicated by the shaded areas.

Figure 11: Responses to a balanced-budget spending increase – Recursive approach



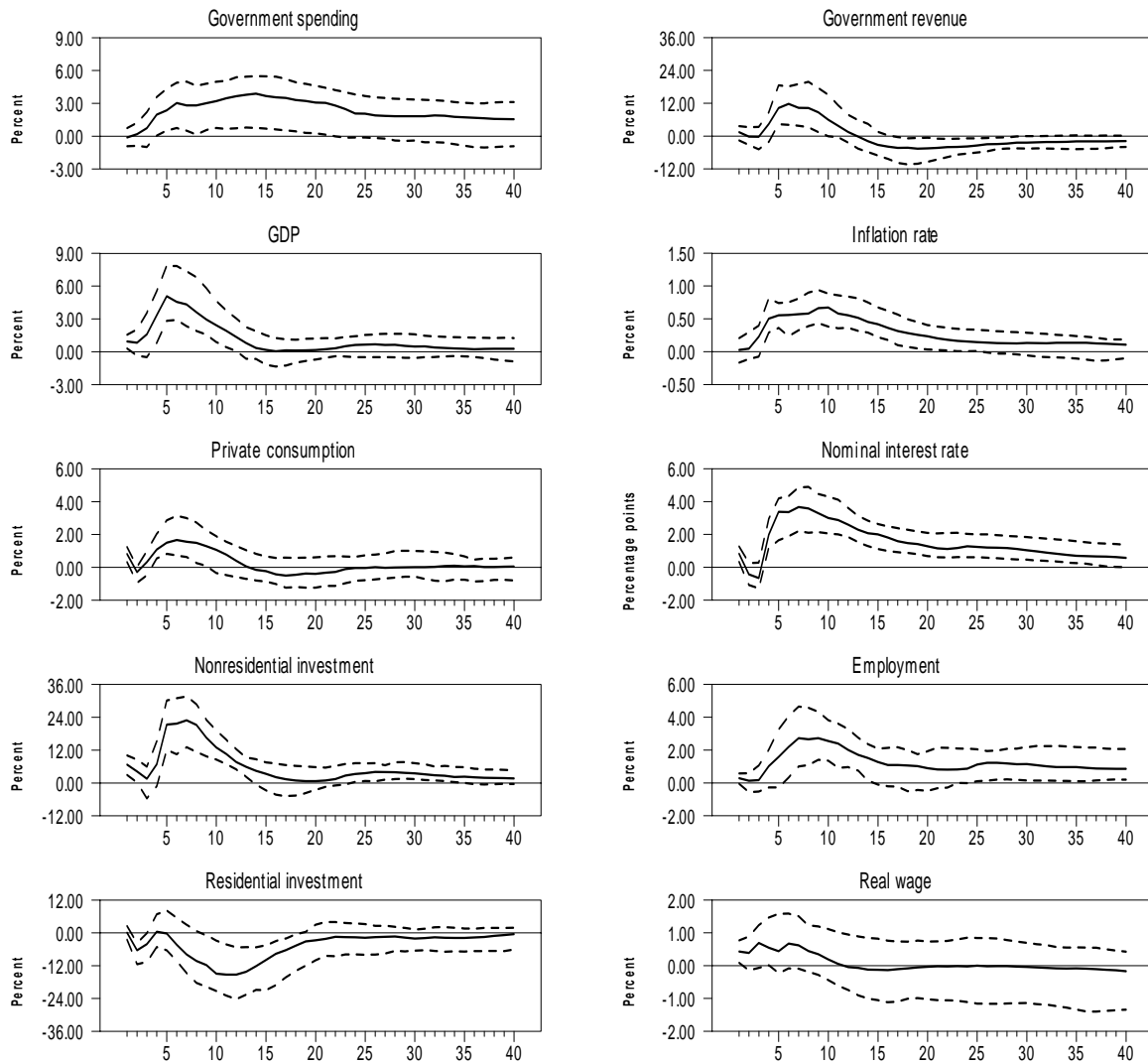
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the recursive identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. This policy experiment is defined as follows: The pure spending and revenue shocks are linearly combined such that the responses of both government spending and government revenue are equal to one dollar for four quarters. For GDP, its components and the fiscal variables the responses are shown in dollar changes, for the other variables they are shown in percentage changes. The restrictions on the impulse responses are indicated by the shaded areas.

Figure 12: Responses to a balanced-budget spending increase – Sign-restrictions approach



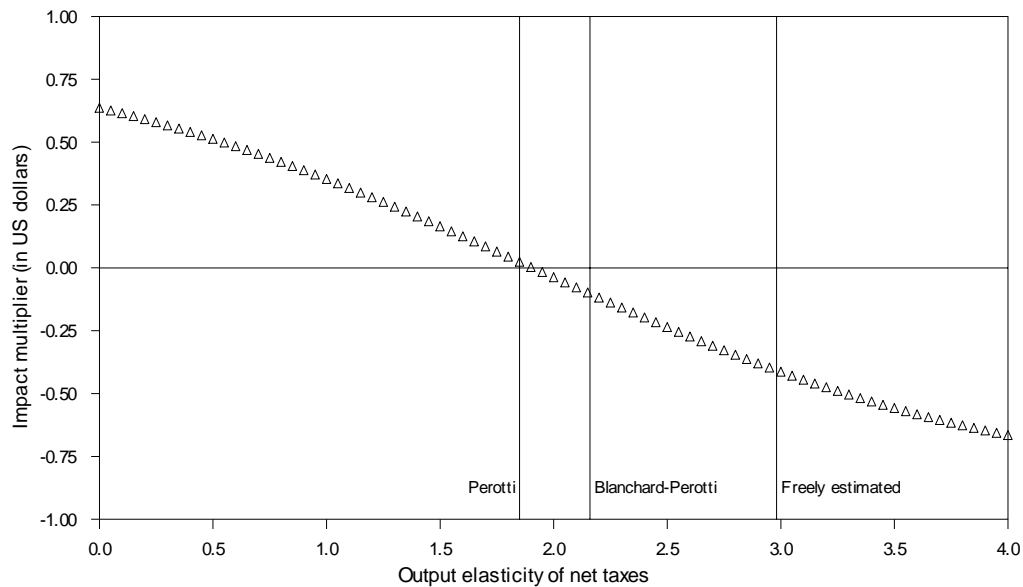
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the sign-restrictions identification approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. This policy experiment is defined as follows: The pure spending and revenue shocks are linearly combined such that the responses of both government spending and government revenue are equal to one dollar for four quarters. For GDP, its components and the fiscal variables the responses are shown in dollar changes, for the other variables they are shown in percentage changes. The restrictions on the impulse responses are indicated by the shaded areas.

