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International Portfolio Rebalancing and Fiscal Policy Spillovers

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Abstract

We evaluate, both empirically and theoretically, the spillover effects that debt-financed fiscal policy interventions of the United States have on other economies. We first consider a two-country dynamic stochastic general equilibrium model with international portfolio rebalancing effects arising from an imperfect substitutability between short- and long-term domestic and foreign bonds. The model shows that US fiscal expansions financed by long-term debt issuance would, on net, hinder economic activity in the rest of the world (ROW). This is despite the standard trade channel's net positive effect on the ROW economy given the depreciation in the ROW currency. The fall in ROW output occurs mainly due to the increase in the ROW term premia and long-term rates through the portfolio rebalancing channel. This is because the relative demand for ROW long-term bonds decreases following the increase in the supply of US long-term bonds accompanying the fiscal expansion. Testing the predictions of our theoretical model by using panel regressions and vector autoregressions, we find empirical support for the negative relationship between ROW output and US fiscal spending. The data also confirm the positive relationship between ROW term spreads and US fiscal spending.

Topics: Economic models; Fiscal policy; International topics
JEL codes: E32, E62, F41, F44

Résumé

Nous évaluons sur le plan théorique et empirique les effets d'entraînement sur les autres économies des mesures de relance budgétaire aux États-Unis financées par l'émission de titres. Pour ce faire, nous nous servons en premier lieu d'un modèle dynamique stochastique d'équilibre général à deux pays dans lequel sont intégrés les effets de rééquilibrage des portefeuilles internationaux causés par la substitution imparfaite entre les obligations variant par origine (nationales et étrangères) et horizon (de court terme et de long terme). Le modèle montre que les mesures de relance budgétaire américaines financées avec des titres de dette à long terme finissent par entraver l'activité économique dans le reste du monde, et ce, malgré les retombées positives nettes que le canal traditionnel du commerce international produit sur l'économie du reste du monde par la dépréciation de sa monnaie. Le recul de la production du reste du monde résulte essentiellement de la hausse de la prime de terme et des taux à long terme qui lui est imposée via le rééquilibrage des portefeuilles. En effet, l'augmentation de l'offre d'obligations à long terme qui accompagne aux États-Unis la relance budgétaire provoque une baisse relative de la demande des titres à long terme émis par le reste du monde. En testant la validité des prédictions de notre modèle théorique à l'aide de régressions sur panel et de vecteurs autorégressifs, nous obtenons des données empiriques probantes confirmant la relation négative entre la production du reste du monde et les dépenses de relance budgétaire aux États-Unis. Les données confirment également la relation positive entre le niveau des dépenses de relance budgétaire américaines et les écarts sur les taux pratiqués à différents horizons.

Sujets : Politique budgétaire; Modèles économiques; Questions internationales
Codes JEL : E32, E62, F41, F44

1 Introduction

Following the economic crisis early in the Covid-19 pandemic, the US government engaged in an unprecedented degree of fiscal stimulus, financed primarily by long-term debt creation. The fiscal measures, along with the conventional and unconventional monetary policy actions of the Federal Reserve, were likely critical in avoiding worse macroeconomic outcomes in the US during and after the crisis. However, the nature of the spillover effects of these fiscal measures on other countries is far from certain. On the one hand, currencies of other countries felt significant depreciation pressures during this period due to capital outflows. This may have helped increase net export demand on their goods and services but at a time when these effects were likely more limited due to disruptions in international supply chains, travel restrictions, and the decline in incomes in export markets. On the other hand, these countries' long-term yields increased along with the increase in US yields following the fiscal expansion in the US. In this paper, we argue that the latter effect is due to international portfolio rebalancing and has helped reverse the potentially positive impact of the US fiscal expansion on other economies, especially for those with significant holdings of US government bonds.

To explore this idea, we theoretically and empirically evaluate the spillover effects of debt-financed fiscal policy interventions in the US on other economies. We first consider a two-country New Keynesian dynamic stochastic general equilibrium (DSGE) model with nominal and real frictions and international portfolio rebalancing effects, similar to Alpanda and Kabaca (2020). The portfolio rebalancing effects arise in the model from imperfect substitutability between short- and long-term bond portfolios in each country, as well as between domestic and foreign bonds within these subportfolios. In particular, an increase in the relative supply of US long-term bonds leads to a decrease in long-term bond prices and a corresponding increase in long-term yields in the US, and this occurs even when short-term rates remain constant, since bond supplies directly affect the term premium component of long-term rates.[1]

