Fiscal Shocks and Cross-Border Spillovers

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Abstract

This paper develops an open economy DSGE model to analyze the cross-border spillovers from expansionary shocks to government spending, lump-sum transfers and distortionary taxes on labor income, capital income and consumption. First, I present a new empirical fact regarding the negative relation between a country's output spillover from government spending shocks and its domestic government debt-to-GDP ratio. Second, I show that the model can rationalize this negative relationship in the presence of a fiscal consolidation regime, i.e. an increase in government debt gives rise to higher tax rates along with reductions in spending and transfers. The key mechanism is that a slower speed of fiscal consolidation is associated with larger accumulations of government debt and higher global interest rates, which dampens foreign activity. Finally, I find long-run spillover effects of fiscal shocks to be substantially different from short-run effects.

JEL classification: E62, F44, H63

Keywords: fiscal policy, cross-border spillovers, debt, fiscal consolidation

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1 Introduction

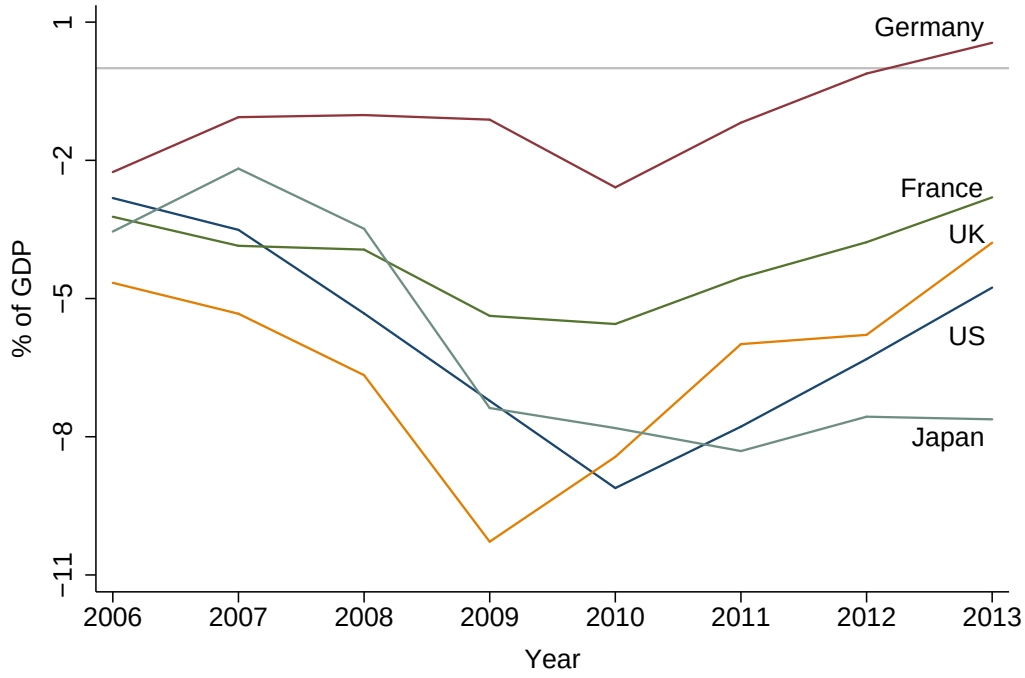
The global recession of 2008-09 prompted large accumulations of government debt in many countries. Lower tax revenues due to high unemployment and weak profits, fiscal stimulus packages implemented to battle the recession, and huge financial bail-outs have all contributed to the unprecedented piling up of public debt. There has been much debate about whether and how quickly fiscal consolidation policies should be implemented.[1] Figure 1 depicts the evolution of general government structural balance as a percent of GDP in the United States, Japan, Germany, France and the United Kingdom.[2] All cases feature a decrease in the structural balance from 2007 to 2009. The UK was the first to act towards abstinence and ended its stimulus in 2010. The US, Germany and France saw an increase in their structural balance in 2011. Japan kept spending and its structural balance did not improve until 2012. Many other countries have been focusing on fiscal consolidation, including a mixture of tax increases and spending cuts. For example, the Hungarian government adopted the "Szell Kalman Plan" and "Szell Kalman Plan 2.0" deficit cuts packages in 2011 and 2012 respectively. In fact, reducing the fiscal deficit to within 3% of GDP is an EU-mandated target, as outlined in the Stability and Convergence Programmes. According to the OECD Economic Outlook, most OECD countries need to stabilize their debt-to-GDP ratio. The OECD expects its members to carry out fiscal consolidation efforts mainly via spending reduction, which is thought to be exerting less adverse effects on the economy than taxes would.

Empirical evidence of fiscal consolidation in the US can be found in Corsetti et al. (2011). They estimate a VAR model on US time series using both the Blanchard-Perotti identification scheme (Blanchard and Perotti, 2002) and the forecast error identification scheme (Ramey, 2011). They find that, robust across the two identification strategies, a positive government spending shock induces a large build-up of public debt, and that government spending falls below trend a few quarters after the shock. In order to examine cross-border spillovers of a US government spending shock, Corsetti and Müller (2013) extend the VAR model to include both US variables and euro area (or UK) variables. Under this extended VAR model, government spending reversal still occurs, i.e. the current spending increase is accompanied by future spending cuts.

[1] Fiscal consolidation, as defined in the OECD Economic Outlook, is "a policy aimed at reducing government deficits and debt accumulation".

[2] The structural balance is the government's budget balance purged of the estimated influences on the budget from the business cycle of the economy. It is designed to be indicative of the government's discretionary fiscal policy adjustments.

Figure 1: General Government Structural Balance



Source: IMF World Economic Outlook Database

The motivation for this paper is best illustrated in Figure 2, which documents the relationship between output spillovers from domestic government spending shocks and the domestic central government debt-to-GDP ratio[3]. The construction of output spillovers will be discussed in detail in the next section. The main information we can obtain from Figure 2 is that there is a negative relation between the two variables, which was never observed before. Countries that bear a large debt-to-GDP ratio, such as Portugal and Belgium, generate relatively large negative output spillovers to other countries, while countries that have smaller debt-to-GDP ratios, such as Norway and New Zealand, spread positive spillovers.

This paper emphasizes the role of fiscal consolidation in generating the negative relationship between output spillovers from government spending shocks and the government debt-to-GDP ratio as shown in Figure 2. I build a two-country DSGE model based on Backus et al. (1994) (hereafter BKK) and estimate it on US and EU data using Bayesian estimation techniques. Government spending, lump-sum transfers, the capital tax rate, the labor tax rate and the consumption tax rate are allowed to adjust systematically to public debt-to-GDP ratio. I follow common practice and estimate the five feedback rules for fiscal

[3]Central government data are used due to the lack of general government data for some countries. For countries where both general and central government data are available, the correlations between the two are larger than 0.9.

policy outside the DSGE model by single-equation OLS. Estimation results show that fiscal consolidation is operative in the US. As the debt-to-GDP ratio increases, the government will reduce its spending, decrease its transfers and increase its taxation on capital income, labor income and consumption expenditures. The speed of fiscal consolidation affects cross-border spillovers in two opposite directions. First, expansionary fiscal shocks stimulate the domestic economy and boost its imports from the foreign country. A higher speed of consolidation attenuates the stimulating effect and hence mitigates spillovers to the foreign country. On the other hand, a higher speed of consolidation leads to less accumulation of government debt and a lower global real interest rate, thus boosting foreign activity. Model results show that a higher speed of fiscal consolidation is associated with a larger output spillover, suggesting that the interest rate channel dominates. As a result, the domestic debt-to-GDP ratio in the model economy is negatively related to the output spillover from a domestic expansionary spending shock.

Empirical VAR studies find conflicting results on the cross-border output spillovers from fiscal stimulus. For example, combining a panel VAR model and a gravity trade equation, Beetsma et al. (2006) find that fiscal stimuli in Germany and France have non-negligible and positive output spillovers in all the other 13 European countries in their sample. Hebous and Zimmermann (2010) use a global VAR model to estimate the spillover effects of a domestic shock to the primary budget balance to GDP ratio in 12 euro area countries. The signs of pair-wise spillovers are mixed, with most of them being negative.

These different estimates come as no surprise if we look at their sample periods and endogenous variables included in the VAR. The sample period in Beetsma et al. (2006) is 1965-2004 and their VAR does not include any government debt variable. In contrast, Hebous and Zimmermann (2010) add the ratio of public debt to GDP over a sample period of 1979-2009, the later years of which feature high debt ratios following the financial crisis. This paper is able to accommodate both positive and negative output spillovers. Due to the fiscal consolidation regime, domestic and foreign macroeconomic variables display waning fluctuations after a fiscal shock. Therefore, there will be both positive and negative spillovers following a domestic fiscal shock.

There have also been theoretical DSGE studies assessing the impact of fiscal spillovers. This paper is most closely related to Corsetti et al. (2010) and Corsetti and Müller (2013). In both papers, the authors allow government spending to consolidate public debt and thus their simulated government spending shock displays a reversal feature, i.e. the current spending increase is accompanied by future cuts in spending. Because the foreign real long-term interest rate decreases in response to a domestic spending increase in their models[4],

[4]Because of the spending reversal, agents expect that real short-term interest rate will decrease in the

foreign output first rises before falling below trend at around the 20th quarter. As a result, their models generate positive output spillovers first when domestic debt is high and then negative spillovers as debt is consolidated, opposite to the empirical fact shown in Figure 2. Moreover, while Corsetti et al. (2010) and Corsetti and Müller (2013) study the cross-border spillovers of government spending shocks, this paper compares the different spillovers of government spending shocks, transfers shocks and tax rate shocks. I find remarkable differences in the spillover effects in the short run and in the long run. First, a domestic spending increase is most favored by the foreign economy to improve its output in the short run; domestic expansionary shocks to transfers and tax rates have contractionary effects on the foreign output in the short run, implying that negative consequences from higher debt dominate positive effects from increased demand for imports. Second, in the long run, the foreign economy would prefer a domestic labor tax cut, with a present value multiplier of 0.53 additional unit of foreign output per unit cut of domestic labor tax revenue. Finally, a capital tax rate cut or a labor tax rate cut is more effective in stimulating the domestic economy than increased spending, increased transfers or a consumption tax rate cut. However, the strength of the stimulating effects is mitigated by the fiscal consolidation regime. The paper is also related to Leeper et al. (2010a) and Leeper et al. (2010b) which use similar fiscal policy rules and explore the impacts of fiscal shocks in a closed economy environment.

The rest of the paper is organized as follows. Section 2 contains the new empirical fact . Section 3 describes the model and the assumptions regarding fiscal policies. Section 4 presents the techniques I use to estimate the model and the prior and posterior distributions. Section 5 discusses in detail the spillovers of domestic fiscal shocks. The forecast-error-variance decomposition and the historical decomposition are implemented in sections 6 and 7 respectively. Section 8 concludes.

2 Empirical fact

Using single equation estimation, Auerbach and Gorodnichenko (2013) estimate cross-border output spillover of government spending with data for a panel of OECD countries. They first regress real-time one-period-ahead forecast errors for government spending from the OECD's "Outlook and Projections Database" in each country on that country's lagged macroeconomic variables (output, government spending, exchange rate, inflation, investment, and imports) as well as a set of country and period fixed effects. The residual from the regression, which is orthogonal to the professional forecasts and lags of the macroeconomic variables, is defined as each country's own fiscal shock. Then for each country, they

future. As a result, long-term interest rate falls on impact.

construct the fiscal shock emanating from other countries by aggregating the other countries' own fiscal shocks weighted according to bilateral trade. After this, they can obtain the cross-border government spending multiplier through panel OLS.

Since my focus is different, i.e. exploring the dynamics between a country's fiscal spillovers and its government debt level, I estimate the effect of each country's own fiscal shock on the other countries' output instead of estimating the effect of the aggregated fiscal shock emanating from other countries. Specifically, each country i's government spending spillover to another country q over a horizon $h \in \{0, 1, \ldots, H\}$ is obtained by running the following regression:

$$\frac{Y_{q,t+h} - Y_{q,t-1}}{Y_{q,t-1}} = \alpha_{iqh}\frac{Shock_{i,t}}{G_{i,t-1}} + \beta_{iqh}\frac{Y_{q,t-1} - Y_{q,t-2}}{Y_{q,t-2}} + \delta_{iqh}\frac{G_{q,t-1} - G_{q,t-2}}{Y_{q,t-2}} + constant_{iqh} + error_{iqh,t}$$

where $Shock_i$ is country i's own spending shock in real terms, Y is real GDP and G is real government spending, all measured in terms of local currency in fixed prices of the base year. The variables are scaled by lagged output or spending in their respective country so that (i) I do not have to worry about exchange rate issues, (ii) the estimated coefficients are put in similar units for different country pairs, and (iii) α_{iqh} denotes country q's output elasticity with respect to country i's government spending, a measure of spillover effect. Country i's spillover to country q is then averaged across different horizons: $\alpha_{iq} = \frac{1}{H+1}\sum_{h=0}^{H}\alpha_{iqh}$. Country i's overall output spillover to other countries is computed as the weighted average according to bilateral trade:

$$\alpha_i \equiv \sum_{q \neq i}\frac{M_{iq,B}}{M_{iT,B}}\alpha_{iq}$$

where $M_{iq,B}$ is country q's imports from country i in the base year measured in US dollars and $M_{iT,B}$ is the total imports from country i to other countries in the base year measured in US dollars.

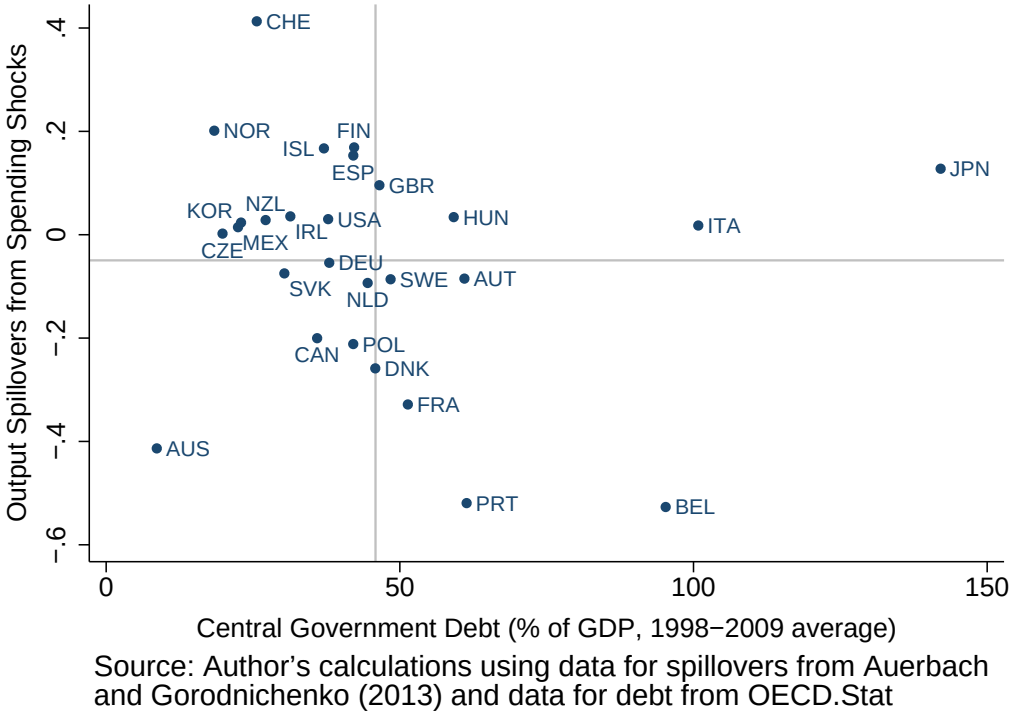
All the data in this section, including $Shock_{i,t}$, are directly from the database constructed by Auerbach and Gorodnichenko (2013) and are available for 27 OECD countries.[5] The data frequency is semiannual. The sample period for "old" OECD members such as the US is 1984s1-2010s1. For newer members such as Poland, the sample period starts from the mid-1990s. The base year is 2005, which is the OECD reference year. I set H equal to 4 (a two year horizon window). Increasing H does not change the pattern of Figure 2 but the estimates are less accurate because of larger standard errors.

Figure 2 plots each country's output spillover, α_i, against its debt-to-GDP ratio. The debt

[5]The 27 countries include Australia, Austria, Belgium, Canada, Switzerland, Czech Republic, Germany, Denmark, Spain, Finland, France, United Kingdom, Hungary, Ireland, Iceland, Italy, Japan, Korea, Mexico, Netherlands, Norway, New Zealand, Poland, Portugal, Slovak Republic, Sweden, and United States.

series is total central government debt as percentage of GDP extracted from OECD.Stat. 1998-2009 are those years over which the debt series is available for all the sample countries. Thus the debt ratio is the average across 1998-2009. The horizontal line and the vertical line represent the average output spillover and the average debt ratio across the 27 countries, respectively. The scatterplot reveals a negative relation between a country's output spillover to other countries and its domestic debt-to-GDP ratio. Regression results in Table 1 validate this negative relation. α_i is regressed on the debt ratio. The negative relation is robust after controlling for GDP growth, the ratio of trade volume to GDP (openness) and the real effective exchange rate (REER). When Japan is excluded from the sample, the negative relation becomes significant.

Figure 2: Government Debt and Output Spillovers from Spending Shocks



Source: Author's calculations using data for spillovers from Auerbach and Gorodnichenko (2013) and data for debt from OECD.Stat

The effect of country i's spending shock on its own output over a horizon $h \in \{0, 1, \ldots, H\}$, α_{ih}, can be easily obtained by running the following regression

$$\frac{Y_{i,t+h} - Y_{i,t-1}}{Y_{i,t-1}} = \alpha_{ih} \frac{Shock_{i,t}}{G_{i,t-1}} + \beta_{ih} \frac{Y_{i,t-1} - Y_{i,t-2}}{Y_{i,t-2}} + \delta_{ih} \frac{G_{i,t-1} - G_{i,t-2}}{Y_{i,t-2}} + constant_{ih} + error_{ih,t}.$$

Appendix A plots this domestic effect against the debt-to-GDP ratio. The stimulating effect of a country's government spending on its own output is also negatively related to its debt-

Table 1: Regression of Spillovers on Debt and Control Variables

Sample	All		Japan excluded		Japan and Italy excluded	
Debt	-0.0011	-0.0017	-0.0036*	-0.0048**	-0.0058**	-0.0078***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
GDP growth		-4.4337		-5.3094		-4.3082
		(5.332)		(4.966)		(4.627)
Openness		0.0195		0.1264		0.2022
		(0.145)		(0.143)		(0.138)
REER		0.6652		1.0457		1.2656**
		(0.665)		(0.643)		(0.605)
Obs	27	27	26	26	25	25

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.10

to-GDP ratio. The negative relation is less significant compared to that of the spillover effect.