Figure 13: Responses to a military build-up – Fiscal dummy variable approach



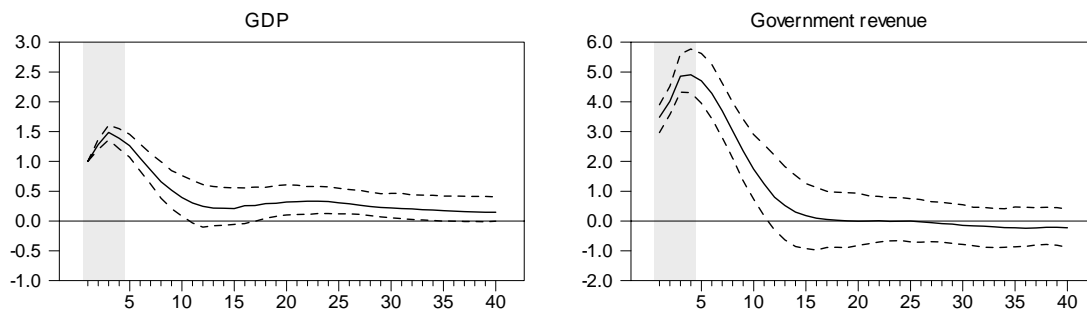
*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the fiscal dummy variable approach. The responses are shown for a horizon of 40 quarters. The responses of government spending, government revenue, GDP, inflation and the interest rate are based on the 5-variable VAR model, the responses of the other variables are based on 6-variable VAR models adding each of the other variables in turn to the benchmark set of variables. For the fiscal dummy variable approach, the VAR models include the current value and four lags of a dummy variable capturing the Ramey-Shapiro episodes relevant for our sample (Vietnam War and Reagan military build-up). The impulse responses to a unit shock to the dummy variable are shown in percentage changes.

Figure 14: Impact response of GDP to a pure revenue shock – Blanchard/Perotti approach  
Response for alternative values of the output elasticity of net taxes



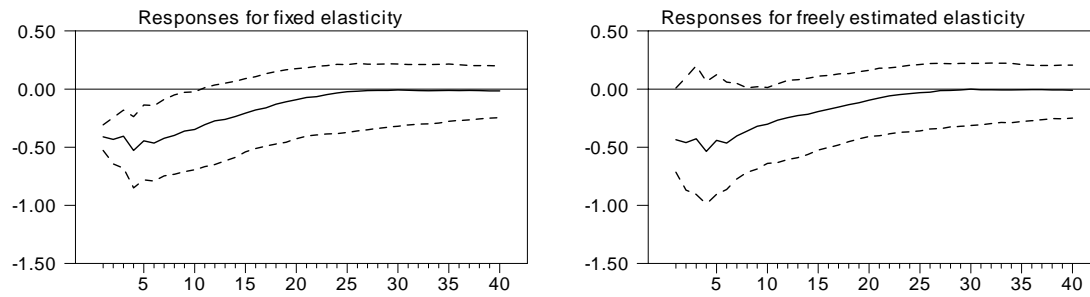
*Note:* The symbols depict the impact response of GDP in US dollars to a pure revenue shock of size one dollar for the Blanchard-Perotti identification approach for alternative values of the output elasticity of net taxes. The vertical lines indicate the values of the output elasticity of net taxes imposed by Perotti (2006), Blanchard and Perotti (2002) and the point estimate that obtains if this elasticity is treated as a free parameter in the estimation, respectively. The responses are based on the 5-variable VAR model.

Figure 15: Responses to a business cycle shock – Sign-restrictions approach



*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses for the sign-restrictions identification approach. The responses are shown for a horizon of 40 quarters. They depict the percentage change in the plotted variables in response to a business cycle shock standardized such that the impact response of GDP is equal to 1 percent. The sign restrictions on the impulse responses are indicated by the shaded areas. The responses are based on the 5-variable VAR model.

Figure 16: Responses of GDP to a pure revenue shock – Blanchard/Perotti approach  
 The consequences of treating the output elasticity of net taxes as fixed



*Note:* The solid lines plot the median, the dotted lines the 16% and 84% fractiles of the posterior distribution of the impulse responses of GDP (in US dollars) to a pure revenue shock of size one dollar for the Blanchard-Perotti identification approach. The responses are shown for a horizon of 40 quarters. The left-hand subplot shows the responses for the specification of the structural VAR model in which the output elasticity of net taxes is fixed at the value of the point estimate (2.98). The right-hand subplot shows the responses for the specification of the structural VAR model in which the output elasticity of net taxes is freely estimated for each draw of the Monte-Carlo simulation. The responses are based on the 5-variable VAR model.