The model shows that US fiscal expansions, primarily financed by long-term debt issuance, would hinder economic activity in the rest of the world (ROW) due to the increase in the ROW term premiums through the portfolio rebalancing channel. This occurs as the relative demand for ROW long-term bonds decreases following a large-scale fiscal expansion and the resulting increase in the supply of long-term bonds in the US. In addition, the depreciation of ROW currencies in response to a US fiscal expansion causes an increase in their inflation due to exchange rate pass-through. This mechanism prompts an increase in short-term rates as well in ROW economies. The increase in both short- and long-term interest rates in turn suppresses spending and output. For a reasonable calibration, we find that these two negative effects of US fiscal policy spillover dominate the standard fiscal spillovers operating through trade, and US fiscal expansions are, on

[1]This is consistent with the empirical evidence presented by Gagnon et al. (2011) and Greenwood and Vayanos (2010, 2014) regarding the relationship between relative bond supplies and the relative returns on government bonds of different maturities. Note that if all bonds were perfectly substitutable, then exogenous changes in the relative bond supplies would not affect the relative bond prices and yields (Curdia and Woodford, 2011).

net, contractionary for the ROW. We also find that negative GDP spillovers remain when we limit monetary policy reaction to inflation, reflecting that our results are not driven mainly by tighter conventional monetary policy in the ROW.

Our DSGE model also has interesting implications for the *domestic* effects of fiscal policy, since the increase in long-term rates attenuates the stimulatory effects of fiscal policy in the domestic economy as well. This is similar to the standard *crowding out* effects of fiscal policy, but here the crowding out effects are due to higher long-term rather than short-term interest rates and are relevant even when the economy is operating at the zero lower bound (ZLB). The model also points out the importance of coordination between monetary and fiscal authorities when it comes to the implementation of large-scale asset purchases or large-scale fiscal expansions. For example, a central bank's quantitative easing (QE) policy is rendered less robust if the government decides to take advantage of the resulting lower long-term interest rates and bias its fiscal financing towards the issuance of long-term debt. This has indeed happened to some degree in past QE episodes in the US, indicating that the effects of QE would have been larger in the absence of this endogenous type of response from the fiscal authority. Finally, a *helicopter drop* type of policy, which combines a long-term debt-financed fiscal expansion with central bank purchases of long-term government bonds (in exchange for bank reserves, which, in a world with interest on reserves, is synonymous with issuing short-term government debt), can have more robust effects on the economy. We show that this type of coordination avoids the crowding out effects of fiscal policy as the QE policy of the central bank pacifies the increase in long-term interest rates. More critical for our paper, we find that the spillover effects of a helicopter drop policy are also expansionary on the ROW economy as the crowding out effects of the portfolio rebalancing channel is muted.

In the final part of our paper, we empirically test and find support for the main mechanisms identified by our DSGE model. Specifically, panel estimations that use data from G-20 countries (excluding the European Union as a bloc) provide support for the trade and portfolio channels of fiscal spillover in the DSGE model. We find that countries experience a real exchange rate depreciation, an increase in trade balance, and an increase in the term premium when there is a US fiscal expansionary shock. The results are reversed when there is a fiscal contractionary shock. In our panel regressions, we include variables that capture the extent of countries' bilateral trade with the US and their holdings of US government bonds to incorporate the two conflicting mechanisms in our DSGE model (trade versus the portfolio rebalancing channels) and we use the updated Ramey (2011) US fiscal shock series, a commonly used narrative variable that represents exogenous change in the stance of US fiscal policy.

Next, we follow the common practice in the literature and conduct a VAR analysis to determine the effects of US fiscal spending on foreign output. We primarily estimate panel VAR (PVAR) models and find that a US fiscal spending shock, consistent with our DSGE model prediction, generates a negative response for foreign output. The inference is the same when we use an alternative US fiscal policy shock series, a panel VAR model with exogenous variables and the local projections method of Jorda (2005) to measure impulse responses. The results from our PVAR analysis suggest that a one percent increase (decrease) in US fiscal spending is related to a 0.15 to 0.25 percent decrease (increase) in foreign output. This quantitative relationship is similar to that implied by our DSGE model. We also find support for the negative relationship between US fiscal spending shocks and foreign output when we conduct a country-level VAR analysis and when we estimate our panel models with foreign output as the dependent variable.

1.1 Related literature

Our paper is related to the literature on the portfolio balancing channel, which dates back at least to Tobin (1969). Andres et al. (2004) incorporate Tobin's ideas into a DSGE model, generating an imperfect substitution between assets through transaction costs on long-term bonds and segmented asset markets, whereby a subset of agents cannot smooth consumption through the use of short-term bonds. Chen et al. (2012a) and Alpanda and Kabaca (2020) use this kind of a setup to study the domestic and international effects of QE policy in closed- and open-economy contexts, respectively.[2] Hau and Rey (2004) find evidence in support of the portfolio balance channel affecting exchange rates using a VAR framework. Also, Valchev (2015) shows that imperfect substitutability between domestic and foreign short-term bonds helps solve the interest rate parity puzzle.[3] In our paper, we find that the international dimension of this portfolio channel is stronger than any positive effects of US fiscal spending that operates through trade. Specifically, we find that the reliance on long-term US bond issuance after fiscal expansion results in an increase in the term premium, suppressing economic activity abroad.