3 Model structure

In order to analyze the spillover effects of fiscal shocks, I add a fully-specified government sector in each country in an otherwise standard two-good, two-country BKK model. Moreover, households in each country can purchase bonds issued by their own government as well as the internationally traded bonds.

The model economy consists of two countries, country 1 and country 2. Country 1 specializes in the production of good X and country 2 in the production of good Z. Labor and capital are internationally immobile. Consumption, investment, and government spending have both domestic and foreign content and use the same proportions of the two goods. They are composites of domestic and foreign goods as follows:

$$C_{1t} + I_{1t} + G_{1t} \equiv Q(X_{1t}, Z_{1t})$$

$$C_{2t} + I_{2t} + G_{2t} \equiv Q(Z_{2t}, X_{2t})$$

where $Q(X,Z) \equiv \left[\omega^{\frac{1}{\eta}} X^{\frac{\eta-1}{\eta}} + (1-\omega)^{\frac{1}{\eta}} Z^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$ is a CES aggregator. η measures the elasticity of substitution between domestic and foreign goods. The weight ω in Q determines the domestic and foreign content of domestic spending.

This is a model without money; all variables are real. Let q_{1t} and q_{2t} denote the prices of the two goods in period t in units of a numeraire (to be described shortly). The price indices in the two countries are given by

$$P_{1t} \equiv \left[\omega(q_{1t})^{1-\eta} + (1-\omega)(q_{2t})^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

$$P_{2t} \equiv \left[\omega(q_{2t})^{1-\eta} + (1-\omega)(q_{1t})^{1-\eta}\right]^{\frac{1}{1-\eta}}.$$

Thus the aggregate demand for the two goods is given by

$$X_{1t} = \omega \left(\frac{q_{1t}}{P_{1t}}\right)^{-\eta} Q(X_{1t}, Z_{1t})$$

$$Z_{1t} = (1-\omega) \left(\frac{q_{2t}}{P_{1t}}\right)^{-\eta} Q(X_{1t}, Z_{1t})$$

$$Z_{2t} = \omega \left(\frac{q_{2t}}{P_{2t}}\right)^{-\eta} Q(Z_{2t}, X_{2t})$$

$$X_{2t} = (1-\omega) \left(\frac{q_{1t}}{P_{2t}}\right)^{-\eta} Q(Z_{2t}, X_{2t})$$

where X_{2t} represents exports from country 1 to country 2, and Z_{1t} denotes imports into country 1. The numeraire is defined as a world price index: $(P_{1t})^{\frac{1}{2}} (P_{2t})^{\frac{1}{2}} = 1$. The real exchange rate, RER_t, is defined as follows:

$$RER_t \equiv \frac{P_{1t}}{P_{2t}}.$$

Therefore, from the perspective of country 1, the real exchange rate is the ratio of the domestic price level relative to the foreign price level.

3.1 Households

The representative household in each country i maximizes intertemporal utility characterized by functions of the form

$$E_0 \sum_{t=0}^{\infty} \beta_{it} \left(\frac{C_{it}^{1-\gamma} - 1}{1-\gamma} - \theta \frac{L_{it}^{1+\kappa}}{1+\kappa}\right)$$

$$\beta_{i0} = 1,\ \beta_{i,t+1} = (1 + \psi C_{it})^{-1} \beta_{it},\ t > 0$$

where C_{it} and L_{it} are consumption and hours worked, respectively, in country i. The endogenous discount factor is used to ensure that the model is stationary.[6]

There are two types of bonds in each country, government bonds D and internationally traded bonds B. The household's budget constraint in country i is

$$(1+\tau^c_{it})P_{it}C_{it}+P_{it}I_{it}+D_{it}+B_{it} = (1-\tau^l_{it})q_{it}w_{it}L_{it}+(1-\tau^k_{it})q_{it}R^k_{it}K_{i,t-1}+R^i_{t-1}D_{i,t-1}+R_{t-1}B_{i,t-1}+P_{it}T_{it}$$

where labor income, capital income, government and internationally traded bonds plus interest payments, and lump-sum transfers from the domestic government, T_{it}, can be allocated to consumption, investment in physical capital and the purchase of new government and international bonds. R^k_{it} is the capital rental rate. τ^c_{it}, τ^l_{it} and τ^k_{it} are tax rates on consumption, labor income and capital income.[7]

The law of motion for capital is given by

$$K_{it} = (1 - \delta)K_{i,t-1} + I_{it} - \frac{\xi}{2}\left(\frac{I_{it}}{K_{i,t-1}} - \delta\right)^2 K_{i,t-1}$$

where δ is the depreciation rate. The last item captures the capital adjustment cost.[8] The household maximizes utility subject to its budget constraint and the law of motion for capital.

3.2 Firms

The representative firm in country 1 specializes in producing good X and the representative firm in country 2 specializes in producing good Z. They rent capital and labor from the household. Production functions in the two countries take the same form: $F(K, L) = K^\alpha L^{1-\alpha}$ where $\alpha \in [0, 1]$. The resource constraints in the two countries are

$$X_{1t} + X_{2t} = Y_{1t} = A_{1t}F(K_{1,t-1}, L_{1t})$$

$$Z_{1t} + Z_{2t} = Y_{2t} = A_{2t}F(K_{2,t-1}, L_{2t})$$

[6] Schmitt-Grohé and Uribe (2003) show that this feature makes the steady-state independent of initial conditions, i.e., the initial level of financial wealth, physical capital, and total factor productivity.

[7] Note that labor income and capital income are in units of the domestic good. Thus they are multiplied by the price of the domestic good. Bond holdings, bond prices and bond returns are expressed in terms of the numeraire.

[8] International business cycle models use capital adjustment costs to reduce the volatility of investment in response to productivity shocks. BKK uses a time-to-build structure for capital formation as in Kydland and Prescott (1982). But convex capital adjustment costs have become more common since the publication of Baxter and Crucini (1995).

where Y_{it} represents output in country i in units of the domestic good, and X_{it} and Z_{it} are uses of the two goods in country i.

The productivity shocks are assumed to follow the processes

$$\log(A_{1t}) = \rho_a \log(A_{1,t-1}) + \nu \log(A_{2,t-1}) + \varepsilon^a_{1t}$$

$$\log(A_{2t}) = \nu \log(A_{1,t-1}) + \rho_a \log(A_{2,t-1}) + \varepsilon^a_{2t}$$

where $\varepsilon^a_{it} \sim N(0, \sigma_a^2)$ and the contemporaneous correlation of the productivity shocks is $\lambda \in (0, 1)$. The parameter ν measures technology spillovers.

The representative firm in each country i maximizes its profit

$$Y_{it} - w_{it}L_{it} - R^k_{it}K_{i,t-1}.$$

Thus, wages and capital rental rates are

$$w_{it} = \frac{(1-\alpha)Y_{it}}{L_{it}}$$

$$R^k_{it} = \frac{\alpha Y_{it}}{K_{i,t-1}}.$$

3.3 Fiscal policy

Government spending and lump-sum transfers are financed through issuance of one-period bonds, and taxation on capital income, labor income and consumption. The government's period budget constraint in each country i is

$$R^i_{t-1}D_{i,t-1} + P_{it}G_{it} + P_{it}T_{it} = D_{it} + \tau^k_{it}q_{it}R^k_{it}K_{i,t-1} + \tau^l_{it}q_{it}w_{it}L_{it} + \tau^c_{it}P_{it}C_{it}.$$

All the five fiscal instruments follow exogenous feedback rules. They are allowed to respond to the debt-to-GDP ratio, as motivated by the empirical fact. Additionally, the output growth rate is included in the rules, reflecting the cyclical influences from the states of the economy.[9] Specifically,

$$\log(F_{it}) = (1-\rho_F)\log(F_i) + \rho_F \log(F_{i,t-1}) + \varphi_F \frac{Y_{it-1} - Y_{it-2}}{Y_{it-2}} + \gamma_F(\log(\widetilde{D}_{i,t-1}) - \log(\widetilde{D}_i)) + \sigma_F \varepsilon^F_{it}$$

[9] The output is detrended. The output growth rate is the gap between GDP growth and trend growth.

where F_{it}, with $F \in \{G, T, \tau^k, \tau^l, \tau^c\}$, denote the fiscal instruments of government spending, lump-sum transfers, the capital tax rate, the labor tax rate, and the consumption tax rate in country i at time t, $\widetilde{D}_t \equiv D_t/q_t Y_t$, and each ε_{it} is an i.i.d. innovation with mean zero and standard deviation one. The variables without a subscript t denote steady state values. The parameters φ_F represent the responsiveness of the fiscal instruments to lagged output growth rate, a measure of output gap (and consistent with that used in Section 2). $\varphi_F > 0$ ($\varphi_F < 0$) implies the procyclicality (countercyclicality) of the policy rule. The parameters γ_F capture the responsiveness of these instruments to lagged debt-to-GDP ratio, a measure of government liabilities. $\gamma_G < 0$, $\gamma_T < 0$, $\gamma_{\tau^k} > 0$, $\gamma_{\tau^l} > 0$, or $\gamma_{\tau^c} > 0$ corresponds to the debt consolidation feature of each fiscal policy. Specifically, government debt is redeemed through decreased spending, decreased transfers, increased capital tax rate, increased labor tax rate, or increased consumption tax rate. Lagged variables rather than contemporaneous variables are used because of delayed fiscal decision and implementation.

3.4 National accounts

Recall that the optimal aggregate demand for the two goods in country 1 is given by $X_{1t} = \omega \left(\frac{q_{1t}}{P_{1t}}\right)^{-\eta} Q(X_{1t}, Z_{1t})$ and $Z_{1t} = (1-\omega) \left(\frac{q_{2t}}{p_{1t}}\right)^{-\eta} Q(X_{1t}, Z_{1t})$. The aggregate demand for the two goods in country 2 is given by $Z_{2t} = \omega \left(\frac{q_{2t}}{P_{2t}}\right)^{-\eta} Q(Z_{2t}, X_{2t})$ and $X_{2t} = (1-\omega) \left(\frac{q_{1t}}{P_{2t}}\right)^{-\eta} Q(Z_{2t}, X_{2t})$. Using $C_{it} + I_{it} + G_{it} = Q_{it}$ and the resource constraints in the two countries, output can be decomposed as

$$Y_{1t} = \underbrace{\left(\frac{P_{1t}}{q_{1t}}\right)^{\eta} (C_{1t} + I_{1t} + G_{1t})}_{\text{absorption}} + \underbrace{X_{2t} - \left(\frac{q_{2t}}{q_{1t}}\right)^{\eta} Z_{1t}}_{\text{net exports}}$$

$$Y_{2t} = \underbrace{\left(\frac{P_{2t}}{q_{2t}}\right)^{\eta} (C_{2t} + I_{2t} + G_{2t})}_{\text{absorption}} + \underbrace{Z_{1t} - \left(\frac{q_{1t}}{q_{2t}}\right)^{\eta} X_{2t}}_{\text{net exports}}$$

where $\left(\frac{P_{it}}{q_{it}}\right)^{\eta} (C_{it} + I_{it} + G_{it})$ is absorption and the rest is net exports. The trade balance is defined as the ratio of net exports to output:

$$TB_{1t} \equiv \left[X_{2t} - \left(\frac{q_{2t}}{q_{1t}}\right)^{\eta} Z_{1t}\right] / Y_{1t}$$

$$TB_{2t} \equiv \left[Z_{1t} - \left(\frac{q_{1t}}{q_{2t}}\right)^{\eta} X_{2t}\right] / Y_{2t}.$$

3.5 Competitive Equilibrium

A competitive equilibrium for this economy is a sequence of
prices $\left\{q_{1t},\, q_{2t},\, P_{1t},\, P_{2t},\, R_t,\, R_t^1,\, R_t^2,\, R_{1t}^k,\, R_{2t}^k,\, w_{1t},\, w_{2t}\right\}_{t=0}^{\infty}$ and
quantities $\{C_{1t},\, C_{2t},\, L_{1t},\, L_{2t},\, D_{1t},\, D_{2t},\, B_{1t},\, B_{2t},\, I_{1t},\, I_{2t},\, K_{1t}, K_{2t}\}_{t=0}^{\infty}$ such that:
(1) households and firms behave optimally in each country;
(2) the government budget constraint holds in each country;
(3) the goods markets clear, i.e. $X_{1t} + X_{2t} = Y_{1t}$ and $Z_{1t} + Z_{2t} = Y_{2t}$;
(4) the bond market clears, i.e. $B_{1t} + B_{2t} = 0$.

Because households can hold international bonds and domestic government bonds, and can rent capital to firms, the no arbitrage condition implies that $R_t = R_t^1 = R_t^2 = R_{1t}^k = R_{2t}^k$. Appendix B lists the optimality conditions for the model.

4 Estimation

The model is estimated on US and EU (15 countries[10]) quarterly data from 1961q1 to 2013q4 using Bayesian estimation techniques. Appendix C describes the data sources and construction.

4.1 Policy rules

As is common practice, the feedback rule for each fiscal instrument $F \in \{G, T, \tau^k, \tau^l, \tau^c\}$, $\log(F_{it}) = (1-\rho_F)\log(F_i)+\rho_F \log(F_{i,t-1})+\varphi_F \frac{Y_{it-1}-Y_{it-2}}{Y_{it-2}}+\gamma_F(\log(\widetilde{D}_{i,t-1})-\log(\widetilde{D}_i))+\sigma_F\varepsilon_{it}^F$, is estimated outside the model and is then fed into the model. Seven US time series including real government spending, real government transfers, capital, labor and consumption tax rates, the GDP growth rate, and the debt-to-GDP ratio are used in the estimation. The estimation results are summarized in Table 2.

As described above, a positive (negative) φ_F suggests procyclicality (countercyclicality) of the fiscal policy. The estimation results show that government spending, the capital tax rate and the labor tax rate are procyclical. In contrast, transfers and the consumption tax rate are countercyclical, although the latter is not significantly so. The signs of γ_F reveal fiscal consolidation efforts by the government: in response to a higher debt-to-GDP ratio, the government cuts spending and transfers while at the same time raising taxation on capital income, labor income and consumption expenditures. Government spending reacts most significantly to the debt-to-GDP ratio, followed by the capital tax rate and the consumption tax rate. The responsiveness of transfers or the labor tax rate, however, is not significant.

[10]The countries are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom.

Overall, the estimation results for γ_F point to operative fiscal consolidation in the US. Finally, estimates for the autoregressive parameters ρ_F reveal the high persistence of fiscal shocks.

Table 2: Parameters in the Fiscal Policy Rules

	G_t	T_t	τ_t^k	τ_t^l	τ_t^c
φ_F	0.0015**	-0.0029**	0.0020*	0.0060***	-0.0006
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
γ_F	-0.0371***	-0.0226	0.0332**	0.0048	0.0173*
	(0.010)	(0.018)	(0.015)	(0.016)	(0.010)
ρ_F	0.9504***	0.9363***	0.9263***	0.8582***	0.8873***
	(0.016)	(0.022)	(0.026)	(0.037)	(0.031)
σ_F	0.0134	0.0254	0.0222	0.0233	0.0147

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.10

4.2 Prior distributions

Five US time series and four EU time series are used as observable variables in the Bayesian estimation. The US data series include real GDP, real consumption, real investment, real government spending, and hours worked. The EU data series include real GDP, real government spending, real exports of goods and services, and real imports of goods and services.

In order to pin down steady state values of the estimated model, some parameters are kept fixed to their calibrated values (which can be viewed as infinitely strict priors). Table 3 reports the calibrated parameters. The discount factor in steady state, β, is set to equal 0.99 (so that the annual steady state real interest rate is 4%). The risk aversion parameter, γ, takes a standard value of 2. Following Chetty et al. (2011), I set the Frisch elasticity of labor supply to $1/\kappa = 0.75$. The utility weight of work parameter, θ, is set to 13.1 (so that hours worked in steady state is 0.33). The depreciation rate of capital, δ, is 0.02 (so that the annual depreciation rate is 8%). The capital share in production, α, is set equal to 0.36 (so to imply a labor share of 64%). The steady state spending to output ratio, debt to output ratio, and tax rates are set to equal their sample means.

Table 3: Calibrated Parameters for the Estimated Model

Parameter	β	γ	κ	θ	δ	α	$\frac{G}{Y}$	$\frac{D}{Y}$	τ^k	τ^l	τ^c
Value	0.99	2	1/0.75	13.1	0.02	0.36	0.176	0.543	0.376	0.216	0.093

The remaining parameters are estimated and their prior distributions are shown in Table 4. The prior and posterior probability density functions are plotted in Appendix D. The prior information is based on previous studies at both the macro and micro level. A Beta distribution is assumed for ω, with a mean of 0.7 and a standard deviation equal to 0.2. Estimates of the elasticity of substitution between domestic and foreign goods η vary substantially in the literature, with disaggregated studies producing much larger estimates than macroeconomic data. In this paper η is assumed to follow a Gamma distribution with mean 3 and standard deviation 1.5 (so that approximately it is centered on 2 and ranges from 0 to 8). The capital adjustment cost ξ is distributed as Gamma with a mean of 2 and a standard deviation of 0.5.

A Beta distribution is assumed for the technology autoregressive coefficient ρ_a, with mean 0.8 and standard deviation 0.1 (so that it will range approximately between 0.5 and 1). The standard deviation of the technology innovation, σ_a, is assumed to be distributed as Inverse Gamma with mean 0.01 and standard deviation 0.01. The technology spillover ν is assumed to follow a Gamma distribution centered on a value of 0.1 with a standard deviation of 0.02. The technology correlation λ is assumed to have a Beta distribution with a mean of 0.4 and a standard deviation of 0.2. The distributions of the two technology parameters span a range of values including those calibrated in Baxter and Crucini (1993) and Backus et al. (1994).

