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# FISCAL STIMULUS IN TIMES OF HIGH DEBT RECONSIDERING MULTIPLIERS AND TWIN DEFICITS

Christiane Nickel and  
Andreas Tudyka



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**Christiane Nickel**

European Central Bank; e-mail: [christiane.nickel@ecb.europa.eu](mailto:christiane.nickel@ecb.europa.eu)

**Andreas Tudyka**

WHU - Otto Beisheim School of Management; e-mail: [andreas.tudyka@whu.edu](mailto:andreas.tudyka@whu.edu)

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<b>Address</b>	Kaiserstrasse 29, 60311 Frankfurt am Main, Germany
<b>Postal address</b>	Postfach 16 03 19, 60066 Frankfurt am Main, Germany
<b>Telephone</b>	+49 69 1344 0
<b>Internet</b>	<a href="http://www.ecb.europa.eu">http://www.ecb.europa.eu</a>
<b>Fax</b>	+49 69 1344 6000

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## Abstract

We investigate the impact of fiscal stimuli at different levels of the government debt-to-GDP-ratio for a sample of 17 European countries from 1970 to 2010. This is implemented in an interacted panel VAR framework in which all coefficient parameters are allowed to change continuously with the debt-to-GDP ratio. We find that responses to government spending shocks exhibit strong non-linear behaviour. While the overall cumulative effect of a spending shock on real GDP is positive and significant at moderate debt-to-GDP ratios, this effect turns negative as the ratio increases. The total cumulative effect on the trade balance is negative at first but switches sign at higher levels of debt. Consequently, depending on the degree of public indebtedness, our results accommodate long-run fiscal multipliers which are greater and smaller than one or even negative as well as twin deficit and twin divergence behaviour within one sample and time period. From a policy perspective, these results lend additional support to increased prudence at high public debt ratios because the effectiveness of fiscal stimuli to boost economic activity or resolve external imbalances may not be guaranteed.

**JEL Classifications:** E62, F32, F41, C32, C11.

**Keywords:** Fiscal policy, debt dynamics, trade account, non-linearities, Bayesian estimation, panel-VAR.

## Non-technical summary

In response to the financial and economic crisis many industrialized countries adopted fiscal stimulus measures of unprecedented scale throughout 2009 and 2010. The fiscal response not only addressed weaknesses in the financial sector but also aimed at stimulating domestic demand to stop the rapid weakening of economic activity. As a consequence, fiscal positions deteriorated significantly across the board leading to high fiscal deficits and a rapid accumulation of government debt. Although incidences of high government debt are by no means historical abnormalities, the degree to which major economies have recently been jointly affected is exceptional. Up to now, with no clear signs of an economic recovery in sight, evidence for the effectiveness of the implemented stimuli is at best mixed.

This paper empirically investigates the effects of fiscal stimuli on other macroeconomic variables such as real GDP, investment and the trade balance in view of rising government debt in Europe. We contribute to the literature in two ways: By using an interacted panel VAR for a sample of 17 European countries from 1970 to 2010, we explicitly allow the behaviour of all variables included in our specification to vary with the degree of indebtedness in response to a fiscal impulse. Therefore, government debt can have both direct and indirect effects through the other variables in our specification. Moreover, we shed light on the question whether an increasing government debt-to-GDP ratio can drive varying responses of the private sector and thus the behaviour of the current account after a fiscal stimulus. The literature so far has largely examined these questions in isolation. For example, a large body of literature exists on both measuring the effectiveness of fiscal policy by means of multiplier analyses and on examining open economy considerations such as the effects of spending on the terms of trade or the current account (twin deficit literature). Furthermore, while non-linear effects of fiscal policy have been investigated mostly in the context of expansionary fiscal consolidations, a negative correlation between debt and growth has only recently received increasing empirical support.

Overall, our findings support the argument that the private sector increasingly internalizes the government budget constraint as the debt-to-GDP ratio grows. Expansionary fiscal shocks measured as a one percentage-point-of-GDP increase in government consumption are first followed by positive cumulative responses of real GDP and negative responses of private investment and the trade balance. At higher levels of the debt-to-GDP ratio, however, the overall effect on real GDP turns negative, crowding-out of investment increases significantly and the trade balance moves into surplus. This indicates support for the presence of features of the Ricardian equivalence proposition in a non-linear fashion in that higher deficits now without coincident taxation will be expected to be reverted in the future by corresponding surpluses.

Our findings suggest that policy makers should diligently scrutinize the government debt situation before implementing fiscal stimuli programs as their effectiveness to boost economic activity or resolve external imbalances may not be guaranteed. Considering our results against the background of the recent surge in public debt levels for nearly all industrialized countries, this suggests that further fiscal stimuli programmes may not only be ineffective but even counterproductive.

# 1 Introduction

In response to the financial and economic crisis many industrialized countries adopted fiscal stimulus measures of unprecedented scale throughout 2009 and 2010. The fiscal response not only addressed weaknesses in the financial sector but also aimed at stimulating domestic demand to stop the rapid weakening of economic activity. As a consequence, fiscal positions deteriorated significantly across the board leading to high fiscal deficits and a rapid accumulation of government debt. Although incidences of high government debt are by no means historical abnormalities, the degree to which major economies have recently been jointly affected is exceptional. Up to now, with no clear signs of an economic recovery in sight, evidence for the effectiveness of the implemented stimuli is at best mixed. This may not come as a surprise because with respect to the size of fiscal multipliers, the empirical literature suggests that the impact of a fiscal stimulus on output is very much state-dependent (Afonso et al., 2010).

Against the backdrop of the recent accumulation of government debt in many countries, this paper empirically investigates the effects of fiscal stimuli on other macroeconomic variables such as real GDP, investment and the trade balance in view of rising government debt in Europe. We contribute to the literature in two ways: We explicitly allow the behaviour of all variables included in our specification to vary with the degree of indebtedness in response to a fiscal impulse. Therefore, government debt can have both direct and indirect effects through the other variables in our specification. Moreover, we shed light on the question whether an increasing government debt-to-GDP ratio can drive varying responses of the private sector and thus the behaviour of the trade balance after a fiscal stimulus. The literature so far has largely examined these questions in isolation. For example, a large body of literature exists on both measuring the effectiveness of fiscal policy by means of multiplier analyses and on examining open economy considerations such as the effects of spending on the terms of trade or the current account (twin deficit literature). Furthermore, while non-linear effects of fiscal policy have been investigated mostly in the context of expansionary fiscal consolidations, a negative correlation between debt and growth has only recently received increasing empirical support (Checherita and Rother, 2010; Reinhart and Rogoff, 2010). To the best of our knowledge however, there exists no research linking these strands of literature.

The external balance (as well as real GDP) of a country may behave non-linearly in response to fiscal actions taken by the government depending on government indebtedness. According to national income accounting identities, the current account must equal the difference between domestic saving (both public and private) and domestic investment. Therefore, the occurrence of a twin deficit essentially rests on how private saving and investment adjust in response to an exogenous change in public saving. In particular, private agents' behaviour may depend on how fiscal actions by the government are perceived or the context in which they take place. For example, if an increase in the budget deficit (equivalently a decrease in public saving) is accompanied by a relatively strong increase in private consumption and a relatively small decrease in investment, as the Keynesian paradigm would predict, by the above identity the external balance has to be negative, resulting in a twin deficit (see Corsetti and Müller, 2006). In contrast, if private agents perceive the current fiscal situation to be unsustainable (for example because public indebtedness is high), they may respond by lowering private consumption (increasing precautionary saving) to a large degree. This mechanism refers to the Ricardian equivalence proposition, which in its strict form implies, that the decrease in public saving will be fully offset by an increase in precautionary private saving in order to pay for higher future taxes whose introduction will eventually be required as a result of the increased deficit.<sup>1</sup> Naturally, the imposition

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<sup>1</sup>Note that under full Ricardian equivalence (given perfect capital markets, perfect foresight, infinitely lived households and non-distortionary taxes) private saving would only fully offset increased government spending if the latter was permanent. In case of a temporary increase in government spending, the decrease in consumption which is necessary to match the higher future tax liabilities is lower such that an expansionary output effect

of higher taxes in the near future may be perceived as much more tangible if indebtedness is high, i.e. if the need for fiscal consolidation becomes more pressing. If, in addition, investment decreases to a degree such that the combined effect outweighs the decrease in public saving, the external balance and the public balance may diverge (see Kim and Roubini, 2008; Nickel and Vansteenkiste, 2008). Therefore, the relationship between the government budget on the one hand and the external balance and the fiscal multiplier on the other may change from being “Keynesian” in nature at low debt-to-GDP ratios, while becoming increasingly “Ricardian” as government indebtedness rises.

Our approach takes up the investigation from a different angle than previous studies and allows the coefficients to vary continuously over the range of within-sample debt ratios. To this end, we use an interacted panel VAR as in Towbin and Weber (2011), which is estimated in Bayesian fashion for 17 European countries. This framework enables us to examine the channels through which debt may be detrimental for growth as all coefficient parameters are allowed to change with the debt-to-GDP ratio. For example, this allows for multipliers which are smaller or larger than one or even negative, and to observe twin deficit or twin divergence behaviour of the current account within one set-up. It also constitutes an interesting alternative investigation, which may be closer to the actual behaviour of the private sector, whose actions may continuously change as the debt-ratio changes rather than to be triggered by threshold levels (and thus to react in a step-wise manner) as is usually assumed in the literature.

Using an interacted panel VAR has several advantages: The panel structure enables us to economize on degrees of freedom while the VAR structure allows us to investigate dynamic effects of fiscal policy. While threshold models impose discrete jumps on the system beyond which the effect of the variable of interest changes, remaining constant thereafter, we can track the varying effects of government spending over the entire range of debt.<sup>2</sup> The Bayesian estimation technique, through the introduction of prior information, further allows us to mitigate problems resulting from the proliferation of parameters, which is characteristic of high dimensional models.

Overall, our findings support the argument that the private sector increasingly internalizes the government budget constraint as the debt-to-GDP ratio grows. Expansionary fiscal shocks measured as a one percentage point of GDP increase in government consumption are first followed by positive cumulative responses of real GDP and negative responses of private investment and the trade balance. At higher levels of the debt-to-GDP ratio, however, the overall effect on real GDP turns negative, crowding-out of investment increases significantly and the trade balance moves into surplus. This indicates support for the presence of features of the Ricardian equivalence proposition in a non-linear fashion. Consequently, the effectiveness of fiscal stimuli to boost economic activity or resolve external imbalances may fade with increasing debt-ratios.<sup>3</sup> From a policy perspective, these results therefore lend additional support to increased prudence at high public debt ratios.

The next section provides a brief overview of the related literature. Section 3 describes the data used in our analysis while section 4 introduces our methodology as well as estimation details. Section 5 presents the results while section 6 tests for their robustness. Section 7 concludes.

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remains.

<sup>2</sup>One could of course impose several thresholds at which debt has different effects and therefore somewhat smooth the jumps. However, the more thresholds are introduced the smaller the respective sample sizes get. Our approach has the advantage that we consistently work with the full sample.

<sup>3</sup>Due to symmetry of the results, in line with the literature on expansionary fiscal consolidations, contractionary policy measures may exert expansionary effects on medium-run economic activity when debt-to-GDP ratios are high (Giavazzi and Pagano, 1990).

## 2 Literature Overview

High and growing public debt has recently attracted renewed attention in the academic literature. In general, debt has been recognized as a central variable in multivariate dynamic settings by Chung and Leeper (2007), Favero and Giavazzi (2007), Corsetti et al. (2012) and Favero et al. (2011) among others. Specifically, these authors emphasize that the exclusion of debt as an endogenous variable or neglecting debt dynamics in general can lead to substantial biases in the estimated coefficients because the feedback from government debt to spending remains unaccounted for. If different sample periods imply different average sample debt ratios and hence correspond to different debt environments, this effect might partly be the cause behind some of the contradictory findings in the literature on fiscal multipliers.

In particular, various authors have emphasized the deleterious impact debt accumulation can have on economic growth once the debt-to-GDP ratio exceeds a certain threshold. For example, using an extensive data set covering over 200 years and 44 countries, Reinhart and Rogoff (2010) find that a level of government debt which exceeds 90% of GDP is significantly associated with lower GDP growth. In line with these findings, Cecchetti et al. (2011) examine government, non-financial corporate and household debt for 18 OECD countries and report that at moderate levels debt improves welfare, while government debt levels above 80% to 100% of GDP, corporate debt above 90% of GDP and household debt above 85% of GDP, have a deleterious impact on growth. Checherita and Rother (2010) find a similar level of 90-100% for a panel of 12 euro area countries beyond which a rising debt-to-GDP ratio is related to a negative effect on long-run growth. However, these studies differ from our approach in that they estimate average effects which stay constant before and after a single threshold level. Moreover, there is no explicit investigation of the time needed until the effect takes place.

Non-linear effects of fiscal policy have been subject to extensive research. This has partly been motivated by opposing predictions of theoretical models for central macroeconomic variables such as private consumption. For an overview of theoretical predictions see for example Beetsma (2008) or Giavazzi et al. (2000). Similarly, there is still no broad consensus on the effects of different fiscal policy tools, which is at least partly rooted in the fact that the fiscal transmission mechanism can act through various channels. This applies to both the policy design, i.e. whether fiscal policy is implemented via the expenditure or revenue side, and within each category to the precise measure being implemented (e.g. government consumption versus investment or taxes versus transfers). With regard to the policy design, the empirical literature largely agrees that, in the short run, increases in government spending are more effective in boosting economic activity than tax reductions (Afonso et al., 2010).

One source for the non-linear effects of fiscal policy is their impact on the expectations formation in the private sector as is assumed by Ricardian equivalence. An increase in government debt, if anticipated to be followed by consolidative fiscal actions in the future, lowers lifetime disposable income. This in turn will curb spending today as precautionary savings increase.<sup>4</sup> Conversely, decisive and permanent deficit reduction now decreases the need for large and disruptive fiscal adjustments in the future and thus may generate a positive wealth effect. Expectations can also work through interest rates if the real interest rate faced by the private sector decreases in response to a lower government bond interest rate caused by credible fiscal consolidation.

An early examination of the interplay between private consumption and public debt is Nicoletti (1988). In a sample of eight OECD countries he finds that “debt accumulation induces

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<sup>4</sup>See Ricardo (1817) and Barro (1974). While the conventional Keynesian view says that higher budget deficits stimulate demand in the short run, so-called Ricardian behaviour exists when forward-looking consumers save the proceeds from a debt-financed fiscal stimulus in anticipation of the future tax increases. Then, budget deficits would have no short-run real economic effects. The latter is also referred to as a “non-Keynesian effect” because the behaviour by consumers annuls the stimulus.

precautionary savings precisely when it surpasses the threshold beyond which its consequences on the economy [...] are felt to be unsustainable". Bertola and Drazen (1993) develop a model in which "nonstandard" effects of current fiscal policy may arise as a function of its own initial level. In contrast, Perotti (1999) and Sutherland (1997) show how fiscal policy effects can depend on the initial level of public debt. Specifically, while at moderate levels of public debt the effects of fiscal policy are of Keynesian style, they reverse into contractionary effects at extreme levels of public debt. Giavazzi and Pagano (1996) find that the non-linearity in private consumption derives from the magnitude of the increase in full-employment primary deficit for a panel of OECD countries. Giavazzi et al. (2000) also investigate empirically if national saving responds non-linearly to fiscal policy impulses and find that non-linear responses by the private sector are more likely when fiscal impulses are large and persistent, that they are larger for changes in net taxes as opposed to changes in public consumption and larger for fiscal contractions than for fiscal expansions while the share of public debt does not seem to play an important role.

In similar vein, Giavazzi and Pagano (1990) examine cases of expansionary fiscal consolidations in their study of Ireland and Denmark in the 1980s in which large fiscal adjustments in the form of spending cuts had expansionary effects. In addition to various characteristics such as the level of development, exchange rate regime and openness to trade, Ilzetzki et al. (2010) investigate whether high government expenditure shocks exert different effects in high debt episodes, defined as a period of three or more years with debt exceeding a threshold of 60%. Their findings indicate that long-run multipliers for these episodes are negative. These findings are also supported by Kirchner et al. (2010), who investigate the determinants of time-varying effects of fiscal policy in the euro area. They find government debt to be the main reason for declining spending multipliers at longer horizons.

For an account of the current account and expansionary fiscal contractions see Beetsma (2008). Furthermore, the monetary-fiscal nexus affects the effectiveness of fiscal policy especially in times of fiscal stress (Leeper, 2010). Chiefly, in normal times (when monetary policy dominates fiscal policy) fiscal shocks may have a significantly different effect on the economy than in times of crises, when monetary policy might shift towards other goals than inflation stabilisation (such as output or financial stabilisation).<sup>5</sup>

Finally, the introduction of open economy considerations can significantly alter the way in which fiscal policy affects the economy. On the one hand, the degree of openness itself can have implications for the effectiveness of fiscal stimuli. For example, Hemming et al. (2002) find some evidence that fiscal policy tends to yield Keynesian outcomes in closed economies, which turn non-Keynesian in open economies. Rzonca and Cizkowicz (2005) find evidence for non-Keynesian effects working through what they call the "export channel".<sup>6</sup> Moreover, Hebous and Zimmermann (2013) report that coordination among member countries of the Euro Area is important because fiscal shocks are more effective and less costly if every member country contributes.

