



Fiscal policy shocks and international spillovers[☆]

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ABSTRACT

The domestic and international transmission mechanism of fiscal policy shocks are analysed in the United States and in Germany. Using a Bayesian VAR approach, we find that in both of these countries a fiscal expansion is associated with increases in output as well as in private consumption and investment. The terms of trade, which affect the international transmission of fiscal policy shocks, depreciate in response to a fiscal expansion, thus transferring some of the increased domestic purchasing power abroad. A US government spending shock is expansionary for all non-US G7 members. A German government spending shock is expansionary for most, but not all European economies, both within and outside the euro area. The dynamics of the BVAR can be rationalised using a dynamic stochastic general equilibrium model where heterogeneous households and firms face borrowing constraints.

1. Introduction

Not since the second World War has fiscal policy been such an important policy instrument. In response to the COVID-19 pandemic, the world is experiencing an unprecedented fiscal expansion. In the light of this, we seek to determine empirically the international spillover effects of an exogenous increase in government spending on relative prices and output. In addition, we inspect the mechanism through which these spillovers operate with the aid of a dynamic stochastic general equilibrium (DSGE) model.

We find that an unanticipated fiscal expansion in Germany and the United State increases output along with consumption and investment, in addition to a depreciation in the real exchange rate and in the terms of trade. Spillovers between the United States and the other G7 economies are positive, as are most of those between Germany and her European neighbours. Our theoretical model provides a potential rationale for understanding the manner in which spending shocks transmit through foreign economies.

In this paper we develop a theoretical model that is consistent with our empirical findings. This is in contrast with the modelling and time series literature on the spillovers of government spending. The bulk of the former finds that the spillovers to foreign output are either negligible or negative, with the larger effects being driven by expected future consolidations. Against this, the time series evidence generally indicates that spillovers are substantial, leading (Gürkaynak, 2011) to criticise DSGE models for embodying features that make small spillovers inevitable.

While the literature on the domestic effects of fiscal expansions is large, spurred in great part by the Great Recession, studies focusing on the international dimensions of such policies are relatively scarce. Moreover, a detailed comparison is hampered by the fact that no standard metric has emerged when analysing the effects of fiscal spending shocks. For example, some authors report

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the effects of a one percent shock to government spending while others rely on shocks equal to one percent of GDP; while present value multipliers are sometimes reported, on other occasions the only values provided are the direct dynamic responses without adjustment.¹

Key findings in the recent literature studying the impacts of government spending shocks on both open economy variables as well as across borders are summarised in [Table 1](#). As a starting point in considering spillovers, panel A provides some time series evidence on the relationship between government spending shocks and trade deficits for specific ‘source’ countries. The first thing to note is that, when using US data, government spending shocks are associated with trade balance surpluses and exchange rate depreciations.² Thus, there is no clear evidence of the ‘twin deficits’ hypothesis. In the case of [Corsetti et al. \(2012\)](#), [Corsetti and Müller \(2006\)](#) and [Kim and Roubini \(2008\)](#), the correlation between the government budget and the trade balance, conditional on government purchases, is either insignificant or positive.³ This evidence is supportive of a financial, rather than a trade, channel for international spillovers of fiscal policy.

By contrast, when other economies are considered, the effects on the trade balance are reversed and the impact on the exchange rate is either muted or reversed so that an appreciation results. For example, [Beetsma and Giuliodori \(2011\)](#) use an annual panel consisting of fourteen EU countries and find that a government spending shock leads to real exchange rate appreciation, peaking after three years.

International spillovers from domestic spending impulses on foreign output are generally found to be positive and persistent, peaking after approximately two years. Moreover, they are not quantitatively trivial. The time series evidence on the spillovers effects for a range of different countries is shown in panel B of [Table 1](#). Fiscal shocks originating from the US have larger output effects on the UK than in the (now) rest of the EU or the euro area, although in all cases real exchange rates depreciate. [Faccini et al. \(2016\)](#) estimate a regime-change factor model with sign restrictions for the US and quantify the magnitude of the fiscal spillovers. While they generally find little evidence of regime-dependence in the international transmission of government spending shocks, spillovers on German output in one of the regimes are negative, while the others are insignificant. The larger spillovers of US spending shocks on UK output compared to those in the EA are also found by [Corsetti and Müller \(2013\)](#) and [Nicar \(2015\)](#). The former relies on the Blanchard–Perotti identification scheme ([Blanchard and Perotti, 2002](#)), while the latter uses sign restrictions as in [Mountford and Uhlig \(2009\)](#), obtaining qualitatively similar results. The table also shows the spillover effects on investment in the foreign economy, I^* , which are positive and larger than those on foreign output. Nonetheless, the effects on this variable have been largely ignored in the literature.

When restricting the sample to EU countries, fiscal spillovers can be large. For example, [Beetsma and Giuliodori \(2011\)](#) consider the effects of a spending shock of 1% of GDP emanating from one of the five largest EU economies on the remaining countries in their sample, finding a peak output effect of 0.35% after two years. [Beetsma et al. \(2006\)](#) adopt a different approach by combining a structural VAR model to identify the spending shocks with a trade model to determine the size of the fiscal spillovers. Their estimates indicate that a 1% of GDP government spending impulse in Germany raises output in Austria and Belgium by over 0.4% after two years. Moreover, they generally find that output spillovers are of a much larger magnitude in other euro area economies than in the UK.

The last two entries in panel B of [Table 1](#) rely on panel data. [Blagrove et al. \(2018\)](#) estimate the spillovers originating in France, Germany, Japan, the UK and the US on fifty five recipient countries but include investment in their measure of government spending. [Auerbach and Gorodnichenko \(2013b\)](#) construct a measure of fiscal shocks in OECD countries based on professional forecasts and compute the shocks for the receiving country as a sum of trade-weighted fiscal shocks, finding that the size of the spillovers is dependent on the state of the business cycle in both the source and the recipient countries.⁴

Overall, the time series evidence is generally indicative of international fiscal spillovers that are positive and sizeable, with some heterogeneity in the responses. In contrast, most macroeconomic models, be they estimated or parameterised, generally struggle to provide a mechanism for the large foreign output spillovers from spending shocks discussed above, as shown in panel C of [Table 1](#). Both [Kollmann et al. \(2015\)](#) and [Gadatsch et al. \(2016\)](#) use estimated three-country models; the former builds on the European Commission’s Quest III model ([Ratto et al., 2008](#)) while the latter can be interpreted as an extension on [Smets and Wouters \(2003\)](#) that also incorporates unemployment. Spillovers (from Germany to the rest of the euro area) in these models are very weak, a result consistent with the findings in [Cwik and Wieland \(2011\)](#), who use the [Taylor \(1993\)](#) model of the G7 economies, and with [Vetlov et al. \(2017\)](#), which relies on the New Multi-Country Model ([Dieppe et al., 2012](#)). Unlike the above, [Corsetti et al. \(2010\)](#) and [Corsetti and Müller \(2013\)](#) do obtain large fiscal spillovers, but it is important to note several points. First, these models are neither estimated nor are the impulse responses formally matched to those from a vector autoregression; instead, the model is parameterised. Secondly, the mechanism by which spillovers are large and positive relies on the presence of spending reversals: a current fiscal expansion leads to the anticipation of strong future fiscal contraction so that the long-term interest rate falls inducing an increase in foreign output. Hence, the reason that spillovers are positive is due to the financial, rather than the trade, channel, which is one reason for the expansionary effect on investment in the foreign economy. As a result, one implication of this analysis pointed out by [Wieland \(2010\)](#) in assessing ([Corsetti et al., 2010](#)) is that any expansionary effects from fiscal policy arise not from the increase in government spending but from the promise of future spending cuts. This leads to the normative policy advice during recessions

¹ The present value multiplier for period k equals $\frac{E_t \sum_{i=0}^k (R_{t+i}^k)^{-1} \Delta Y_{t+k}}{E_t \sum_{i=0}^k (R_{t+i}^k)^{-1} \Delta G_{t+k}}$.

² Bilateral relationships vis-à-vis specific economies will be discussed below.

³ [Kim and Roubini \(2008\)](#) is not included in the table as they rely on shocks to the government budget deficit, rather than spending.

⁴ The value reported in [Table 1](#) refers to the case where the recipient economy is in recession.

Table 1
Related literature.

Panel A					
Effects of government spending on international trade variables (peak responses)					
Economy	Paper	RER	TB		
US	Müller (2008)	5*	0.5		
	Corsetti and Müller (2006)		0.1		
	Faccini et al. (2016)	30	–		
	Monacelli and Perotti (2010)	10	–0.5		
	Enders et al. (2011)	3	3		
EU-5	Beetsma et al. (2008)	1	–0.8		
	Beetsma and Giuliadori (2011)	–2			
UK	Corsetti and Müller (2006)		–0.6		
	Monacelli and Perotti (2010)	4	–0.8		
Canada	Corsetti and Müller (2006)		–0.7		
	Monacelli and Perotti (2010)	–	–0.7		
Australia	Corsetti and Müller (2006)		–		
	Monacelli and Perotti (2010)	–	0.4		
Panel B					
Direct spillovers of government spending shock (peak responses)					
Source/Recipient	Paper	RER	TB	Y*	I*
US/EA	Corsetti and Müller (2013)	10	0.2	0.5	
	Faccini et al. (2016)		–	–1	3.5
US/France	Faccini et al. (2016)		–	1.5	6
US/Japan	Faccini et al. (2016)		–	1	4
US/UK	Corsetti and Müller (2013)	5	0.03	1	
	Faccini et al. (2016)		–	3.5	6
	Nicar (2015)	9	–9.4	2.7	
US/Canada	Faccini et al. (2016)		–	10	3
	Nicar (2015)	4.7	4.8		–1.3
Germany/Spain	Beetsma et al. (2006)			0.09	
	Alloza et al. (2019)		–	0.2	
	Dabla-Norris et al. (2017)		–	0.1	
Germany/France	Beetsma et al. (2006)			0.11	
	Alloza et al. (2019)		–	0.4	
	Dabla-Norris et al. (2017)		–	0.1	
Germany/Italy	Beetsma et al. (2006)			0.1	
	Alloza et al. (2019)		–	–	
Germany/UK	Beetsma et al. (2006)			0.07	
Large Panels/OECD	Blagrove et al. (2018)			0.2	
	Auerbach and Gorodnichenko (2013b)		0.1	3.3	
Panel C					
Direct spillovers in estimated or parameterised models					
Recipient	Model/Paper	RER	TB	Y*	
EA	Corsetti et al. (2010)	0.5	–0.07	0.2	
	Corsetti and Müller (2013)	0.1	–0.05	0.15	
UK	Corsetti and Müller (2013)	0.1	–0.02	0.22	
rEA	Kollmann et al. (2015)		–0.35	0.02	
rEA	Vetlov et al. (2017)			0.05	
France	Cwik and Wieland (2011)			0.05	
Italy	Cwik and Wieland (2011)			0.02	
rEA	Gadatsch et al. (2016)			–0.02	

Increase in the real exchange rate (*RER*) denotes depreciation while *TB* represent the trade balance as a proportion of GDP. Values adjusted so that shock is 1% of GDP. Müller (2008) uses the nominal exchange rate. Hyphen (‘–’) denotes insignificant at standard confidence level. *I** represents investment in the foreign economy.

of advising future spending consolidations and not altering policy in the present. Indeed, in both (Corsetti et al., 2010; Corsetti and Müller, 2013) the models absent spending reversals imply negative spillovers.

We next proceed to provide estimates of government spending spillovers emanating from the US and from Germany, and to provide a DSGE model consistent with such evidence.

2. Identifying fiscal policy shocks in the data

There is an ongoing debate in the literature on how fiscal policy shocks should be identified (see Ramey, 2011a, 2016, for a review of the literature). The existing empirical literature on the effects of government spending is mostly based on an SVAR model with a small set of three to six core variables, while the propagation of the shock to the other variables of interest is studied using a marginal approach by adding one variable at a time to the small VAR model (see Blanchard and Perotti, 2002; Corsetti et al., 2012). To identify the government spending shock, theory-based restrictions are imposed on the VAR impulse responses using either the recursive method, as in Blanchard and Perotti (2002), or the sign restrictions approach of Mountford and Uhlig (2009). Some studies

also employ the local projections method of Jordà (2005) in a single-equation iteration to analyse state-dependent effects of fiscal policy (see Ramey and Zubairy, 2018; Owyang et al., 2013; Auerbach and Gorodnichenko, 2013a) and Auerbach and Gorodnichenko (2013b).

The use of small fiscal SVARs in the literature is beset with two major problems: first, the identified government spending shock potentially suffers from the problem of non-fundamentality or non-invertibility due to anticipation effects of changes in fiscal policy as a result of decision and implementation lags. This phenomenon is known as fiscal foresight and has been examined in relation to tax shocks (e.g. Leeper et al., 2013) and government spending shocks (e.g. Ramey, 2011b; Forni and Gambetti, 2016). The second problem is related to the potential for omitted variable bias in the small VAR specifications, with adverse consequences for structural analysis. This is known as the information insufficiency issue and estimated VAR models with this problem produce inconsistent results. As a consequence, econometricians cannot fully recover the true structural shocks from the data.

To resolve these challenges – non-fundamentality and information insufficiency – the recent empirical studies on fiscal policy employ models that utilise a large information set. One strand of such literature uses factor models or factor-augmented VAR (FAVAR) models of Stock and Watson (2005) and Bernanke et al. (2005), where a large dataset is used to construct several common factors, which are then used to augment the standard fiscal VAR to provide more information (see, for instance, Laumer, 2020; Fragetta and Gasteiger, 2014; Forni and Gambetti, 2010, 2014). An alternative approach uses large Bayesian VARs with informative priors, which allows the system to estimate a large number of parameters with a large information set while employing standard VAR framework and identification strategies. This model has also been used to analyse the effects of fiscal policy shocks (e.g. Ellahie and Ricco, 2017) and monetary policy shocks (e.g. Giannone et al., 2015; Bańbura et al., 2010).