Table 4: Prior and Posterior Distributions

Parameter	Prior distribution			Posterior distribution		
	Density	Mean	St. Dev.	Mean	90% interval	
Domestic share ω	beta	0.7	0.2	0.69	0.64	0.74
Elasticity of subs. η	gamma	3	1.5	3.38	2.20	4.49
Capital adj. cost ξ	gamma	2	0.5	1.66	1.41	1.92
Tech. AR coeff. ρ_a	beta	0.8	0.1	0.90	0.89	0.92
Tech s.d. σ_a	invg	0.01	0.01	0.0068	0.0064	0.0073
Tech. spillover ν	gamma	0.1	0.02	0.073	0.060	0.087
Tech correlation λ	beta	0.4	0.2	0.27	0.15	0.37

4.3 Posterior distributions

The posterior distributions of the estimated parameters are obtained in two steps. First, Chris Sims's optimization routine csminwel is used to maximize the log posterior function. Second, the random walk Metropolis–Hastings algorithm is used to sample from the posterior. Right columns of Table 4 summarize estimated means and 5% and 95% percentiles. Two Markov chains were run starting from different initial conditions randomly selected around the posterior mode. The acceptance ratios are 24.82% and 24.78%, respectively. A sample of 100,000 draws was created with the first 50,000 used as a burn-in period. Convergence was checked using standard diagnostics as in Brooks and Gelman (1998). The mean estimates for the domestic share (ω) and elasticity of substitution between domestic and foreign goods (η) are 0.6929, and 3.3757, respectively. These estimates imply a steady state imports to output ratio of 30.71%, which is between the US imports share 14.45% and the EU imports share 35.71% over the sample period.[11] The means of technology persistence (ρ_a) and standard deviation (σ_a) are 0.9021 and 0.0068, respectively. The technology spillover (ν) and correlation (λ) are estimated to have a mean of 0.0732 and 0.2676, respectively.

5 Quantitative analysis

Before turning to the results, let me first discuss the channels through which fiscal shocks exert influence on both domestic and cross-border economic activities. In the domestic economy, the government finances fiscal expansions by issuing government bonds. Since part of the government bonds are purchased by foreign residents, domestic private wealth necessarily decreases. Because of negative wealth effect, domestic consumers increase their labor supply while at the same time cutting their consumption. In the meantime, a higher level of government debt pushes up the real interest rate in the economy, thus crowding out private investment.

There are three international transmission channels of fiscal shocks in the model. The first one is the trade channel. Following an expansionary fiscal shock, the domestic levels of consumption, investment and government spending will change. Since these three components of output are an aggregate of domestic and foreign products, consumers will directly spend part of their income abroad, changing the demand for foreign imports and thus foreign production. The second channel is the interest rate channel. Debt financed fiscal expansions will drive up real interest rate in the bond markets. Recall that cross-border arbitrage of returns across capital and bonds implies a common interest rate in the model. Hence a higher level of interest rate will discourage foreign investment. The third channel is the exchange

[11] The steady state imports to output ratio is equal to $1 - \omega$.

rate channel. In response to a fiscal expansion, the domestic consumers' demand for the home goods will be relatively larger than that for the foreign goods because of home bias in the Armington aggregator. As a result, the exchange rate appreciates for the domestic consumers and the foreign country's international competitiveness is enhanced, boosting its exports to the domestic economy.

We now turn to the domestic and spillover effects of expansionary fiscal shocks. Figures 4-13 plot the impulse responses following a temporary one standard deviation exogenous change in each fiscal instrument in country 1. The blue solid line is generated with the mean of the posterior distribution. The red dashed line represents the simulation result where debt stabilization is realized through non-distortionary transfers only.[12] Foreign economy variables are indicated with an asterisk (*).[13]

5.1 Domestic government spending shock

Figure 4 shows how key domestic variables adjust to the domestic government spending impulse. On impact, because of the negative wealth effect, consumption decreases and the labor supply increases. Domestic consumers become borrowers in the international bond market as shown by a negative response of the international bond. Since the increased spending is debt-financed, we see an increase in the government debt level and hence an increased real interest rate in the economy. Private investment is crowded out and stays below steady state until quarter 17. With a lower marginal product of labor, labor turns negative in quarter 11 and stays so till quarter 17. The below steady-state investment and labor lead to negative responses of output between quarter 4 and quarter 31.

However, responses of these variables change signs as a result of the spending reversal: government spending drops below steady-state in quarter 15 to consolidate debt. The negative responses of spending between quarter 15 and quarter 26 in turn contribute to a below steady-state government debt level between quarter 20 and quarter 38. This fiscal consolidation regime results in fluctuations in the responses of macroeconomic variables.[14]

[12] I shut off the fiscal consolidation regime by setting $\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$ and $\gamma_T = -0.114$ (so that the simulations are not explosive). The other parameters are kept the same as in Section 4 (mean value for the estimated parameters are used).

[13] Overall, we observe a considerable amount of fluctuations following a fiscal shock. For model validation purpose, I implement an eleven variable VAR with a lag length of 4 to see if fluctuations appear following a fiscal shock. The variables are Cholesky-ordered as follows: US fiscal variable, US real GDP, US real consumption, US real investment, US hours worked, EU real GDP, EU real consumption, EU real investment, US real exports, US real imports and US real government debt, where the US fiscal variable belongs to one of the five fiscal instruments. The data sources and the time span are the same as those used in the Bayesian estimation. The results are shown in Appendix E. It turns out that the VARs also display fluctuations. Changing the order of the variables or the lag length does not affect this feature.

[14] Fluctuations also exist in Corsetti et al. (2010) and Corsetti and Müller (2013).

In contrast, theses fluctuations disappear when lump-sum transfers are the only instrument used to stabilize debt. In this case, government spending reverts back to its steady state smoothly as do other variables in the economy (except government debt and transfers). Labor supply stays above steady-state throughout the 40 years. Consumption decreases by a larger margin without the fiscal consolidation regime. Investment is crowded out between quarter 0 and quarter 38. Investment turns positive in quarter 39 (but only slightly so because the effect of above steady-state marginal product of capital and the effect of above steady-state interest rate nearly cancel each other out). These responses of investment and labor lead to positive responses of output throughout the 40 years.

The cross-border impacts of a one standard deviation increase in domestic government spending appear in Figure 5. We can analyze the responses through the three international transmission channels. (i) The trade channel: the fall in domestic consumption and investment decreases imports from the foreign country whereas the increase in government spending raises imports. (ii) The exchange rate channel: real exchange rate appreciates in the domestic country, boosting its imports and reducing its exports. The overall effect of (i) and (ii) is that imports increase (and stay positive till quarter 4) and exports decrease (and stay negative till quarter 5) in the domestic country. Correspondingly, the trade balance turns positive in the foreign country. (iii) The interest rate channel: the increased global real interest rate depresses foreign investment which stays negative till quarter 3. Higher demand from the domestic country leads to an increase of output and labor supply in the foreign country. Higher real interest rate encourages foreign consumers to reduce consumption and hold more international bonds (which stay above steady state till quarter 8, not shown in Figure 5) and government bonds. With respect to the other components of the foreign government's budget constraint (not shown in Figure 5), spending stays positive till quarter 36; capital tax revenues and labor tax revenues stay positive till quarter 29 and quarter 32 respectively; consumption tax revenues stay negative till quarter 40; transfers stay positive between quarter 2 and quarter 35. Again, we can see fluctuations of responses when the fiscal consolidation regime is in place.

We may summarize the main findings for the effects of a positive domestic government spending shock: (1) cross-country spillovers are significant, i.e. foreign variables respond in magnitude comparable to that of domestic variables; (2) the fiscal consolidation regime leads to fluctuations of macroeconomic variables both at home and abroad.

5.2 Domestic transfers shock

Figure 6 reports the domestic responses to a one standard deviation increase in the domestic lump-sum transfers shock. Government debt stays positive till quarter 18. Domestic

households spend their increased transfers on more consumption goods and leisure and they hold more international bonds and government bonds. In spite of higher government debt, higher demand for bonds pushes down real interest rate which stays negative till quarter 29. Labor also stays negative till quarter 29. Due to lower labor supply hence lower marginal production of capital, investment falls. Decreased investment and labor result in negative responses of output.

The spillovers of a one standard deviation increase in the domestic transfers shock are illustrated in Figure 7. Imports decrease on impact and stay negative till quarter 19. This negative impact response can be attributed to the negative response of domestic government spending (not shown in Figure 6). In contrast, under a government spending shock, domestic spending stays positive for a while as shown in Figure 4. Because part of government spending falls directly on foreign goods, decreased spending leads to decreased demand for foreign goods. As domestic households save in the international bond market, foreign households become borrowers and the negative responses of international bonds (not shown in Figure 7) are accompanied by positive responses of consumption.

Again, the fluctuating responses after the fiscal shock can be attributed to the fiscal consolidation regime. If only transfers adjust to stabilize debt, we shall see zero responses of macroeconomic variables both at home and abroad (except government debt and transfers), since transfers are non-distortionary in the model.

5.3 Domestic capital tax rate shock

Figure 8 describes the domestic responses to a one standard deviation decrease in the domestic capital tax rate. Because of a higher return on capital, investment jumps up and stays positive till quarter 32. With a delay of 2 quarters, consumption rises above steady-state. Labor stays positive for 4 quarters before it turns below steady-state. Output stays positive till quarter 51. Domestic households are borrowers in the international bond market in the first 26 quarters but later on they become savers. We can conclude that fiscal stimulus via a capital tax rate cut is more effective in boosting domestic economy than increased government spending or transfers, in the sense that output, consumption and investment remain above steady-state for the first 8 years after the shock. The cross-border spillovers are shown in Figure 9. Although foreign trade balance increases on impact and stays positive for 6 quarters, foreign output stays negative between quarter 2 and quarter 49. This is because foreign investment decreases by a very large margin due to higher global real interest rate.

Under a domestic capital tax rate shock, output, consumption and investment behave very differently at home and abroad. The capital tax rate cut effectively stimulates domestic

output, consumption and investment. In the foreign country, however, it has contractionary effect for the first few years.

5.4 Domestic labor tax rate shock

Impacts of a one standard deviation decrease in the domestic labor tax rate appear in Figures 10 and 11. In the domestic economy, the labor supply increases in response to the tax rate cut. The labor tax rate shock raises disposable income of households who increase their consumption and bond holdings accordingly. The real interest rate stays negative till quarter 28 because of higher demand for bonds. Output stays positive till quarter 10. The domestic households save in the international bond market throughout the 40 years. For spillover effects, the real exchange rate depreciates on impact, meaning that the domestic economy has gained international competitiveness after a labor tax rate cut. The patterns of the foreign variables are similar to those under the transfers shock.

5.5 Domestic consumption tax rate shock

Figure 12 illustrates the domestic effects of a lower domestic consumption tax rate. The behavioral patterns of domestic variables are very similar to those under the transfers shock, as both shocks tend to boost domestic consumption but depress investment and output. The spillover effects, shown in Figure 13, are also similar to those under the transfers shock.

5.6 Fiscal multipliers

To further compare the domestic and cross-border effects of fiscal shocks, as well as between the two scenarios with and without the fiscal consolidation regime, I document present value output multipliers in Tables 5 and 6. The following formula is used to calculate present value output multipliers over a k-quarter horizon window:

$$\frac{\sum_{j=0}^{k}\left(\prod_{i=0}^{j} R_{t+i}^{-1}\right)\triangle Y_{t+j}}{\sum_{j=0}^{k}\left(\prod_{i=0}^{j} R_{t+i}^{-1}\right)\triangle F_{t+j}}$$

or

$$\frac{\sum_{j=0}^{k}\left(\prod_{i=0}^{j} R_{t+i}^{-1}\right)\triangle Y_{t+j}^{*}}{\sum_{j=0}^{k}\left(\prod_{i=0}^{j} R_{t+i}^{-1}\right)\triangle F_{t+j}}$$

where $\triangle Y_{t+j}$, $\triangle Y_{t+j}^{*}$ and $\triangle F_{t+j}$ denote level changes of the variables from their steady states and $F \in \{$government spending, transfers, capital tax revenues, labor tax revenues, consumption tax revenues$\}$.[15]

[15] The present value multiplier formula follows from Mountford and Uhlig (2009) and Leeper et al. (2010a).

Table 5: Domestic Output Multipliers

Instrument	Specification	Impact	4	8	20	40	∞
Spending	Baseline	0.13	0.04	-0.07	-0.57	-0.55	-0.49
	Transfers only	0.28	0.28	0.29	0.30	0.33	0.45
Transfers	Baseline	-0.14	-0.24	-0.37	-0.80	-0.74	-0.88
	Transfers only	0.00	0.00	0.00	0.00	0.00	0.00
Capital tax	Baseline	-0.07	-0.14	-0.19	-0.37	-0.72	-0.72
	Transfers only	-0.18	-0.33	-0.47	-0.78	-1.03	-1.08
Labor tax	Baseline	-0.61	-0.57	-0.50	-0.36	-0.49	-0.32
	Transfers only	-0.68	-0.72	-0.75	-0.82	-0.85	-0.77
Cons. tax	Baseline	0.02	0.11	0.23	0.51	0.40	0.43
	Transfers only	-0.07	-0.07	-0.07	-0.06	-0.07	-0.13

The domestic effects of fiscal shocks are summarized in Table 5. Consistent with Mountford and Uhlig (2009), capital tax multipliers and labor tax multipliers are larger than spending multipliers. Moreover, capital and labor tax cuts work better when only non-distortionary transfers adjust to stabilized debt, indicating that the fiscal consolidation regime attenuates the domestic stimulating effects of fiscal shocks. Under the fiscal consolidation regime, spending multipliers are positive in the short run but turn negative in the long run. In contrast, spending multipliers are positive in the long run without the fiscal consolidation regime, since agents do not expect a reversal of fiscal variables. Increasing transfers or cutting labor tax would reduce output in the domestic economy. Overall, the domestic output multipliers are smaller than 1, which is typical for real business cycle models.

Table 6 shows the cross-border output spillovers from domestic fiscal shocks. Short-run and long-run multipliers differ remarkably. Under both the baseline and the alternative specifications, impact and long run multipliers have opposite signs for all five fiscal instruments.[16] Within two years under the fiscal consolidation regime, a domestic transfers increase, or a domestic tax rate cut would lead to a decrease in the foreign output. Therefore, a spending increase is most favored by the foreign economy in the short run. In the long run, the

Tax revenues are computed as $T_t^k = \tau_t^k \alpha Y_t$, $T_t^{k*} = \tau_t^{k*} \alpha Y_t^*$, $T_t^l = \tau_t^l (1-\alpha) Y_t$, $T_t^{l*} = \tau_t^{l*} (1-\alpha) Y_t^*$, $T_t^c = \tau_t^c C_t$, $T_t^{c*} = \tau_t^c C_t^*$.

[16] Except the "transfers only" case for transfers shocks where all the multipliers are zero.

Table 6: Foreign Output Multipliers

Instrument	Specification	Impact	4	8	20	40	∞
Spending	Baseline	0.03	0.03	0.03	0.16	0.17	-0.14
	Transfers only	0.11	0.09	0.08	0.03	-0.05	-0.23
Transfers	Baseline	-0.07	-0.06	-0.04	0.13	0.25	0.35
	Transfers only	0.00	0.00	0.00	0.00	0.00	0.00
Capital tax	Baseline	-0.05	0.06	0.16	0.34	0.35	0.17
	Transfers only	-0.12	-0.01	0.09	0.30	0.42	0.35
Labor tax	Baseline	0.06	0.05	0.03	-0.14	-0.29	-0.53
	Transfers only	0.03	0.03	0.03	0.01	-0.06	-0.21
Cons. tax	Baseline	0.01	0.01	0.00	-0.10	-0.11	-0.07
	Transfers only	-0.04	-0.03	-0.02	0.01	0.07	0.17

foreign economy would prefer a domestic labor tax rate cut, with a present value multiplier of 0.53 (0.21) additional unit of foreign output under the fiscal consolidation (alternative) specification.

5.7 Domestic government debt and foreign output multipliers

In Section 2, I have shown that output spillovers from domestic spending shocks are negatively related to the domestic economy's average debt-to-GDP ratio. This section investigates the model prediction of the relationship between these two variables. In order to generate different levels of average debt-to GDP ratio, I vary the speed of fiscal consolidation in the fiscal policy rules. More specifically, γ_F is multiplied by the speed variable s

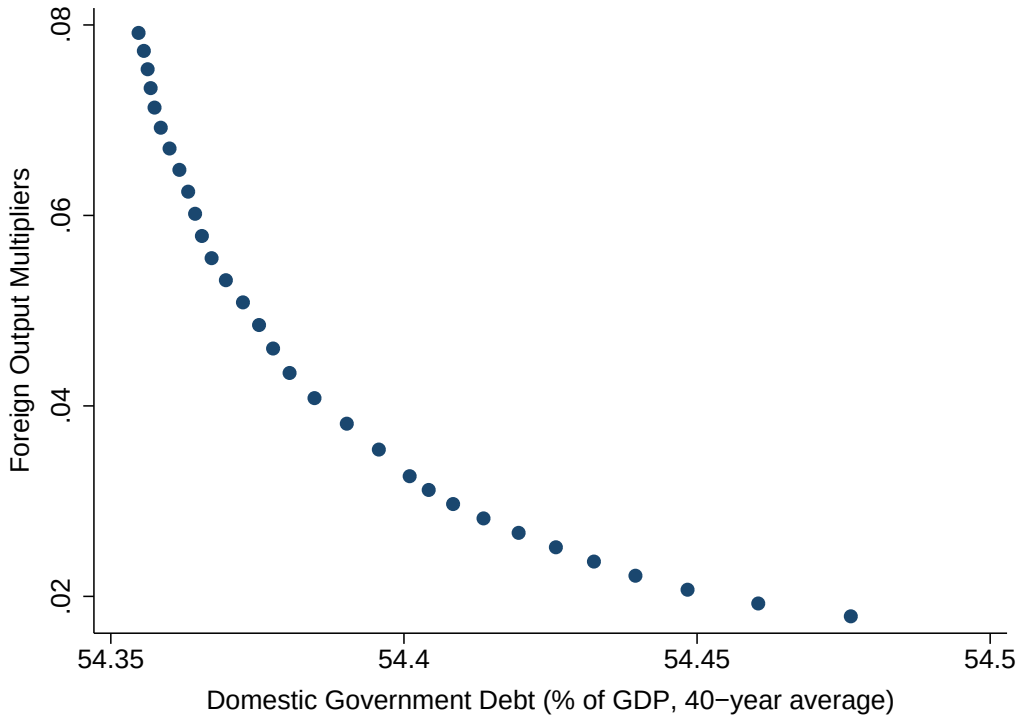
$$\log(F_{it}) = (1-\rho_F)\log(F_i)+\rho_F \log(F_{i,t-1})+\varphi_F \frac{Y_{it-1}-Y_{it-2}}{Y_{it-2}}+s\gamma_F(\log(\widetilde{D}_{i,t-1})-\log(\widetilde{D}_i))+\sigma_F\varepsilon^F_{it}$$

while the other parameters are kept the same as in Section 4 (mean value for the estimated parameters are used). $s > 1$ ($s < 1$) corresponds to a higher (lower) speed of fiscal consolidation. Appendix F plots the debt ratio against s. It shows that a higher speed of fiscal consolidation is associated with a smaller average debt-to-GDP ratio. Figure 3 plots foreign present value output multipliers over a horizon of two years (same as in the empirical section)

against the domestic average debt-to-GDP ratio over the simulation periods (40 years). The present value foreign output multiplier is a good proxy for the output spillover in Section 2, which is foreign output elasticity with respect to domestic government spending. As we can see from Figure 3, the model succeeds in capturing the negative relation between the two variables as observed in the empirical fact. The mechanism is the dominating interest rate channel: higher domestic debt drives up global real interest rate and dampens foreign activity while lower domestic debt is associated with a lower interest rate, boosting foreign activity.