On the other hand, how fiscal policy affects a country's external position itself is of high theoretical and practical relevance. For example, Corsetti and Müller (2006) investigate the effects of fiscal policy on the trade account and find that fiscal policy shocks worsen the trade account in economies that are relatively open and in which fiscal expansions are persistent. Beetsma et al. (2008) enter the components of the trade balance separately into their specification and find evidence for the twin-deficit hypothesis for 14 EU countries. Ravn et al. (2007) find a deterioration of the trade balance and a depreciation of the real exchange rate in response to a positive government spending shock, which is contradictory to the implications of many theoretical models. However, when introducing deep habits into a two-country model they are able

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<sup>5</sup>See also Sargent and Wallace (1981) and their "Unpleasant Monetarist Arithmetic".

<sup>6</sup>The export channel is essentially a supply-side channel that operates through wages and salaries reducing wage pressures in response to a negative expenditure or positive tax rate shock.



to explain this behaviour. Monacelli and Perotti (2010) show that this abnormality is also not explainable if rule-of-thumb consumers are introduced into neo-Keynesian-type open economy models, and further provide evidence in support of a traditional “twin-deficit” hypothesis.

Ali Abbas et al. (2011) investigate the relationship between fiscal policy and the current account using different estimation techniques for a panel of over 100 countries. They find a worsening of the current account balance in response to a positive government spending shock, with the effect being stronger for emerging and low-income countries and in countries in which real GDP is above potential. For developing countries they report a weakening of the fiscal policy vs. current account association for levels of external indebtedness above 45 percent.

Enders et al. (2011) employ sign restrictions to identify the structural errors and find, leaving the response of net exports unrestricted, a positive albeit small response of net exports and a depreciation of the real exchange rate for the US as a result of a positive government spending shock. Kim and Roubini (2008) on the other hand find a negative correlation between fiscal and current account balances in response to a fiscal policy shock, which they attribute to partially Ricardian behaviour, i.e. private saving increasing and investment crowding-out which, they term a “twin-divergence” effect. Likewise, Corsetti et al. (2012) document an initial (but insignificant) fall of net exports in response to a positive spending shock, followed by a significantly positive response after about 3 years. Similarly, Müller (2008) finds evidence of an improvement of the current account after an expansionary fiscal shock. Corsetti and Müller (2006) note that their finding of a weaker response of the trade balance, compared to Müller (2008), may be due to different sample starting dates. However, as they note, this might be due to the characteristics of the US economy. Generally, this literature does not explicitly consider the effects of public debt.

Because we include both open economy considerations and non-linearities, this paper is closest to Nickel and Vansteenkiste (2008), who employ a dynamic threshold panel approach for 21 industrialized countries to study the effects of the government balance and the current account in different debt regimes. They find that the fiscal and current account deficits are positively correlated for countries with a debt-to-GDP ratio below 85% and negatively, but insignificantly correlated for countries above that threshold.

### 3 Data

We use annual data on an unbalanced panel of 17 European countries for the period 1970:2010. All variables are taken from the EU Commission’s AMECO database. The choice of countries is largely dictated by the question under investigation: as we are interested in different debt regimes, we only include countries in our sample which experienced a debt-to-GDP ratio of at least 70% of GDP at some point in time. These countries are Austria, Belgium, Bulgaria, Cyprus, Denmark, France, Germany, Greece, Hungary, Ireland, Iceland, Italy, Malta, Netherlands, Portugal, Sweden and the United Kingdom. For each country we include the following variables: real government consumption, real GDP, real private investment, the general government debt-to-GDP ratio and the trade balance defined as exports minus imports divided by GDP. We focus on the spending side rather than on taxes for several reasons. First, since the empirical and theoretical literature has devoted more attention to the former, comparison of our results to existing studies is straightforward. Second, fiscal instruments which directly stimulate aggregate demand, like government consumption and investment, are usually deemed to be more effective than, for example, tax cuts. Finally, identification of tax shocks is more controversial as automatic stabilisers may be substantial regarding taxes. For the same reason, within the spending side we concentrate on government consumption because this is the com-

ponent of overall spending which probably reacts least to real GDP changes.<sup>7</sup> Furthermore, we choose the trade balance instead of the current account for reasons of data availability and data quality, based on the inclusion of net factor payments in the latter (Beetsma et al., 2008). All variables except for the trade balance are expressed in natural logs. Furthermore, we demean and detrend each variable by regressing each series on a constant and a linear and a quadratic trend and subsequently take deviations from the respective fitted values. Figure 1 shows the distribution of country-year observations in 5% intervals for the debt-to-GDP variable. The mode of the distribution is at a debt ratio of 64%, after which the number of observations drops rather quickly. About 5% of the observations lie above 130%.

The use of annual data poses potential drawbacks in that we have much fewer observations than in the case of quarterly variables. Furthermore, our identification assumptions become stronger. However, truly quarterly, i.e. non-interpolated, data of fiscal variables for European countries that reach sufficiently back in time are available for only few countries. Moreover, as Beetsma et al. (2006) note, the use of annual data also has advantages. First, there is no need to worry about seasonal effects in annual data. Also, the fiscal budget is decided upon and published once a year. This means that although intra-year revisions can and do take place, they are comparatively small, so that true government spending shocks should be well-captured by annual data. Moreover, structural shocks uncovered with annual data should be closer to truly unanticipated shocks as, in contrast to quarterly data, policy actions are unlikely to be anticipated one year ahead. Similarly, implementation lags of purchasing decisions are more likely to be a concern for quarterly data, which may result in incorrect dating of policy shocks. In addition, the institutional framework reflected in differences in tax collection lags and payment methods across countries is much less pronounced in annual data (Perotti, 2005).

## 4 Methodology

### 4.1 Empirical Model and Identification

We estimate the impact of government spending shocks using a panel VAR. Specifically, the structural model takes the following form,

$$y_{i,t}A_{i,0} = \sum_{p=1}^P y_{i,t-p}A_{i,p} + \epsilon_{it}, \quad (1)$$

for  $p = 1, \dots, P; i = 1, \dots, N; t = 1, \dots, T$ , where  $P$  denotes the lag length,  $N$  denotes the number of cross-sectional units (countries)  $i$ , and  $T$  denotes the number of time periods  $t$ .  $y_{i,t}$  is a  $1 \times K$  vector containing the variables described in section 3. The  $K \times K$  matrices  $A_{i,0}$  and  $A_{i,p}$  contain the contemporaneous and lagged relationships between all endogenous variables respectively. The components of the  $1 \times K$  vector  $\epsilon_{it}$  are mutually uncorrelated structural *iid*  $N(0, \Sigma)$  errors ( $\Sigma$  being diagonal), which we want to recover.

As is very common in the literature (see for example Blanchard and Perotti (2002) for the U.S. and Beetsma et al. (2006) for the EU) we identify the structural model by imposing that all except the first element of the first column of  $A_{i,0}$  be zero. This is equivalent to imposing a

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<sup>7</sup>Government wage payments constitute a large fraction of government consumption. Since the wage setting behaviour of the public sector is likely to differ from that of the private sector due to a number of factors - such as a higher degree of unionisation, political objectives, the difficulties of measuring labour productivity in the public sector-, the different status that civil servants enjoy might make public wages less reactive to the business cycle (Lamo et al., 2008).

recursive structure on the system, in which all variables in the system react contemporaneously to government consumption but government consumption does not react to any other variable on impact. This implies the imposition of a Wold causal ordering on the system such that  $A_{i,0}$  is upper triangular with ones on the main diagonal. Note that since we are only interested in spending shocks, the ordering of the variables below our spending variable is irrelevant.

We assume the parameter matrices  $A_{ip}$  to be common across countries ( $A_{ip} = A_p$ ) as for example in Ardagna et al. (2007). Imposing parameter homogeneity when in fact parameters are heterogeneous across countries can have negative consequences: For large  $T$  and  $N$  Pesaran and Smith (1995) show that conventional fixed effects estimators are inconsistent when there is heterogeneity in the slope parameters. As a solution, they propose the mean group estimator, which is an arithmetic average of the estimated parameters over cross-sections. The drawback of this approach, however, is that when the time dimension is small, as in our case, the small sample bias of the mean group estimator may outweigh the heterogeneity bias of the fixed effects estimator. Rebucci (2003) extends their analysis to a panel VAR context and shows by means of Monte Carlo simulations that for typical macro panels, i.e. panels of moderate size, heterogeneity in the slope parameters would have to be substantial to induce a significant bias. Consequently, resorting to the mean group estimator might just trade one problem for another. Furthermore, if moderate degrees of persistence in the VAR system is present, the IV estimator as introduced by Holtz-Eakin et al. (1988) performs worst. Similarly, Hsiao et al. (1998) do not advise the use of the mean group estimator when  $T$  is not sufficiently large relative to  $N$ . Instead, they propose the use of hierarchical or empirical Bayesian methods which successfully have been applied to panel VAR models by e.g. Canova and Ciccarelli (2004).

We allow for deterministic heterogeneity of various forms. First, our approach explicitly allows the coefficients to vary with the country-specific debt ratio. Moreover, we include country-specific fixed effects as well as country-specific linear and quadratic trends. This should alleviate biases caused by slope heterogeneity. Finally, our sample consists of EU countries only. As these countries share many similarities the assumption of a homogenous coefficient matrix seems well-justified.

## 4.2 Interaction Terms

We want to investigate the impact of government spending innovations at varying degrees of country-indebtedness and therefore augment the panel VAR in (1) with an interaction term as in Towbin and Weber (2011) and Sa et al. (2011). In particular, we allow each endogenous variable to interact with the debt-to-GDP ratio in  $t - 1$ .<sup>8</sup> For what follows, it is convenient to express (1) by imposing the homogeneity assumption for the parameter matrices ( $A_{ip} = A_p$ ) and adding  $y_{i,t}(I_K - A_{i,0})$  to both sides of the equation. As a result, the interacted panel VAR can be expressed as

$$y_{i,t} = A_0^* y_{i,t} + \sum_{p=1}^P y_{i,t-p} A_p + \epsilon_{i,t}, \quad (2)$$

where  $A_0^* = I_K - A_0$  is an upper diagonal matrix with zeros on the main diagonal.<sup>9</sup> Each element of the coefficient matrices  $A_p$  in (2) is now given by

$$A_p = B_p^0 + B_p^1 \left( \frac{Debt}{GDP} \right)_{i,t-1}. \quad (3)$$

<sup>8</sup>Using for example  $t - 2$  interaction terms has almost no effect on the results, which are available upon request.

<sup>9</sup>Hence, the  $k$ -th equation in (2) may contain  $y_{1it}, \dots, y_{(k-1)it}$ , but not  $y_{kit}, \dots, y_{Kit}$  on the right-hand side (see Luetkepohl (2005)).

The same applies to  $A_0^*$ , with the only difference being that  $A_0^*$  has only  $k \times (k - 1)/2$  entries. Therefore, all contemporaneous and lagged parameters vary deterministically with country-indebtedness.<sup>10</sup> As a direct consequence, the response of variable  $k$  to an innovation in variable  $j$  is dependent on the debt-to-GDP ratio.<sup>11</sup> Since we explicitly stress the importance of debt-dynamics, the debt-to-GDP ratio additionally enters in levels to capture the direct impact that indebtedness may have on the other endogenous variables. Note that since only the  $t - 1$  value of the debt-to-GDP ratio enters the RHS of (2) our identification approach remains unaffected.

The introduction of continuous interaction variables provides a convenient way to track responses of all endogenous variables at various levels of debt. We implement this by evaluating (3) for given draws of the parameters contained in  $B_p^0$  and  $B_p^1$  at various percentiles of  $(\frac{Debt}{GDP})$ , defined over the range of values we observe in our sample. This ranges from about 18% to about 143%. However, to get a sense of representative values we restrict the bandwidth which is effectively used for the interaction variables to lie within the 5th and the 95th percentiles of the  $(\frac{Debt}{GDP})$  distribution.<sup>12</sup> Impulse responses at various degrees of indebtedness are then easily calculated after inversion of the impact matrix  $A_0$ , which is readily available after equation-by-equation estimation. Consequently, the reduced form covariance matrix  $\tilde{\Sigma} = A_0'^{-1}\Sigma A_0^{-1}$  also varies with the debt-to-GDP ratio.

### 4.3 Estimation

We estimate the model using Bayesian methods for the specification, as stated above, with a lag length of one. The choice of Bayesian methods is especially attractive for several reasons. First, the introduction of prior information allows us to considerably alleviate problems resulting from the dimensionality of the model. This is very helpful as the time series dimension of our sample is at most 41 observations per variable, which is further reduced due to the unbalanced nature of the panel. Moreover, the introduction of an interaction variable doubles the number of coefficient parameters to be estimated. In addition, computation of probability bands is facilitated to a large degree. Furthermore, following a Bayesian estimation approach circumvents the problem of unit roots and cointegrating relationships because for appropriate prior choices both the likelihood and posterior p.d.f. are Gaussian in shape even in the presence of unit roots and hence inference does not require special treatment (Sims, 1988; Sims and Uhlig, 1991).

In what follows, we present the implementation of our estimation approach. In order to describe the estimation procedure define each equation of the structural panel VAR as

$$y_{ikt} = z'_{ikt}\alpha_k + e_{ikt} \quad (4)$$

for  $t = 1, \dots, T$  observations,  $k = 1, \dots, K$  variables and  $i = 1, \dots, N$  countries where  $y_{ikt}$  is the  $t^{th}$  observation on the  $k^{th}$  variable for country  $i$ ,  $z_{ikt}$  is an  $m_k$  vector containing the  $t^{th}$  observation of the vector of explanatory variables relevant for the  $k^{th}$  variable for country  $i$ ,  $\alpha_k$  is the corresponding  $m_k$  vector of regression coefficients and  $e_{ikt}$  is a normally distributed *iid* error term (see Koop and Korobilis (2010) for a similar derivation).<sup>13</sup> Next, stack all observations

<sup>10</sup>Therefore, each equation has a different number of parameters to be estimated. In particular, going from left to right in the row vector  $y_{i,t}$  each additional equation has two more parameters to be estimated.

<sup>11</sup>Expressed differently, any *row* -  $j$ , *column* -  $k$  element in  $B_p^0$  shows the effect which variable  $j$  in lag  $p$  has on variable  $k$  in period  $t$  when the debt-to-GDP ratio equals zero. Taken by themselves, the coefficients in  $B_p^0$  are therefore uninteresting, especially since our data set does not include countries with 0% debt. Also note that the magnitude of  $B_p^0$  varies with the magnitude of  $(\frac{Debt}{GDP})$  and hence should be interpreted carefully.

<sup>12</sup>Alternatively, we could split our sample according to a certain percentile of the interaction variable and estimate separate sets of coefficients. However, joint estimation greatly increases the degrees of freedom.

<sup>13</sup>The overall number of coefficient parameters is hence defined as  $m = \sum_{j=1}^K m_j$ .

on variable  $k$  over time and the resulting vectors country-wise such that the equation for each variable  $k$  can be expressed as

$$y_k = Z_k \alpha_k + e_k \quad (5)$$

where now  $y_k$  is an  $NT$  vector of observations for variable  $k$ ,  $Z_k$  is an  $NT \times m_k$  matrix of explanatory variables relevant for equation  $k$ ,  $\alpha_k$  is the corresponding  $m_k$  vector of regression coefficients and  $e_k \sim N(0, \sigma_k^2)$ . Expressing the model in this way allows us to directly impose the recursive structure and hence to estimate the model equation by equation.

We use an independent Normal-Gamma prior. Although this requires the use of a computationally intensive Gibbs MCMC algorithm for the derivation of the posterior distribution, we follow this route in order to benefit from increased flexibility with regard to the prior specification of  $\alpha_k$  compared to a natural conjugate alternative (Koop, 2003).<sup>14</sup> In our baseline specification, we follow Canova and Ciccarelli (2009) and centre our prior for the coefficient parameters  $\alpha_k$  and the inverse of the error variances  $h_k = \frac{1}{\sigma_k^2}$  over the results of an initial OLS estimation over the entire sample, as our relatively short time series makes the sacrifice of a training sample prohibitive. In particular, our prior takes the following form

$$p(\alpha_k, h_k) = p(\alpha_k)p(h_k)$$

where

$$\alpha_k \sim N(\underline{\alpha}_k, \underline{V}_k)$$

$$h_k \sim G\left(\frac{\underline{\nu}}{2}, \frac{\underline{\nu} \underline{s}_k^2}{2}\right)$$

and  $N$  and  $G$  denote the multivariate Normal and Gamma distributions respectively.<sup>15</sup> Consequently, for our baseline specification we set  $\alpha_k = \hat{\alpha}_k$ ,  $\underline{V} = 10 \times \hat{V}$ ,  $\underline{s}_k^2 = \hat{\sigma}_k^2$  and  $\underline{\nu} = .01 \times T$  where *hats* over parameters denote the respective OLS estimates. This prior is subjective and informative, though to a low extent. In particular, by scaling  $\hat{V}$  by a factor of 10 we attribute substantial prior probability for the parameter variances to large deviations from the OLS values. Moreover,  $\underline{\nu}$  implies that we only attribute 1% of the weight our data information carries to our prior information and thus the degree of prior uncertainty about  $\sigma_k^2$  is also substantial.

Draws from the respective marginal posterior distributions can then be taken by alternately sampling from

$$\alpha_k | y_k, h_k \sim N(\bar{\alpha}_k, \bar{V}_k)$$

where

$$\bar{\alpha}_k = \bar{V}_k (\underline{V}_k^{-1} \underline{\alpha}_k + h_k Z_k' y_k)$$

$$\bar{V}_k = (\underline{V}_k^{-1} + h_k Z_k' Z_k)^{-1}$$

and

$$h_k | y_k, \alpha_k \sim G\left(\frac{\bar{\nu}}{2}, \frac{\bar{\nu} \bar{s}_k^2}{2}\right)$$

<sup>14</sup>The natural conjugate prior variance for  $\alpha_k$  is directly proportional to  $\sigma_k$ , which we want to avoid.