In this paper, we estimate a fiscal VAR model using full Bayesian techniques with Gibbs sampling. We examine the domestic effects of government spending shocks in the G7 economies and the cross-border effects of changes in US government spending on the rest of G7 economies as well as German government spending on other European economies. In setting the prior distribution, we follow the standard practice by using the Minnesota prior. As Bańbura et al. (2010) note, the underlying principle behind this prior specification is that more recent lags in the VAR system provide more information than the older ones and that own lags should have a higher explanatory power than lags of other variables. Thus, this prior simply shrinks the diagonal elements of the lag matrix in the VAR system towards one and the remaining elements towards zero. Since we intend to analyse the propagation of government spending shocks on a reasonably large number of domestic and foreign variables, this approach is suitable to address the curse of dimensionality problem relating to estimating large numbers of parameters in VAR models.

2.1. Bayesian VAR specification and identification

Let $X_t = (x_{1,t} \ x_{2,t} \ \dots \ x_{n,t})'$ be a vector of random variables. A VAR(p) model can be specified as:

$$\begin{aligned} X_t &= c + A_1 X_{t-1} + \dots + A_p X_{t-p} + u_t \\ E(u_t' u_s) &= \Sigma \quad \text{if } t = s \\ E(u_t' u_s) &= 0 \quad \text{if } t \neq s \\ E(u_t) &= 0 \end{aligned} \tag{1}$$

where $c = (c_1, \dots, c_n)'$ is an n -dimensional vector of constants, A_1, \dots, A_p are $n \times n$ lag matrices, while u_t is an n -dimensional vector of normally distributed white noise terms.

For our analysis of the domestic effects of fiscal policy in the G7 economies, we set up a VAR model that contains 10 country-specific variables in the following order: government consumption spending, g_t ;⁵ OECD government spending growth forecast, Δg_t^{fc} ; output, y_t ; real government debt, d_t ; the 10-year government bond rate, r_t ; the terms of trade, tot_t ; the real effective exchange rate, $reer_t$; the trade balance-to-GDP ratio, tby_t ; private consumption, c_t , and investment, i_t . Government spending, output, consumption and investment variables are all defined in real terms using the GDP-price deflator. Following Ramey (2016), we transform these GDP components using the procedure proposed by Gordon and Krenn (2010) by dividing the GDP component series and government debt with Hamilton-filtered trend GDP.⁶ Both the terms of trade and the real effective exchange rate are defined in log levels such that an increase implies a depreciation. All the variables are multiplied by 100 so that the impulse responses can be interpreted as percent change or percentage-point changes for the interest rate. Further information about the variables is presented in Table 2. The country-specific vector of endogenous variables is given by:

$$x_t = [g_t \ \Delta g_t^{fc} \ d_t \ y_t \ r_t \ tot_t \ reer_t \ tby_t \ c_t \ i_t]'$$
(2)

⁵ We also considered total government consumption and investment spending, but the data series for public investment is only available for five of the G7 economies. The results of the VAR model with this series are not substantially different from those of government consumption spending alone, since government consumption accounts for more than 70% of total government spending in G7 economies.

⁶ The Gordon–Krenn transformation procedure involves estimating a polynomial GDP trend and dividing the GDP component series with this trend GDP. However, due to the end-point problem with the estimation of GDP trend both in polynomial estimation and in Hodrick–Prescott filter, we instead rely on the recently proposed Hamilton (2018)'s procedure to extract the GDP trend. The Gordon–Krenn transformation has two advantages: first, as Ramey (2016) notes, while the impulse responses from using this transformation are quite similar to those using log levels, it produces relatively narrow confidence bands compared to the log levels. Second, the Gordon–Krenn transformation circumvents the ad-hoc approaches to computing fiscal multipliers from log-level estimations, as the multiplier can be computed directly as the ratio of the estimated impulse response of the trend-adjusted GDP to trend-adjusted government spending.

Table 2
Data definitions and sources.

Variables in VAR	Definition	Detrended by	Construction	Countries ^a
g_t	real government consumption	Hamilton trend of GDP (Y_{ht}^T)	$100 \times (\ln G_t - \ln Y_{ht}^T)$	G7
Δg_t^{fc}	government spending growth forecast		see text	G7
d_t	real government debt	Hamilton trend of GDP (Y_{ht}^T)	$100 \times (\ln D_t - \ln Y_{ht}^T)$	G7
y_t	real GDP	Hamilton trend of GDP (Y_{ht}^T)	$100 \times (\ln Y_t - \ln Y_{ht}^T)$	G7 + E15
r_t	10-year bond rate		$100 \times \ln(1 + R_t/100)$	G7
tot_t	terms of trade		$100 \times \ln(P^{imports}/P^{exports})$	G7
$reer_t$	real effective exchange rate		$100 \times \ln(1/REER)$	G7
tby_t	trade balance/GDP		$100 \times (tbal/GDP)$	G7
c_t	real private consumption	Hamilton trend of GDP (Y_{ht}^T)	$100 \times (\ln C_t - \ln Y_{ht}^T)$	G7
i_t	real investment	Hamilton trend of GDP (Y_{ht}^T)	$100 \times (\ln I_t - \ln Y_{ht}^T)$	G7
y_t^*	foreign real GDP	Hamilton trend of GDP* (Y_{ht}^{T*})	$100 \times (\ln Y_t^* - \ln Y_{ht}^{T*})$	G6 + E14
rer_t	bilateral real exchange rate		$100 \times \ln(S \times P^*/P)$	G6 + E14

All data are from the OECD database and span the period 1997Q4–2019Q4.

^aG7 = USA, Japan, Germany, France, UK, Italy and Canada. G6 = G7 - USA, E15 = Germany, France, UK, Italy, Spain, Netherlands, Belgium, Austria, Ireland, Finland, Portugal, Greece, Switzerland, Sweden, Norway, Denmark. E14 = E15 - Germany.

In line with the existing literature, we order the government spending variable first and identify the government spending shock using Cholesky decomposition, as in [Blanchard and Perotti \(2002\)](#). However, we deviate from most previous work in this area (e.g. [Ilzetzki et al., 2013](#)) by explicitly controlling for anticipation effects of changes in fiscal policy by including government spending growth forecast variable in our dataset, as in [Born et al. \(2013\)](#). This allows us to uniquely identify the unanticipated shock to government spending in the presence of fiscal foresight. Meanwhile, previous studies have also shown that the inclusion of market-based forward-looking variables, such as interest rates, stock prices and exchange rates, helps to alleviate the foresight problem in the fiscal SVAR model (see [Beetsma and Giuliodori, 2011](#); [Fisher and Peters, 2010](#); [Forni and Gambetti, 2010](#); [Yang, 2007](#)). Furthermore, [Ricco and Ellahie \(2012\)](#) and [Ellahie and Ricco \(2017\)](#) document that using a large information approach, which reveals the broader behaviour of the economic agents over time, is able to overcome the non-fundamentalness issues associated with anticipation effects of fiscal policy changes and to resolve the problems relating to sample instability of fiscal multiplier estimates. For example, [Ricco and Ellahie \(2012\)](#) find no strong evidence of non-fundamentalness even in a medium-scale Bayesian VAR model with nine variables like ours.

Given the cross-country nature of our analysis, we rely on macroeconomic series from the OECD's Statistics and Projections database at quarterly frequency for the period 1995Q1–2019Q4.⁷ The use of OECD data for our analysis is beneficial in a number of ways. First, the OECD data and projections are prepared using a unified methodology for all the countries, thereby eliminating any bias or complications that may arise in the way different countries compile and report their data. Second, the OECD prepares semi-annual forecasts for several macroeconomic variables (the so-called OECD Economic Outlook) such as output, inflation, government spending and fiscal balance. These forecasts are consistently available for all G7 countries since the mid-1980s and incorporate a good amount of information on domestic and global developments for each country. The forecasts are very popular in both academic and policy circles; perform comparably well with other forecasts from country-specific sources, such as the Survey of Professional Forecasters in the US and the Office for Budgetary Responsibility in the UK; and they have been used in other academic research (e.g. [Auerbach and Gorodnichenko, 2013a](#); [Born et al., 2013](#)). Third, the OECD database is publicly available, facilitating replication attempts.

2.2. Domestic effects of fiscal policy shocks

[Figs. 1 to 2](#) show impulse responses to a one unit shock to domestic government consumption (as a proportion of GDP) for the United States and Germany.

Although there is some qualitative heterogeneity in the responses of individual variables, a broad and consistent picture emerges. An unanticipated increase in government consumption is expansionary in both the US and in Germany. Many of the responses of the remaining variables in our VAR run counter to the intuition arising from standard flexible price macroeconomic models.

⁷ The estimation sample actually covers the period 1997Q4–2019Q4 after applying the Hamilton filter procedure to the GDP series. Also, the government spending growth forecast from the Projection database, which is originally reported semi-annually, is interpolated to a quarterly series using a mid-point averaging method.

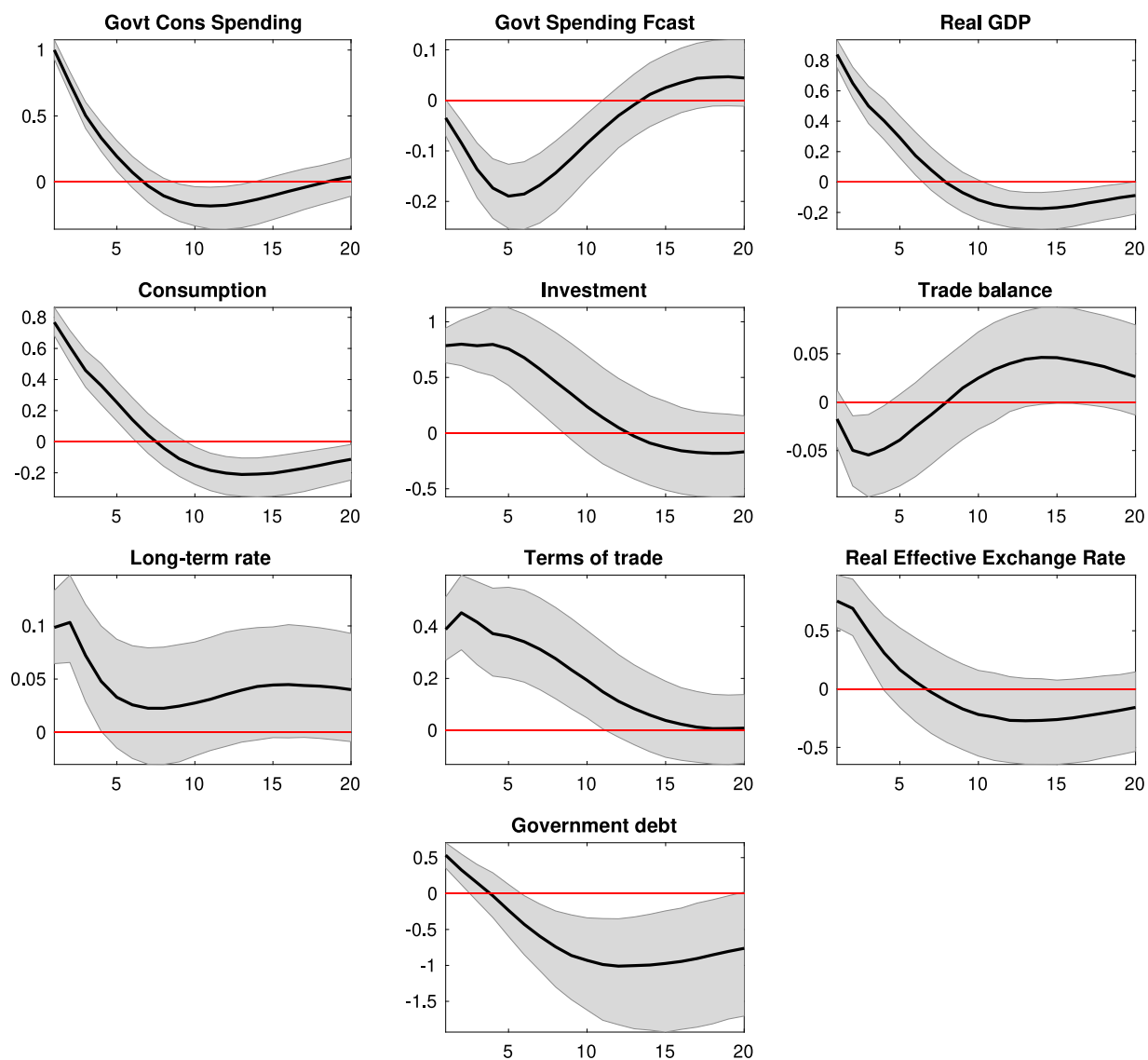


Fig. 1. Unanticipated shock to government consumption spending in the United States of America. Note: The black solid line denotes the median impulse response of the data a shock a one percent of GDP shock to government consumption. The grey shaded area is the 16–84 percentile draw band. All data definitions are reported in Table 2.