The two figures imply that a higher speed of fiscal consolidation is associated with a higher foreign output multiplier. The speed of fiscal consolidation influences foreign output in two opposite directions. First, domestic expansionary shocks can stimulate foreign output through increased imports (the trade channel and the exchange rate channel). A faster consolidation regime, however, mitigates this positive effect, leading to smaller foreign output multipliers. On the other hand, accelerated fiscal consolidation ensures less debt accumulation and lower global interest rates, leading to larger foreign output multipliers (the interest rate channel). Therefore, the results reveal that the interest rate channel dominates in the model economy.

Figure 3: Domestic Government Debt and Foreign Output Multipliers



6 Variance Decomposition

Tables 7 and 8 present the contributions of productivity and fiscal shocks to the variance of key model variables. The decompositions help us evaluate the relative importance of productivity shocks and fiscal shocks in accounting for business cycle fluctuations in key model variables. The forecast-error-variance decompositions are reported on 6 horizons.

Table 7: Fraction Attributed to Productivity Shocks and Fiscal Shocks (1)

	output		consumption		investment		gov't spending		trade balance	
Horizon	prod.	fiscal	prod.	fiscal	prod.	fiscal	prod.	fiscal	prod.	fiscal
1	93.19	6.81	81.61	18.39	46.97	53.03	0	100	13.53	86.47
4	94.01	5.99	84.32	15.68	47.89	52.11	0.46	99.54	12.02	87.98
8	93.69	6.31	86.83	13.17	48.17	51.83	3.77	96.23	9.75	90.25
20	90.45	9.55	91.3	8.7	49.54	50.46	14	86	6.78	93.22
40	90.79	9.21	93.39	6.61	46.89	53.11	16.68	83.32	6.89	93.11
∞	91.66	8.34	94.07	5.93	45.58	54.42	21.14	78.86	8.24	91.76

Table 8: Fraction Attributed to Productivity Shocks and Fiscal Shocks (2)

	labor		exchange rate		interest rate		gov't debt		int'l bond	
Horizon	prod.	fiscal	prod.	fiscal	prod.	fiscal	prod.	fiscal	prod.	fiscal
1	15.15	84.85	75.58	24.42	18.22	81.78	9.43	90.57	1.18	98.82
4	15.12	84.88	79.53	20.47	19.03	80.97	8.7	91.3	2.11	97.89
8	14.79	85.21	80.67	19.33	21.93	78.07	8.32	91.68	3.31	96.69
20	18.07	81.93	68.18	31.82	26.03	73.97	8.34	91.66	7.13	92.87
40	42.59	57.41	54.48	45.52	27.07	72.93	8.39	91.61	23.24	76.76
∞	57.48	42.52	50.52	49.48	37.82	62.18	8.45	91.55	31.35	68.65

The quarterly fluctuations in output and consumption are largely dominated by productivity shocks both in the short and the long run. In contrast, fiscal shocks account for major part of fluctuations in government spending, the trade balance, the real interest rate, government debt and the international bond.

In terms of short horizons, most (around 85 percent) of the variation in labor supply are explained by fiscal shocks, and they still represent 82 percent after five years, while productivity shocks gain more importance in the long run. The exchange rate is strongly affected in the short run by productivity shocks and, in the long run, by both productivity and fiscal shocks. For the variation in investment, both shocks play a role with fiscal shocks being slightly more important.

7 Historical Decomposition

The observed data (deviations from the steady state) for US GDP, US investment, US hours, US government spending, EU output and EU trade balance over the 1961q1-2013q4 period are decomposed into the contributions of productivity and fiscal shocks.[17] The results are shown in Figures 14-19. It comes as no surprise that both US and EU GDP fluctuations are driven mostly by productivity shocks[18], and that most of the variations in US government spending are identified as fiscal shocks. Interestingly, fiscal shocks are more important than productivity shocks behind the historical fluctuations in US hours and EU trade balance. Fiscal shocks have also contributed strongly to US investment movements since 2007.[19]

8 Conclusion

In this paper, I document the fact that the output spillover of increased government spending is negatively related to the domestic government debt-to-GDP ratio. In order for the model to generate results consistent with this fact, I incorporate the fiscal consolidation component in the policy rules of all five fiscal instruments. For example, after a temporary increase above steady-state, spending has to fall below steady-state to consolidate debt. By varying the speed of fiscal consolidation, the model successfully replicates the negative relationship between domestic debt and foreign output. With a slower speed of fiscal consolidation, the domestic economy accumulates more debt and the global real interest rate is higher, hurting the foreign economy. In contrast, when the domestic economy quickly consolidates its debt, the increase in global interest rate is smaller and thus the foreign activity is not dampened as much.

I have also compared the domestic and cross-border effects of different fiscal instruments. In the domestic economy, capital tax rate and labor tax rate cuts are more effective in stimulating output than spending or transfers increase, or a consumption tax rate cut. However, the fiscal consolidation regime mitigates the strength of the stimulating effects. This is because the fiscal consolidation regime leads to waning fluctuations of macroeconomic variables before they return to steady states. If we shut off the fiscal consolidation regime, the fluctuations would disappear and the stimulating effects would be stronger. For the foreign country,

[17] Each data series is decomposed into a productivity shocks component, a fiscal shocks component and an initial value component. The initial value component dies out quickly and is not plotted in the figures.

[18] Fiscal shocks have become more relevant in the historical movements of US GDP in the later years of the sample.

[19] The forecast-error-variance decomposition and the historical decomposition conducted here only assess the relative importance of productivity shocks and fiscal shocks in explaining the business cycle movements of key model variables. More non-policy shocks need to be modeled if we want to investigate the role of fiscal shocks as sources of business cycle fluctuations.

the impact and cumulative effects of domestic fiscal shocks can differ a lot. In the short run, a domestic government spending increase is most favorable to the foreign country, while in the long run a domestic labor tax cut works best in boosting foreign output.

The current model abstracts from monetary policies which may alter the way the interest rate channel works as described in this paper. It would be important to explore how the interplay between monetary and fiscal policies influences cross-border spillovers of fiscal stimulus. I am interested in pursuing this direction of research in the future.

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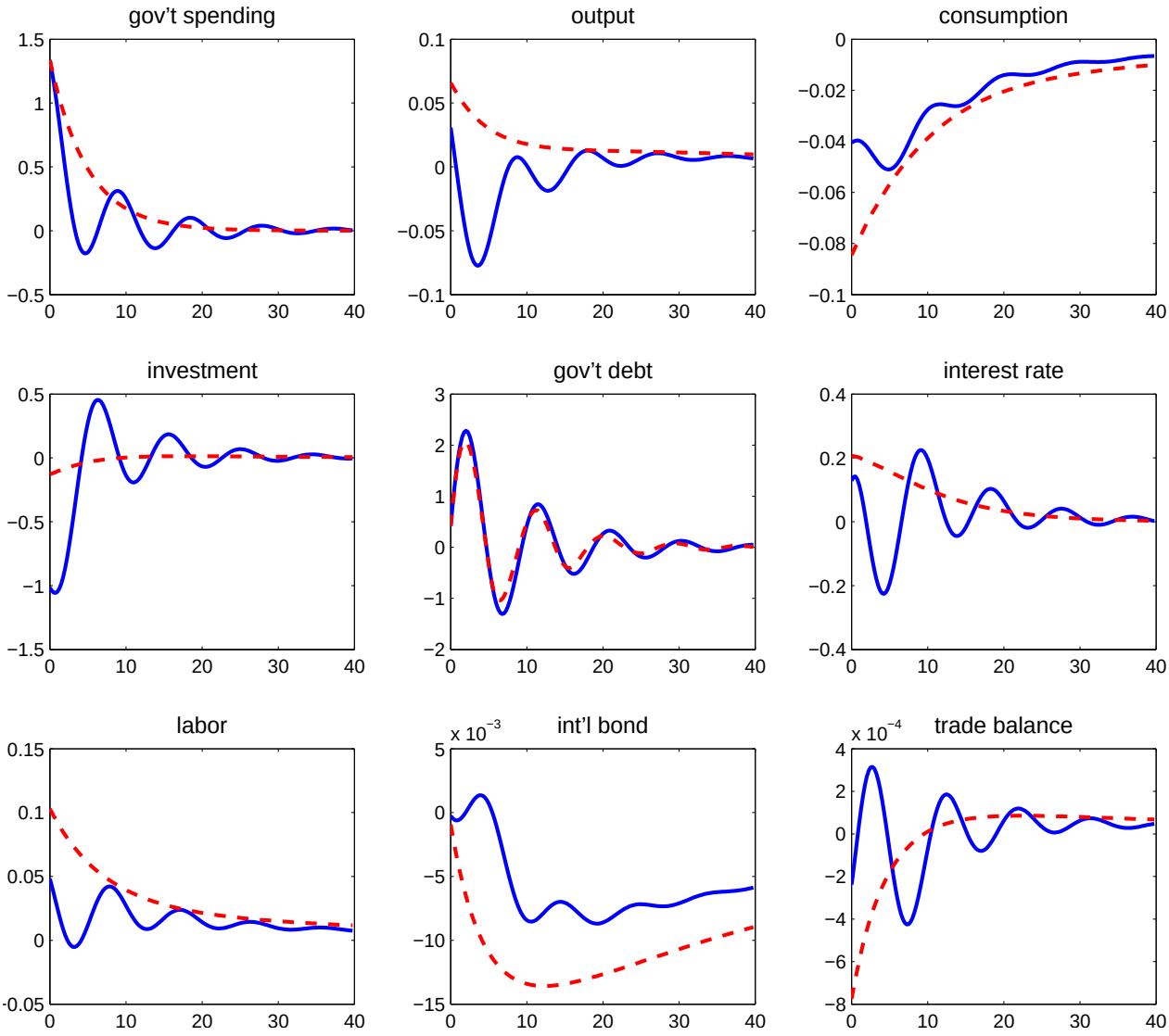
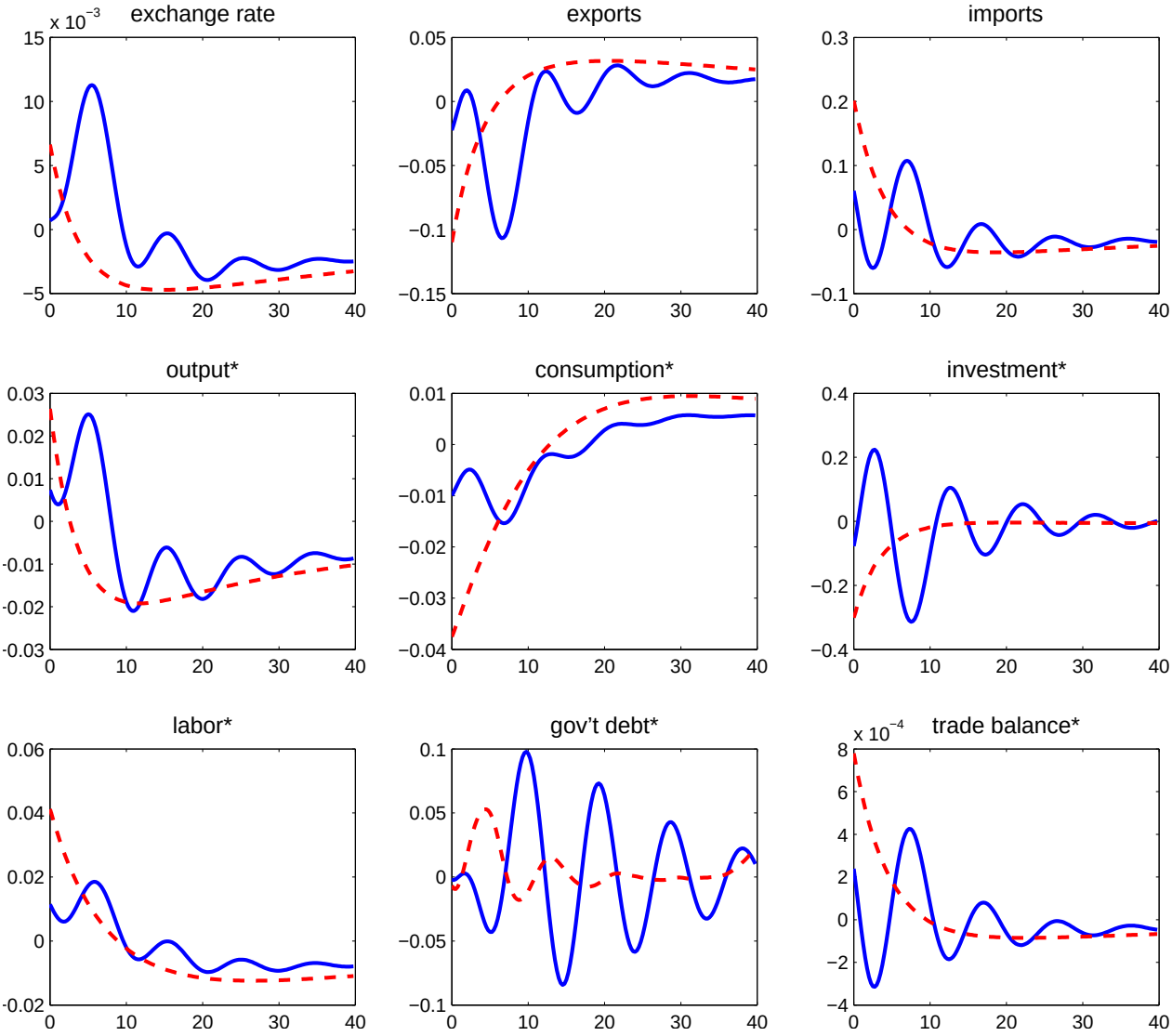
Figures

Figure 4: Responses to a One Standard Deviation Increase in Domestic Government Spending Shock: Key Domestic Variables



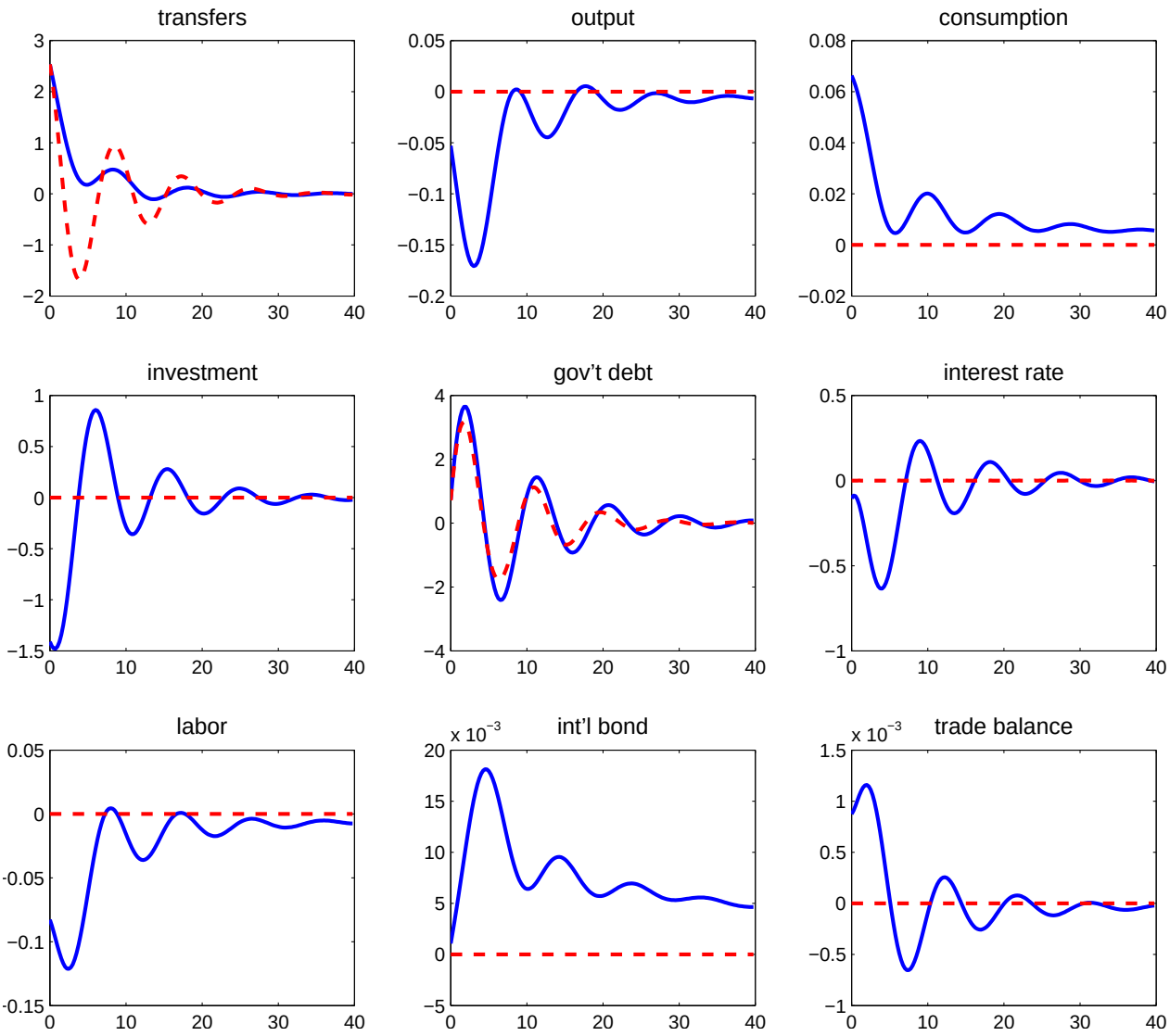
Notes: Baseline (solid line) vs. debt stabilization through lump-sum transfers only ($\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$, dashed line). Interest rate is measured in basis points deviation from the steady-state. International bond and the trade balance are measured in level deviation from the steady-state. All other variables are measured in percentage deviation from the steady-state. Horizontal axes measure time in years.