<sup>15</sup>The Gamma distribution is parameterized in terms of shape and inverse scale parameters. For details see the appendix to e.g. Gelman et al. (2003).

where

$$\bar{\nu} = \underline{\nu} + T$$

$$\overline{\nu s}_k^2 = (y_k - Z_k \alpha_k)'(y_k - Z_k \alpha_k) + \underline{\nu s}_k^2$$

We take 50,000 draws from the posterior densities and discard the first 30,000 as burn-in draws. Of the remaining 20,000 draws we report posterior quantities of interest such as impulse responses and probability bands. As a check for convergence of the drawn MCMC sequence we calculate convergence diagnostics as suggested by Geweke (1992) based on the first 10% and last 40% of post burn-in draws.<sup>16</sup> The results (available upon request) indicate that convergence has been achieved for all parameters.

## 5 Results

Our main results are presented in figures 2 and 3, which show impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ), the debt-to-GDP ratio ( $D$ ) and the trade balance ( $TB$ ) to a one percentage point of GDP shock to government consumption respectively. Rows within panels correspond to (cumulative) responses of variables as indicated on the left. Columns correspond to different choices of interaction values as designated in the respective column headers. In all plots, horizontal axes indicate periods after the shock. Vertical axes are defined as follows: The responses of real government consumption ( $G$ ) and real private investment ( $I$ ) are expressed as percentage shares of GDP ( $Y$ ) by multiplying the log response from the panel VAR by the sample average share of GDP of the respective variable.<sup>17</sup> Scales of the vertical axes within rows are the same in order to make comparison easier. The trade balance ( $TB$ ) and government debt ( $D$ ) are already expressed as percentage shares of GDP. Moreover, the initial shock to government consumption is normalized to 1 percentage point of GDP. The solid line corresponds to the median (50<sup>th</sup> percentile) impulse response and the shaded areas are the 16<sup>th</sup> and 84<sup>th</sup> percentiles of the respective posterior distribution as (one standard deviation) probability bands.

Overall, the results show that the impulse responses to an increase in government consumption exhibit strong non-linear effects, such that the effects on the economy change substantially with a growing government debt-to-GDP ratio. Our findings support the proposition that including debt is essential in dynamic specifications. For each variable in our specification, the detailed results shown in figure 2 are as follows:

Government consumption ( $G$ ) responds in a very persistent manner in that it takes about three years for the effect to reduce by half, but the higher the debt ratio, the earlier the response turns negative and the more pronounced are negative responses at later horizons. Consequently, the impulse responses of government spending display a self-reversing shape. This behaviour is consistent with Chung and Leeper (2007) and Corsetti et al. (2012), who also document that government spending first increases persistently but then turns negative before it again reaches its pre-shock path. If one takes into account that debt-financed increases in public demand may generate expectations of future fiscal retrenchment captured by the feedback from public debt to spending (as postulated by Ricardian equivalence), this finding suggests that at high levels of debt, governments are more likely to engage in debt-stabilizing policy decisions.

<sup>16</sup>Here we make use of Jim LeSage's MATLAB Econometrics Function Library available at <http://www.spatial-econometrics.com/>. The convergence diagnostic is asymptotically standard normally distributed.

<sup>17</sup>The average share of GDP is defined as the average over all observations and therefore countries included in the sample.

Real GDP ( $Y$ ) increases by 1.2% upon impact after which it gradually reverts back, reaching its pre-shock path after approximately 10 years, which is nearly identical to the finding of Beetsma et al. (2008). This pattern holds up to a debt ratio of about 60% beyond which real GDP undershoots its trend value at longer horizons in a statistically significant manner before it returns to trend. Moreover, this effect becomes more pronounced at higher government debt ratios while remaining statistically significant (albeit widening probability bands). Furthermore, it is noteworthy that the impact multiplier stays approximately constant across all debt ratios. However, while being purely positive and very persistent at low levels of debt, the response of real GDP exhibits an increasingly inverted hump-shape at higher debt ratios.

Private investment ( $I$ ) initially responds positively for all interaction values but drops below trend after about two periods. However, the negative response gets both larger in absolute size and statistically more significant as the debt ratio increases. The effect resembles that of real GDP but sets in earlier and more pronounced. Consequently, the degree of crowding-out of private investment through increased government purchases becomes stronger at higher government debt ratios.<sup>18</sup>

The effect that a spending shock exerts on the degree of indebtedness ( $D$ ) depends on the debt environment in which it takes place. At relatively low debt-to-GDP ratios, government debt reaches its peak response after around 5 periods. However, as the debt to GDP ratio approaches a range of 90% - 110% the response becomes more and more pronounced and more hump-shaped. In particular, the more strained the debt situation already is, the larger the impact of an additional percentage point of GDP in government consumption on the degree of indebtedness. Therefore, in high-debt environments debt accumulation exhibits accelerating features as well as more persistent behaviour in response to government consumption. This has very important policy implications, because it calls for more prudence when implementing fiscal packages in highly indebted countries.

Finally, compared to real GDP ( $Y$ ) and the debt-to-GDP ratio ( $D$ ) the response of the trade balance ( $TB$ ) initially exhibits much less persistence but as the debt to GDP ratio rises, the response becomes stronger and also more persistent (the impulse response crosses the zero line earlier and the subsequent positive effect on net exports becomes stronger and more significant). At a debt ratio of around 110% the initial drop of 0.5 percentage points of GDP is matched by an equivalent positive peak response after 8 periods, after which it slowly reverts back. Both effects, above and below the zero line, are statistically significant.

Depending on which debt scenario we examine, our results therefore accommodate the inconclusive results of previous studies, which either document positively correlated or divergent behaviour of government activity and the trade balance or the current account. In sum, our findings lead us to conclude that the contradictory findings of previous studies may be the result of estimation within a static debt regime when indeed the debt regime is dynamic. A consequence of this may for instance be that, when estimating responses over the entire range of debt ratios, the effect on the current account may well show up as insignificant because positive and negative effects cancel out.

Figure 3 reports cumulative responses for the flow variables of the same specification. The results yield further support for our findings. Increased government consumption exhibits a self-reversing pattern at higher debt ratios, reflected by increasingly hump-shaped cumulative impulse responses. Moreover, while the overall effect on real GDP is expansive even at very long horizons, the higher the debt ratio, the less this is the case. Eventually, at very high debt ratios, the overall effect on real GDP becomes significantly negative. These findings are similar to the findings of Ilzetzki et al. (2010).

Figure 4 summarizes figures 2 and 3. It displays the superimposed median (cumulative)

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<sup>18</sup>In an alternative specification (results are available upon request) we replaced real GDP by private consumption. The effect largely resembles that of real GDP, leaving all other responses almost unchanged.

impulse responses for each flow variable over all columns in one graph respectively. Probability bands are omitted to keep the graphs legible.

Against the backdrop of figures 2 and 3, from a policy perspective the implementation of expansive fiscal packages should be regarded with caution in highly indebted countries and may actually be counter-productive. In highly indebted countries, the increasing doubts about debt sustainability curb the expansive effects of higher government consumption. While the overall effect on private investment is statistically not different from zero at first, crowding-out becomes very sizeable and significant when the debt ratio increases. Finally, the cumulative effect on the trade balance is negative at low levels of debt but becomes positive and significant as the debt ratio increases. Figures 5 and 6 take up the question whether the changing (cumulative) impulse responses shown in the previous figures differ from each other (that is in different debt environments) in a statistically significant way besides being significantly different from zero at interesting horizons. Specifically, the figures show pairwise differences between impulse responses at different interaction choices together with the corresponding probability bands. Rows again correspond to variables, columns indicate which interaction choices are being subtracted from each other. Column 1 shows the difference of the outermost (cumulative) impulse responses and column 2 the differences of the second-outermost (cumulative) impulse responses shown in figures 2 and 3 (i.e. column 1 shows impulse responses evaluated at a debt-to-GDP ratio of 109% minus impulse responses evaluated at a debt-to-GDP ratio of 40%). This indicates that in addition to being individually sizeable, the responses vary across interaction choices in a statistically significant way. This is especially evident at intermediate horizons while the difference is statistically less clear at very short and longer horizons. Interestingly, even the more “neighbouring” responses are significantly different from each other, which suggests that fiscal policy effects change rapidly as the debt-to-GDP ratio increases. An interesting question especially for policy making is the degree of indebtedness at which the outcomes of fiscal expansions change signs. To provide some guidance on this issue, the left columns of figures 7 and 8 show the (cumulative) median impulse responses over the entire within-sample range of possible interaction choices, beginning from the 5th percentile and ending at the 95th percentile. Probability bands are omitted to keep the graphs legible. The black plane represents the zero plane. The right columns display the intersections of the median impulse response hyperplane and the zero plane. Accordingly, the resulting curve (equivalently the contour of the impulse response hyperplane at a response of zero) indicates at which horizon the median (cumulative) impulse responses first become negative as a function of the debt-to-GDP ratio. The dark region in the zero-contour plots denote impulse responses above the zero plane while the white region reflects the opposite.

Consequently, the zero-contour plot of figure 7 shows that the response of government consumption stays positive over the entire horizon up to a debt-to-GDP ratio of about 37%, where it becomes negative for the first time after about 14 periods. For debt-to-GDP ratios above 37% government consumption responds negatively progressively earlier as the debt ratio increases. This restates our finding of a self-reversing pattern of government consumption, indicating that this behaviour starts at surprisingly low levels of government debt and sets in progressively earlier at higher degrees of government indebtedness. In combination with figure 8, however, we can see that the negative effect of the impulse responses at later horizons is not enough to offset the positive effect at earlier horizons such that the cumulative impulse responses never cross the zero plane.

Real GDP responds positively up to a debt-to-GDP ratio of about 35% where it becomes negative for the first time. Beyond this ratio, real GDP crosses the zero plane successively earlier such that at debt-to-GDP ratios of approximately 105% real GDP responds negatively after 2-3 years already. The cumulative responses for real GDP indicate that the overall effect becomes negative successively earlier beyond debt-to-GDP ratios of around 65%. Interestingly, this level is fairly close to the 60% debt ratio as set forth in the Maastricht Treaty. This happens



relatively late - after 14 periods for the first time. Beyond debt-ratios of 65%-70%, however, the overall effect on real GDP becomes negative after a shorter time. For example, at debt-ratios of around 100% of GDP it takes about 6-7 periods until the cumulative effect on real GDP remains negative. These results are similar to earlier findings in the literature linking debt to economic performance.

The responses of private investment enter the negative range after about 2 periods over the entire range of debt ratios and turn positive again after 8 periods at low debt ratios and 15-16 periods at debt ratios beyond 50% of debt-to-GDP. Overall, this translates into a cumulative effect which stays negative beyond 27% of debt. The timing of the negative effect changes from 8 years at 27% to approximately 3 years at debt-to-GDP ratio of 100%. Therefore, we conclude that crowding-out is present at rather low debt ratios with the effect setting in progressively earlier as the debt ratio increases.

The debt-to-GDP ratio displays a more homogeneous behaviour in terms of crossing from positive to negative and vice versa. Therefore, persistence seems to set in at approximately the same time.

The cumulative response of the trade balance behaves very similarly to the mirror image of real GDP across the zero-plane. However, both in terms of the debt-ratio and time-wise it does so somewhat earlier. In particular, beyond about 60% of debt-to-GDP the cumulative response of the trade balance turns and remains positive after around 17 periods. However, this time period becomes progressively shorter as the debt ratio increases. At a debt ratio of about 100%, a one percentage point of GDP shock to government consumption is followed by a trade surplus after 5-6 periods. These findings are close to the findings in Nickel and Vansteenkiste (2008) and in this sense provide support for Ricardian equivalence.

Tables 1 and 2 present an overview of the periods it takes after the shock until (cumulative) impulse responses first cross the zero plane, i.e. change signs. For illustrative purposes, we start at a debt-to-GDP ratio of 35% for impulse responses and 65% in the case of cumulative responses (of the flow variables) because in each case this debt-to-GDP ratio is close to the lowest percentage at which the (cumulative) impulse response of real GDP becomes negative for the first time.<sup>19</sup> 112% represents the observation corresponding to the 95<sup>th</sup> percentile of our debt-to-GDP observations - the last observation we use for interaction values. In essence, for all variables other than the debt-to-GDP ratio itself, the number of years after which the (cumulative) response changes sign for the first time successively becomes smaller as the debt-to-GDP ratio increases. Again, this restates our earlier findings.

## 6 Alternative Specifications, Identifying Restrictions and Prior

### Sensitivity

A natural benchmark to test our model against is our baseline specification estimated without interaction terms. Figures 9 and 10 show the corresponding (cumulative) impulse responses. Perhaps unsurprisingly, the responses are similar to our baseline specification with the interaction terms evaluated at the median debt-to-GDP ratio. In particular, we observe that in response to a one percentage point of GDP shock to government consumption, the same variable reacts in a persistent manner and real GDP responds positively in the short to medium horizon while this effect reverts back to zero at very long horizons. Private investment crowding-out is also present and significant. Moreover, the trade balance reacts strongly and negatively upon impact

<sup>19</sup>Note that these values do not present discrete thresholds – the debt ratio is continuous. These values were chosen for illustration in tables 1 and 2.

but switches signs at longer horizons. Although the magnitude of the positive response is much smaller, it lasts for a longer period such that the cumulative response moves from negative to zero after around 14 periods. Interestingly, without any interaction terms the self-correcting behaviour of government consumption and debt as well as the sign-switching pattern of the cumulative responses of real GDP and the trade balance are no longer present. This suggests that conditioning on the debt regime is important when estimating the effects of fiscal actions. Consequently, this may partly explain the contradictory findings in the literature which investigates the magnitude of fiscal multipliers. Moreover, this also applies to studies related to the twin-deficits hypothesis as can be seen from figure 10: Estimating our model over the entire range of debt-to-GDP ratios without interaction terms supports the twin-deficit hypothesis as in Corsetti and Müller (2006) - a common finding in the literature. On the other hand, our previous analysis (figure 3) shows that allowing the impulse responses to vary with the degree of indebtedness accommodates both - a twin deficit result as well as twin-divergence behaviour at higher debt-to-GDP ratios as in Kim and Roubini (2008) or Nickel and Vansteenkiste (2008). Importantly, the different results occur within the same sample and thus underline the importance to condition on the degree of indebtedness when estimating fiscal reaction functions. The findings again suggest that policy makers may want to diligently scrutinize the current debt situation of a country before implementing fiscal stimuli programs as their effectiveness may not be guaranteed. This result holds for the effects of fiscal stimuli on aggregate macroeconomic activity as well as for resolving external imbalances.

Long-term interest rates are central to consumption-savings decisions of the private sector and may therefore influence the presence of Ricardian features in data. We therefore follow Perotti (2005) and include real long-term rates in an alternative specification. Figures 11 and 12 show the corresponding (cumulative) impulse responses. The general conclusions from our baseline specification remain valid. However, probability bands are now wider than before such that some of the results lose significance over some horizons after the shock. We attribute the increase in uncertainty to the burden the increased number of parameters places on the estimation. Additionally, the real long-term interest rate increases by 0.2 percentage points upon impact for low levels of indebtedness with a peak response of around 0.4 percentage points after about 4 years. The hump-shaped response remains almost unchanged as the debt-to-GDP ratio increases but becomes increasingly insignificant. This is somewhat surprising as one might expect interest rates to be affected stronger the higher the debt-ratio is as investors demand a higher risk premium. Estimating this specification without interaction terms leaves the results literally unchanged as can be seen in figures 13 and 14. Again, the (cumulative) impulse responses are close to the interacted version of the specification evaluated at the median debt-to-GDP ratio and the interest rate is significantly positive over most of the horizon after the shock.

We further check the robustness of our results by adding the GDP deflator as an additional endogenous variable to our baseline specification positioned before public consumption. The corresponding responses are shown in figures 15 and 16. The basic results remain qualitatively unchanged. The deflator responds increasingly positively and persistently over the entire range of interaction values. From a quantitative perspective, the responses of real GDP and private investment are stronger. When adding the real long-term interest rate to this specification, the results remain largely the same. However, the impulse responses are now estimated very imprecisely.

We also check the identification restriction for our policy variable, government consumption, which is ordered first vis-à-vis the interaction variable debt-to-GDP ratio by positioning debt first. The results of this estimation are shown in figures 17 and 18 and indicate that the main results remain largely unaffected as the shape of all responses are almost unaltered. However, the probability bands of real GDP are now much wider such that the negative response at high debt-to-GDP ratios is now insignificant. The response of the trade balance still switches sign

and becomes significantly positive.

Bayesian estimation is always subject to criticism due to the prior information it introduces, which can be more or less subjective. We therefore check the sensitivity of our results to the choice of prior by setting the prior hyperparameters to uninformative values. In particular, we set  $\alpha_k = \mathbf{0}$  where  $\mathbf{0}$  is a zero vector of length  $m_k$ ,  $\underline{V}_k^{-1} = 0 \times I$ , where  $I$  is the identity matrix and  $\underline{\nu} = 0$ . The results (available upon request) leave all basic implications of our baseline specification unchanged. We do observe some widening of the probability bands as may be expected in the absence of any prior information. However, given that these changes are very small we feel reassured that our results are almost completely driven by the data.