Private consumption, far from being crowded out by an increase in government spending, rises in both the US and Germany. Private investment, which one would expect to be crowded out by higher government spending, responds positively to an increase in government consumption. It is noteworthy that although the crowding in of consumption is a common finding, the effects on investment are less commonly studied. Our results are consistent with those in [Beetsma and Giuliodori \(2011\)](#), despite the fact that they used annual data for 14 EU countries and covered a different time period (1970 – 2004). We also find that the trade balance relative to GDP worsens in both countries. Most of the literature cited above also found this deterioration in the trade balance, such as [Beetsma and Giuliodori \(2011\)](#) and [Monacelli and Perotti \(2010\)](#), and in contrast to [Corsetti et al. \(2012\)](#)

The effective real exchange rate also behaves in a counter-intuitive fashion. In a standard flexible price open economy model, one would expect the real exchange rate to appreciate following a positive demand shock. In our VAR, the effective real exchange rate depreciates in both the US and Germany. Note that the US experiences a much larger real depreciation than Germany. Most related studies found similar results (e.g. [Ravn et al., 2012](#); [Corsetti and Müller, 2013](#)), although exceptions include ([Beetsma and Giuliodori, 2011](#); [Beetsma et al., 2006](#)). We also include the terms of trade, defined as the price of imports relative to exports, in the VAR. The terms of trade are positively correlated with the effective real exchange rate, which suggests that the dynamics of the real exchange rate are not primarily driven by the dynamics of the relative price of non-traded goods. Thus for both the US and

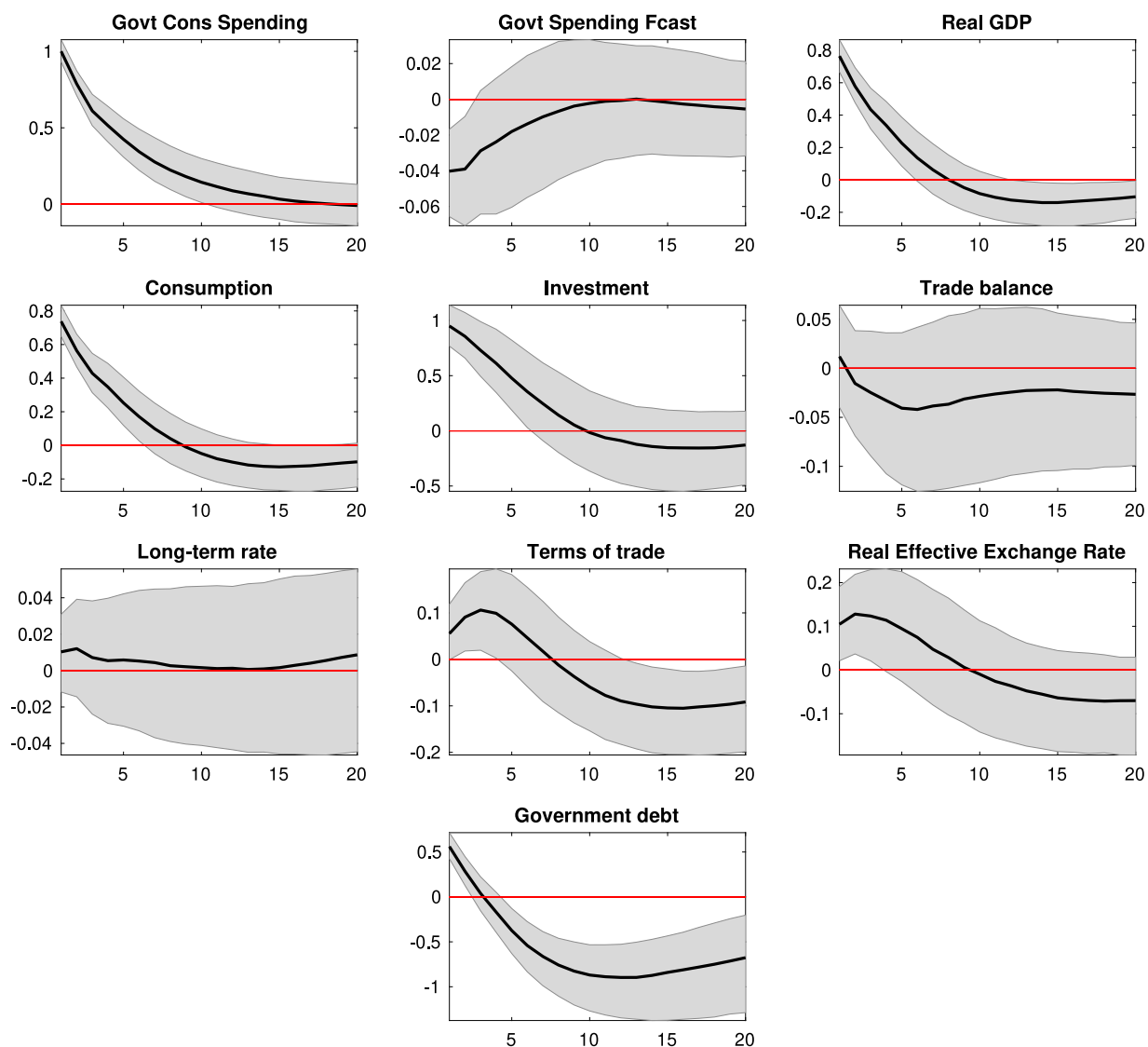


Fig. 2. Unanticipated shock to government consumption spending in Germany. Note: The black solid line denotes the median impulse response of the data to a one percent of GDP shock to government consumption. The grey shaded area is the 16–84 percentile draw band. All data definitions are reported in Table 2.

Germany a government spending shock is expansionary for the components of GDP, worsens the trade balance and depreciates the real exchange rate. For both countries the impact multiplier on GDP is around 0.8.

To help identify the fiscal impulse, we include a measure of expected government spending growth as well as the ten-year government bond rate. The former falls following the fiscal expansion while the latter shows that the cost of government borrowing rises. However, in the case of Germany these responses are quantitatively very small and largely insignificant. These results are qualitatively similar to those in [Beetsma and Giuliodori \(2011\)](#) but in contrast to [Corsetti et al. \(2012\)](#), where the decrease in the long-term rate is linked to the future spending reversal. Our findings, however, indicate that the future fiscal contraction only occurs in the US and that it is of short duration, which may help explain the positive interest rate response.

2.3. International spillovers

How do government spending shocks in the United States and in Germany, the largest economy in the world and the biggest in Europe, respectively, affect output and relative prices abroad? To answer this question, we augment the VAR for the US and Germany with foreign output, y_t^* , and replace the effective real exchange rate of the US and Germany with bilateral real exchange rates of the partner country, rer_t . Foreign output has been transformed with the foreign GDP trend using the same procedure as for

domestic output discussed above, while the bilateral real exchange rate is defined in log levels such that an increase implies a real currency depreciation for the foreign economy. The vector of endogenous variables in the bilateral VAR model is given by:

$$x_t = [g_t \ \Delta g_t^{fc} \ d_t \ y_t \ r_t \ tot_t \ rer_t \ tby_t \ c_t \ i_t \ y_t^*]' \quad (3)$$

International transmission of government spending shocks can be viewed as operating through two distinct channels: the trade channel via greater US demand for foreign goods and the wealth channel, operating via the real exchange rate. Faccini et al. (2016) and Corsetti and Müller (2013) argue in favour of a 'financial channel' where the fiscal stimulus is accompanied by future spending reversals, which have the effect of lower long-term interest rates and thereby producing positive spillovers. This mechanism is put forward as an alternative to the trade channel given that they find an insignificant effect on the US trade balance (vis-à-vis the EA and the UK) following the government spending shock. Our results are not supportive of such a channel as we find an increase in long-term interest rates in both the US and Germany following the increase in spending at the same time that the trade balance deteriorates. Therefore, our results and potential mechanisms are closer to those in Beetsma and Giuliodori (2011) and Monacelli and Perotti (2010).

As shown in Fig. 3, a positive US government spending shock has a significant positive effect on the GDP of the remaining six G7 economies. This is consistent with the summary of the literature provided in Table 1, at least qualitatively. Bar Japan and Italy, output rises on impact and the effects are at least as persistent as those on US GDP.

Given that the US effective real exchange rate depreciates following a government spending shock, it is not surprising that, except in Japan, the bilateral real exchange rates of the other G7 economies, relative to the US dollar, appreciate on impact. The initial US depreciation shifts some of the purchasing power of US consumers onto foreign consumers. After about five quarters, this second transmission channel is reversed and the US's trading partners experience a real depreciation.

To analyse the transmission mechanism of a government spending shock originating in Germany, we look at responses of output and the bilateral real exchange rate of the 10 biggest EA economies and 5 non-euro area economies. Figs. 4 to 5 show that within the EA, a German government spending shock has a significantly positive effect on GDP for seven out of the ten countries in our sample. Only in Greece, Portugal and Ireland do we observe either a fall in output or an effect that is not significantly different from zero. Using annual data, Dabla-Norris et al. (2017) find large output impacts of German spending shocks after one year in Finland and the Netherlands (of almost 0.2), although in contrast to our results, they obtain the largest spillover multiplier in Ireland. For the remaining big-three EA economies (France, Italy and Spain) output rises on impact, after which Italy and Spain experience output contractions prior to returning to the steady state. Alloza et al. (2019) also considered fiscal spillovers but only within the four biggest EA members, finding that the peak impacts all occur after a lag and in the case of Italy, the output effect is largely contractionary.

The output responses of non-EA countries to a government spending shock originating in Germany, shown in Fig. 6, are generally about the same size as within the euro area. The spillovers between Germany and the UK are roughly of the same magnitude as those between Germany and Italy or France. Likewise, the spillovers between Germany and Austria are similar to those between Germany and Switzerland.

Within the single currency, real exchange rate movements only reflect changes in relative prices and not variations in the nominal exchange rate. The real exchange rate response to a German government spending shock is up to an order of magnitude larger in non-EA economies than in the member countries. Within the euro area, only Greece experiences a real exchange rate change similar in magnitude to that on non-EA countries. Here, the real exchange rate responds with a 'hump-shape' and persistently depreciates.

3. A dynamic stochastic general equilibrium model

Having analysed fiscal policy shocks in a BVAR framework, we now put forward a DSGE model to help us rationalise the domestic as well as the international transmission mechanism of fiscal policy shocks.

The challenge in trying to capture the dynamics of the BVAR in a DSGE model lies in the fact that private sector consumption and investment increase in response to a fiscal expansion. We address this challenge with a two-country New Keynesian DSGE model. In order for private consumption to rise in response to a government spending increase, we introduce households without access to financial markets. For the fiscal expansion to crowd-in investment, we separate the decision to accumulate capital from the financially-unconstrained household, whose savings increase in a Ricardian manner. Government spending is initially bond-financed, while a tax rule ensures that the debt-to-GDP ratio remains stationary. The aim is to set up a relatively canonical model that can help explain the domestic as well as the international transmission mechanism of government spending shocks in the German data. The baseline model therefore assumes a currency union between the two countries in the model. In what follows, we give an outline of the model used, with a full set of equilibrium conditions presented in Table 3.

3.1. Households

There are two types of households in the model that differ in their ability to smooth consumption via their access to financial markets. Ricardian agents can borrow and save in the form of bonds. By contrast, as in Galí et al. (2007), we assume the presence of rule-of-thumb (RoT) households that consume their current disposable income.⁸ As a result, in the aggregate consumption can be crowded-in by government spending.

⁸ The agents are also often referred to as non-Ricardian.

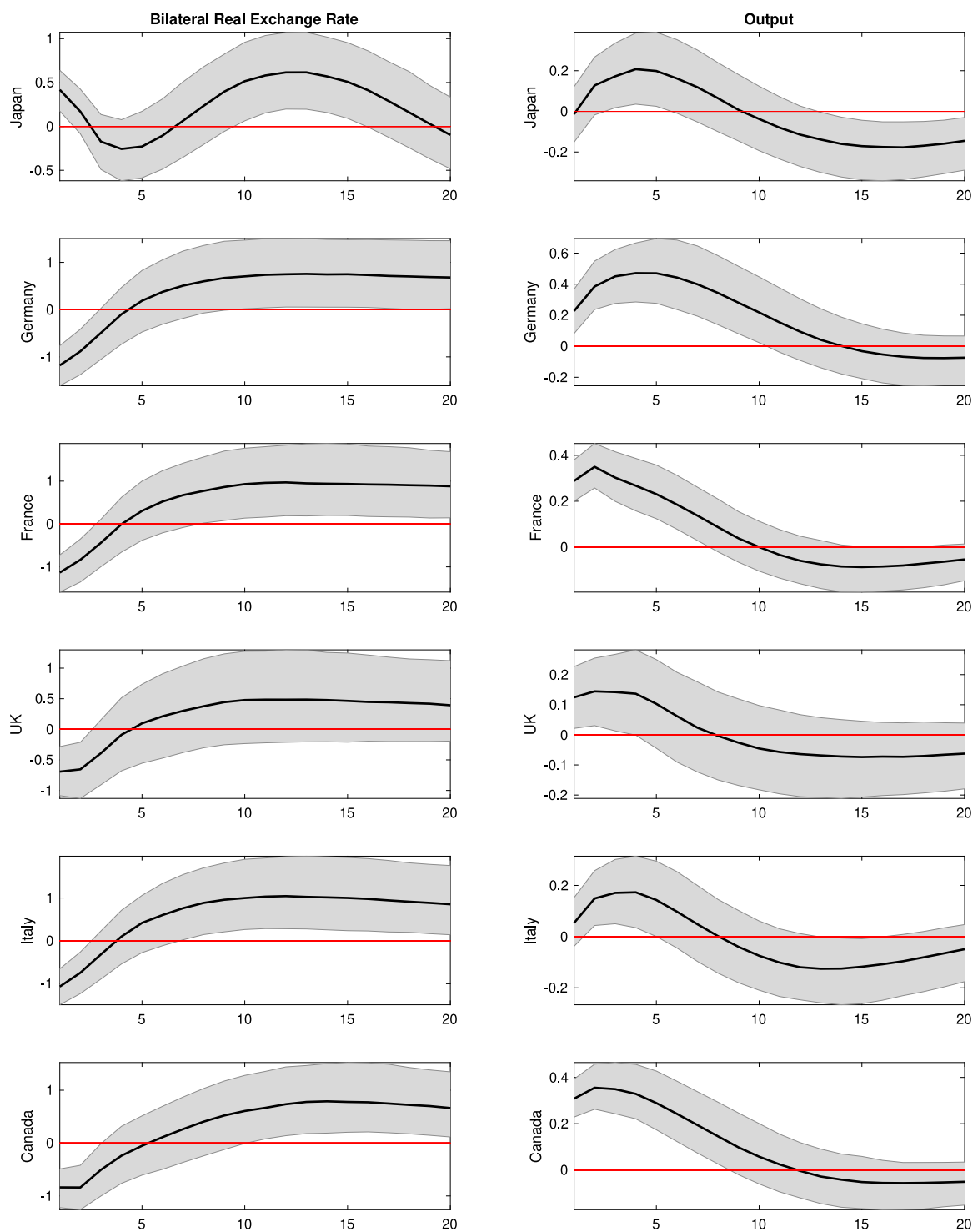


Fig. 3. US government consumption spillovers to G7. Note: See Fig. 1. An increase in a country's real exchange rate denotes a real depreciation in that country's real exchange rate.