Figure 5: Responses to a One Standard Deviation Increase in Domestic Government Spending Shock: Cross-Country Spillovers



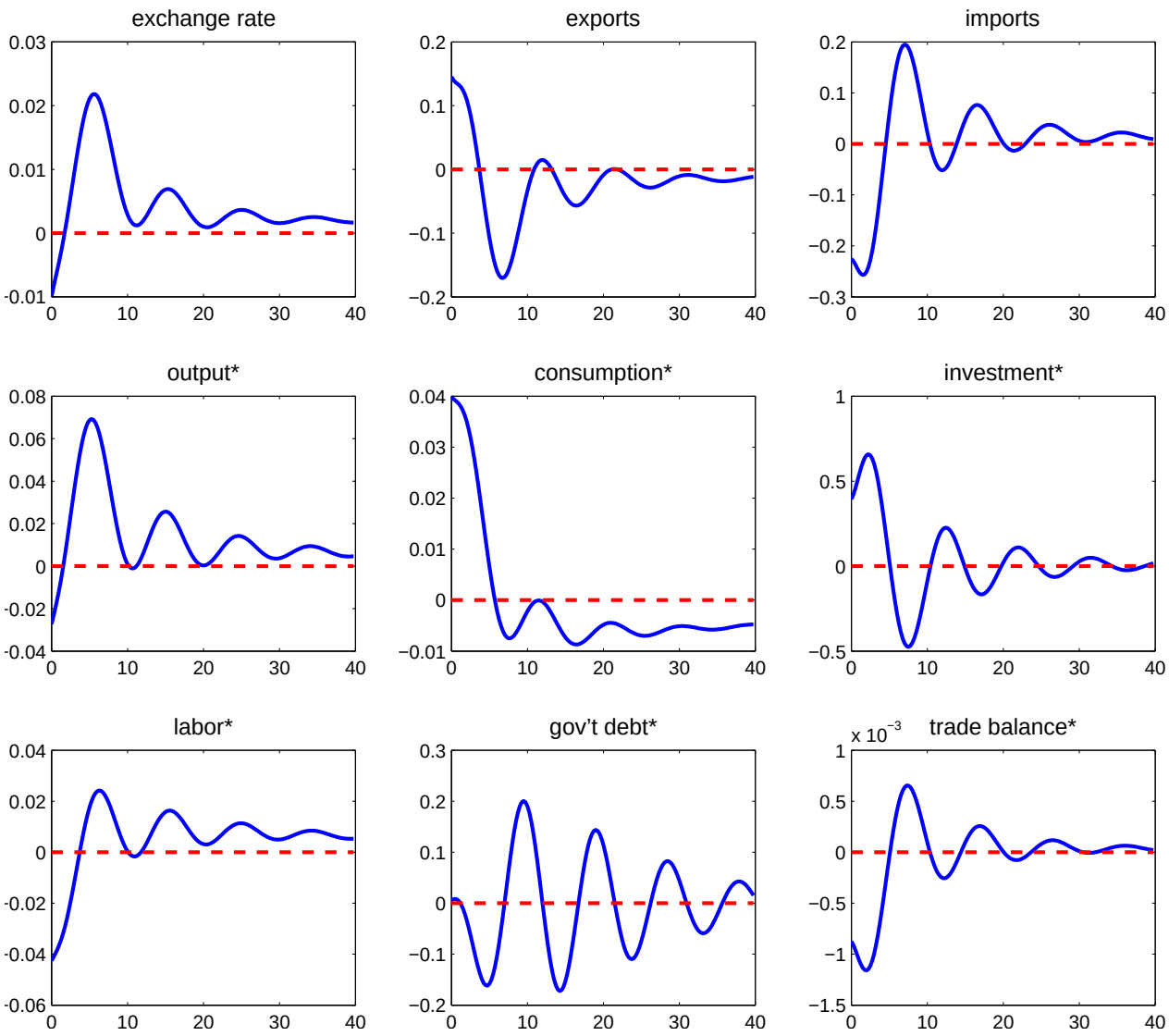
Notes: Baseline (solid line) vs. debt stabilization through lump-sum transfers only ($\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$, dashed line). Interest rate is measured in basis points deviation from the steady-state. International bond and the trade balance are measured in level deviation from the steady-state. All other variables are measured in percentage deviation from the steady-state. Horizontal axes measure time in years.

Figure 6: Responses to a One Standard Deviation Increase in Domestic Transfers Shock: Key Domestic Variables



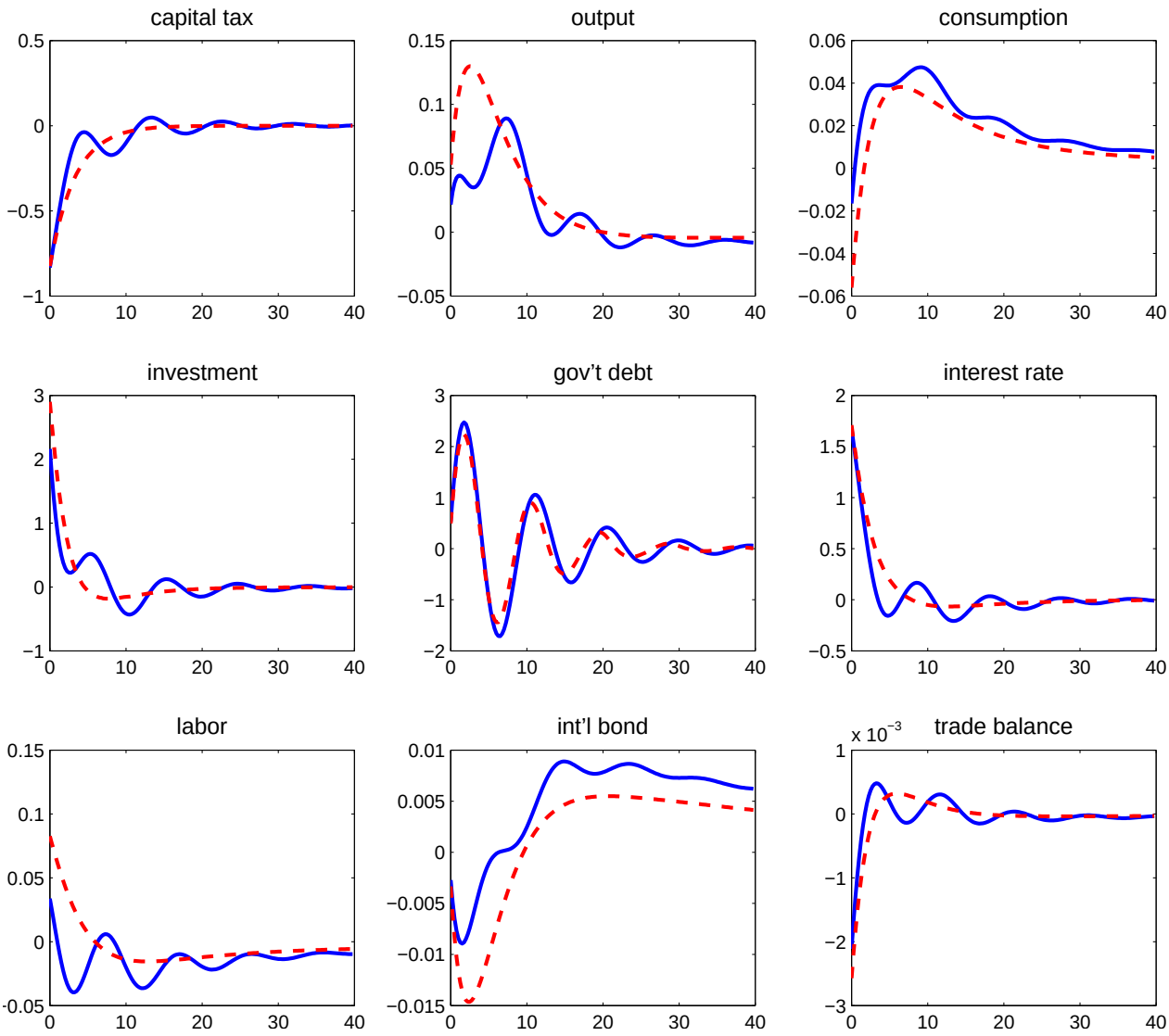
Notes: Baseline (solid line) vs. debt stabilization through lump-sum transfers only ($\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$, dashed line). Interest rate is measured in basis points deviation from the steady-state. International bond and the trade balance are measured in level deviation from the steady-state. All other variables are measured in percentage deviation from the steady-state. Horizontal axes measure time in years.

Figure 7: Responses to a One Standard Deviation Increase in Domestic Transfers Shock: Cross-Country Spillovers



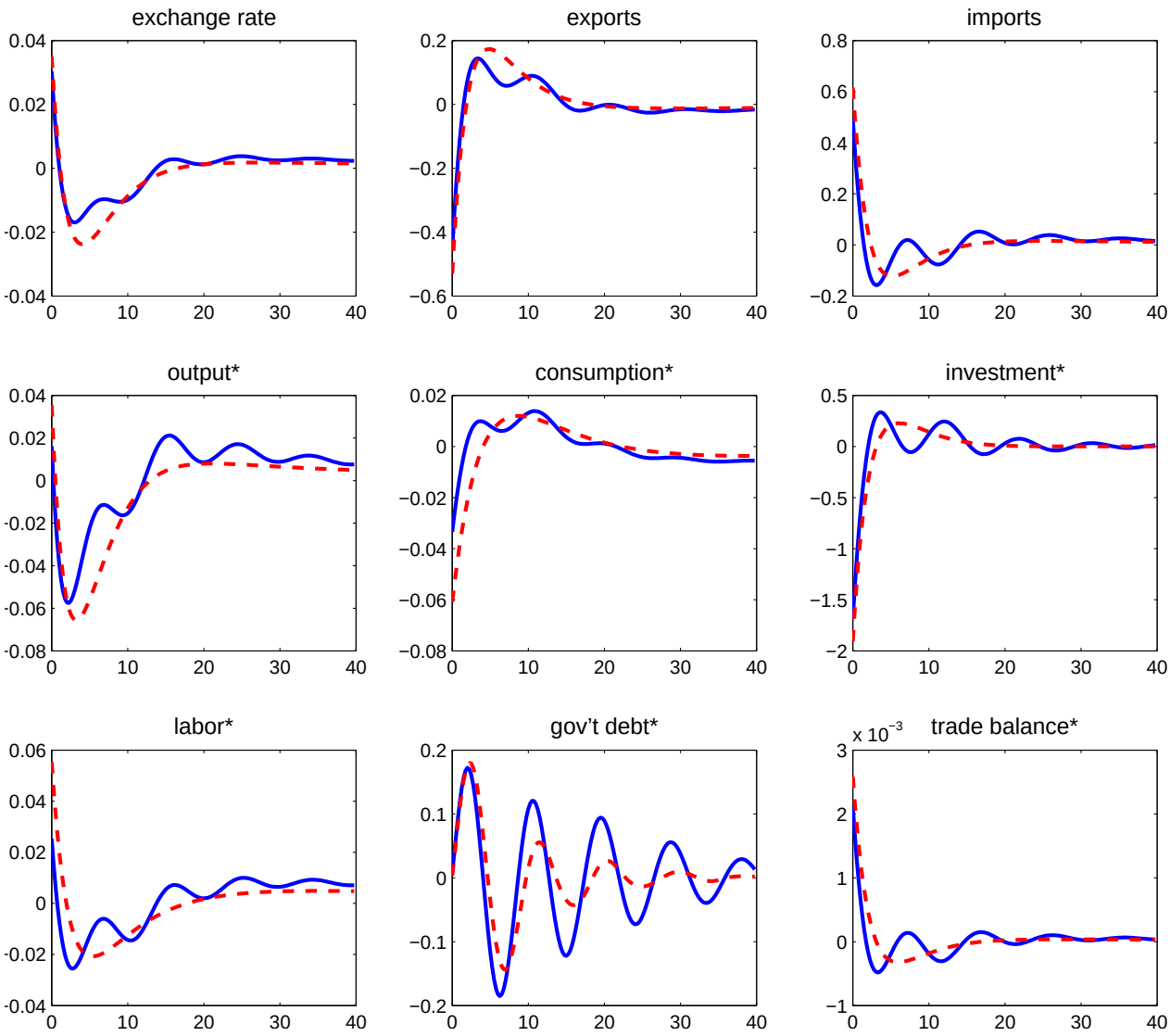
Notes: Baseline (solid line) vs. debt stabilization through lump-sum transfers only ($\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$, dashed line). Interest rate is measured in basis points deviation from the steady-state. International bond and the trade balance are measured in level deviation from the steady-state. All other variables are measured in percentage deviation from the steady-state. Horizontal axes measure time in years.

Figure 8: Responses to a One Standard Deviation Decrease in Domestic Capital Tax Rate Shock: Key Domestic Variables



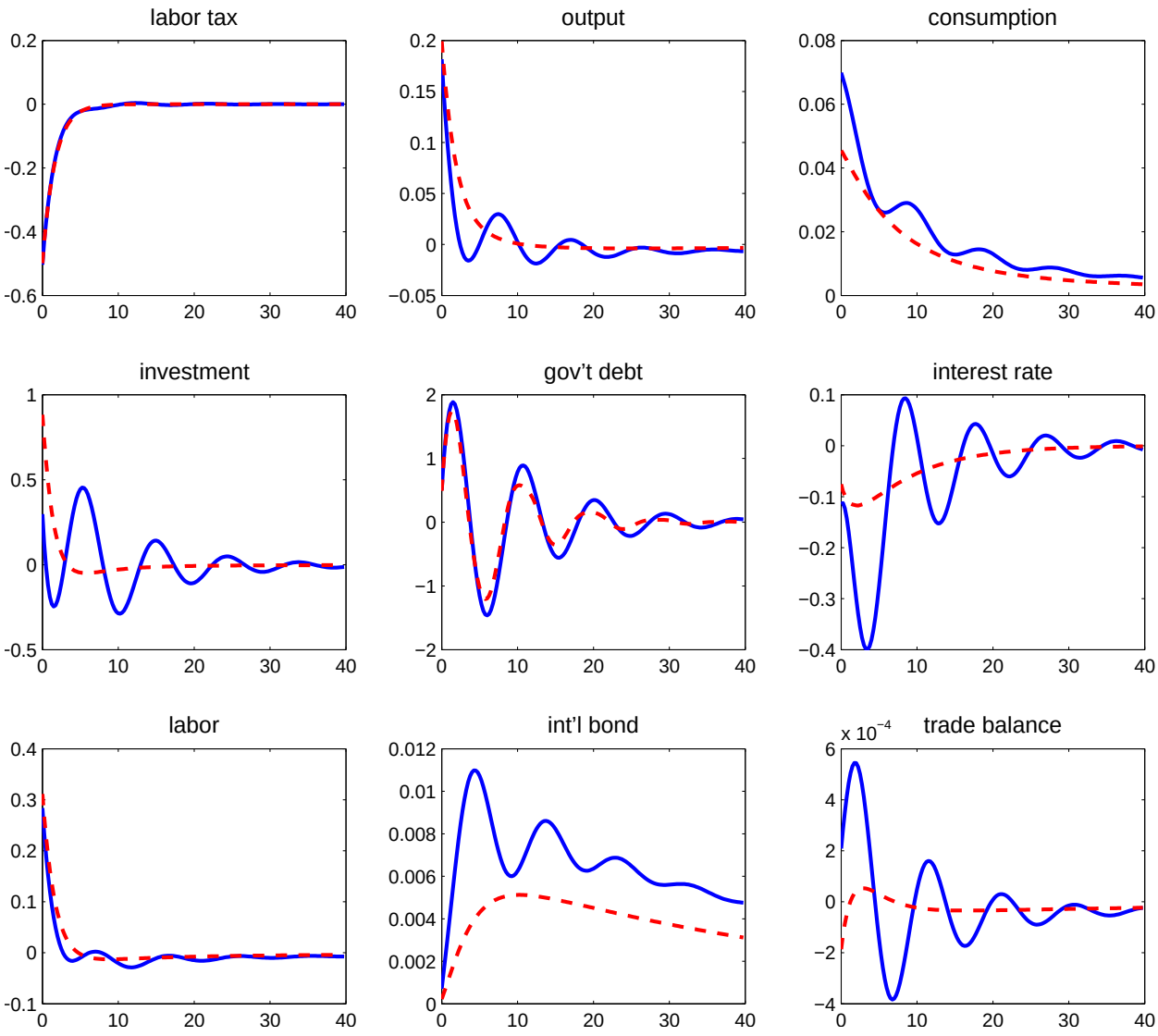
Notes: Baseline (solid line) vs. debt stabilization through lump-sum transfers only ($\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$, dashed line). Interest rate is measured in basis points deviation from the steady-state. International bond and the trade balance are measured in level deviation from the steady-state. All other variables are measured in percentage deviation from the steady-state. Horizontal axes measure time in years.