## 7 Conclusion

In this paper we explored the effects of fiscal stimuli at varying degrees of public indebtedness. To this end, we employed an interacted panel VAR to a sample of 17 European countries for the period 1970:2010 which is estimated in Bayesian fashion. Our results indicate that the private sector increasingly displays Ricardian features as the degree of indebtedness rises. This qualifies debt as an important endogenous variable, which helps to capture the internalization of the government budget constraint by the private sector. In particular, while fiscal stimuli exert expansionary effects on macroeconomic activity at low debt-to-GDP ratios, the overall effect on real GDP becomes less positive or even negative at earlier points after the shock with increasing debt-to-GDP ratios. This finding provides support for the negative association of debt and growth found in the literature so far. The trade balance reacts in the same direction as the shock to government consumption when public indebtedness is low but switches sign as the debt-to-GDP ratio increases. Therefore, our findings accommodate both a twin deficits phenomenon at low levels of debt and a twin divergence behaviour at high levels of debt when the private sector seems to develop Ricardian features. Consequently, the seemingly contradictory findings of the previous literature concerning the current account may be the result of not conditioning on the debt regime. Further investigation without interaction terms supports our results by replicating the common finding of a negative response of the trade balance. Moreover, government consumption is very persistent but exhibits self-reversing behaviour such that at high levels of debt, governments are more likely to engage in debt-stabilizing policy decisions. Similarly, the debt ratio exhibits persistent as well as accelerating features in high-debt environments. It reacts more pronounced at higher debt ratios in response to a given shock to government consumption but also exhibits self-reversing features when the debt ratio is high. Also, investment crowding-out becomes increasingly pronounced. Overall, our findings provide support for debt limits such as set forth in the Maastricht Treaty.

Our findings suggest that policy makers should diligently scrutinize the government debt situation before implementing fiscal stimuli programs as their effectiveness to boost economic activity or resolve external imbalances may not be guaranteed. Seeing our results against the background of the recent surge in public debt levels for nearly all industrialized countries, this suggests that further fiscal stimuli programmes may not only be ineffective but even counter-productive.

## References

- Afonso, A., C. Checherita, M. Trabandt, and T. Warmedinger (2010). Euro area fiscal policies: Response to the economic crisis. In A. van Riet (Ed.), *Euro area fiscal policies and the crisis*, Number 109 in Occasional Papers. European Central Bank.
- Ali Abbas, S. M., J. Bouhga-Hagbe, A. Fatas, P. Mauro, and R. Velloso (2011). Fiscal policy and the current account. *IMF Economic Review* 59(4), 603–629.
- Ardagna, S., F. Caselli, and T. Lane (2007). Fiscal discipline and the cost of public debt service: Some estimates for OECD countries. *The B.E. Journal of Macroeconomics* 7(1), Art. 28.
- Barro, R. J. (1974). Are government bonds net wealth? *Journal of Political Economy* 82(6), 1095–1117.
- Beetsma, R. (2008). A survey of the effects of discretionary fiscal policy. University of Amsterdam, Manuscript.
- Beetsma, R., M. Giuliadori, and F. Klaassen (2006). Trade spill-overs of fiscal policy in the European Union: A panel analysis. *Economic Policy* 21(48), 639–687.
- Beetsma, R., F. Klaassen, and M. Giuliadori (2008). The effects of public spending shocks on trade balances and budget deficits in the European Union. *Journal of the European Economic Association* 6(2-3), 414–423.
- Bertola, G. and A. Drazen (1993). Trigger points and budget cuts: Explaining the effects of fiscal austerity. *American Economic Review* 83(1), 11–26.
- Blanchard, O. and R. Perotti (2002). An empirical characterization of the dynamic effects of changes in government spending and taxes on output. *The Quarterly Journal of Economics* 117(4), 1329–1368.
- Canova, F. and M. Ciccarelli (2004). Forecasting and turning point predictions in a Bayesian panel VAR model. *Journal of Econometrics* 120(2), 327–359.
- Canova, F. and M. Ciccarelli (2009). Estimating multi-country VAR models. *International Economic Review* 50(3), 929–959.
- Cecchetti, S. G., M. S. Mohanty, and F. Zampolli (2011). The real effects of debt. Technical report, presented at the "Achieving Maximum Long-Run Growth" symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, 25-27 August 2011.
- Checherita, C. and P. Rother (2010). The impact of high and growing government debt on economic growth: An empirical investigation for the euro area. Working Paper Series 1237, European Central Bank.
- Chung, H. and E. M. Leeper (2007). What has financed government debt? Working Paper 13425, National Bureau of Economic Research.
- Corsetti, G., A. Meier, and G. Müller (2012, November). Fiscal stimulus with spending reversals. *The Review of Economics and Statistics* 94(4), 878–895.

- Corsetti, G. and G. J. Müller (2006). Twin deficits: Squaring theory, evidence and common sense. *Economic Policy* 21(48), 597–638.
- Enders, Z., G. J. Müller, and A. Scholl (2011). How do fiscal and technology shocks affect real exchange rates? New evidence for the United States. *Journal of International Economics* 83(1), 53–69.
- Favero, C. and F. Giavazzi (2007). Debt and the effects of fiscal policy. Working Paper 12822, National Bureau of Economic Research.
- Favero, C., F. Giavazzi, and J. Perego (2011). Country heterogeneity and the international evidence on the effects of fiscal policy. Working Paper 17272, National Bureau of Economic Research.
- Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin (2003). *Bayesian Data Analysis* (2 ed.). Chapman and Hall/CRC.
- Geweke, J. (1992). Evaluating the accuracy of sampling-based approaches to the calculation of posterior moments. In J. Bernardo, J. Berger, A. Dawid, and A. Smith (Eds.), *Bayesian Statistics 4*, pp. 641–649. Oxford University Press.
- Giavazzi, F., T. Jappelli, and M. Pagano (2000). Searching for non-linear effects of fiscal policy: Evidence from industrial and developing countries. *European Economic Review* 44(7), 1259–1289.
- Giavazzi, F. and M. Pagano (1990). Can severe fiscal contractions be expansionary? Tales of two small European countries. *NBER Macroeconomics Annual* 5, 75–111.
- Giavazzi, F. and M. Pagano (1996). Non-Keynesian effects of fiscal policy changes: International evidence and the Swedish experience. NBER Working Papers 5332, National Bureau of Economic Research.
- Hebous, S. and T. Zimmermann (2013). Estimating the effects of coordinated fiscal actions in the euro area. *European Economic Review* 58(0), 110 – 121.
- Hemming, R., S. Mahfouz, and A. Schimmelfennig (2002). Fiscal policy and economic activity during recessions in advanced economies. IMF Working Papers 02/87, International Monetary Fund.
- Holtz-Eakin, D., W. Newey, and H. S. Rosen (1988). Estimating vector autoregressions with panel data. *Econometrica* 56(6), 1371–1395.
- Hsiao, C., M. H. Pesaran, and A. K. Tahmiscioglu (1998). Bayes estimation of short-run coefficients in dynamic panel data models. Cambridge Working Papers in Economics 9804, Faculty of Economics, University of Cambridge.
- Ilzetzki, E., E. G. Mendoza, and C. A. Végh (2010). How big (small?) are fiscal multipliers? Working Paper 16479, National Bureau of Economic Research.
- Kim, S. and N. Roubini (2008). Twin deficit or twin divergence? Fiscal policy, current account, and real exchange rate in the U.S. *Journal of International Economics* 74(2), 362–383.
- Kirchner, M., J. Cimadomo, and S. Hauptmeier (2010). Transmission of government spending shocks in the euro area: Time variation and driving forces. Working Paper Series 1219, European Central Bank.

- Koop, G. (2003). *Bayesian Econometrics*. John Wiley & Sons.
- Koop, G. and D. Korobilis (2010). Bayesian multivariate time series methods for empirical macroeconomics. *Foundations and Trends in Econometrics* 3(4), 267–358.
- Lamo, A., J. J. Pérez, and L. Schuknecht (2008). Public and private sector wages - co-movement and causality. Working Paper Series 963, European Central Bank.
- Leeper, E. M. (2010). Monetary science, fiscal alchemy. Working Paper 16510, National Bureau of Economic Research.
- Luetkepohl, H. (2005). *New Introduction to Multiple Time Series Analysis*. Springer.
- Monacelli, T. and R. Perotti (2010). Fiscal policy, the real exchange rate and traded goods. *The Economic Journal* 120(544), 437–461.
- Müller, G. J. (2008). Understanding the dynamic effects of government spending on foreign trade. *Journal of International Money and Finance* 27(3), 345–371.
- Nickel, C. and I. Vansteenkiste (2008). Fiscal policies, the current account and Ricardian equivalence. Working Paper Series 935, European Central Bank.
- Nicoletti, G. (1988). Private consumption, inflation and the “debt neutrality hypothesis”: The case of eight OECD countries. OECD Economics Department Working Papers 50, OECD Publishing.
- Perotti, R. (1999). Fiscal policy in good times and bad. *The Quarterly Journal of Economics* 114(4), 1399–1436.
- Perotti, R. (2005). Estimating the effects of fiscal policy in OECD countries. CEPR Discussion Papers 4842, CEPR Discussion Papers.
- Pesaran, M. and R. Smith (1995). Estimating long-run relationships from dynamic heterogeneous panels. *Journal of Econometrics* 68(1), 79–113.
- Ravn, M. O., S. Schmitt-Grohé, and M. Uribe (2007). Explaining the effects of government spending shocks on consumption and the real exchange rate. NBER Working Papers 13328, National Bureau of Economic Research.
- Rebucci, A. (2003). On the heterogeneity bias of pooled estimators in stationary VAR specifications. IMF Working Papers 03/73, International Monetary Fund.
- Reinhart, C. M. and K. S. Rogoff (2010). Growth in a time of debt. *American Economic Review* 100(2), 573–78.
- Ricardo, D. (1817). On the principles of political economy and taxation. In P. Sraffa (Ed.), *The works and correspondence of David Ricardo*, Volume 1, 1951. Cambridge University Press.
- Rzonca, A. and P. Cizkowicz (2005). Non-Keynesian effects of fiscal contraction in new member states. Working Paper Series 519, European Central Bank.
- Sa, F., P. Towbin, and T. Wieladek (2011). Low interest rates and housing booms: The role of capital inflows, monetary policy and financial innovation. Bank of England working papers 411, Bank of England.
- Sargent, T. J. and N. Wallace (1981). Some unpleasant monetarist arithmetic. *Federal Reserve Bank of Minneapolis Quarterly Review* (Fall).

- Sims, C. A. (1988). Bayesian skepticism on unit root econometrics. *Journal of Economic Dynamics and Control* 12(2-3), 463–474.
- Sims, C. A. and H. Uhlig (1991). Understanding unit rooters: A helicopter tour. *Econometrica* 59(6), 1591–1599.
- Sutherland, A. (1997). Fiscal crises and aggregate demand: Can high public debt reverse the effects of fiscal policy? *Journal of Public Economics* 65(2), 147–162.
- Towbin, P. and S. Weber (2011). Limits of floating exchange rates: The role of foreign currency debt and import structure. IMF Working Papers 11/42, International Monetary Fund.

## Tables

Table 1: Years after which impulse responses change signs for the first time

response variable	debt-to-GDP ratio				sign changes
	35%	60%	90%	112%	
<b>G</b>	15	9	8	7	from positive to negative
<b>Y</b>	8	4	3	2	from positive to negative
<b>I</b>	2	2	2	1	from positive to negative
<b>D</b>	-	1	1	1	from negative to positive
<b>TB</b>	4	4	3	2	from negative to positive

Table 1 shows the number of periods after which responses change signs for the first time for selected debt-to-GDP ratios after a one percentage-point-of GDP shock to government consumption. The responding variables (in column 1) are government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ), the debt-to-GDP ratio ( $D$ ) and the trade balance ( $TB$ ). Debt-to-GDP ratios as well as years are rounded to the next integer. This table only shows the first sign change of the respective impulse responses and ignores any sign changes thereafter.

Table 2: Years after which cumulative impulse responses change signs for the first time

response variable	debt-to-GDP ratio				sign changes
	65%	85%	105%	112%	
<b>G</b>	-	-	-	-	always positive
<b>Y</b>	14	8	6	5	from positive to negative
<b>I</b>	4	4	3	3	from positive to negative
<b>TB</b>	11	7	5	3	from negative to positive

Table 2 shows the number of periods after which cumulative responses change signs for the first time for selected debt-to-GDP ratios after a one percentage point of GDP shock to government consumption. The responding variables (in column 1) are the following flow variables: government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ) and the trade balance ( $TB$ ). Debt-to-GDP ratios as well as years are rounded to the next integer. Sign changes of cumulative responses in this table are final, i.e. responses never change signs more than once.



# Figures

Figure 1: Distribution of Debt to GDP Ratios

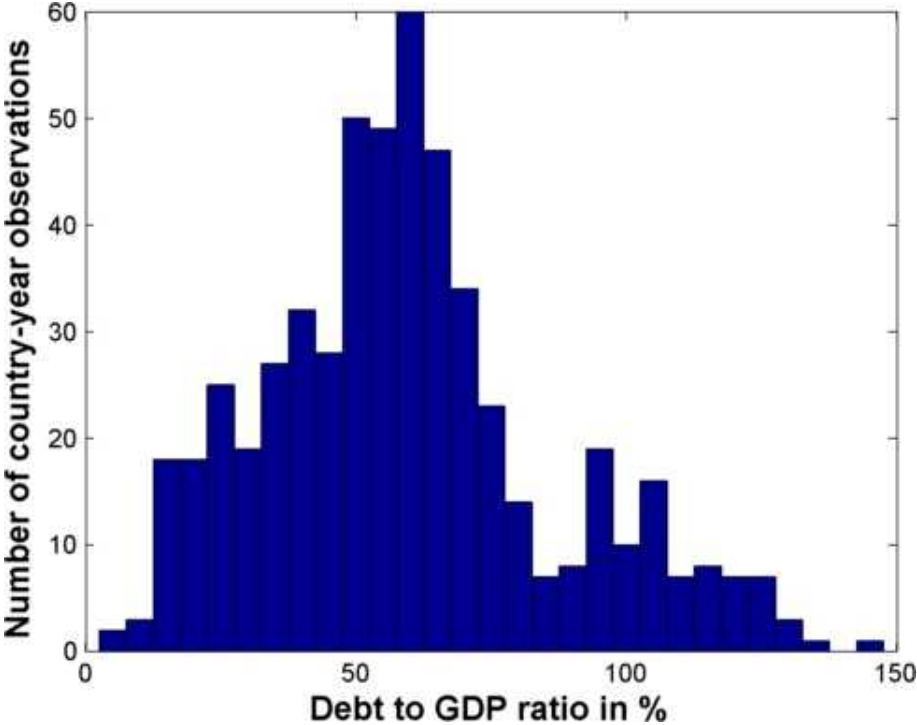


Figure 1 shows the distribution of country-year observations in 5% intervals for the debt-to-GDP variable. The mode of the distribution is at a debt ratio of 64%.

Figure 2: Impulse responses to a one percentage point of GDP shock to government consumption at various interaction levels

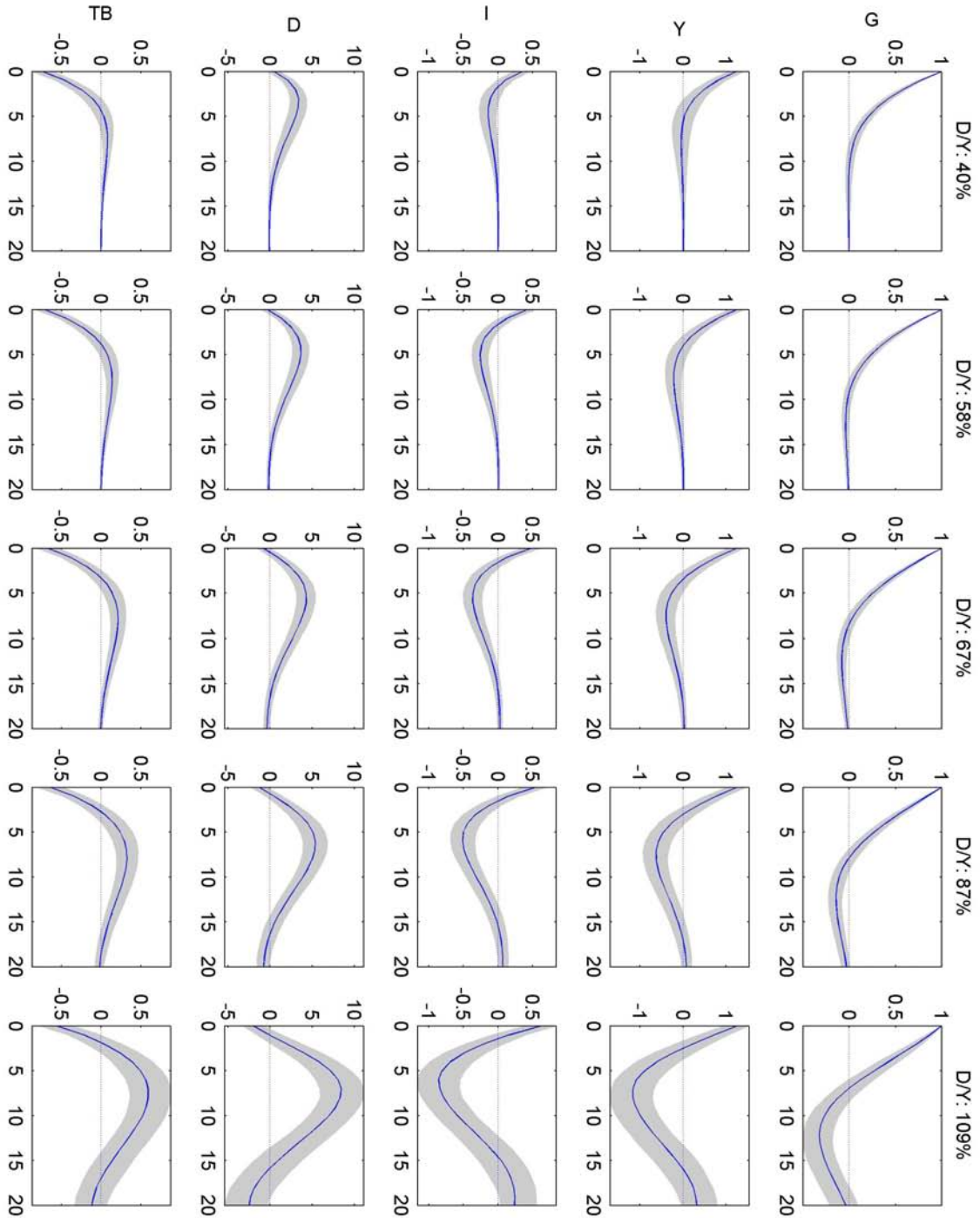


Figure 2 shows the impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ), the debt-to-GDP ratio ( $D$ ) and the trade balance ( $TB$ ) to a one percentage point of GDP shock to government consumption respectively. Rows within panels correspond to responses of variables as indicated on the left. Columns correspond to different choices of interaction values as designated in the respective column headers. The solid line corresponds to the median ( $50^{th}$  percentile) impulse response and the shaded areas are the  $16^{th}$  and  $84^{th}$  percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes are in percentage shares of GDP.