3.1.1. Ricardian households

Ricardian households receive utility from the consumption of goods, c^t , and dis-utility from providing work hours, n^t . A single prime denotes the variables pertaining to Ricardian households. Households form external habits over consumption, such that the

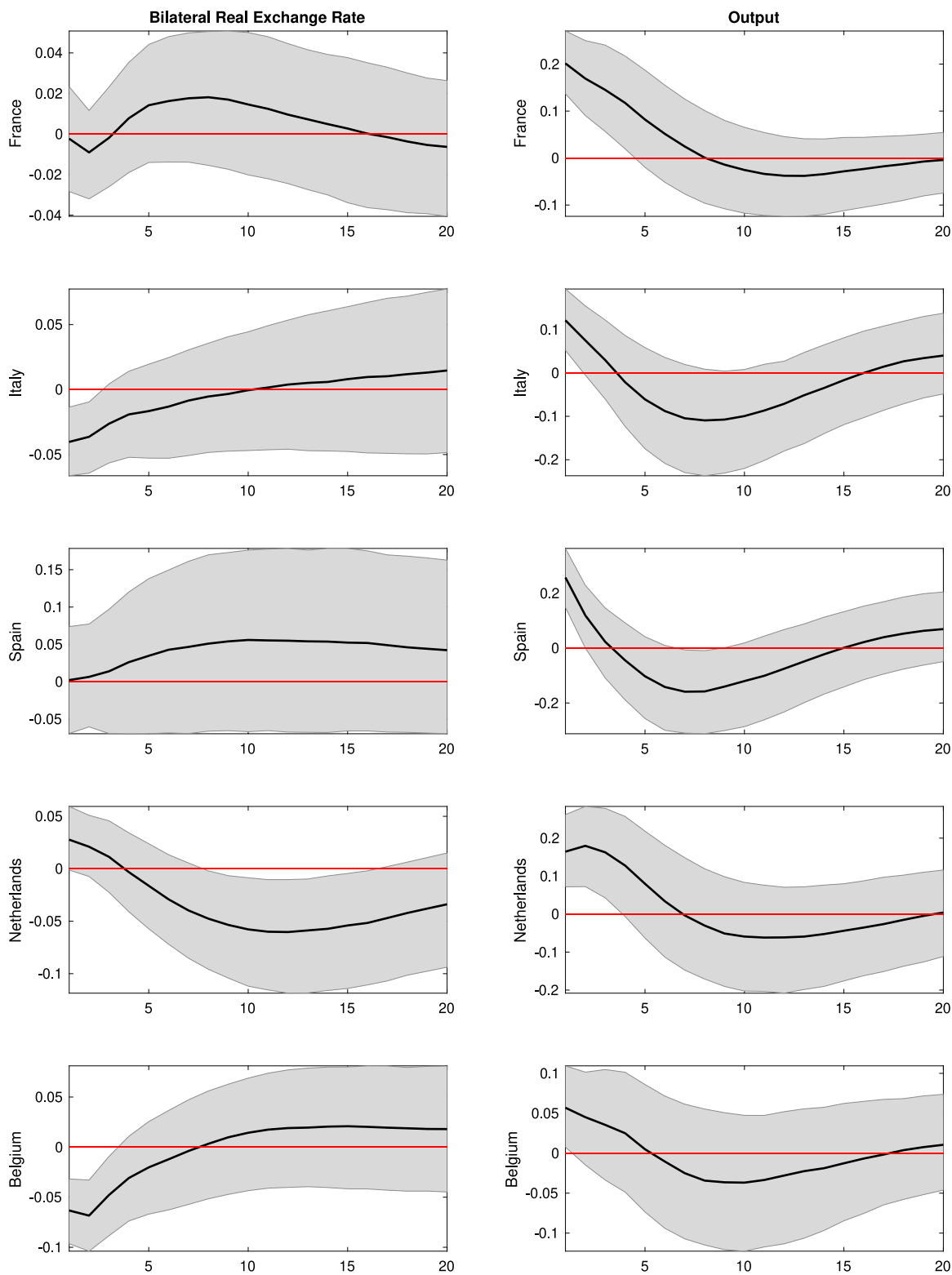


Fig. 4. German government consumption spillovers to Euro Area Europe (i). Note: See Fig. 1. An increase in a country's real exchange rate denotes a real depreciation in that country's real exchange rate.

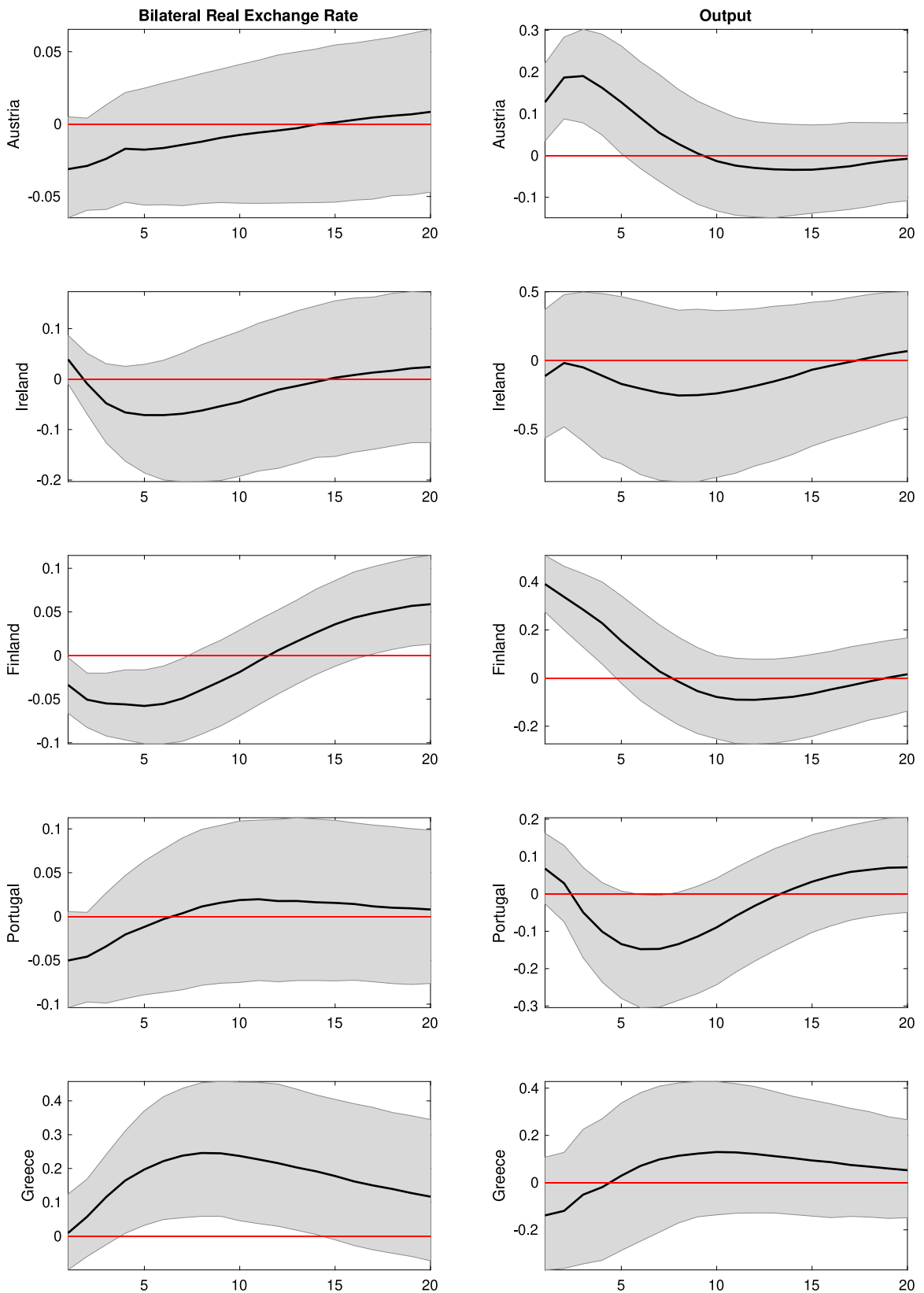


Fig. 5. German government consumption spillovers to Euro Area (ii). Note: See Fig. 1. An increase in a country's real exchange rate denotes a real depreciation in that country's real exchange rate.

Table 3
Equilibrium conditions and constraints.

Description	Model equation	
FOC c_t (hf)	$\frac{r_t}{c_t' - \epsilon_c c_{t-1}'} = \lambda_t'$	[i]
FOC n_t (hf)	$-\phi_0 n_t'' + \lambda_t' w_t = 0$	[ii]
FOC b_t^h (h)	$-\lambda_t' + \beta E_t \lambda_{t+1}' (1 + r_t^\mu) \phi_t \frac{x_{t+1}^\mu}{x_t^\mu} \frac{rer_{t+1}}{rer_t} = 0$	[iii]
FOC b_t^f (f)	$-\lambda_t^{f*} + \beta E_t \lambda_{t+1}^{f*} (1 + r_t^\mu) \phi_t \frac{x_{t+1}^\mu}{x_t^\mu} = 0$	[iv]
RoT BC (hf)	$c_t'' = w_t n_t'' - tax_t''$	[v]
RoT FOC c_t (hf)	$\frac{r_t''}{c_t'' - \epsilon_c c_{t-1}''} = \lambda_t''$	[vi]
RoT FOC n_t (hf)	$-\phi_0'' n_t'' + \lambda_t'' w_t = 0$	[vii]
Ent BC (hf)	$c_t^e = \rho_t^k k_{t-1} - x_t + d_t^e - (1 + r_{t-1}^\mu) \frac{d_{t-1}^e}{\pi_t}$	[viii]
Ent KC (hf)	$k_t = (1 - \delta) k_{t-1} + \left(1 - \frac{\psi}{2} \left(\frac{x_t}{x_{t-1}} - 1\right)^2\right) x_t$	[ix]
Ent BorrC (hf)	$(1 + r_t^\mu) d_t^e = (1 - \rho^D) M E_t q_{t+1} k_t \pi_{t+1} (1 - \delta) - \rho^D (1 + r_{t-1}^\mu) \frac{d_{t-1}^e}{\pi_t}$	[x]
Ent FOC c_t (hf)	$\frac{r_t}{c_t' - \epsilon_c c_{t-1}'} = \lambda_t^e$	[xi]
Ent FOC k_t (hf)	$q_t = E_t \frac{\beta^e \lambda_{t+1}^e}{\lambda_t^e} (q_{t+1} (1 - \delta) + \rho_t^k) + \Delta_t (1 - \rho^D) M E_t q_{t+1} (1 - \delta) \pi_{t+1}$	[xii]
Ent FOC x_t (hf)	$1 = q_t \left[\left(1 - \frac{\psi}{2} \left(\frac{x_t}{x_{t-1}} - 1\right)^2\right) - \psi \left(\frac{x_t}{x_{t-1}} - 1\right) \frac{x_t}{x_{t-1}} \right] + \dots$ $\dots \beta^e E_t q_{t+1} \frac{\lambda_{t+1}^e}{\lambda_t^e} \psi \left(\frac{x_{t+1}}{x_t} - 1\right) \left(\frac{x_{t+1}}{x_t}\right)^2$	[xiii]
Total consumption (hf)	$c_t = c_t^e + \mu c_t'' + (1 - \mu) c_t'$	[xiv]
Total hours (hf)	$n_t = \mu n_t'' + (1 - \mu) n_t'$	[xv]
Firms' Output (hf)	$y_{h,t} = n_t^{1-\alpha} k_{t-1}^\alpha$	[xvi]
Firms' FOC n_t (hf)	$(1 - \alpha) y_{h,t} p_{h,t} = x_{p,t} w_t n_t$	[xvii]
Firms' MPK (hf)	$\alpha y_{h,t} p_{h,t} = x_{p,t} r_{k,t} k_{t-1}$	[xviii]
Price inflation PC (hf)	$\log(\pi_{h,t} / \bar{\pi}) = \beta E_t \log(\pi_{h,t+1} / \bar{\pi}) - \frac{(1 - \theta_x)(1 - \beta \theta_x)}{\theta_x} \log(x_{p,t} / \bar{x}_p)$	[xix]
Price inflation (hf)	$\pi_{h,t} = \pi_t \frac{p_{h,t}}{p_{h,t-1}}$	[xx]
Monetary policy	$\log(1 + r_t^\mu) = r_R \log(1 + r_{t-1}^\mu) + (1 - r_R) \left(r_x \log\left(\frac{p_{h,t}^\mu}{\bar{p}_{h,t}^\mu}\right) + r_y \log\left(\frac{y_t^\mu}{\bar{y}_t^\mu}\right) + \log(1 + \bar{r}^\mu) \right)$	[xxi]
Government BC (h)	$tax_t + d_t^g = p_{h,t} g_t + (1 + r_{t-1}^\mu) \phi_{t-1} \frac{1}{\pi_t} d_{t-1}^g$	[xxii]
Government BC (f)	$tax_t^* + d_t^{g*} = p_{f,t}^* g_t^* + (1 + r_{t-1}^\mu) \frac{1}{\pi_t^*} d_{t-1}^{g*}$	[xxiii]
Fiscal rule (hf)	$tax_t = \zeta_g d_{t-1}^g + \bar{g}$ $g_t = g_s \frac{\zeta}{\bar{y}}$ $\log(g_s) = \rho_g \log(g_{s,t-1}) + \epsilon_{g,t}$	[xxiv] [xxv] [xxvi]
Market clearing (h)	$y_{h,t} = g_t + (1 - (1 - N)\gamma) p_{h,t}^{-\theta} (c_t + x_t) + (1 - N)\gamma p_{h,t}^{*-\theta} (c_t^* + x_t^*)$	[xxvii]
Market clearing (f)	$y_{f,t} = g_t^* + (1 - N\gamma) p_{f,t}^{*-\theta} (c_t^* + x_t^*) + N\gamma p_{f,t}^{-\theta} (c_t + x_t)$	[xxviii]
Current account	$c_t + x_t + p_{h,t} g_t + (rer_t) b_t^* = (1 + r_{t-1}^\mu) \phi_{t-1} \frac{x_t}{\pi_t} (rer_t) b_{t-1}^* + y_{h,t} p_{h,t}$	[xxix]
Terms of trade	$T_t = P_{f,t} / P_{h,t}$	[xxx]
Real exchange rate	$rer_t = \frac{p_{h,t}}{p_{f,t}^*}$	[xxxi]
Relative prices	$p_{h,t}^{\theta-1} = (1 - (1 - N)\gamma) + (1 - N)\gamma T_t^{1-\theta}$ $p_{f,t}^{\theta-1} = (1 - (1 - N)\gamma) T_t^{\theta-1} + (1 - N)\gamma$ $p_{h,t}^{*\theta-1} = N\gamma + (1 - N\gamma) T_t^{1-\theta}$ $p_{f,t}^{*\theta-1} = N\gamma T_t^{\theta-1} + (1 - N\gamma)$	[xxxii] [xxxiii] [xxxiv] [xxxv]