Figure 9: Responses to a One Standard Deviation Decrease in Domestic Capital Tax Rate Shock: Cross-Country Spillovers



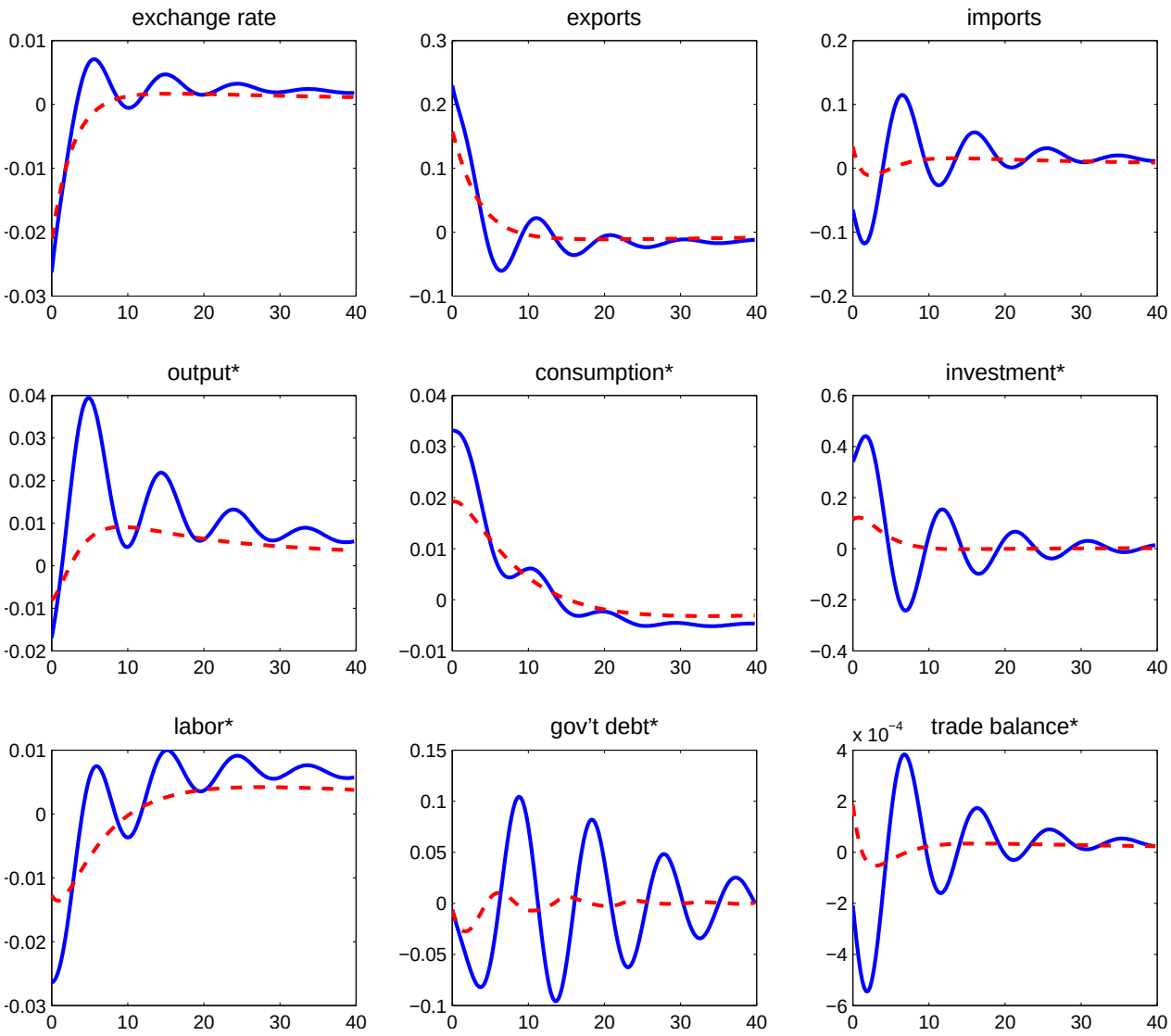
Notes: Baseline (solid line) vs. debt stabilization through lump-sum transfers only ($\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$, dashed line). Interest rate is measured in basis points deviation from the steady-state. International bond and the trade balance are measured in level deviation from the steady-state. All other variables are measured in percentage deviation from the steady-state. Horizontal axes measure time in years.

Figure 10: Responses to a One Standard Deviation Decrease in Domestic Labor Tax Rate Shock: Key Domestic Variables



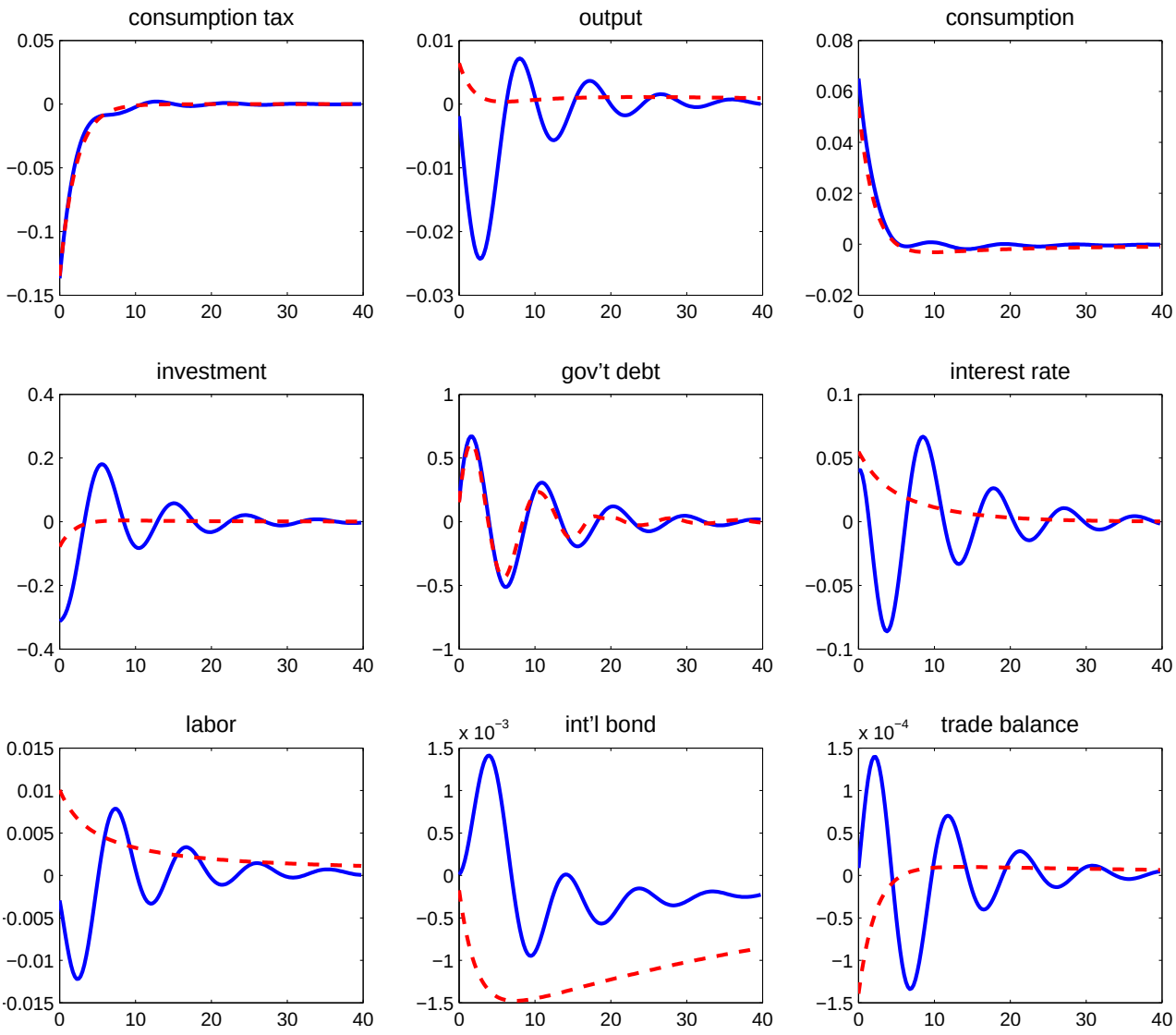
Notes: Baseline (solid line) vs. debt stabilization through lump-sum transfers only ($\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$, dashed line). Interest rate is measured in basis points deviation from the steady-state. International bond and the trade balance are measured in level deviation from the steady-state. All other variables are measured in percentage deviation from the steady-state. Horizontal axes measure time in years.

Figure 11: Responses to a One Standard Deviation Decrease in Domestic Labor Tax Rate Shock: Cross-Country Spillovers



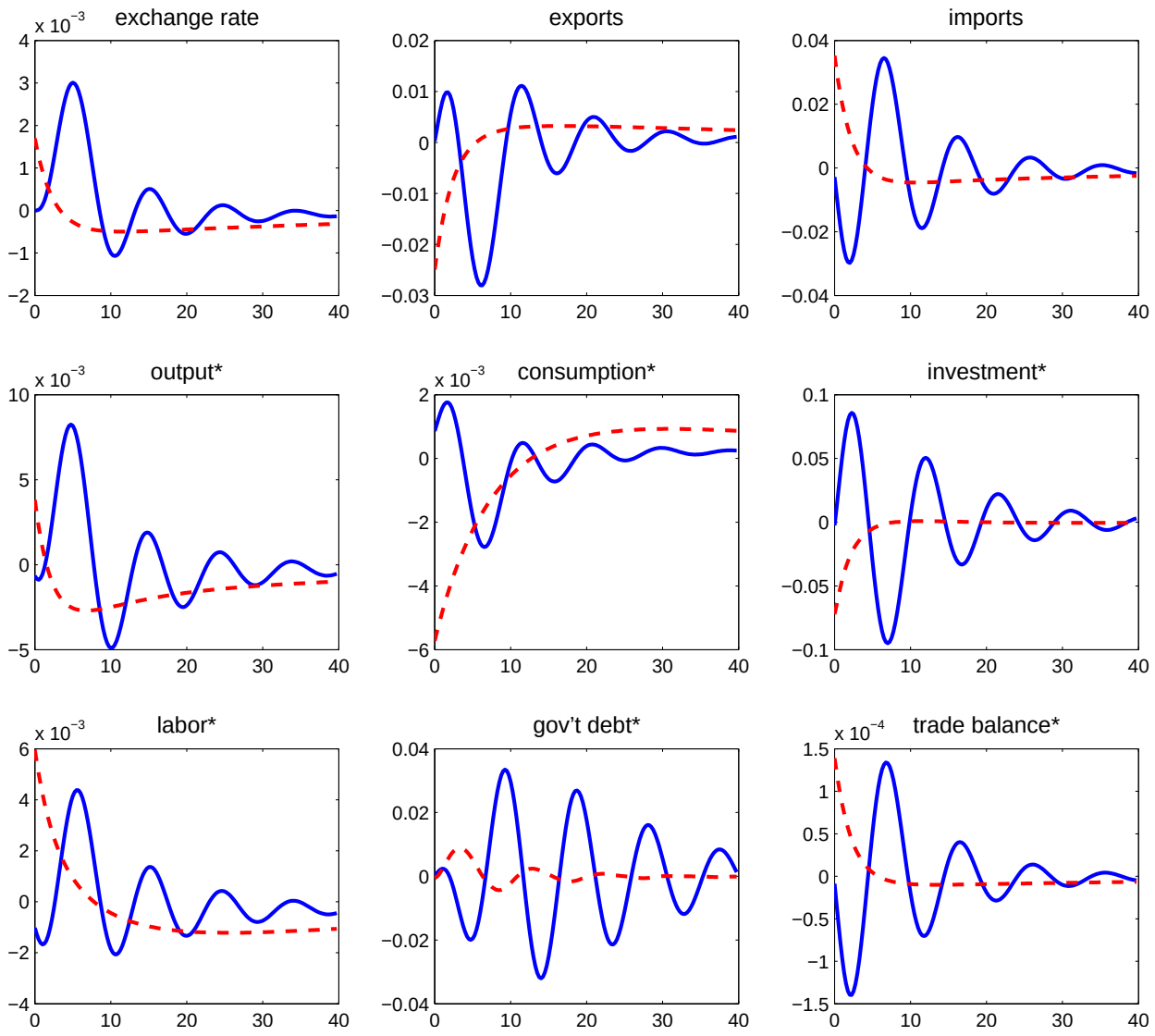
Notes: Baseline (solid line) vs. debt stabilization through lump-sum transfers only ($\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$, dashed line). Interest rate is measured in basis points deviation from the steady-state. International bond and the trade balance are measured in level deviation from the steady-state. All other variables are measured in percentage deviation from the steady-state. Horizontal axes measure time in years.

Figure 12: Responses to a One Standard Deviation Decrease in Domestic Consumption Tax Rate Shock: Key Domestic Variables



Notes: Baseline (solid line) vs. debt stabilization through lump-sum transfers only ($\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$, dashed line). Interest rate is measured in basis points deviation from the steady-state. International bond and the trade balance are measured in level deviation from the steady-state. All other variables are measured in percentage deviation from the steady-state. Horizontal axes measure time in years.

Figure 13: Responses to a One Standard Deviation Decrease in Domestic Consumption Tax Rate Shock: Cross-Country Spillovers



Notes: Baseline (solid line) vs. debt stabilization through lump-sum transfers only ($\gamma_G = \gamma_{\tau^k} = \gamma_{\tau^l} = \gamma_{\tau^c} = 0$, dashed line). Interest rate is measured in basis points deviation from the steady-state. International bond and the trade balance are measured in level deviation from the steady-state. All other variables are measured in percentage deviation from the steady-state. Horizontal axes measure time in years.