Figure 3: Cumulative impulse responses to a one percentage point of GDP shock to government consumption at various interaction levels

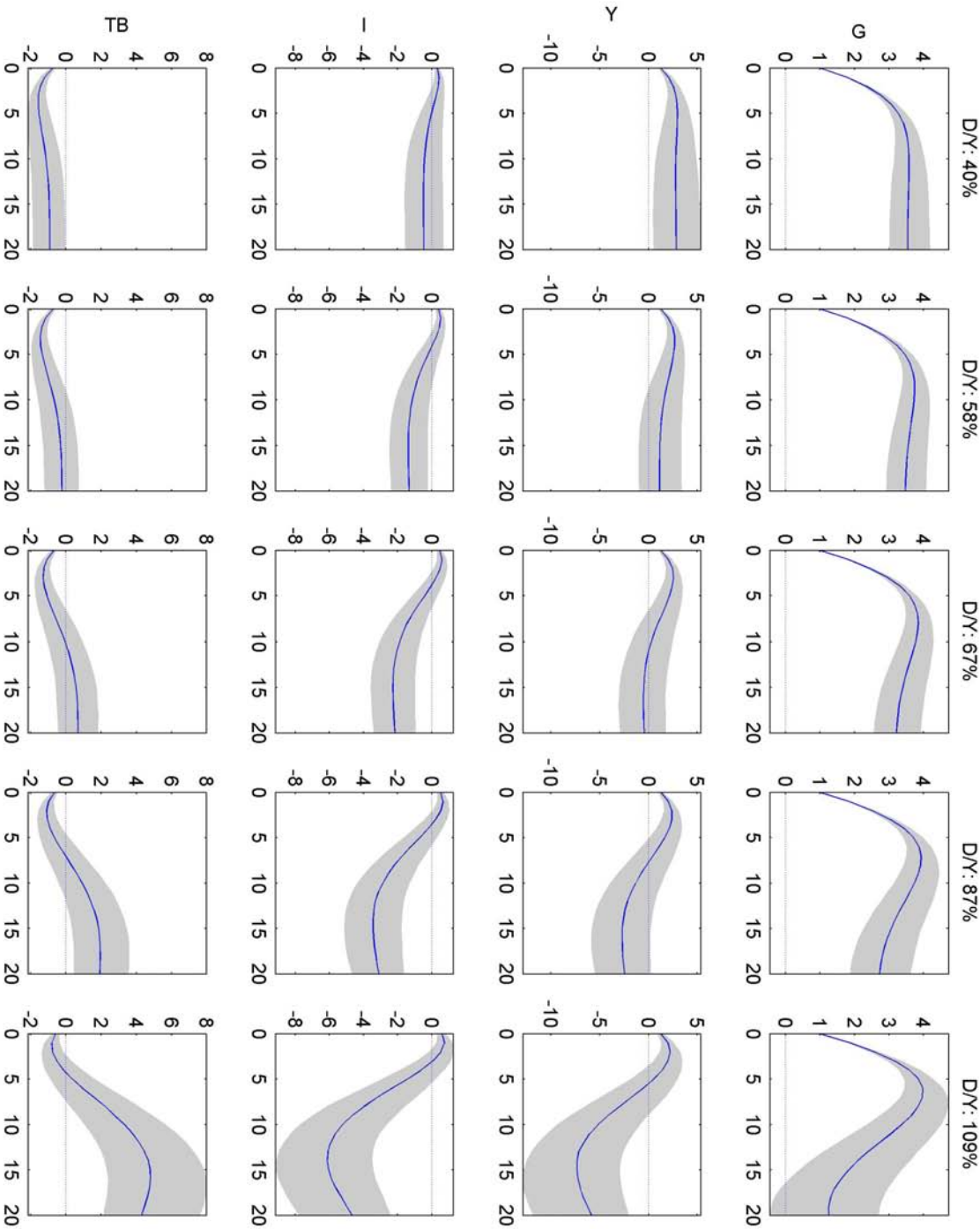
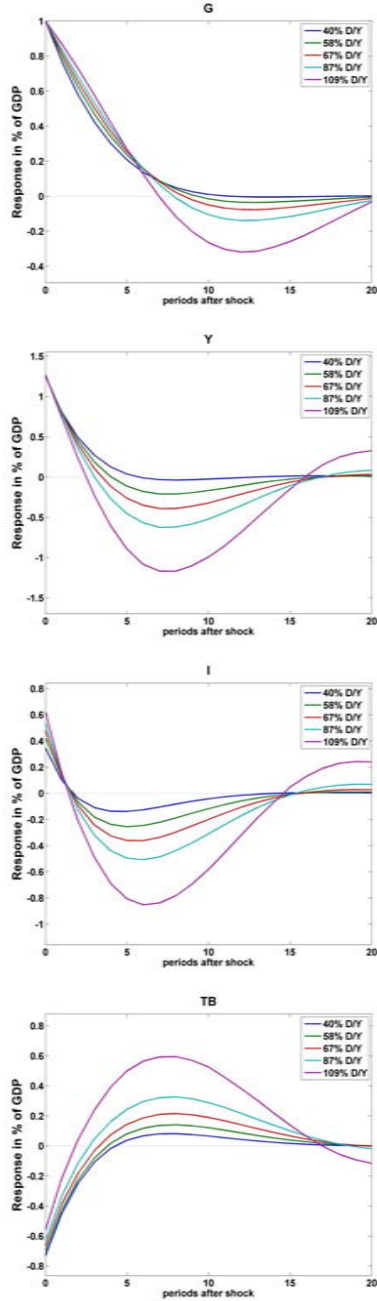


Figure 3 shows the cumulative impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ) and the trade balance ( $TB$ ) to a one percentage point of GDP shock to government consumption respectively. Rows within panels correspond to cumulative responses of variables as indicated on the left. Columns correspond to different choices of interaction values as designated in the respective column headers. The solid line corresponds to the median ( $50^{th}$  percentile) impulse response and the shaded areas are the  $16^{th}$  and  $84^{th}$  percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes are in percentage shares of GDP.

Figure 4: (Cumulative) Impulse Responses over various interaction values superimposed

Medians of Impulse Responses



Medians of Cumulative Impulse Responses

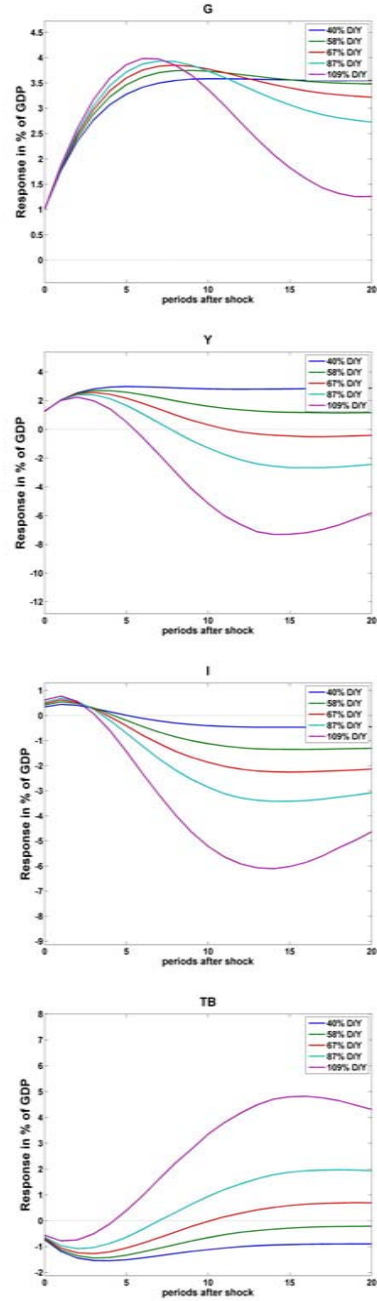


Figure 4 shows the superimposed median (cumulative) impulse responses for the following flow variables: government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ) and the trade balance ( $TB$ ) over several debt ratios respectively. Probability bands are omitted to keep the graphs legible. Horizontal axes show periods after the shock. Vertical axes are in percentage shares of GDP.

Figure 5: Differences of impulse responses to a one percentage point of GDP shock to government consumption at various interaction levels

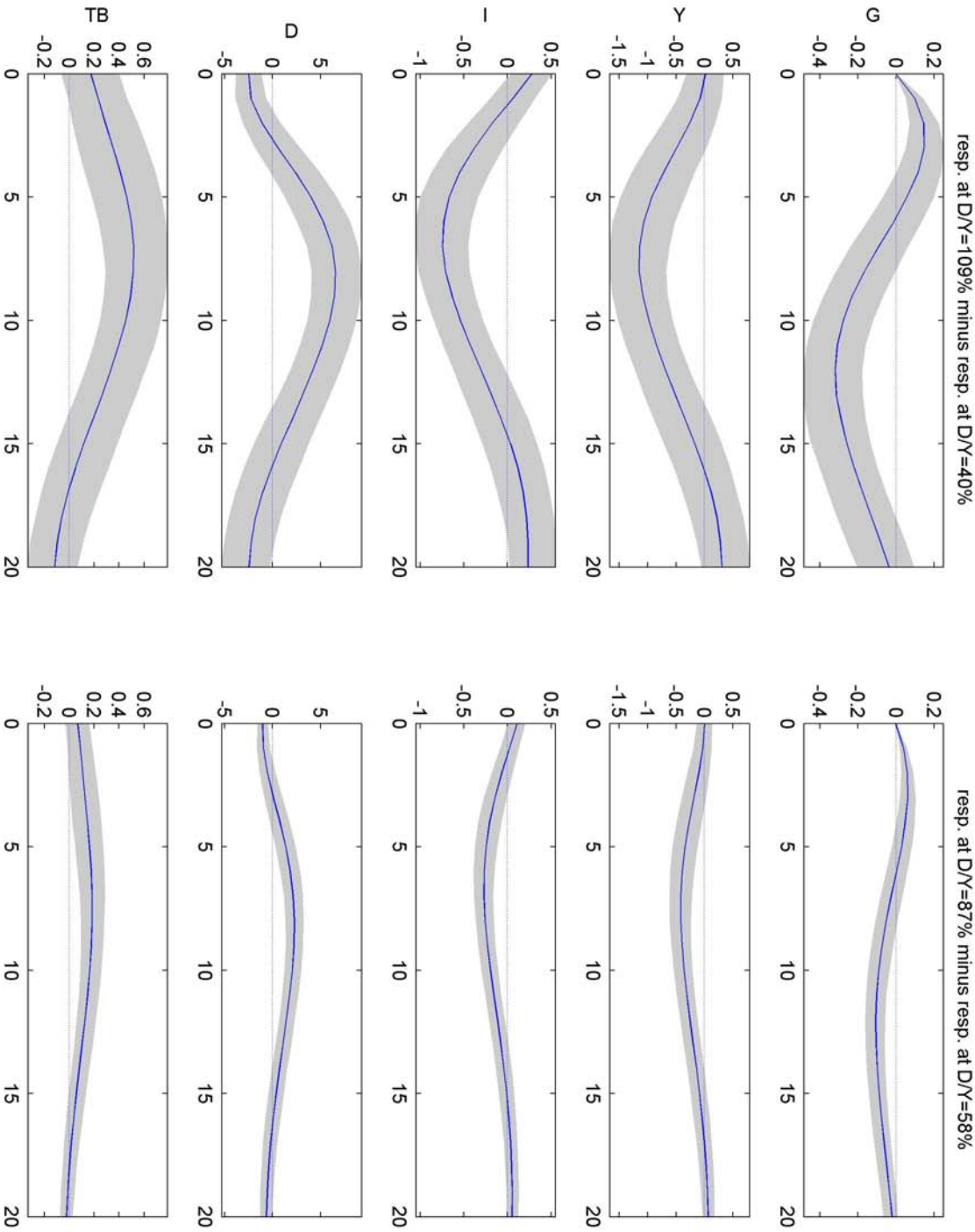


Figure 5 shows pairwise differences between impulse responses at different interaction choices together with the corresponding one standard deviation probability bands to a one percentage point of GDP shock to government consumption ( $G$ ). Rows correspond to the variables government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ), the debt-to-GDP ratio ( $D$ ) and the trade balance ( $TB$ ). Columns indicate which interaction choices are being subtracted from each other. Horizontal axes indicate periods after the shock. Vertical axes are in percentage shares of GDP.

Figure 6: Differences of cumulative impulse responses to a one percentage point of GDP shock to government consumption at various interaction levels