Notes: (h) = home, (f) = foreign, (hf) = applies to home and foreign, FOC = first order condition, BC = budget constraint, RoT = rule-of-thumb, Ent = entrepreneurs, KC = capital accumulation constraint, BorrC = borrowing constraint, MPK = marginal product of capital, PC = Phillips curve, $p_{h,t} = P_{h,t} / P_t$, $p_{f,t} = P_{f,t} / P_t$, $p_{h,t}^* = P_{h,t}^* / P_t^*$, $p_{f,t}^* = P_{f,t}^* / P_t^*$.

expected utility of the Ricardian household can be described as:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\Gamma_c \log(c_t' - \epsilon_c c_{t-1}') - \frac{\phi_0}{1 + \eta} n_t^{1+\eta} \right) \tag{4}$$

where $\Gamma_c = (1 - \epsilon)$ is a constant that ensures that steady state consumption is not affected by the presence of external habits, with c_t' denoting aggregate consumption of all Ricardian households. The inverse of the labour supply elasticity is given by η , ϵ determines the strength of consumption habits and ϕ_0 the disutility of labour. Households consume a constant elasticity of substitution (CES) aggregate of home and foreign-produced final goods:

$$c_t' = \left[v^{\frac{1}{\theta}} \left(c_t^{h'} \right)^{\frac{\theta-1}{\theta}} + (1 - v)^{\frac{1}{\theta}} \left(c_t^{f'} \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{5}$$

where θ denotes the constant elasticity of substitution between home and foreign-produced intermediate goods and v is the share of home-produced intermediate goods in total home-consumption. Households maximise expected utility subject to the following

flow budget constraint:

$$c'_t + d_t^g + d_t^e + (rer_t) b_t^* = w_t n'_t + (1 + r_{t-1}^\mu) \phi_{t-1} \frac{\pi_t^\mu}{\pi_t^*} (rer_t) b_{t-1}^* + (1 + r_{t-1}^\mu) \frac{1}{\pi_t} d_{t-1}^g + (1 + r_{t-1}^\mu) \frac{d_{t-1}^e}{\pi_t} - tax'_t + div_t. \tag{6}$$

In the ‘home’ country, which is assumed to be a relatively small part of the currency union, households are able to smooth consumption by holding two types of assets: bonds issued by domestic entrepreneurs (d_t^e) and the government (d_t^g), which pay in domestic currency; and internationally-traded bonds, b_t^* , that pay out in terms of the union price level, with rer_t denoting the real exchange rate.

The domestic CPI inflation rate is denoted by $\pi_t = P_t/P_{t-1}$ and union-wide inflation by $\pi_t^\mu = P_t^\mu/P_{t-1}^\mu$, where P_t^μ denotes the union-wide price level, which is a size-weighted average of home and foreign prices: $P_t^\mu = P_t^N P_t^{*(1-N)}$, with N denoting the relative size of the home country. The nominal interest rate on domestic bonds is r_t^μ while the rate on internationally-traded bonds is r_t^* adjusted by a small bond holding cost, ϕ_t , that increases along with the degree of net indebtedness.⁹ In addition to holding assets, the household receives wage income, pays lump-sum taxes and receives dividend income from owning monopolistically competitive retailers. Equations [i] to [iv] in Table 3 capture the Ricardian household’s optimal choice of consumption, hours and bond holdings.

3.1.2. Rule-of-thumb households

A proportion μ of households have no access to financial markets; their only source of income is from wages. Variables pertaining to rule-of-thumb households are denoted by a double prime. All households, regardless of their ability to smooth consumption, share the same type of utility function.

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\Gamma_c \log(c''_t - c_c c''_{t-1}) - \frac{\phi_0}{1 + \eta} n_t''^{1+\eta} \right) \tag{7}$$

Just as for Ricardian households, consumption of rule-of-thumb households is a CES aggregate of home and foreign-produced final goods

$$c''_t = \left[v^{\frac{1}{\theta}} (c''^h_t)^{\frac{\theta-1}{\theta}} + (1-v)^{\frac{1}{\theta}} (c''^f_t)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{8}$$

The rule-of-thumb household’s consumption is constrained to equal its wage income net of taxes

$$c''_t = w_t n_t'' - tax''_t \tag{9}$$

Both types of households supply labour to the same market and thus receive the same real wage. Given the constraints faced by the rule-of-thumb agents, they make optimal choices over consumption and hours worked.

3.2. Entrepreneurs

For investment to rise, we separate the decision to accumulate capital from the Ricardian household, whose savings increase in order to pay future taxes in response to a fiscal expansion. Following Kamber and Thoenissen (2013), we introduce entrepreneurs who produce capital goods, which are then rented out to the intermediate goods producers. Entrepreneurs receive utility from consumption and are assumed to be less patient than households, implying that the discount factor applicable to entrepreneurs, denoted β^e , is lower than that of Ricardian households. They are thus subject to a binding collateral constraint when borrowing for investment.¹⁰ This way, investment responds to higher aggregate demand generated by the fiscal expansion and not to anticipated higher taxes.¹¹

The entrepreneur maximises expected utility defined over consumption of final goods:

$$E_0 \sum_{t=0}^{\infty} \beta^{e,t} \Gamma_c \log(c_t^e - c_c c_{t-1}^e) \tag{10}$$

subject to a flow budget constraint,

$$c_t^e = \rho_t^k k_{t-1} - x_t + d_t^e - (1 + r_{t-1}^\mu) \frac{d_{t-1}^e}{\pi_t} \tag{11}$$

a capital accumulation constraint,

$$k_t = (1 - \delta)k_{t-1} + \left(1 - \frac{\psi}{2} \left(\frac{x_t}{x_{t-1}} - 1 \right)^2 \right) x_t \tag{12}$$

⁹ This small bond holding cost ensures that net asset position is stationary and allows the model to be solved by a linear solution algorithm.

¹⁰ We ensure that the borrowing constraint is binding by assuming (a) ‘sufficient’ impatience and (b) that shocks hitting the economy are relatively small.

¹¹ We also assume that the entrepreneur does not pay taxes.

where x_t denotes investment, ρ_t^k is the marginal product of capital, and δ_t^e is the entrepreneur's borrowing from the domestic household. Because the entrepreneur is assumed to be impatient relative to the Ricardian household, she faces a borrowing constraint:

$$(1 + r_t^\mu) d_t^e = (1 - \rho^D) M E_t q_{t+1} k_t \pi_{t+1} (1 - \delta) - \rho^D (1 + r_{t-1}^\mu) \frac{d_{t-1}^e}{\pi_t} \tag{13}$$

where ρ^D is a parameter that smooths the effect of borrowing constraint; M is the loan-to-value ratio and q_{t+1} is the expected value of the capital stock in the next period. The amount the entrepreneur can borrow in period t is constrained to a fraction M of the expected value of the undepreciated capital stock at the time the borrowing has to be repaid. The entrepreneur's optimality conditions are equations [viii] to [xiii] in Table 3.

3.2.1. Aggregate households

Aggregate consumption, in either of the two economies, consists of the weighted sum of Ricardian and rule-of-thumb consumption plus the entrepreneur's consumption. Aggregate labour effort is defined as the weighted sum of Ricardian and rule-of-thumb labour efforts.

$$c_t = c_t^e + (1 - \mu) c_t^r + \mu c_t^e \tag{14}$$

$$n_t = (1 - \mu) n_t^r + \mu n_t^e \tag{15}$$

where μ denotes the share of rule-of-thumb households in the economy.

3.3. Firms

In order to capture nominal price rigidities, we differentiate between flexible price wholesale firms and final goods firms that operate under monopolistic competition and face price adjustment costs.

3.3.1. Wholesale firms

Wholesale firms rent capital from entrepreneurs and hire labour services from households. They maximise the following profit function

$$\max p_{h,t} \frac{y_t}{x_{p,t}} - w_t n_t - r_{k,t} k_{t-1} \tag{16}$$

where $p_{h,t} = \frac{P_{h,t}}{P_t}$ is the relative price of home-produced final good and $x_{p,t}$ denotes the price markup of the final over the wholesale good. Wholesale goods production is characterised by a standard Cobb–Douglas production function defined over capital and labour.

$$y_{h,t} = n_t^{1-\alpha} k_{t-1}^\alpha \tag{17}$$

3.3.2. Final goods firms

There are Calvo-style nominal rigidities in prices and wages in the final goods sector. Final good firms buy wholesale goods in competitive markets, differentiate these goods at no cost and sell them at a markup $x_{p,t}$ over their marginal cost. Given the well-understood Calvo mechanism, where $1 - \theta_p$ denotes the probability that a final goods firm is able to set prices in a given period, this setup yields a forward-looking Phillips curve that, after linearisation, can be written as:

$$\log(\pi_{h,t}/\bar{\pi}) = \beta E_t \log(\pi_{h,t+1}/\bar{\pi}) - \frac{(1 - \theta_p)(1 - \beta\theta_p)}{\theta_p} \log(x_{p,t}/\bar{x}_p) \tag{18}$$

The consumer price index is linked to the inflation rate of home-produced goods via the relative price of home-produced goods:

$$\pi_{h,t} = \frac{P_{h,t}}{P_{h,t-1}} \pi_t \tag{19}$$

where $p_{h,t} = \frac{P_{h,t}}{P_t}$.

3.4. Monetary policy in a currency union

Monetary policy follows a simple Taylor-type rule that responds to deviations in CPI inflation from its steady state value.

$$\log(1 + r_t^\mu) = r_R \log(1 + r_{t-1}^\mu) + (1 - r_R) \left(r_\pi \log\left(\frac{\pi_t^\mu}{\bar{\pi}^\mu}\right) + r_y \log\left(\frac{y_t^\mu}{\bar{y}^\mu}\right) + \log(1 + \bar{r}^\mu) \right) \tag{20}$$

where the union-wide target for inflation and output are defined as:

$$\pi_t^\mu = \pi_t^N \pi^{*(1-N)}$$

$$y_t^\mu = y_t^N y_t^{*(1-N)}$$

3.5. Fiscal policy

The fiscal authority funds government spending by raising taxes and by borrowing from domestic households. The public sector faces the following borrowing constraint:

$$tax_t + d_t^g = \frac{P_{h,t}}{P_t} g_t + (1 + r_{t-1}^\mu) \frac{1}{\pi_t} d_{t-1}^g \quad (21)$$

For the baseline model we assume that all government spending is on home-produced goods.¹² Taxes are set according to a simple tax rule where taxes respond with a lag to additional government borrowing, whilst maintaining a balanced budget in the steady state.

$$tax_t = \zeta_g d_{t-1}^g + \bar{g} \quad (22)$$

The fiscal impulse, g_t , is modelled as an AR(1) process that affects the amount of government spending relative to GDP.¹³

$$g_t = g_{s,t} \frac{\bar{g}}{\bar{y}} \quad (23)$$

$$\log(g_{s,t}) = \rho_g \log(g_{s,t-1}) + \epsilon_{g,t} \quad (24)$$

3.6. Market clearing

Home-produced goods are used for government consumption as well as in the production of consumption and investment goods, both at home and abroad. γ is a measure of trade openness linked to the share of home-produced goods in total consumption in Eq. (5): $v = 1 - (1 - N)\gamma$ and $v^* = N\gamma$. The uses of the home-produced good are thus given by

$$y_{h,t} = g_t + (1 - (1 - N)\gamma) p_{h,t}^{-\theta} (c_t + x_t) + (1 - N)\gamma p_{h,t}^{*-\theta} (c_t^* + x_t^*) \quad (25)$$

and analogously for the foreign-produced good

$$y_{f,t} = g_t^* + (1 - N\gamma) p_{f,t}^{*-\theta} (c_t^* + x_t^*) + N\gamma p_{f,t}^{-\theta} (c_t + x_t) \quad (26)$$

Consolidating the household's, the entrepreneur's and government's budget constraints we obtain an expression for the current account in the home country

$$c_t + x_t + p_{h,t} g_t + r_{e,t} b_t^* = (1 + r_{t-1}^\mu) \phi_{t-1} \frac{\pi_{t-1}^\mu}{\pi_t} r_{e,t-1} b_{t-1}^* + p_{h,t} y_{h,t} \quad (27)$$

4. Reconciling the model to the BVAR

We have now built a model that has the required features to allow both consumption and investment to rise in response to a positive government spending shock. The performance of the baseline model, applied to Germany, is assessed using a strategy that minimises the distance between the impulse responses of the BVAR and the impulse responses of the DSGE model similar to [Bodenstein et al. \(2018\)](#). In doing so, we distinguish between calibrated and optimised parameters, which are listed in the top and bottom halves of [Table 4](#), respectively. The latter are optimised to match the impulse responses of the model to those of the German data BVAR. Parameters selected for this task are those that do not affect the steady state of the model but which will allow the model to match the dynamics of German government spending, real GDP, consumption, investment, net trade and the real exchange rate.