On the effects of fiscal spending spillovers from a large open economy, empirical findings in the literature are mixed. While studies such as Auerbach and Gorodnichenko (2013), Carmignani (2015), Beetsma and Giuliodori (2011), and Beetsma et al. (2006) find positive international spillover effects using data from OECD countries, Blanchard et al. (2016), Gadatsch et al. (2016), Arce et al. (2016), Benassy-Quere (2006), Arin and Koray (2009), and Arin (2012) draw the opposite inference from their empirical analysis.[4] We should note that the literature mostly focuses on fiscal spillovers among EU economies or pairs of neighbouring countries. Our empirical work by contrast investigates the broader and more widespread spillover effects of fiscal policy.

While the theoretical mechanism of Mundell-Fleming linking fiscal expansion to exchange rate appreciation and a worsening trade balance in the originating country is long-standing, the empirical literature here also offers mixed evidence. Studies such as Kim and Roubini (2008), Monacelli and Perotti (2010), and Ravn et al. (2012), for example, find that local currency depreciates in

[2] Also see Priftis and Vogel (2016) who analyze the effects of QE in the Euro Area using a similar approach.

[3] See also Benes et al. (2013a), Blanchard et al. (2005) and Kumhof (2010), who investigate the portfolio balance channel in open economy models.

[4] It should be noted here that the magnitude and the direction of the spillover in these papers depend on factors such as geographical proximity, the stage of the business cycle, monetary responsiveness, and institutional factors such as openness to trade. We do not include these factors in our empirical analysis and simply find a negative relationship between US fiscal policy and output growth rates of G-20 countries. Similarly, in the DSGE model, we are silent about the monetary reaction of G-20 economies to US fiscal expansion and various other factors that may impact the degree of the fiscal spillover.

response to a fiscal expansion. Our empirical findings and the responses from our DSGE model are consistent with empirical evidence that support the standard Mundell-Fleming theory, indicating local currency appreciation (e.g., Auerbach and Gorodnichenko, 2016). Similarly, our findings are consistent with Monacelli and Perotti (2010), Ravn et al. (2012) and Garcia-Solanes et al. (2011), while Corsetti and Müller (2006) and Kim and Roubini (2008) offer contrary evidence. While the literature is mixed on the effects of US fiscal policy on exchange rates, it agrees that a debt-financed (especially through long-term debt) US fiscal expansions generate higher term premiums in foreign economies (see, Cardarelli and Kose, 2004). The empirical literature on the effects of US policies on portfolio balancing and foreign term premiums offer evidence, for both emerging market and advanced economies, that is consistent with the mechanisms in our model (see, Fratzscher et al., 2016; Lim et al., 2014; Tillman, 2016; Chari et al., 2017; Bluwstein and Canova, 2016; Chen et al., 2012b, 2016; Haberis and Lipinska, 2012; Bhattarai et al., 2017).

The decline in foreign yields during this period suggests that a portfolio rebalancing by international investors was under way as the fall in US long-term yields increased the attractiveness of ROW assets. In their survey of the literature on US unconventional policy, Bhattarai and Neely (2016) note that the portfolio balance channel appears to be an important conduit of unconventional policy, and event studies and VARs have identified, on net, positive international spillover effects from these policies. Similarly, Fratzscher et al. (2016) analyze the effects of the Federal Reserve's QE on portfolio flows in the US and in 52 other countries using high frequency data and find that the policy announcements and asset purchases related to QE2 and QE3 have resulted in portfolio rebalancing towards non-US assets. Similarly, Lim et al. (2014), Tillman (2016), and Chari et al. (2017) find a sizeable role for US unconventional policies in generating capital inflows to emerging markets and appreciation in their currencies. See also Bluwstein and Canova (2016), who find significant international spillover effects from the unconventional policies of the European Central Bank. There are also other studies that find significant international spillover effects from unconventional policies in major advanced economies. See for example, Chen et al. (2012b, 2016), Haberis and Lipinska (2012), and Bhattarai et al. (2017).

The remainder of the paper proceeds as follows. The next section introduces the DSGE model, and Section 3 discusses the parameterization of model parameters and key results obtained from the model. Section 4 presents the empirical tests we conduct based on the implications of our theoretical framework, and Section 5 concludes.