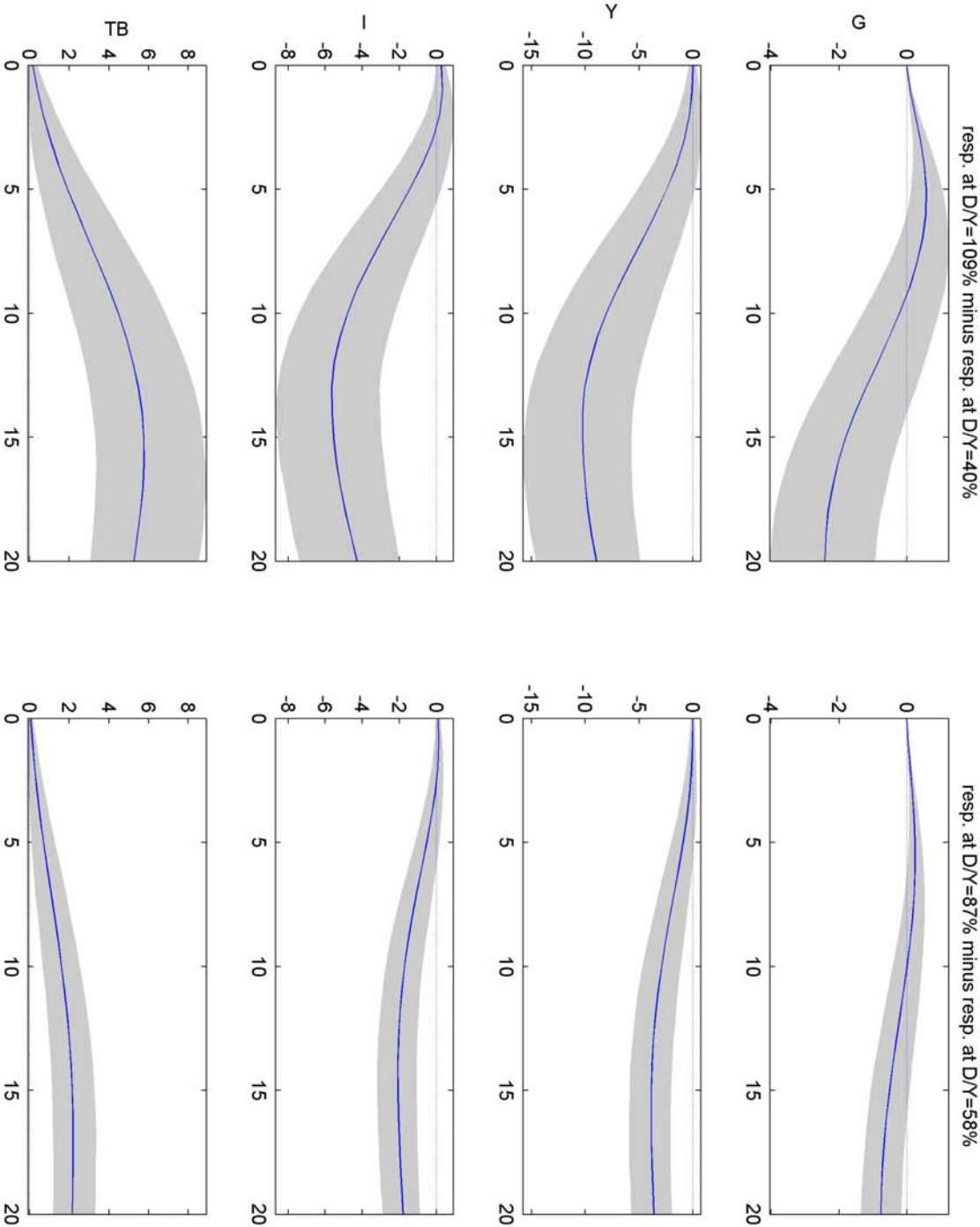
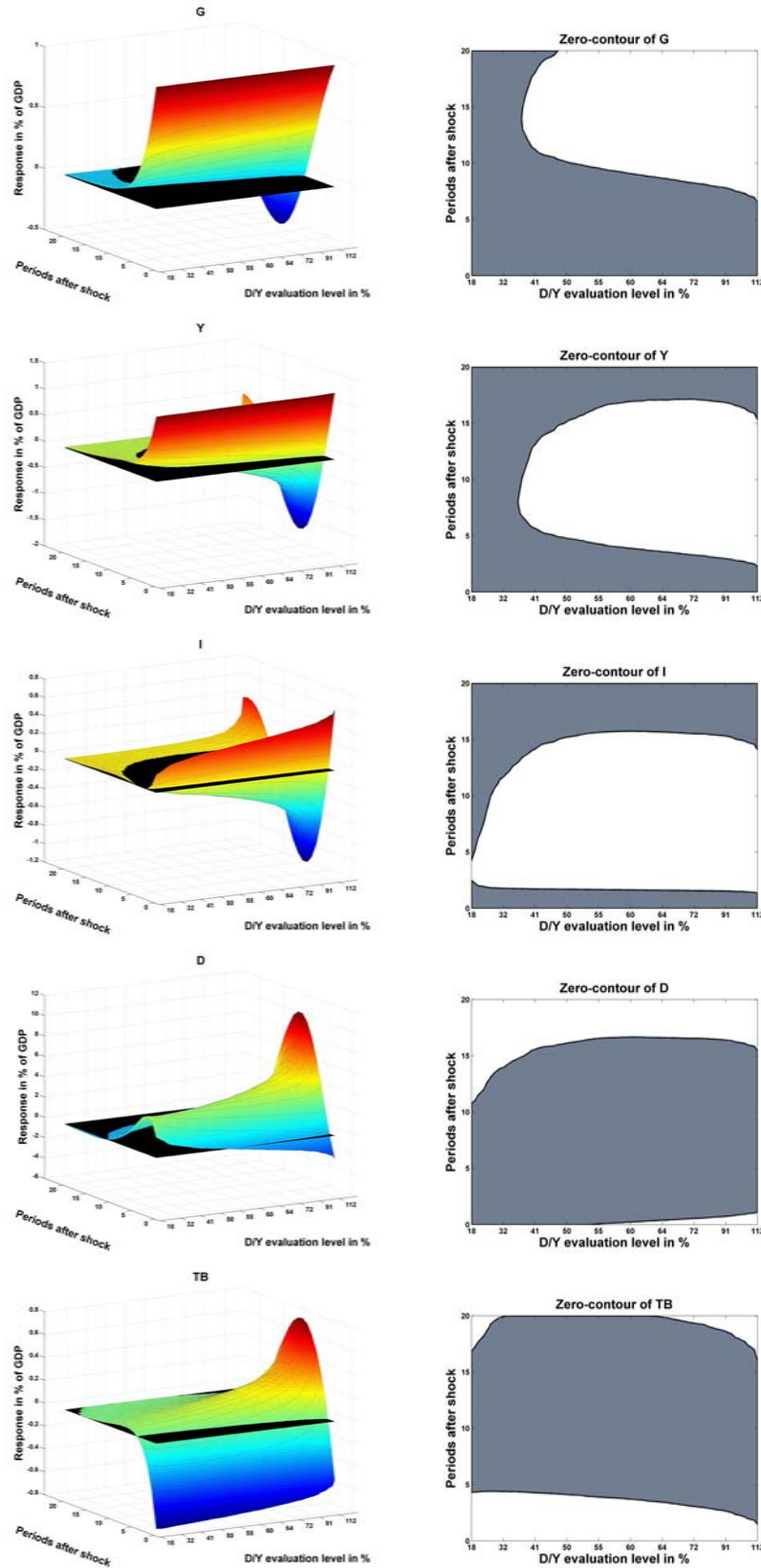


Figure 6 shows pairwise differences between cumulative impulse responses at different interaction choices together with the corresponding one standard deviation probability bands to a one percentage point of GDP shock to government consumption ( $G$ ). Rows correspond to the flow variables government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ) and the trade balance ( $TB$ ). Columns indicate which interaction choices are being subtracted from each other. Horizontal axes indicate periods after the shock. Vertical axes are in percentage shares of GDP.

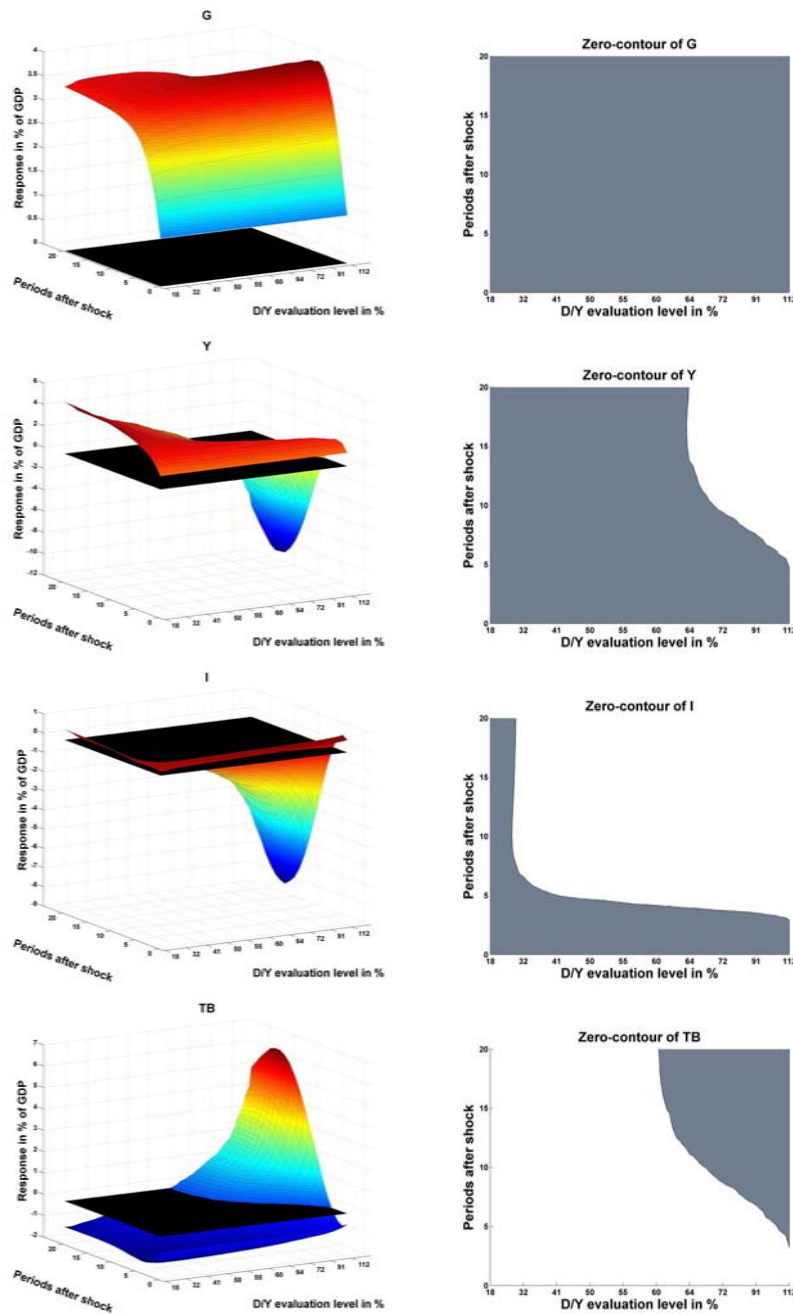


Figure 7: Impulse responses and zero contours over all interaction values



The left column of figure 7 shows the median impulse responses over the entire within-sample range of possible interaction choices, beginning from the 5th percentile and ending at the 95th percentile. The black plane is the zero plane. The right column shows the intersections of the median impulse response hyperplane and the zero plane. The resulting contour indicates at which horizon the median impulse responses first become negative as a function of the debt-to-GDP ratio. The dark region therefore denotes impulse response above the zero plane while the white region reflects the opposite.

Figure 8: Cumulative impulse responses and zero contours over all interaction values



The left column of figure 8 shows the median cumulative impulse responses over the entire within-sample range of possible interaction choices, beginning from the 5th percentile and ending at the 95th percentile. The black plane is the zero plane. The right column shows the intersections of the median cumulative impulse response hyperplane and the zero plane. The resulting contour indicates at which horizon the median impulse responses first become negative as a function of the debt-to-GDP ratio. The dark region therefore denotes impulse response above the zero plane while the white region reflects the opposite.



Figure 9: Impulse responses to a one percentage point of GDP shock to government consumption - No Interaction Terms

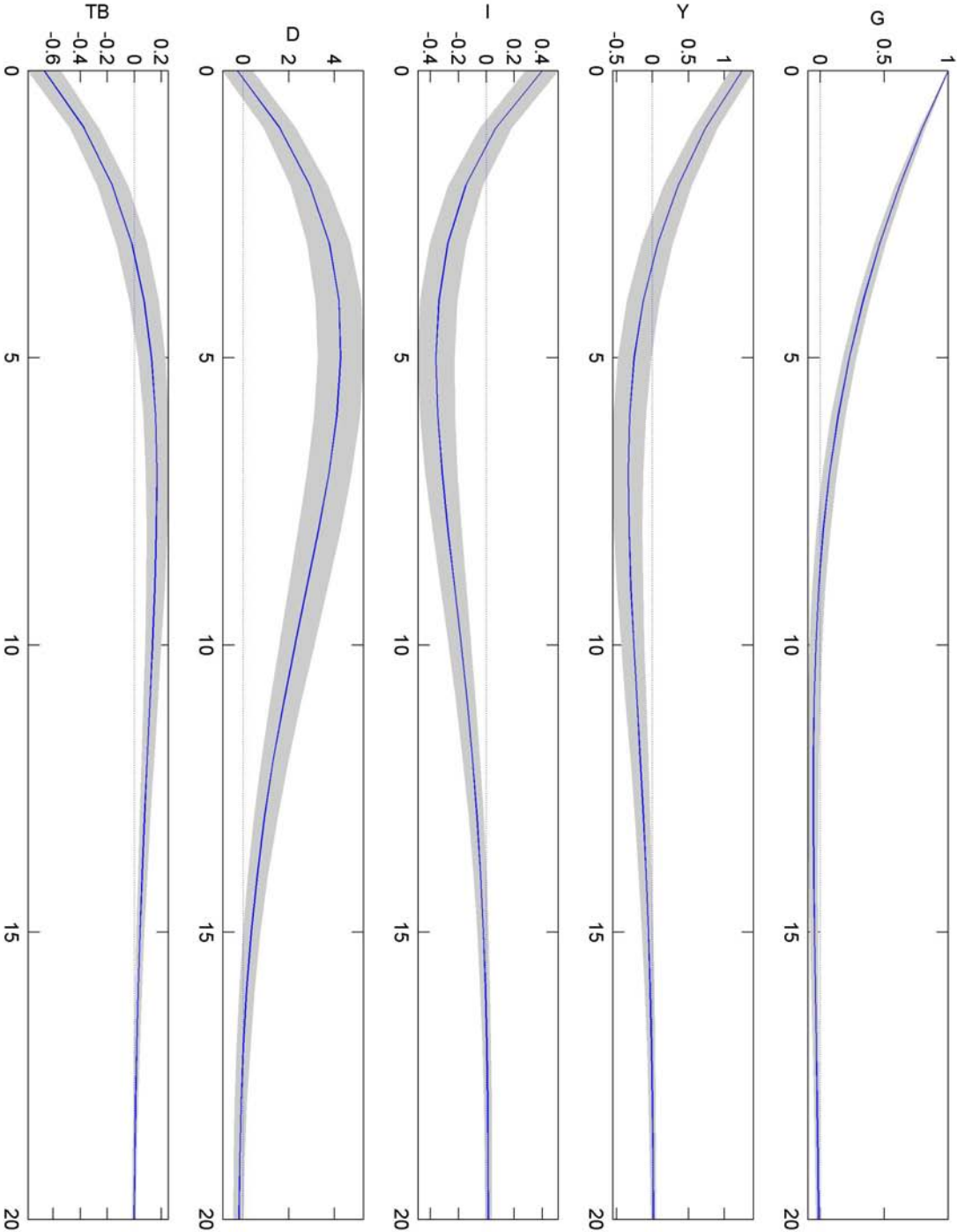


Figure 9 shows the impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ), the debt-to-GDP ratio ( $D$ ) and the trade balance ( $TB$ ) to a one percentage point of GDP shock to government consumption in a specification without interaction terms respectively. The solid line corresponds to the median ( $50^{th}$  percentile) impulse response and the shaded areas are the  $16^{th}$  and  $84^{th}$  percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes are in percentage shares of GDP.

Figure 10: Cumulative impulse responses to a one percentage point of GDP shock to government consumption - No Interaction Terms

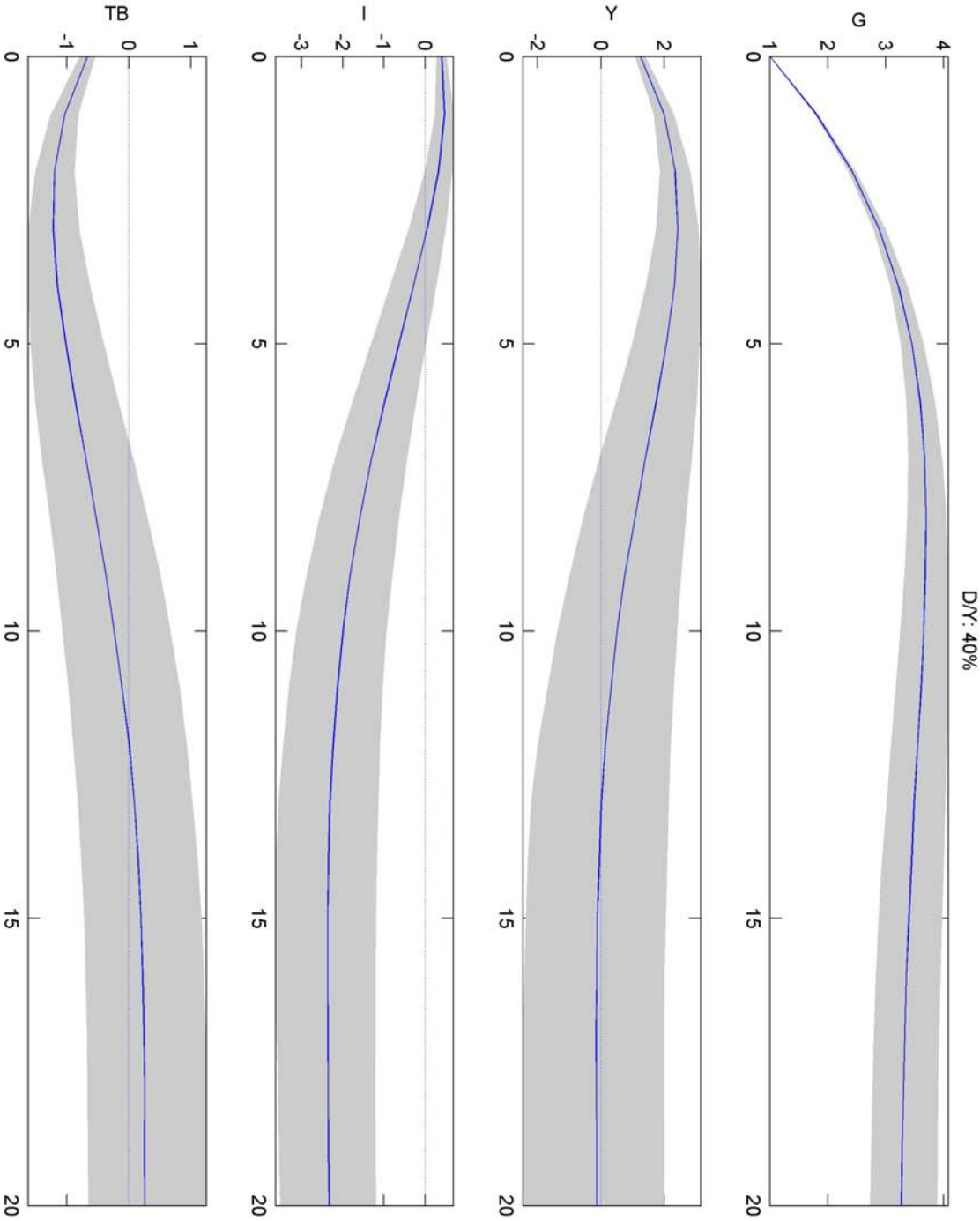


Figure 10 shows the cumulative impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ) and the trade balance ( $TB$ ) to a one percentage point of GDP shock to government consumption in a specification without interaction terms respectively. The solid line corresponds to the median ( $50^{th}$  percentile) cumulative impulse response and the shaded areas are the  $16^{th}$  and  $84^{th}$  percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes are in percentage shares of GDP.