Figure 14: Stochastic Components of US GDP

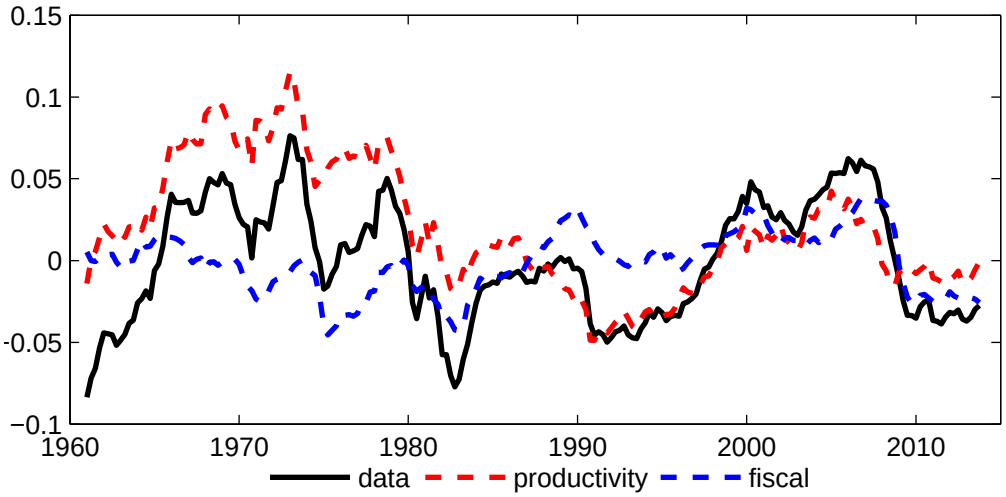


Figure 15: Stochastic Components of US Investment

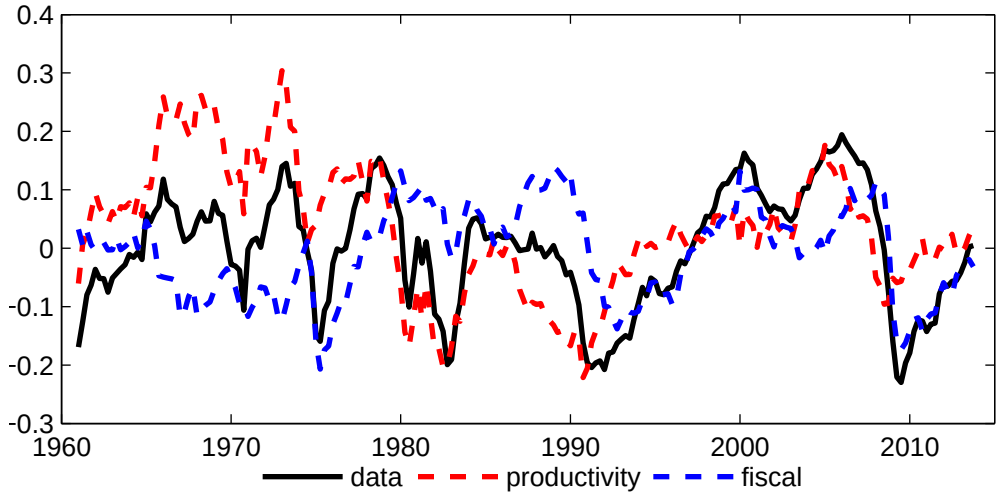


Figure 16: Stochastic Components of US Hours

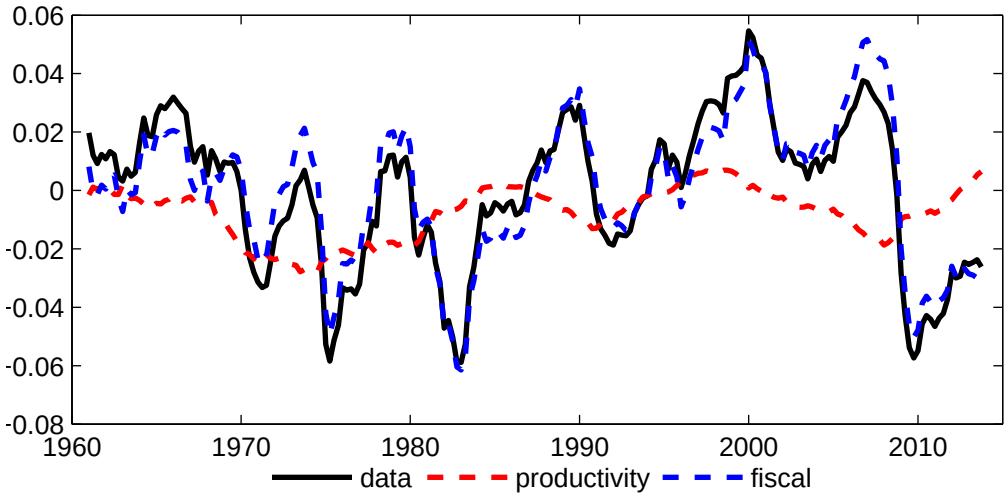


Figure 17: Stochastic Components of US Gov't Spending

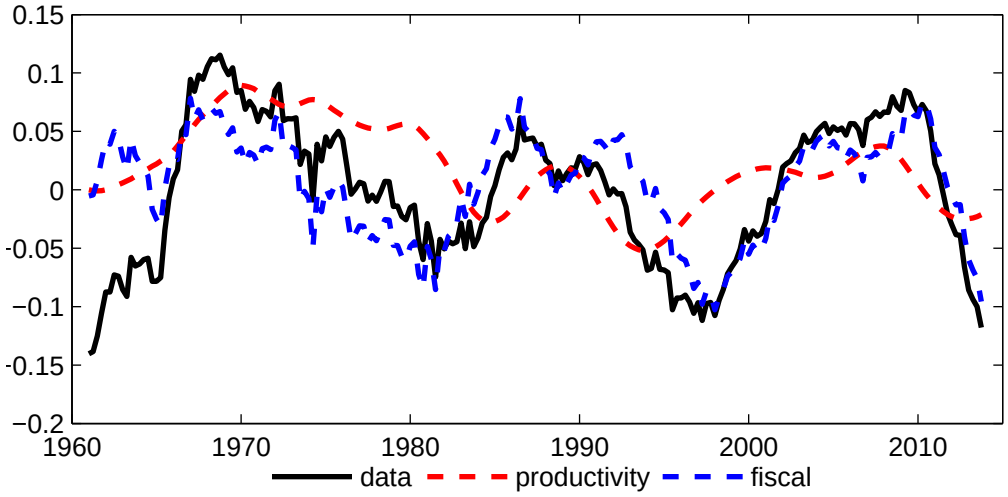


Figure 18: Stochastic Components of EU GDP

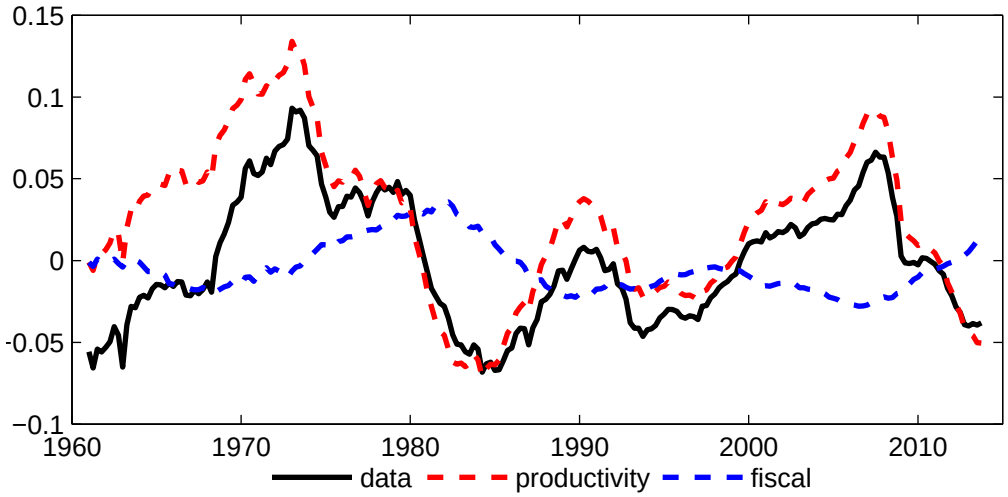
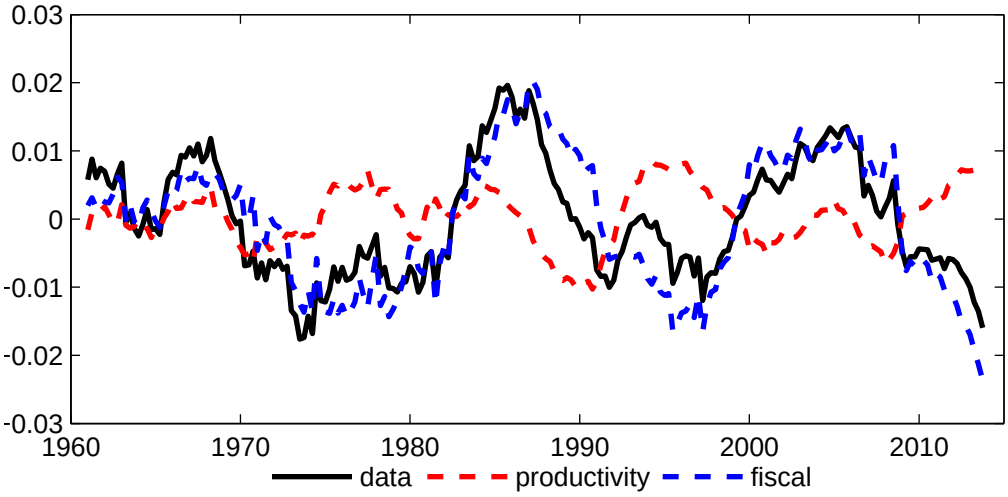
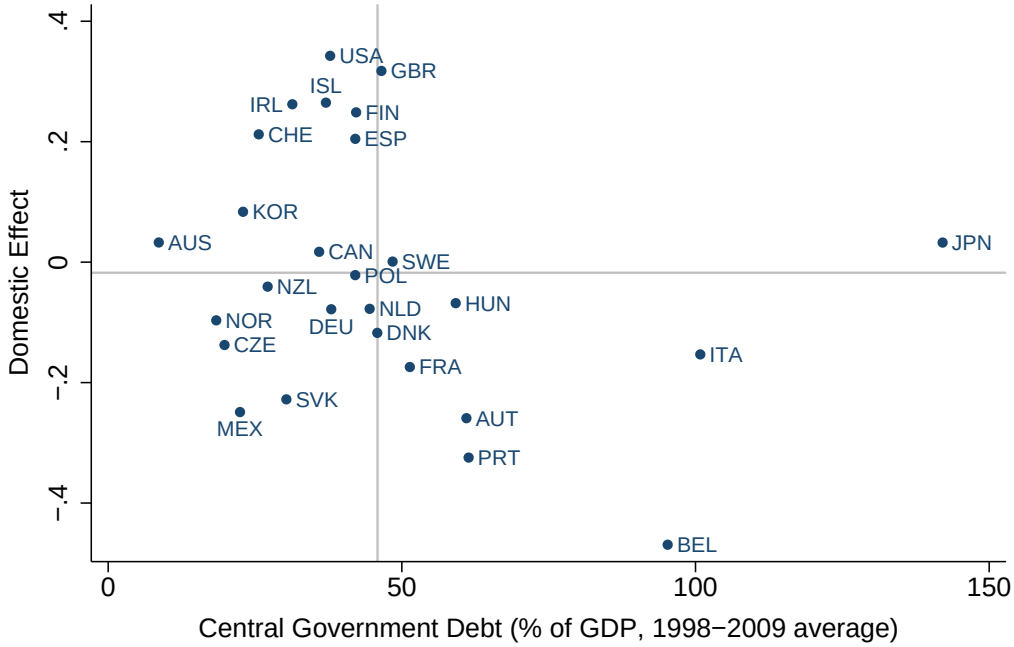


Figure 19: Stochastic Components of EU Trade Balance



Appendix A. Domestic output effect from a spending increase and domestic debt-to-GDP ratio

Figure 20: Domestic Effect and Domestic Debt



Source: Author's calculations using data for spillovers from Auerbach and Gorodnichenko (2013) and data for debt from OECD.Stat

Table 9: Regression of Domestic Effect on Debt and Control Variables

Sample	All		Japan excluded		Japan and Italy excluded	
Debt	-0.0019	-0.0017	-0.0040**	-0.0037*	-0.0048**	-0.0045*
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
GDP growth		2.4279		1.8626		2.1426
		(4.655)		(4.543)		(4.640)
Openness		-0.1896		-0.1206		-0.0994
		(0.126)		(0.131)		(0.138)
REER		0.5461		0.7917		0.8532
		(0.581)		(0.588)		(0.606)
Obs	27	27	26	26	25	25

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.10

Appendix B. Optimality conditions

Euler equation for bonds

$$\frac{C_{it}^{-\gamma}}{(1+\tau_{it}^{c})P_{it}} = (1+\psi C_{it})^{-1} E_t \frac{C_{i,t+1}^{-\gamma} R_t}{(1+\tau_{i,t+1}^{c})P_{i,t+1}}$$

Euler equation for capital

$$\frac{1}{1-\xi\left(\frac{I_{it}}{K_{i,t-1}}-\delta\right)} = (1+\psi C_{it})^{-1} E_t \frac{C_{i,t+1}^{-\gamma}(1+\tau_{it}^{c})}{C_{it}^{-\gamma}(1+\tau_{i,t+1}^{c})} \times \ldots$$

$$\left\{(1-\tau_{i,t+1}^{k})\frac{q_{i,t+1}}{P_{i,t+1}}\frac{\alpha Y_{i,t+1}}{K_{it}} + \frac{1}{1-\xi\left(\frac{I_{i,t+1}}{K_{it}}-\delta\right)}\left[1-\delta+\frac{\xi}{2}\left(\frac{I_{i,t+1}}{K_{it}}\right)^{2}-\frac{\xi}{2}\delta^{2}\right]\right\}$$

FOC for labor

$$\theta L_{it}^{1+\kappa}(1+\tau_{it}^{c})P_{it} = C_{it}^{-\gamma}(1-\tau_{it}^{l})q_{it}(1-\alpha)Y_{it}$$

Appendix C. Data sources and construction

C.1. General description

The four EU time series (GDP, general government final consumption expenditure, exports of goods and services, and imports of goods and services) are from OECD.Stat' Quarterly National Accounts (CPCARSA: Millions of US dollars, current prices, current PPPs, annual levels, seasonally adjusted).

US hours worked are defined as $\frac{H*Emp}{100}$ where H is nonfarm business sector average weekly hours (PRS85006023) and Emp is Civilian Employment (CE16OV), both from the Bureau of Labor Statistics. The construction of ten US time series (GDP, consumption, investment, exports, imports, capital, labor and consumption tax rates, government consumption, and transfers) uses data from the Bureau of Economic Analysis' NIPA. The government debt series uses additional data from the Federal Reserve Bank of St. Louis and the Federal Reserve Bank of Dallas. The source and methodology of processing these data are the same as in Leeper et al. (2010b). Fiscal variables include federal and state and local governments.

Nominal data are converted to real values using the price deflater for private final consumption expenditure from OECD.Stat (DOBSA: Deflator, OECD reference year, seasonally adjusted). The logarithm of each variable is detrended with a quadratic trend.

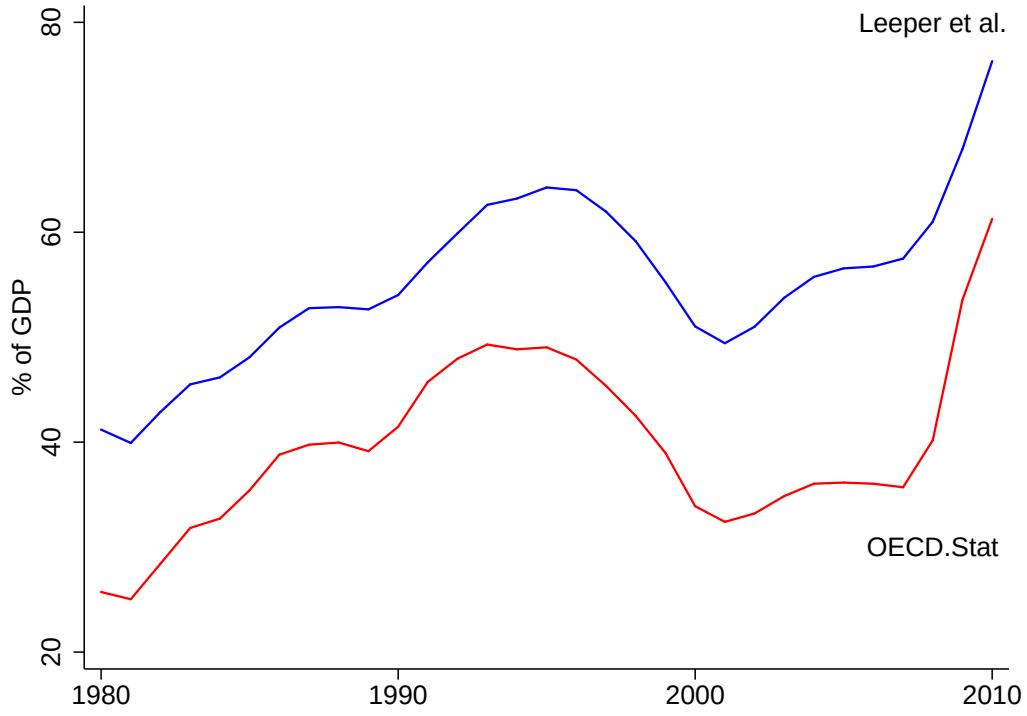
C.2. Construction of US tax rates and government debt

The average consumption tax rate is calculated as $\tau^c = \frac{T^c}{C-T^c}$ where T^c is taxes on production and imports less property taxes. Jones's (2002) definition of average personal income tax rate is $\tau^p = \frac{IT}{W+PRI/2+CI}$ where IT is personal current tax revenues, W is wage and salary accruals, PRT is proprietors' income and CI is capital income. Capital income is computed as the sum of rental income, corporate profits, interest income, and $PRI/2$. Then the average labor income tax rate is calculated as $\tau^l = \frac{\tau^p(W+PRI/2)+CSI}{EC+PRI/2}$ where CSI is contributions for government social insurance and EC is compensation of employees. The average capital income tax rate is computed as $\tau^k = \frac{\tau^p CI+CT+PT}{CI+PT}$ where CT is taxes on corporate income and PT is property taxes.

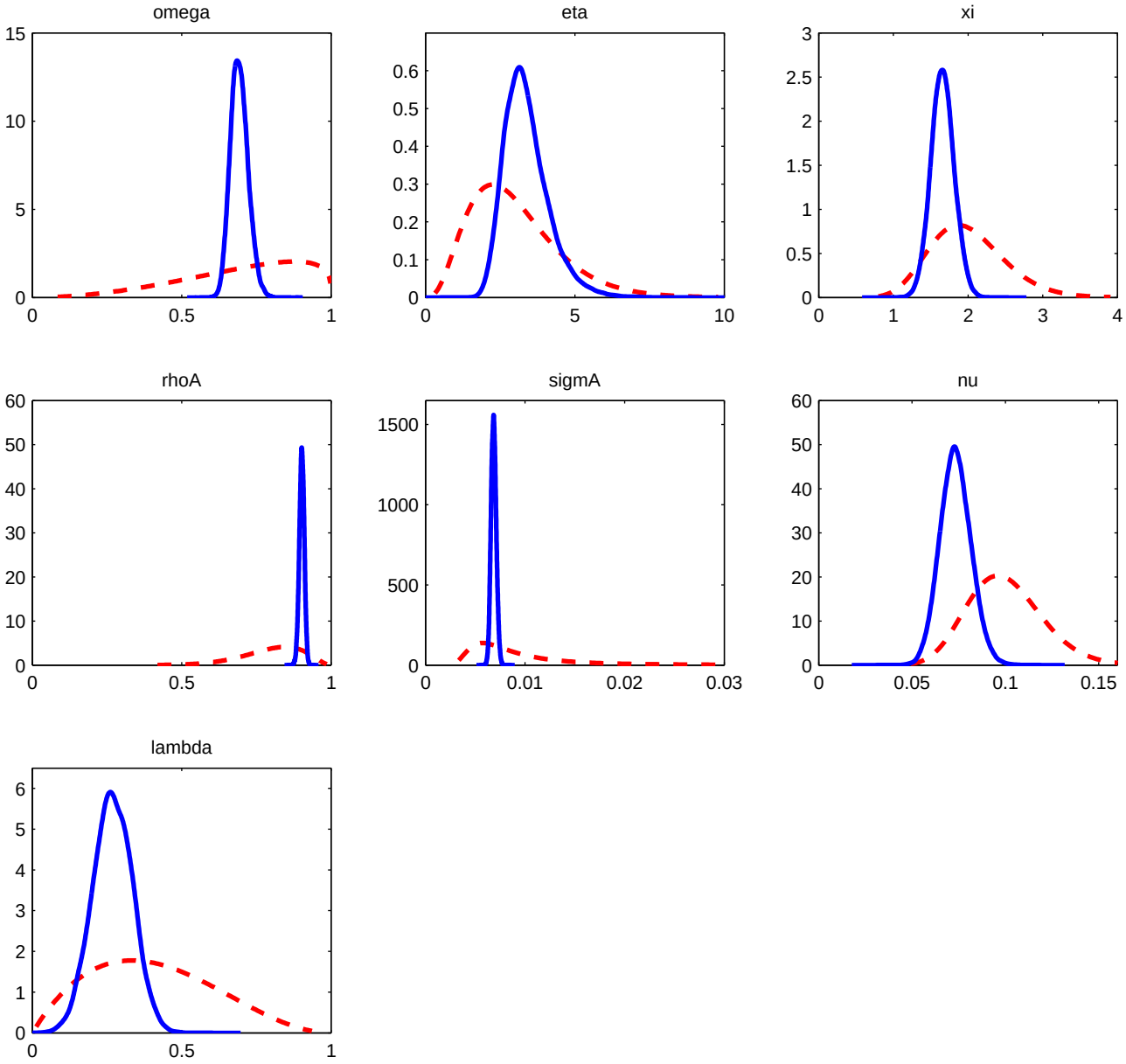
Government debt at t is defined as the sum of net borrowing at t and government debt at $t-1$ less seigniorage. Net borrowing is the sum of government consumption, interest payment and transfers less total tax revenues. Seigniorage is $M_t - M_{t-1}$ where M is St. Louis Fed's adjusted monetary base.

C.3. Comparison of debt-to-GDP ratios

The following figure compares the debt-to-GDP ratio constructed following Leeper et al. (2010b) and the central government debt-to GDP ratio from OECD.Stat.



Appendix D. Prior and posterior distributions



Notes: Prior (dashed line) vs. posterior (solid line) distributions.

Appendix E. VAR Evidence

The VAR exercise includes 11 variables Cholesky-ordered as follows: US fiscal variable, US real GDP, US real consumption, US real investment, US hours worked, EU real GDP, EU real consumption, EU real investment, US real exports, US real imports and US real government debt, where the US fiscal variable belongs to one of the five fiscal instruments.

The data sources and the time span are the same as those used in the Bayesian estimation. The lag length is 4. Changing the order of the variables or the lag length does not affect the fluctuating feature of the macroeconomic variables.