Given the values of the calibrated parameters—stacked in the vector θ^c —we estimate the remaining ones—stacked in the vector θ^e —by minimising the weighted distance between the empirical impulse response functions (IRFs) from the BVAR for Germany, denoted by G , and the impulse response function implied by the theoretical model, denoted by $G(\theta^c, \theta^e)$:

$$\hat{\theta}^e = \underset{\theta^e}{\operatorname{argmin}} [G - G(\theta^c, \theta^e)]' \Omega^{-1} [G - G(\theta^c, \theta^e)] \quad (28)$$

The diagonal weighting matrix Ω is obtained from the variance of the median IRF at each observation of the BVAR. Ω penalises those elements of the estimated impulse responses with wide error bands. We minimise the objective (28) over the whole length of the estimated impulse response. In a Bayesian VAR, we do not have a single variance-covariance matrix of the estimated impulse response functions, hence we cannot derive the standard errors associated with our estimates. We can, however, provide a range of parameter estimates associated with the 16 – 84% confidence bands (see [Fig. 6](#)).

Many of the calibrated parameter values are standard in business cycle research and the ability of the model to match the salient features of the analysed subset of the data does not depend on any specific calibrated parameter values. The discount rate

¹² See [Brühlhart and Trionfetti \(2004\)](#) for European Union evidence of a much higher home-bias in government purchases compared to that in private consumption.

¹³ [Corsetti et al. \(2012\)](#) have highlighted the potential role of spending reversals. However, we find no empirical support for this mechanism for Germany, which is the economy that we want our model to match.

Table 4
Model parameters.

Parameter	Description	Value	
<i>Calibrated parameters</i>			
β	Discount rate Ricardian household	1/1.005	
β^e	Discount rate impatient entrepreneur	1/1.0075	
η	Inverse of Frisch elasticity	1	
α	Share of capital in output	0.33	
δ	Depreciation rate	0.025	
\bar{x}_p	Steady state markup prices	1.1	
θ	Trade elasticity	1	
μ	Share of rule-of-thumb agents	0.35	
γ	Openness parameter	0.32	
ϕ^b	Bond holding cost	0.001	
N	Country size	0.25	
$\frac{G}{Y}$	Government to GDP ratio	0.193	
M	Loan-to-value ratio	0.5	
ρ^D	Borrowing constraint smoothing	0.8	
r_R	Taylor rule coefficient on lagged r	0.9	
r_π	Taylor rule coefficient on inflation	2	
r_Y	Taylor rule coefficient on output	0	
ζ_g	Tax rule coefficient	0.5	
<i>Optimised parameters</i>			
			16–84 Range
ρ^G	AR(1) government spending	0.782	[0.720–0.846]
Ψ	Investment adjustment costs	25.9	[25.9–32.3]
ϵ	Consumption habits	0.759	[0.699–0.798]
θ_p	Calvo parameter prices	0.883	[0.863–0.894]

Notes: The range of values for the optimised parameters are based on the 16 – 84% confidence bands for the impulse response functions estimated in Section 2.

for households is set at an annualised rate of 2% while that of impatient entrepreneurs is set at an annualised rate of 3%. The share of capital in output is 0.33 and the depreciation rate is set to the usual 2.5% on a quarterly basis. The share of government consumption in GDP is 0.193 which is the average observation of G/Y over the sample in the German data. The relative size of Germany, N , depends very much on the context of the two-country model. If the ‘foreign’ economy is modelled as the rest of the world, N would need to be close to zero. Since we are interested in whether the model can match spillovers between Germany and other European economies, we set N to 0.25, which is the approximate size of Germany in the European Union. The openness parameter, γ , is calibrated as the share of imports in GDP. Over the sample period, this figure is 0.32 for Germany. γ also determines the degree of home-bias ($1 - \gamma$). The greater is γ , the smaller is the degree of consumption and investment home-bias and the larger will be the spillover from domestic government spending to foreign output. The trade elasticity, θ , which determines the elasticity of substitution between home and foreign-produced goods, is set 1.¹⁴ The share of rule-of-thumb consumers, μ , affects the response of total consumption to a government spending shock. Since consumption of rule-of-thumb consumers rises and that of Ricardian consumers falls in response to a government spending shock, a larger value of μ implies a greater overall response of consumption. We set this parameter to 0.35, which is consistent with the estimated values in Forni et al. (2009). The parameters of the monetary policy rule assume that the central bank reacts only to deviations of inflation from target and changes the policy rate in a very smooth fashion, as in Corsetti et al. (2010) and Corsetti and Müller (2013).

The top two rows of Fig. 7 show the impulse response functions of the DSGE model (red dotted lines) and those of the BVAR along with their corresponding error bands. Given the optimised parameters, the model is able to match the dynamics of government consumption, real GDP, consumption and investment. Where the model struggles to match the data is in the shape, but not in the sign, of the response of net trade and the real exchange rate. In the model, net trade falls, but unlike in the data, most of the fall occurs in the initial period. The model has but one source of deviation from purchasing power parity, namely consumption home-bias. With the real exchange rate only deviating from PPP due to movements in the terms of trade, the model is not able to replicate either the sign or the magnitude of effective real exchange rate in the data.

The bottom two rows of Fig. 7 plot the IRFs of a number of ‘foreign’ variables as well as the union-wide policy rate in response to a government spending shock in the home country. Given the optimised parameters, the DSGE model captures the magnitude and the shape of ‘foreign’ GDP, where the IRF for foreign real GDP is taken from the French response to a German fiscal expansion, as reported in Fig. 4. Even though no attempt has been made to match these IRFs in the optimisation, the magnitude and path of the foreign output response fit French data well. Crucially, our model is consistent with the evidence of there being substantial output spillovers, unlike much of the theoretical literature in this area, presented in Table 1. It is worth noting that while Corsetti et al.

¹⁴ The trade elasticity has a strong influence on the volatility of relative prices following a supply shock. In the case of the estimated government spending shock there is no value of this parameter that allows the model to match the volatility of the real exchange rate. Indeed, using a range of standard values, from 0.5 to 5 yields a similar fit of the model to the data. As a result, this parameter is not optimised formally; a canonical value from the literature is chosen instead.

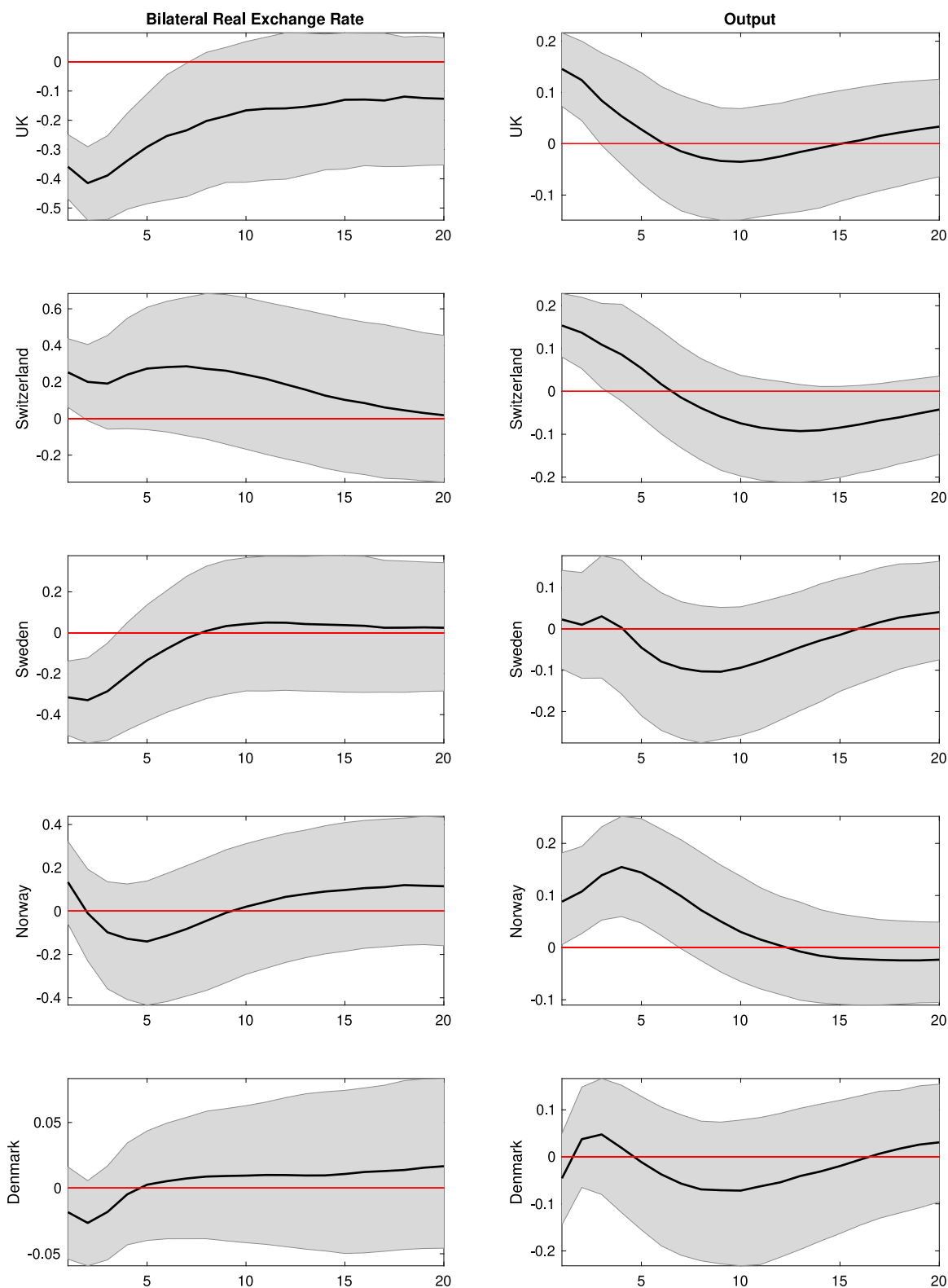


Fig. 6. German government consumption spillovers to non-Euro Area Europe. Note: See Fig. 1. An increase in a country's real exchange rate denotes a real depreciation in that country's real exchange rate.

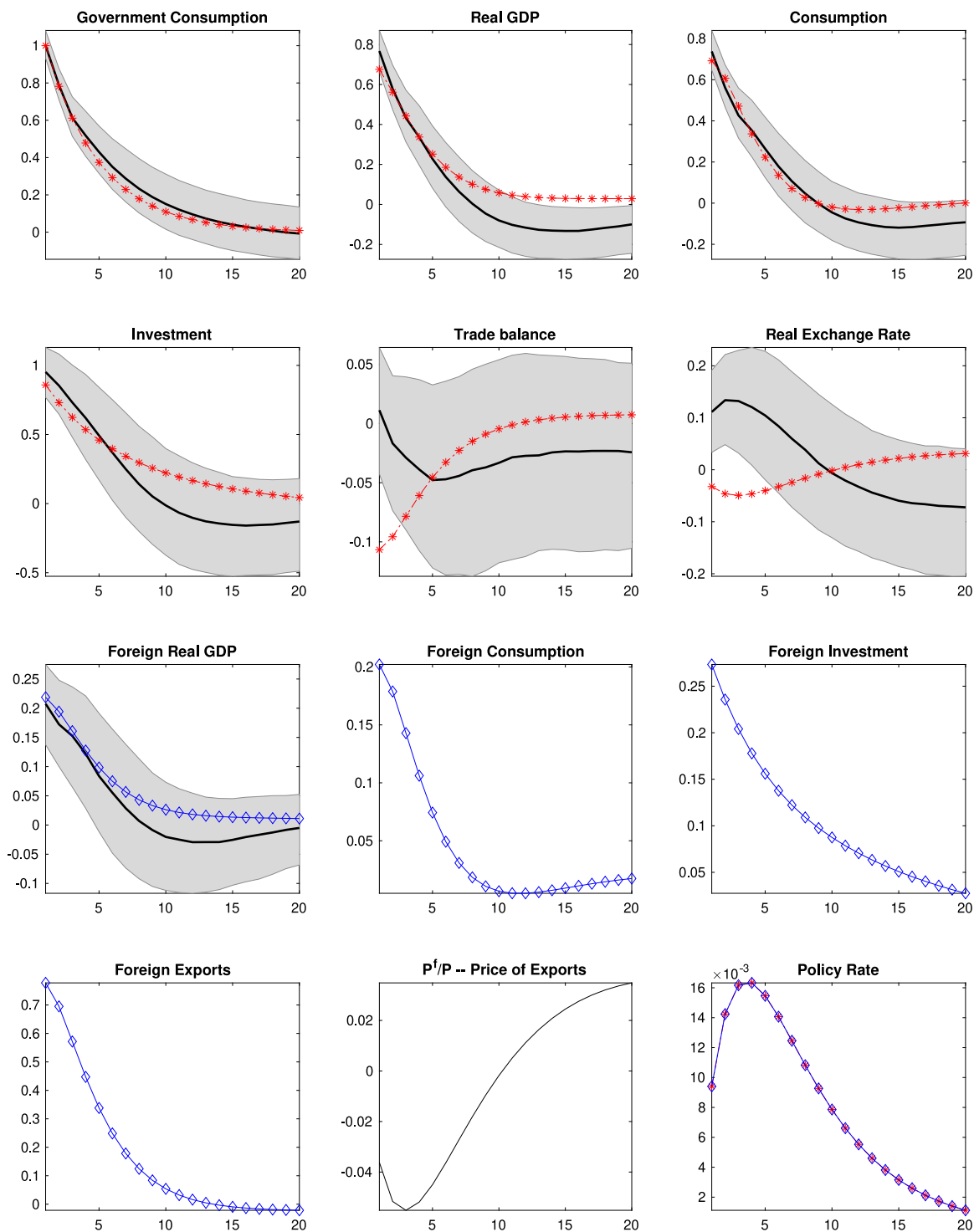


Fig. 7. Unanticipated shock to government consumption spending in Germany — BVAR and DSGE model. Note: The top two rows show IRFs of the DSGE model matched to BVAR. The solid black lines and the grey shaded area corresponds to the German BVAR. The red dashed star line refers to the IRFs generated by the DSGE model. The bottom two rows show IRFs of the DSGE model that are not matched to the BVAR. Foreign Real GDP VAR taken from the reaction of output in France to government spending shock in Germany and the blue dashed diamond line corresponds the IRF of the foreign economy in the DSGE model.