Figure 11: Impulse responses to a one percentage point of GDP shock to government consumption at various interaction levels with long-term interest rate included

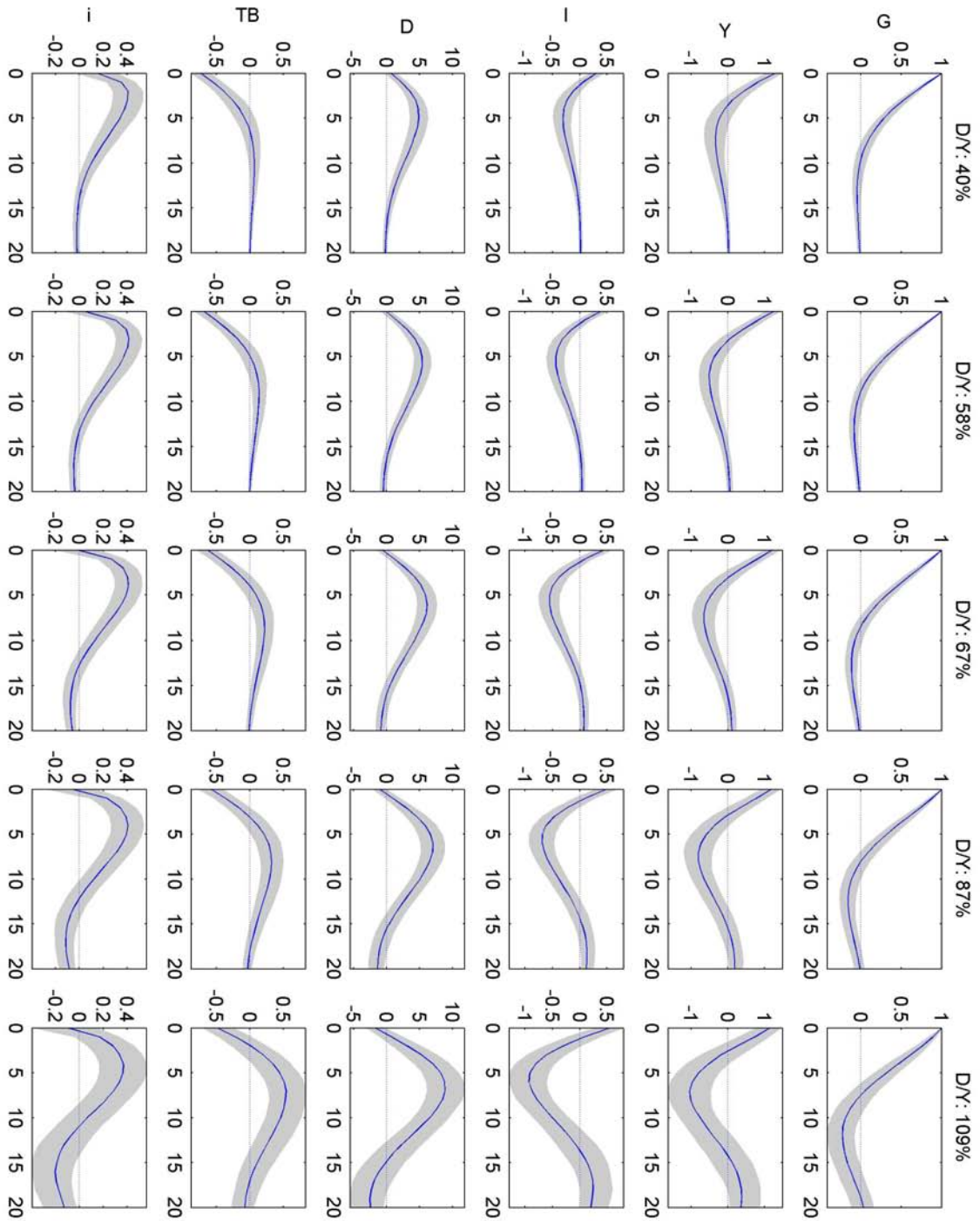


Figure 11 shows the impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ), the debt-to-GDP ratio ( $D$ ), the trade balance ( $TB$ ) and the long-term interest rate ( $i$ ) to a one percentage point of GDP shock to government consumption respectively. Rows within panels correspond to responses of variables as indicated on the left. Columns correspond to different choices of interaction values as designated in the respective column headers. The solid line corresponds to the median ( $50^{th}$  percentile) impulse response and the shaded areas are the  $16^{th}$  and  $84^{th}$  percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes except for ( $i$ ) are in percentage shares of GDP.

Figure 12: Cumulative impulse responses to a one percentage point of GDP shock to government consumption at various interaction levels with long-term interest rate included

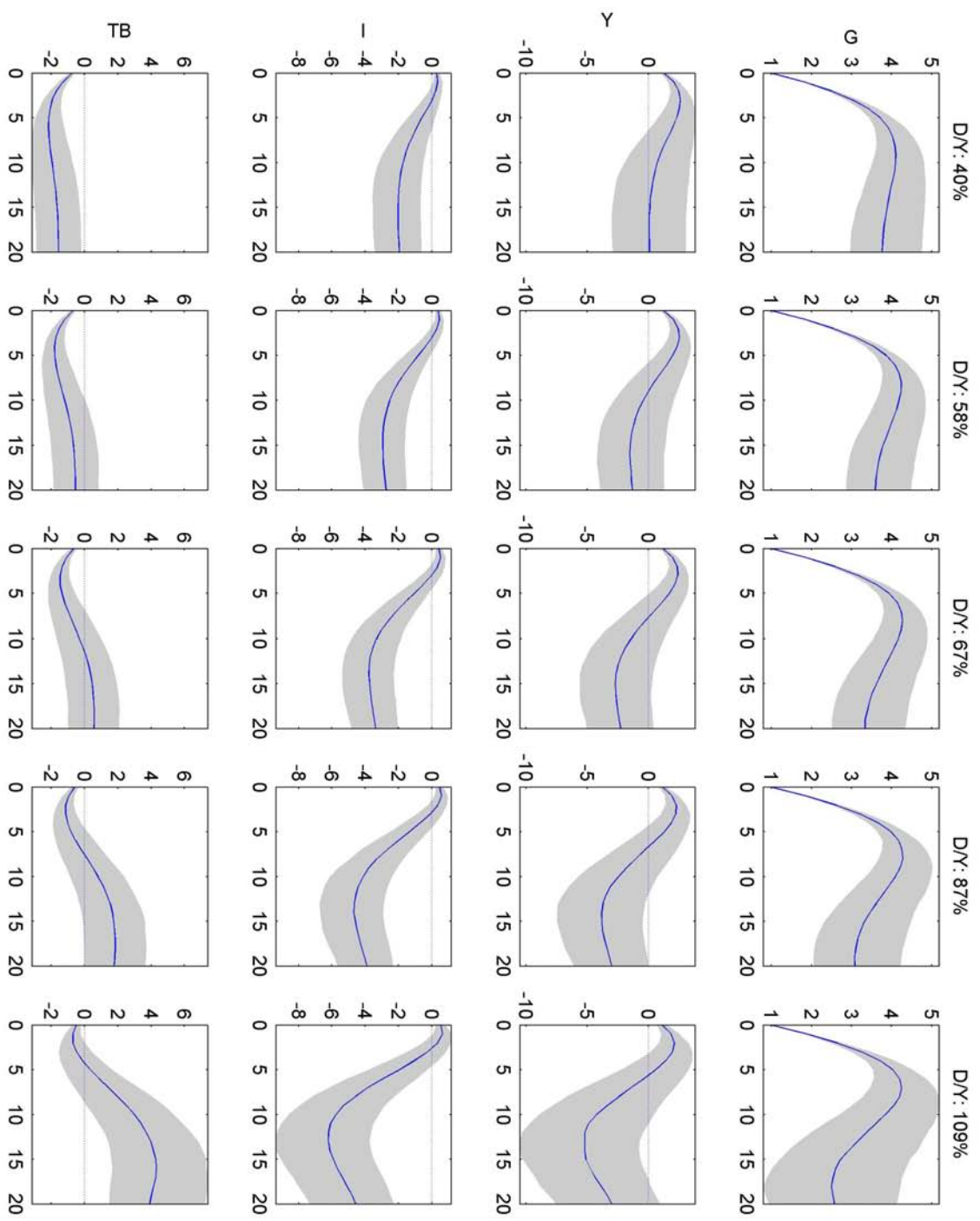


Figure 12 shows the cumulative impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ) and the trade balance ( $TB$ ) to a one percentage point of GDP shock to government consumption respectively. Rows within panels correspond to cumulative responses of variables as indicated on the left. Columns correspond to different choices of interaction values as designated in the respective column headers. The solid line corresponds to the median ( $50^{th}$  percentile) impulse response and the shaded areas are the  $16^{th}$  and  $84^{th}$  percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes except for ( $i$ ) are in percentage shares of GDP.

Figure 13: Impulse responses to a one percentage point of GDP shock to government consumption - No Interaction Terms and long-term interest rate included

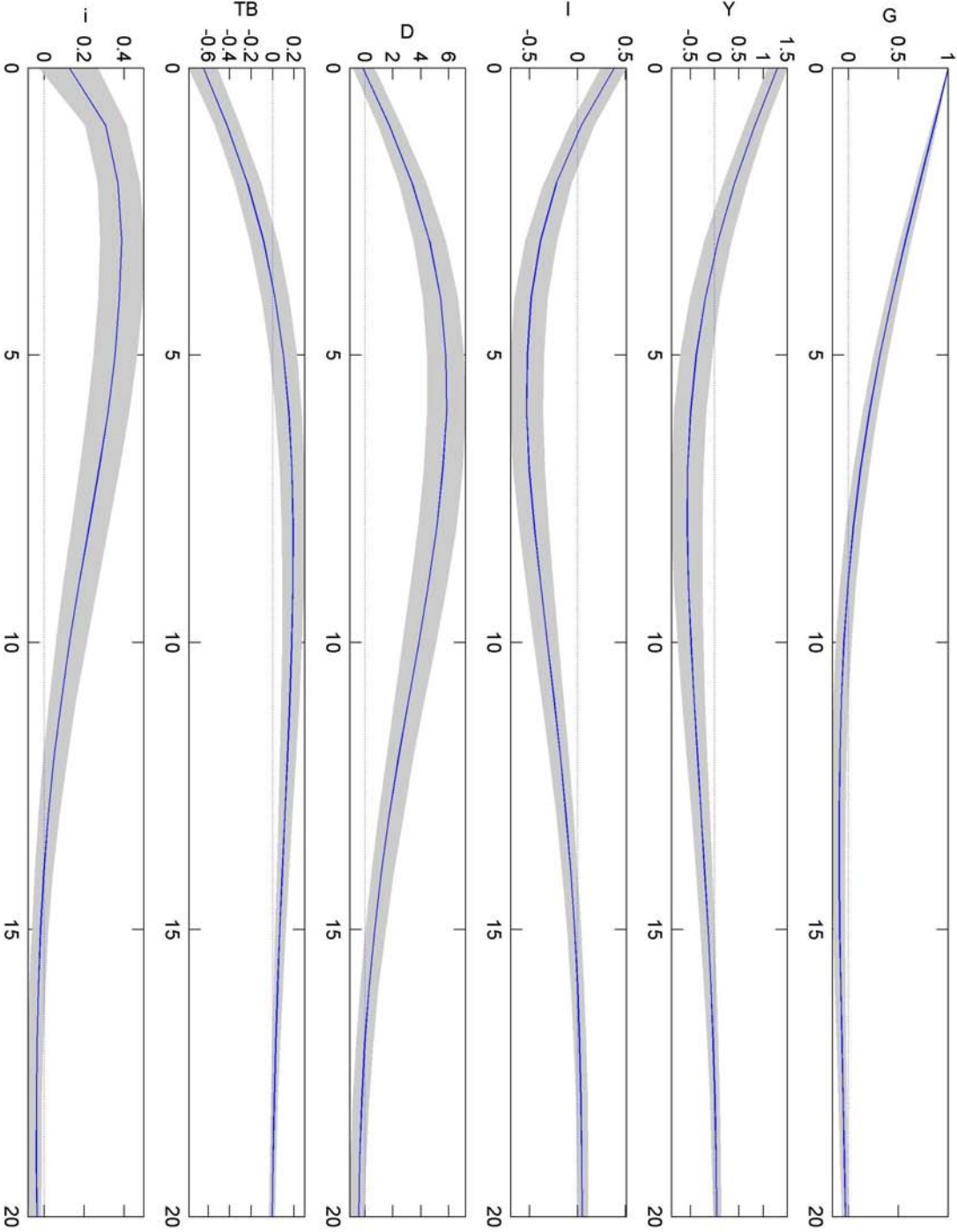


Figure 13 shows the impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ), the debt-to-GDP ratio ( $D$ ), the trade balance ( $TB$ ) and the long-term interest rate ( $i$ ) to a one percentage point of GDP shock to government consumption in a specification without interaction terms respectively. The solid line corresponds to the median ( $50^{th}$  percentile) impulse response and the shaded areas are the  $16^{th}$  and  $84^{th}$  percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes except for ( $i$ ) are in percentage shares of GDP.

Figure 14: Cumulative impulse responses to a one percentage point of GDP shock to government consumption - No Interaction Terms and long-term interest rate included

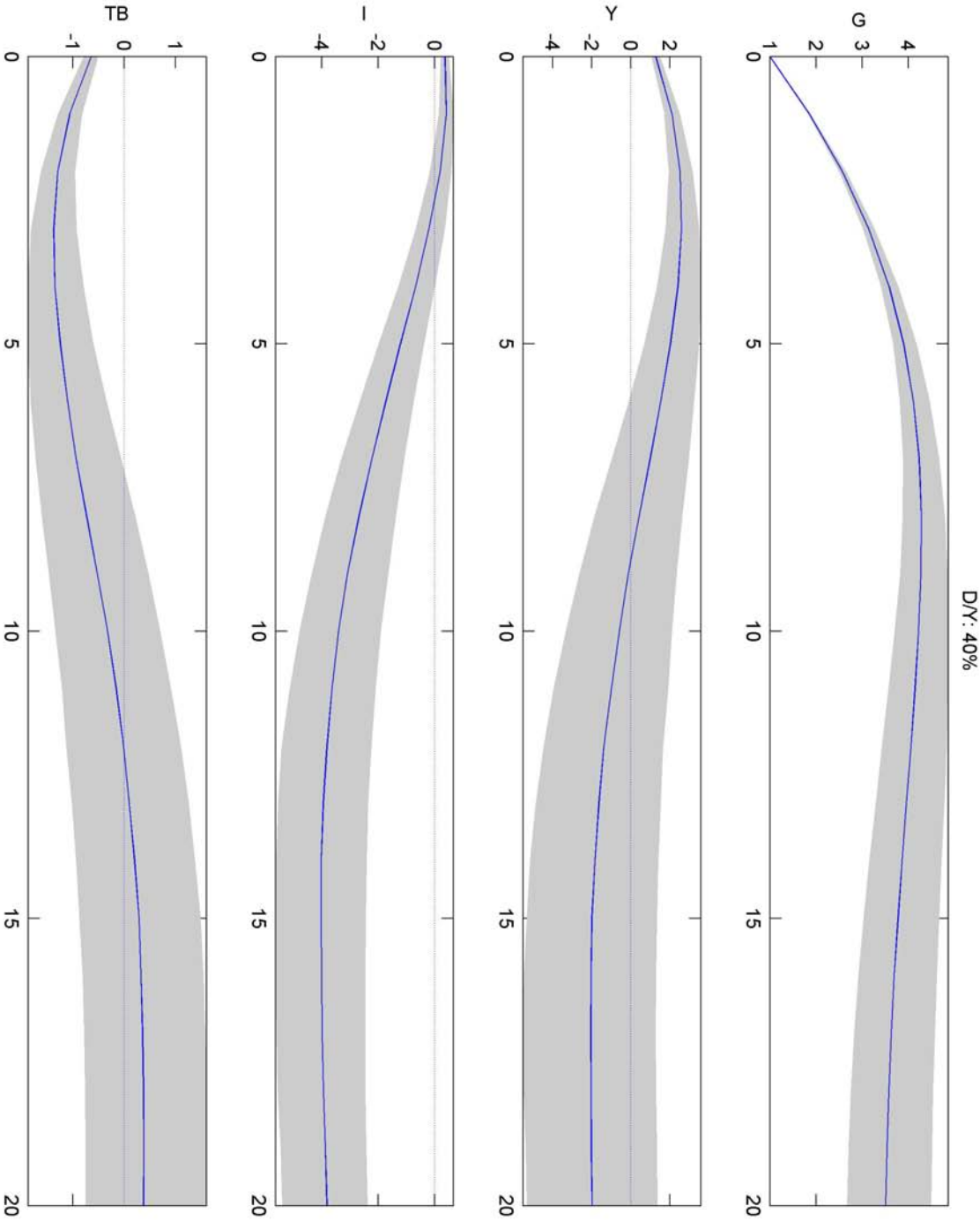


Figure 14 shows the cumulative impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ) and the trade balance ( $TB$ ) to a one percentage point of GDP shock to government consumption in a specification without interaction terms respectively. The solid line corresponds to the median ( $50^{th}$  percentile) cumulative impulse response and the shaded areas are the  $16^{th}$  and  $84^{th}$  percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes are in percentage shares of GDP.