Figure 21: Responses to a One Standard Deviation Shock to US Government Spending

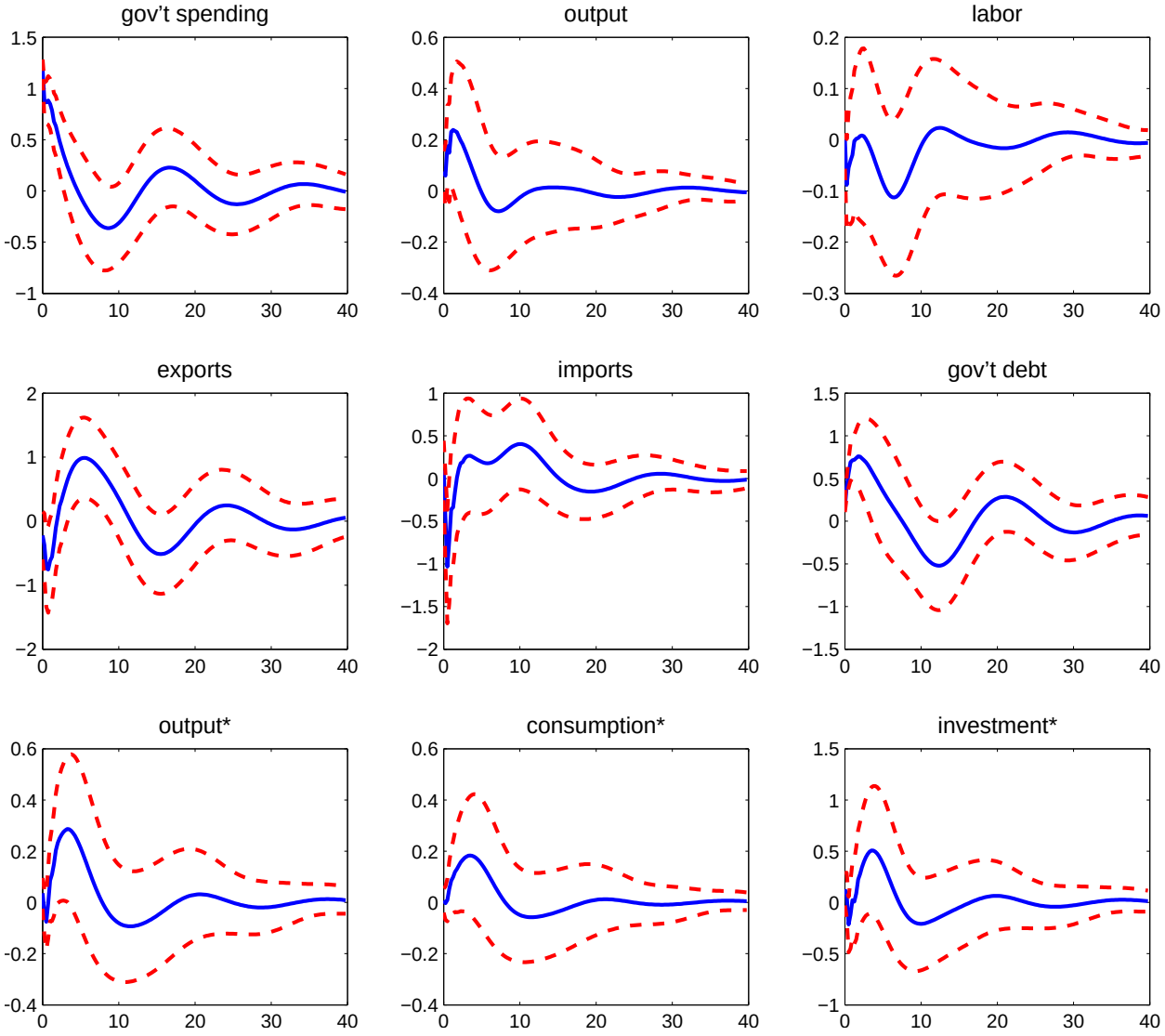


Figure 22: Responses to a One Standard Deviation Shock to US Transfers

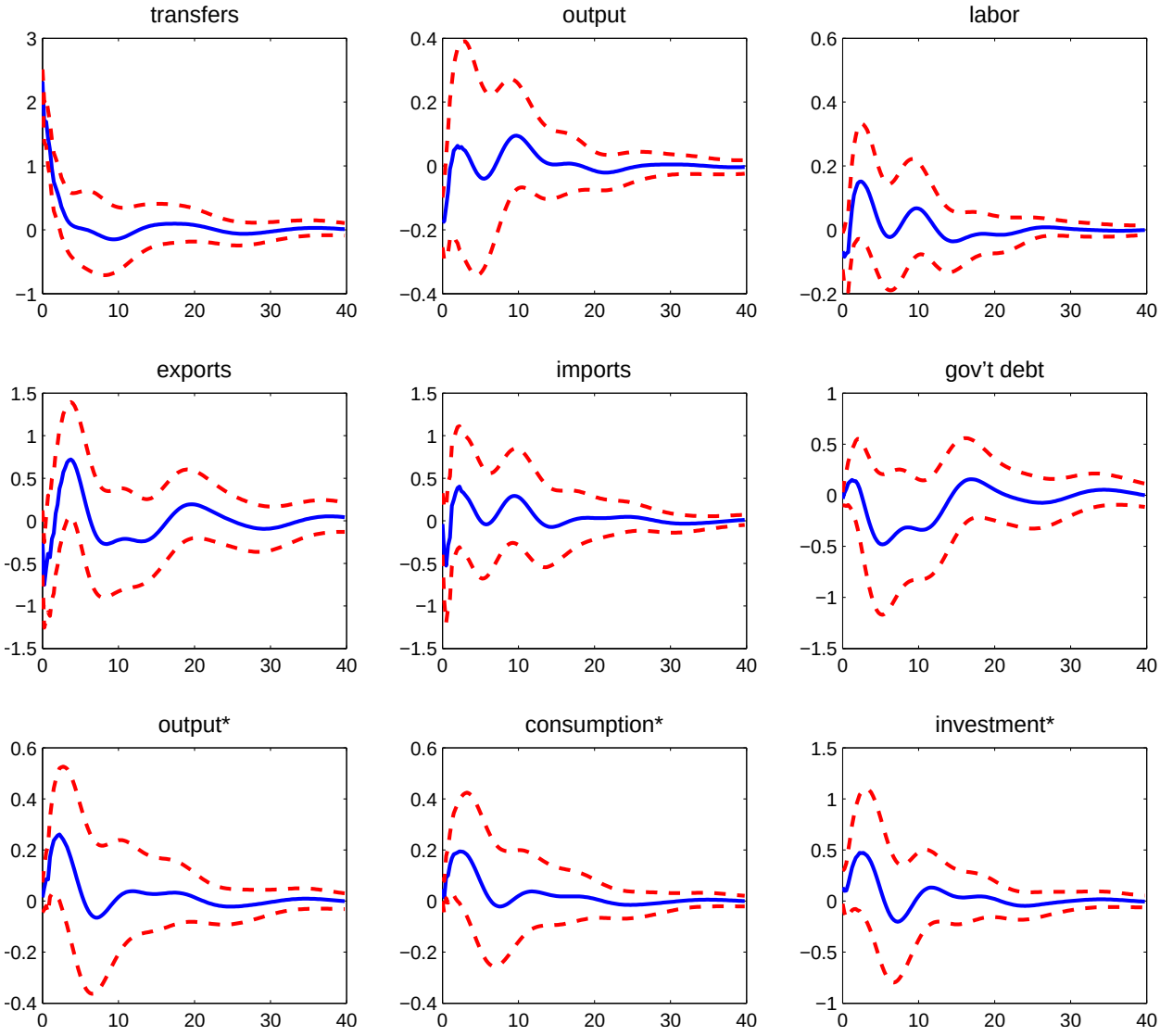


Figure 23: Responses to a One Standard Deviation Shock to US Capital Tax Rate

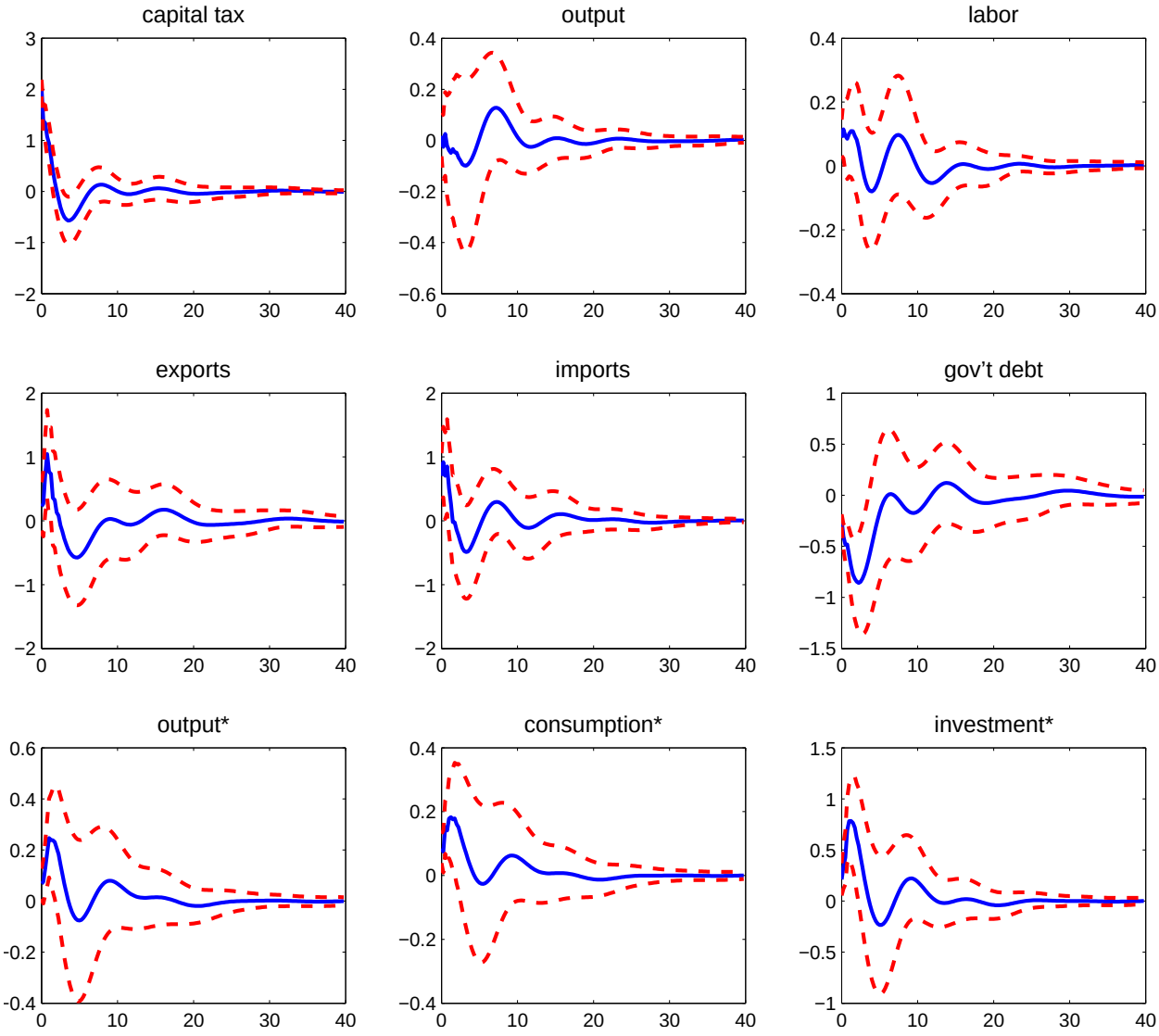


Figure 24: Responses to a One Standard Deviation Shock to US Labor Tax Rate

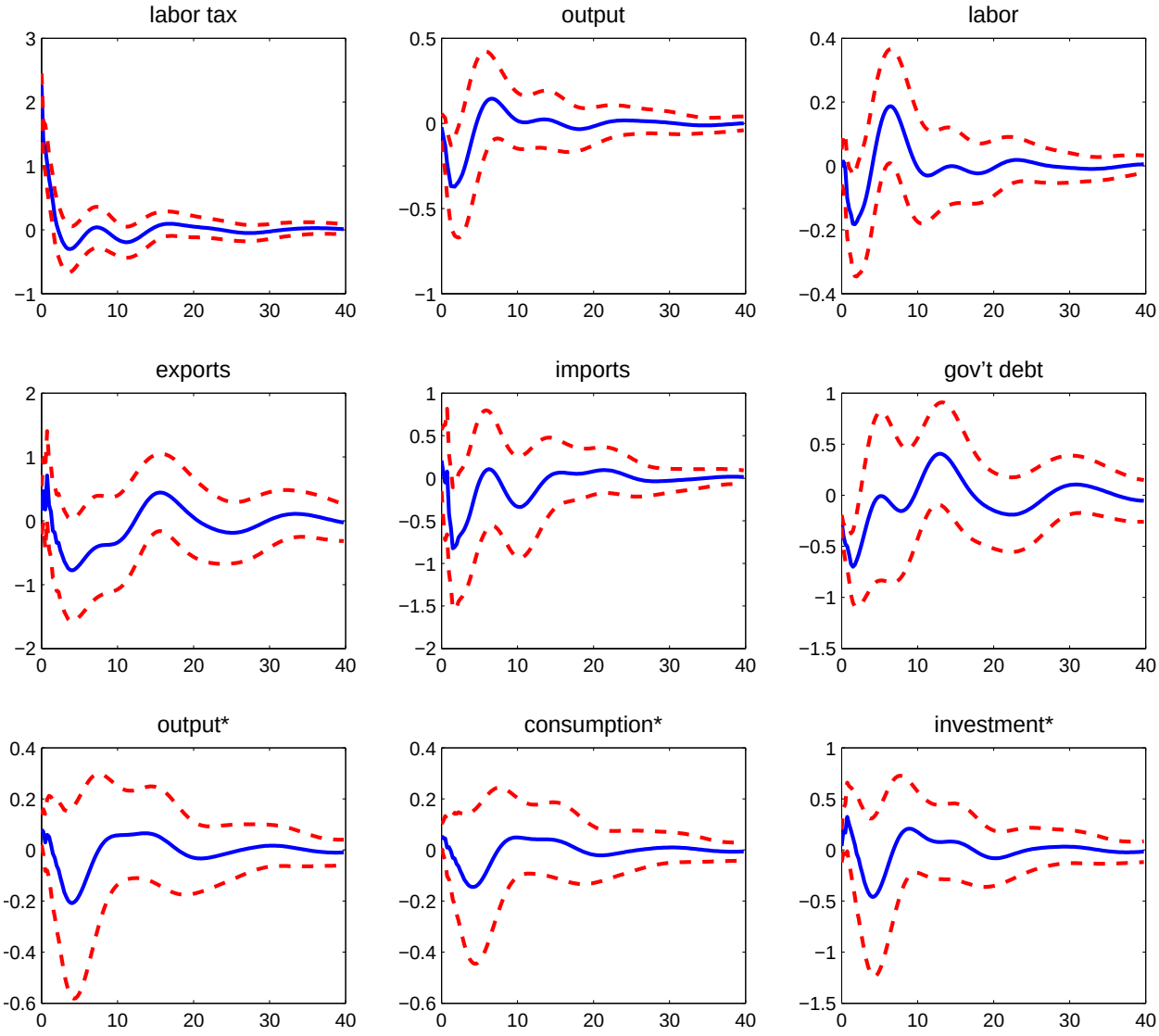
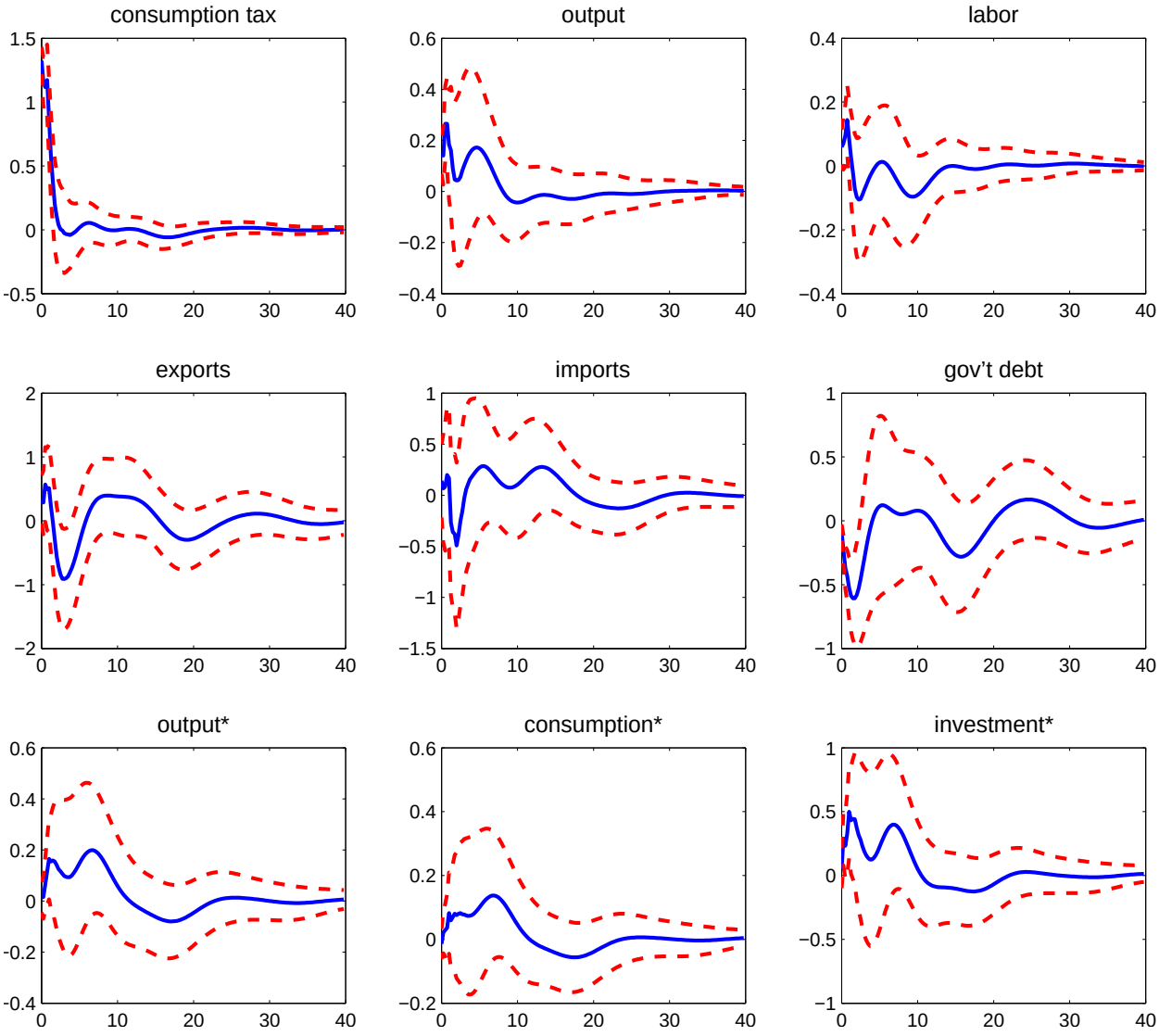


Figure 25: Responses to a One Standard Deviation Shock to US Consumption Tax Rate



Appendix F. Speed of fiscal consolidation and average government debt ratio