(2010) and Corsetti and Müller (2013) also find substantial spillovers in a parameterised model, their mechanism relies on spending reversals, for which there is little evidence in German data.

5. What affects the size of the international spillover?

There are two channels through which government spending shocks in one country can affect output in another: a direct trade channel and a wealth or intertemporal substitution channel working through relative prices and the interest rate. The trade channel can best be illustrated using the market clearing condition for foreign-produced goods, Eq. (26) above.

$$y_{f,t} = g_t^* + (1 - N\gamma) p_{f,t}^{*-\theta} (c_t^* + x_t^*) + N\gamma p_{f,t}^{-\theta} (c_t + x_t)$$

The third term on the right-hand side accounts for the demand for foreign-produced goods coming from the 'home' country, or foreign-country exports. Exports depend on total consumption and investment in the home country, the relative price of foreign-produced goods in the 'home' country market, $p_{f,t}$, the trade elasticity, θ , the degree of trade openness of the 'home' country, γ as well as the relative size of the 'home' country, N . The bottom row of Fig. 7 shows the conventional result that 'foreign exports' increase in response to a fiscal expansion in the home country. This increase comes about because of higher consumption and investment in the home country. The rise in exports is larger than the subsequent increase in foreign output because, in the two-country model, the 'home' country is relatively small ($N = 0.25$) and not completely open to trade ($\gamma = 0.32$). Thus changes in exports have only a relatively modest effect on output.

A further contributing factor to the rise in exports in the DSGE model is a fall in the price of foreign-produced goods relative to the home country price index. A fiscal expansion in the home country, in the presence of consumption and investment home-bias, lowers the relative price of foreign-produced goods, which increases demand for foreign exports. Fig. 7 shows that the fall in the relative price of foreign goods is quite small. Given the size of the trade elasticity, $\theta = 1$, this is not a key determinant of the size of the international spillover. Indeed, the behaviour of international relative prices is where the model fails to match the data, where spillovers are positive even as the real exchange rate depreciates.¹⁵

Fig. 8 illustrates what happens to international spillovers when we assume a relatively larger home country. The larger is the country doing the fiscal expansion, keeping all other model parameters unchanged, the larger will be the output spillover to the foreign economy. This, in part, helps us to understand why the spillover from the US to France and Italy is larger than that from Germany to these countries.

Another important factor determining the size of the spillover is the degree of trade openness, captured by the parameter γ . Fig. 9 assumes a home country in which imports only make up 15% (as opposed to 32%) of GDP. A less open economy, keeping all other parameters the same, results in a higher domestic fiscal multiplier, but a smaller spillover onto the rest of the world.

The baseline model assumes that all government purchases are on home-produced goods. Fig. 10 relaxes this assumption and treats government spending the same as private consumption, that is, a mix of home and foreign goods. This model generates a somewhat smaller domestic multiplier and, as most government consumption now falls on imported goods, a larger spillover. In summary, the larger and the more open the economy, and the larger is the import component of government spending the larger will be the international spillover of government spending.

The response of monetary policy plays a vital role in efficacy of fiscal policy. It has been argued, by for instance (Christiano et al., 2011), that fiscal policy is particularly effective in the absence of a contemporaneous monetary policy response. The model corresponding to Fig. 11 imposes a monetary policy rule that only responds to inflation with a lag of three quarters. Keeping the remaining model parameters unchanged from their baseline values, the delayed monetary policy response results in a slightly larger domestic fiscal multiplier and a doubling of the output spillover. Without a contemporaneous rise in the union-wide interest rate, foreign consumption rises by more on impact, thus raising the magnitude of the foreign output response.¹⁶

5.1. Flexible exchange rates

Comparing the fiscal policy spillovers across euro and non-EA economies reveals few systematic differences in terms of output. A German fiscal policy shock generates output spillovers in the UK that are very similar to those in France or Italy. The output response of Norway is quantitatively similar to the that of the Netherlands. This suggests that the exchange rate regime, per se, is not a significant contributor to fiscal policy spillovers.

Fig. 12 presents the impulse responses of a model where the home and foreign economy pursue independent monetary policies. To turn the baseline DSGE model into one with a flexible exchange rate, we replace the union-wide Taylor rule, Eq. (20), with two country-specific monetary policy feedback rules. Households in the home country are now able to trade in both home and foreign-currency denominated bonds. A complete set of model equations for the flexible exchange rate model can be found in Table 5 in the appendix.

¹⁵ The working paper version of this paper (Ilori et al., 2020), with a slightly richer model, generates positive spillovers as well as a real depreciation.

¹⁶ The appendix shows the BVAR re-estimated for a sample that excludes the period of low policy rates from the ECB. We find that spillovers from Germany to other EA economies are slightly smaller, in the short sample, thus lending some support to the model's predictions.

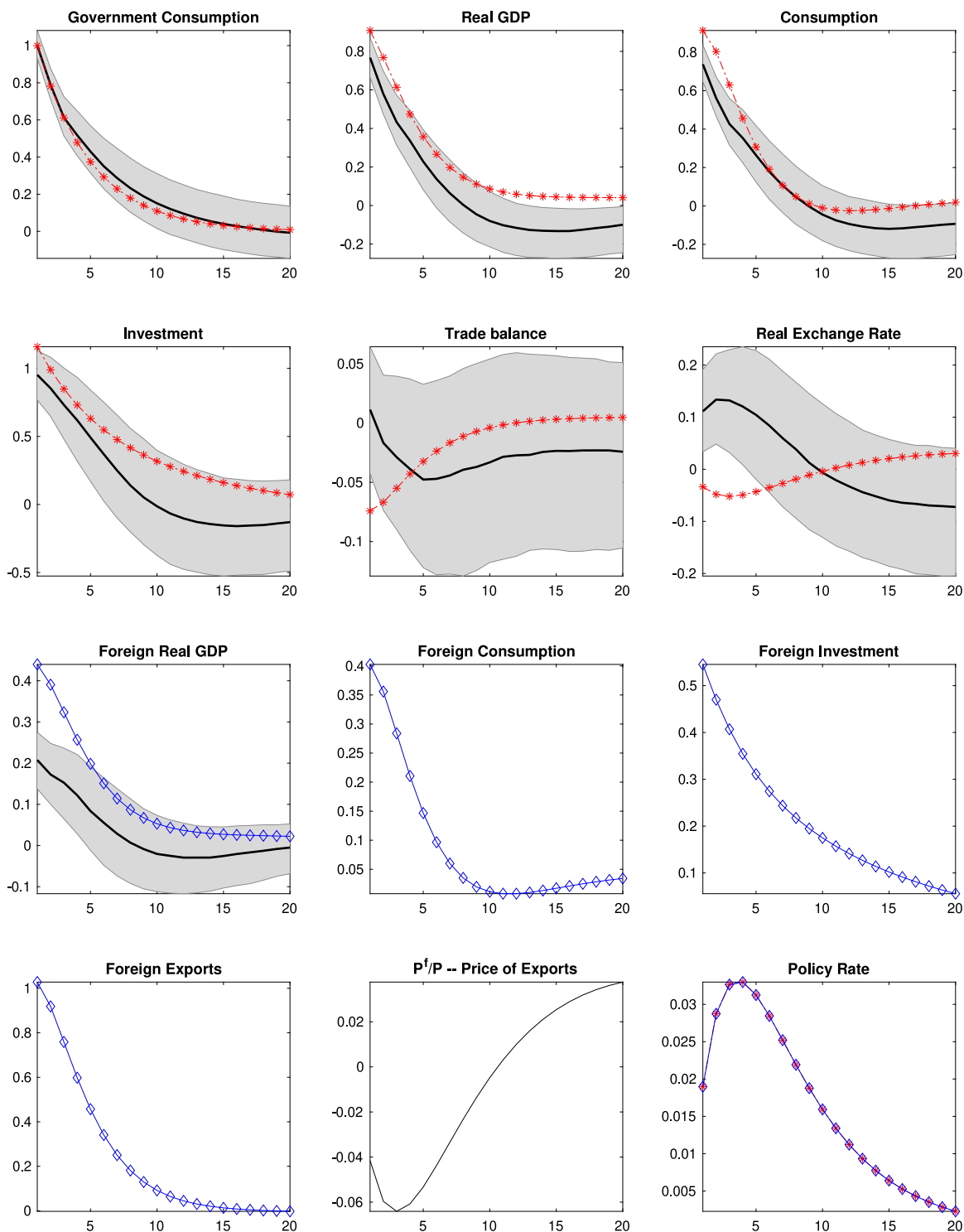


Fig. 8. Unanticipated shock to government consumption spending in Germany — BVAR and DSGE model. Large home country. Note: The simulation takes the calibrated and estimated parameters from Table 4, but assumes that the relative size of the home country is 0.5 instead of 0.25.

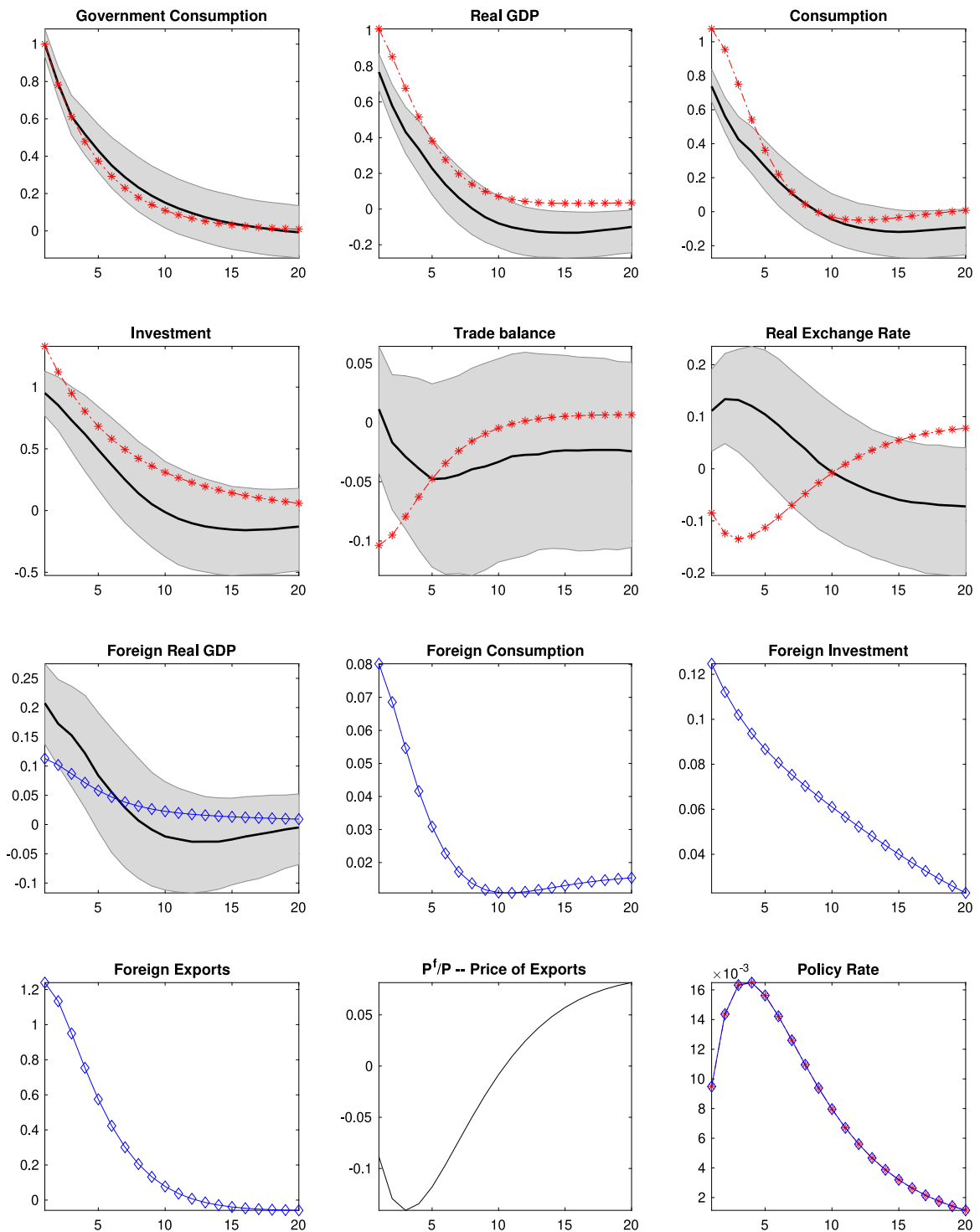


Fig. 9. Unanticipated shock to government consumption spending in Germany — BVAR and DSGE model. Smaller trade openness. Note: The simulation takes the calibrated and estimated parameters from Table 4, but assumes that the trade openness parameter is 0.15 instead of 0.32.