Figure 15: Impulse responses to a one percentage point of GDP shock to government consumption at various interaction levels with GDP deflator included

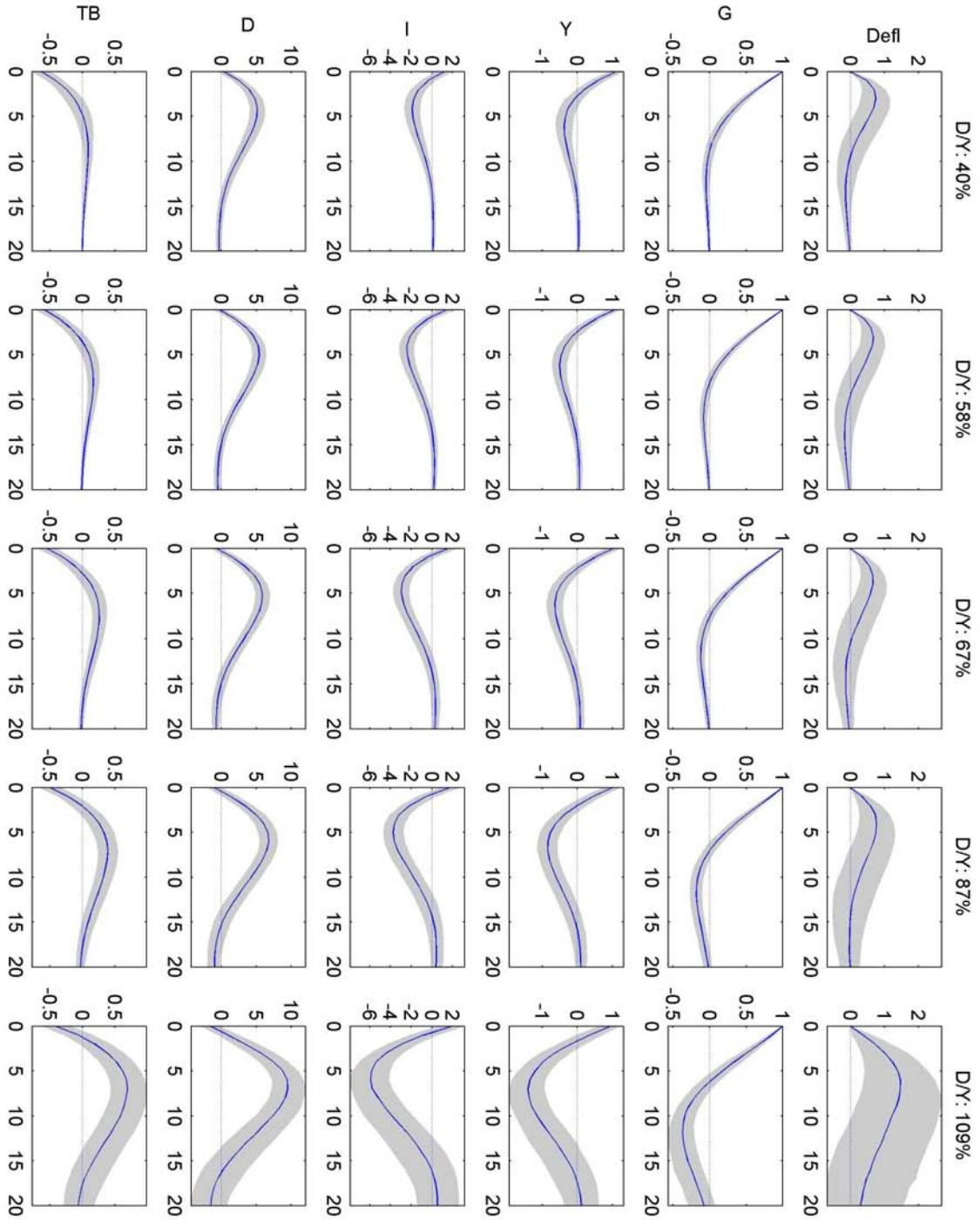


Figure 15 shows the impulse responses of the GDP deflator (*Defl*), government consumption (*G*), real GDP (*Y*), private investment (*I*), the debt-to-GDP ratio (*D*) and the trade balance (*TB*) to a one percentage point of GDP shock to government consumption respectively. Rows within panels correspond to responses of variables as indicated on the left. Columns correspond to different choices of interaction values as designated in the respective column headers. The solid line corresponds to the median (50<sup>th</sup> percentile) impulse response and the shaded areas are the 16<sup>th</sup> and 84<sup>th</sup> percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes except for (*Defl*), which is in percentage points, are in percentage shares of GDP.

Figure 16: Cumulative impulse responses to a one percentage point of GDP shock to government consumption at various interaction levels with GDP deflator included

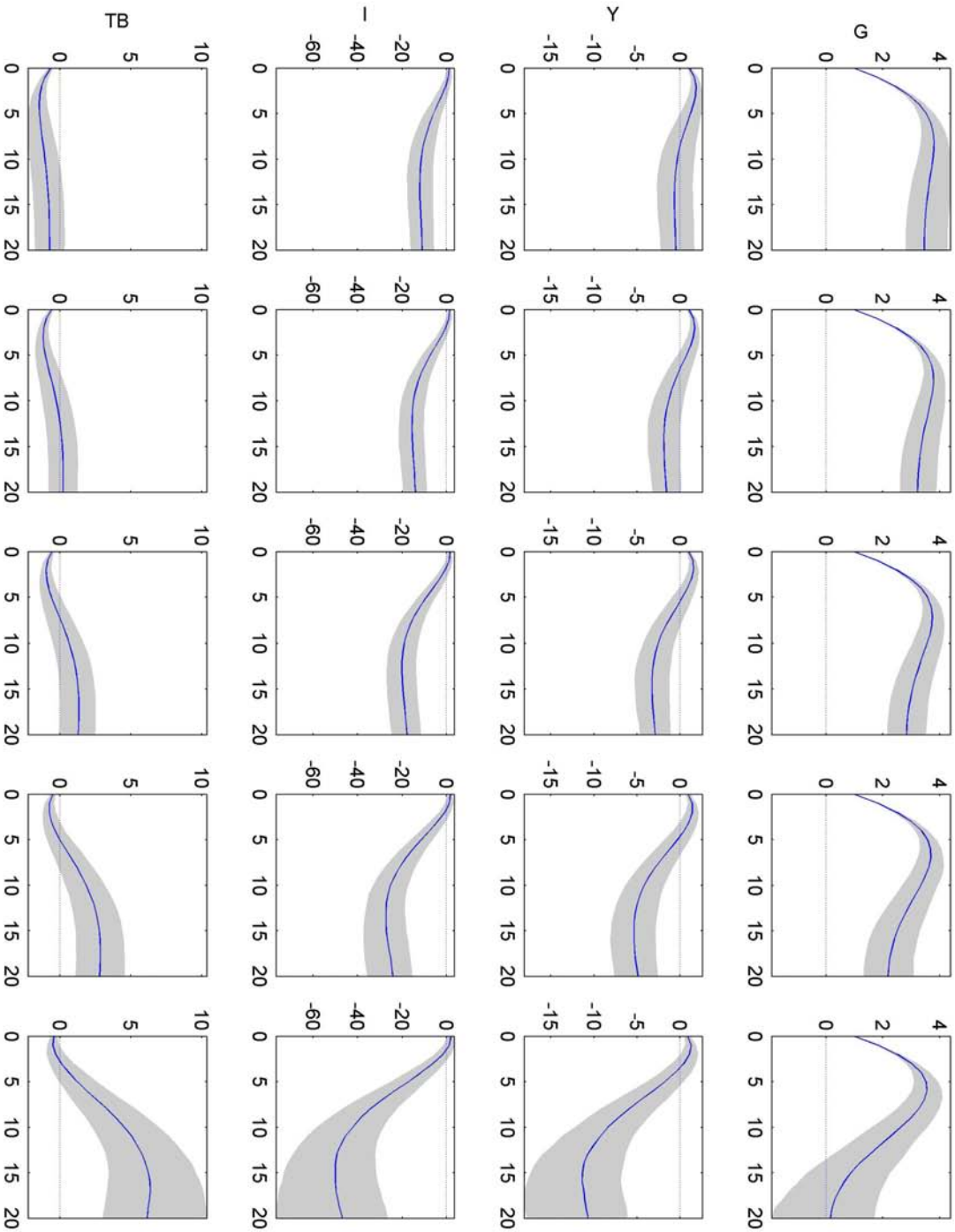


Figure 16 shows the cumulative impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ) and the trade balance ( $TB$ ) to a one percentage point of GDP shock to government consumption respectively. Rows within panels correspond to cumulative responses of variables as indicated on the left. Columns correspond to different choices of interaction values as designated in the respective column headers. The solid line corresponds to the median (50<sup>th</sup> percentile) impulse response and the shaded areas are the 16<sup>th</sup> and 84<sup>th</sup> percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes are in percentage shares of GDP.



Figure 17: Impulse responses to a one percentage point of GDP shock to government consumption at various interaction levels with debt ordered first

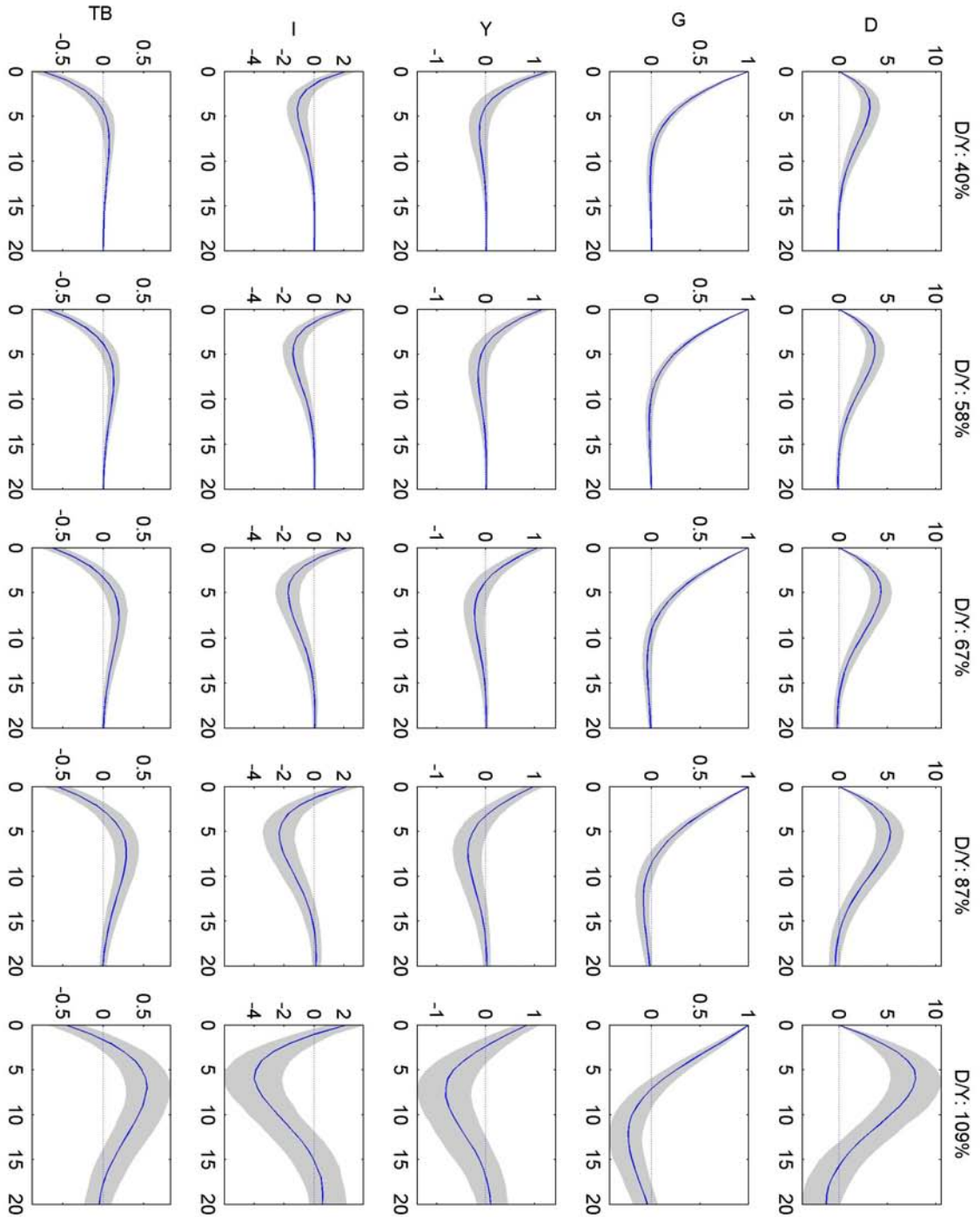


Figure 17 shows the impulse responses of the debt-to-GDP ratio ( $D$ ), government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ) and the trade balance ( $TB$ ) to a one percentage point of GDP shock to government consumption respectively. Rows within panels correspond to responses of variables as indicated on the left. Columns correspond to different choices of interaction values as designated in the respective column headers. The solid line corresponds to the median ( $50^{th}$  percentile) impulse response and the shaded areas are the  $16^{th}$  and  $84^{th}$  percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes are in percentage shares of GDP.

Figure 18: Cumulative impulse responses to a one percentage point of GDP shock to government consumption at various interaction levels with debt ordered first

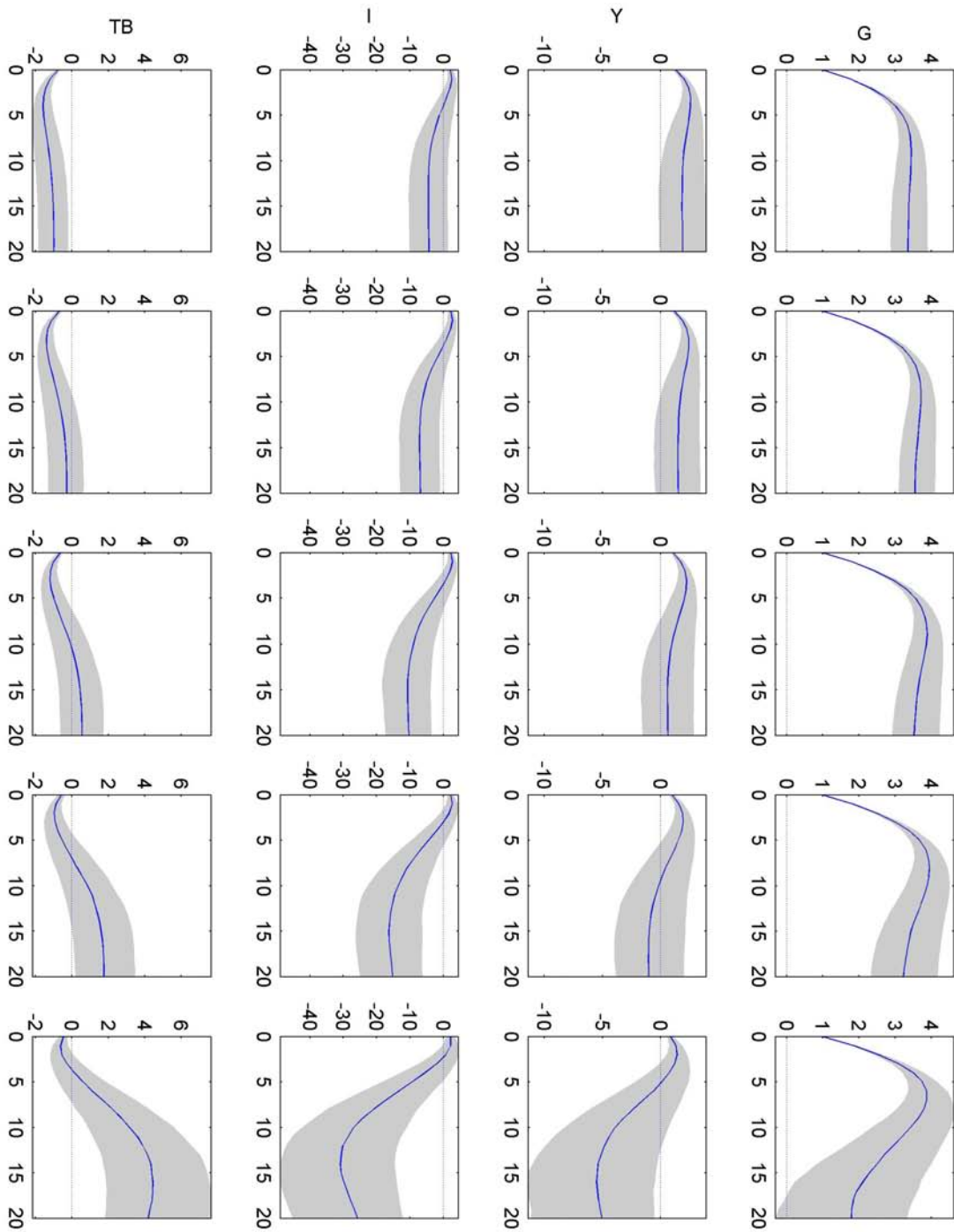


Figure 18 shows the cumulative impulse responses of government consumption ( $G$ ), real GDP ( $Y$ ), private investment ( $I$ ) and the trade balance ( $TB$ ) to a one percentage point of GDP shock to government consumption respectively. Rows within panels correspond to cumulative responses of variables as indicated on the left. Columns correspond to different choices of interaction values as designated in the respective column headers. The solid line corresponds to the median ( $50^{th}$  percentile) cumulative impulse response and the shaded areas are the  $16^{th}$  and  $84^{th}$  percentiles of the respective posterior distribution as (one standard deviation) probability bands. In all plots, horizontal axes indicate periods after the shock. Vertical axes are in percentage shares of GDP.