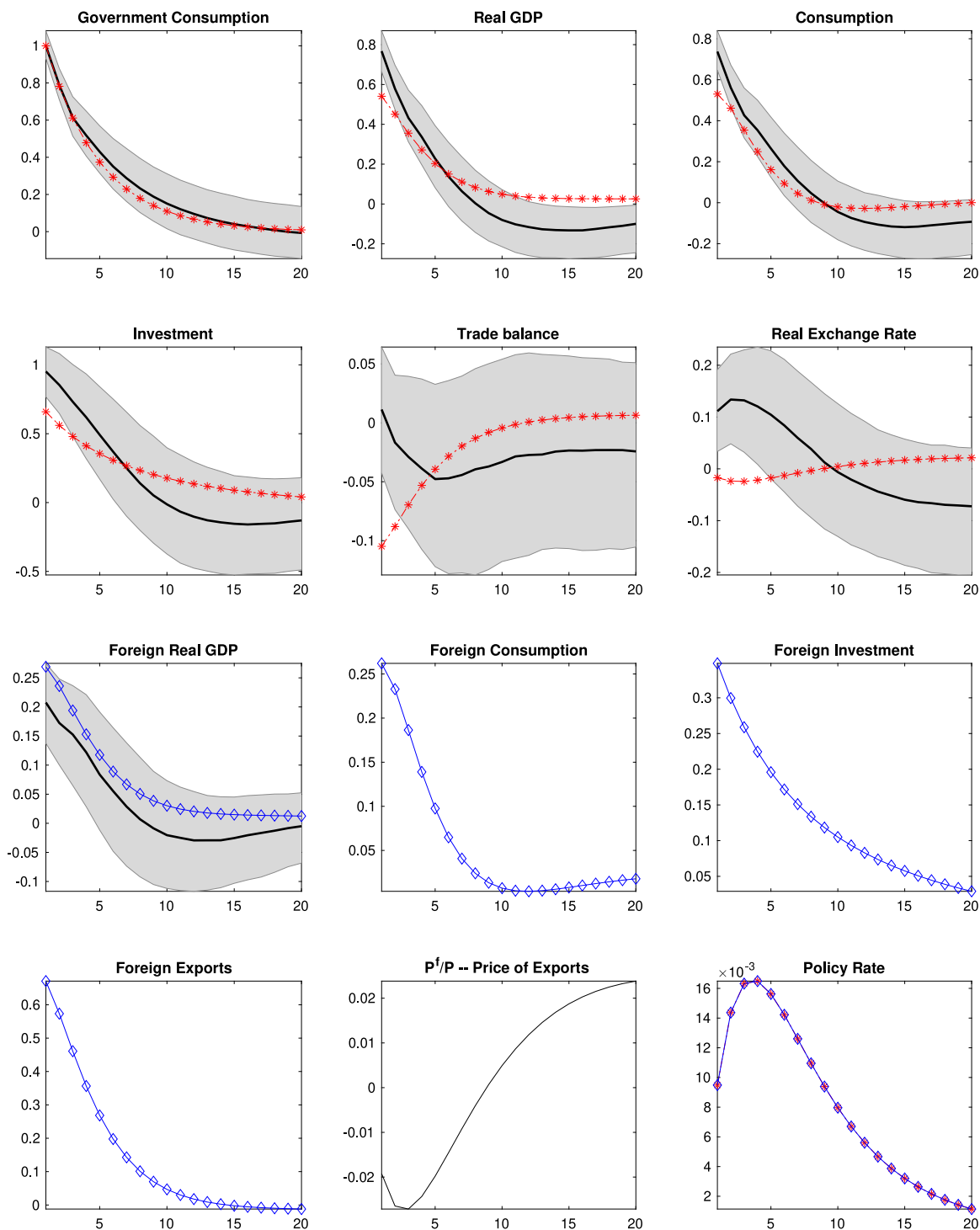


Fig. 10. Unanticipated shock to government consumption spending in Germany — BVAR and DSGE model. Higher import component of government consumption. Note: The simulation takes the calibrated and estimated parameters from Table 4, but assumes that government consumption spending is a CES aggregate of home and foreign intermediate goods.

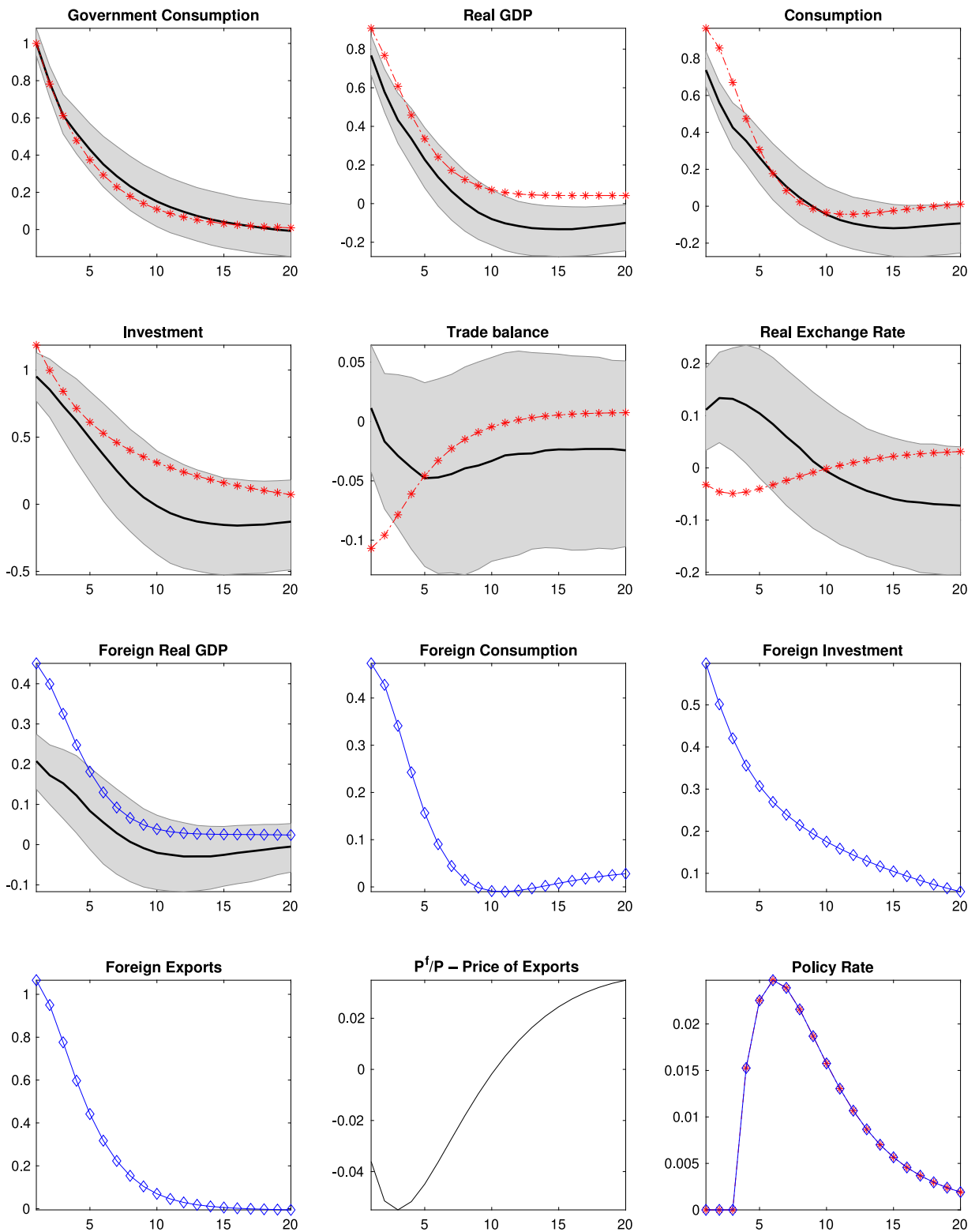


Fig. 11. Unanticipated shock to government consumption spending in Germany — BVAR and DSGE model. Delayed monetary policy response. Note: The simulation takes the calibrated and estimated parameters from Table 4, but assumes that monetary policy only responds to inflation with a lag of 3 periods.

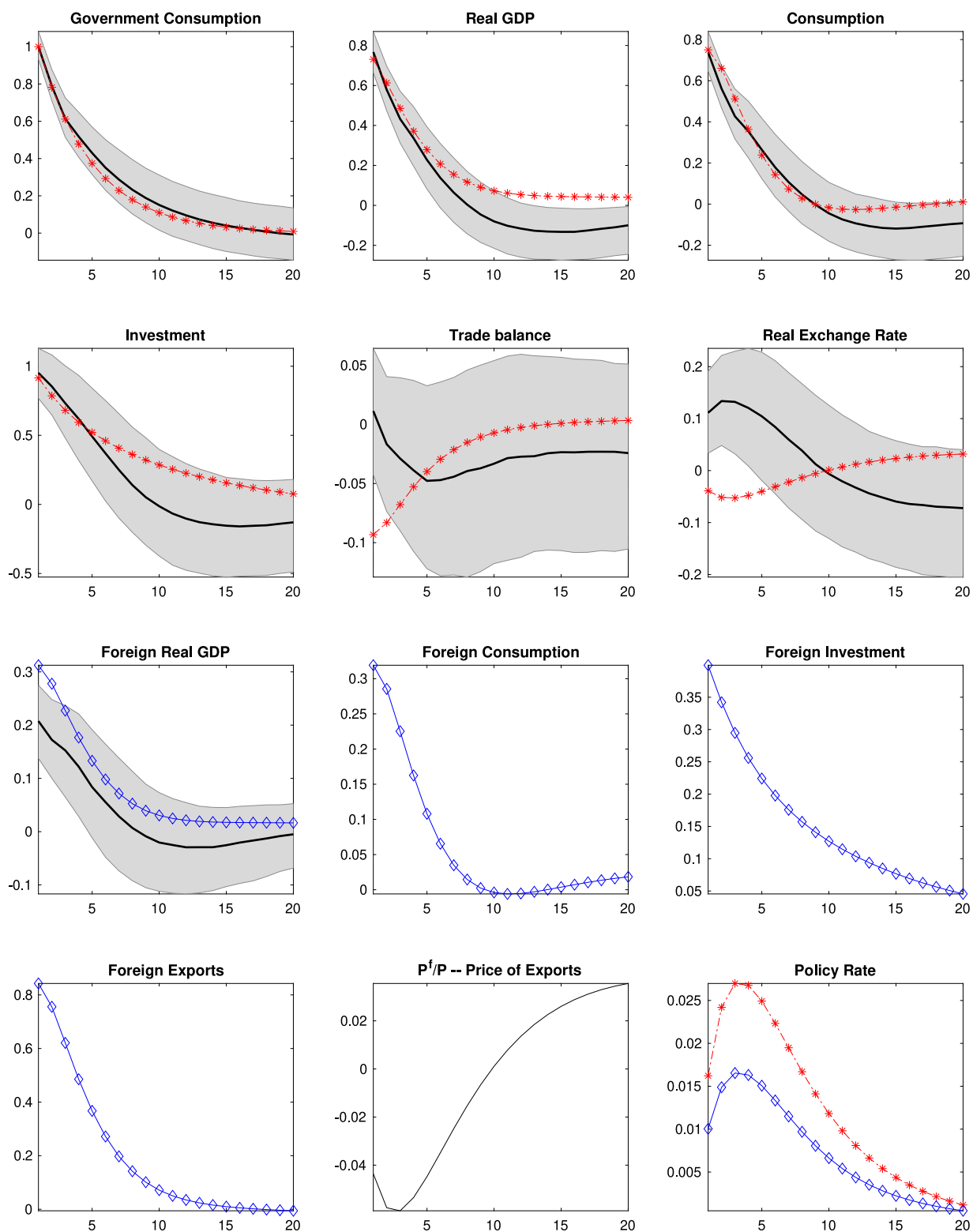


Fig. 12. Unanticipated shock to government consumption spending in Germany — BVAR and DSGE model. Flexible exchange rate. Note: The simulation takes the calibrated and estimated parameters from Table 4, but assumes that both the home and foreign country follow independent monetary policies.

Parameter values remain the same as in the baseline model.¹⁷ The domestic effects of the fiscal expansion are largely the same as in a currency union. With independent monetary policies, home and foreign interest rates diverge, with the latter rising by less than the former. With relatively less monetary tightening, foreign consumption and hence output are able to rise by more than would be the case in the currency union. Given the model and calibration, a flexible exchange rate results in slightly larger international fiscal policy spillovers. The main reason we do not see more of a difference between a currency union and flexible exchange rate model is that the relative price of foreign goods, P^f/P , and the response on the home country, are not affected in a meaningful way.

An important caveat to our analysis is that the DSGE model is unable to explain the behaviour of the real exchange rate, nor the difference in the dynamics of the real exchange rate that we observe between euro area and non-EA countries. In the model, the real exchange rate response to a fiscal expansion is not significantly affected by moving from a currency union to a flexible nominal exchange rate regime. The only reason the real exchange rate can deviate from purchasing power parity in the model is because of consumption home-bias. This turns the real exchange rate into a simple function of the terms of trade. Because the terms of trade are not a direct function of the nominal exchange rate, fixing the latter does not significantly affect the dynamics of the real exchange rate.¹⁸

6. Conclusion

Using data from the late 1990s until 2019 for the United States and Germany, we find that an increase in government spending is expansionary. It raises output, consumption and crowds in private sector investment. The increase in domestic absorption does not come at the cost of an appreciated real exchange rate. Indeed, the relative price of home-produced goods actually falls, causing the real exchange rate and terms of trade to depreciate. The expansionary effects of government spending are not confined to the home economy. Spillovers between the US and the G7 countries are positive, as are those between Germany and her European neighbours. The dynamics of the macroeconomy implied by the BVAR pose a challenge for macroeconomic modelling, with most existing studies finding negligible or even negative spillovers, as pointed out by Cwik and Wieland (2011). We show that a model with heterogeneous households, firms facing borrowing constraints and nominal rigidities can explain the key salient empirical features following a government spending shock. The model sheds light on potential factors determining the size of international spillovers in response to fiscal shocks. Relative country size matters, with bigger economies generating larger spillovers, as does openness to trade and the import content of government spending. The monetary policy response to fiscal policy also matters; a delayed monetary tightening to what is an inflationary fiscal expansion greatly increases the size of the international spillover. Neither the empirical evidence, nor the theoretical model, suggest an important role for the exchange rate regime in determining the size of the spillover effects of fiscal policy shocks.

Criticism of policy proposals for fiscal coordination often hinge on the lack of supporting evidence for international spillovers. Our findings shed new light on this topic by showing not only that the estimated foreign output effects of domestic spending shocks are large but also, that these can be explained with a relatively parsimonious DSGE model.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at <https://doi.org/10.1016/j.euroecorev.2021.103969>.

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¹⁷ To avoid introducing a further change to the model, we assume that the monetary policy reaction functions are the same in term of parameters as those of the currency union.

¹⁸ Klein and Linnemann (2021) suggest that the depreciation we observe in response to a domestic fiscal shock can be explained by an increase in labour productivity caused by a fiscal expansion.

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