2 Open-Economy DSGE Model

In this section, we build a two-country, large open-economy DSGE model with portfolio balancing effects similar to Alpanda and Kabaca (2020). Each country in the model is populated by two types of households (unrestricted and hand-to-mouth), capital producers, final-goods aggregators, domestic producers, and importers, as well as fiscal and monetary policy rules. As a medium-scale DSGE model, our setup also features various nominal and real rigidities such as price and wage stickiness, indexation of prices and wages to past inflation, habit formation in consumption, adjustment costs in investment, and costs of capital utilization, which are important for capturing the key properties of business cycle dynamics (Christiano et al., 2005; Smets and Wouters, 2007; Adolfson et al., 2008; Justiniano and Preston, 2010).

In what follows, we focus on the features of the model that are related to fiscal policy as well as the portfolio balancing channel and the associated transmission mechanism of fiscal and monetary policy shocks to the domestic and foreign economies through long-term interest rates and the exchange rate. The description of the more standard features of the model, such as production and nominal rigidities, are deferred to Appendix A. Note that we only describe the agents in the *domestic* economy below, but the *foreign* economy is analogous in our setup. When variables from the foreign economy are necessary in the description, we denote them with a superscript asterisk (*).[5]

2.1 Unrestricted households

The economy is populated by a unit measure of infinitely lived unrestricted households indexed by i, whose intertemporal preferences over consumption, $c_{U,t}$, bond portfolio, a_t, and labor supply, $n_{U,t}$, are described by the following expected utility function:

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left(\log \left[c_{U,\tau}(i) - \zeta c_{U,\tau-1} \right] + \xi_a \log a_\tau (i) - \xi_n \frac{n_{U,\tau}(i)^{1+\vartheta}}{1+\vartheta} \right), \tag{1}$$

where t indexes time, $\beta < 1$ is the time-discount parameter, ζ is the external habit parameter for consumption, ϑ is the inverse of the Frisch-elasticity of labor supply, and ξ_a and ξ_n are level parameters that determine the relative importance of the bond portfolio and labor in the utility function, respectively.

The bond portfolio term in the utility function, a_t, is a CES aggregate of subportfolios consisting of short-term government bonds, $a_{S,t}$, and long-term government bonds, $a_{L,t}$:

$$a_t(i) = \left[\gamma_a^{\frac{1}{\lambda_a}} a_{S,t}(i)^{\frac{\lambda_a - 1}{\lambda_a}} + (1-\gamma_a)^{\frac{1}{\lambda_a}} a_{L,t}(i)^{\frac{\lambda_a - 1}{\lambda_a}} \right]^{\frac{\lambda_a}{\lambda_a - 1}}, \tag{2}$$

where γ_a determines the share of short-term bonds in the aggregate portfolio and λ_a is the elasticity of substitution between short- and long-term bonds. Introducing government bonds in the utility function is motivated by the liquidity and safety benefits provided by these securities relative to holding less liquid and riskier assets, similar to Krishnamurthy and Vising-Jorgensen (2012), Valchev (2015), and Alpanda and Kabaca (2020). Imperfect substitution among the various types of government bonds captures the differential convenience benefits generated by these assets, as well as financial institutions' relative portfolio preferences with respect to the different types of government bonds.[6]

[5] In our policy experiments using the DSGE model in Section 4, we treat the US as the *foreign* economy where fiscal shocks originate and the ROW as the *domestic* economy, which is affected by the spillover effects of these policies.

[6] We impose imperfect substitution across the various government bonds of different maturities and currencies

The short-term bond subportfolio is a CES aggregate of short-term *domestic* government bonds, $B_{HS,t}$, and short-term *foreign* government bonds, $B_{FS,t}$:

$$a_{S,t}(i) = \left[\gamma_S^{\frac{1}{\lambda_S}} \left(\frac{B_{HS,t}(i)}{P_t} \right)^{\frac{\lambda_S - 1}{\lambda_S}} + (1-\gamma_S)^{\frac{1}{\lambda_S}} \left(\frac{e_t B_{FS,t}(i)}{P_t} \right)^{\frac{\lambda_S - 1}{\lambda_S}} \right]^{\frac{\lambda_S}{\lambda_S - 1}}, \tag{3}$$

where P_t is the aggregate price level, e_t is the nominal exchange rate (in units of domestic currency per unit of foreign currency), γ_S determines the share of domestic bonds in the short-term bond subportfolio, and λ_S is the elasticity of substitution between domestic and foreign short-term bonds. Similarly, the long-term bond subportfolio is a CES aggregate of long-term domestic government bonds, $q_{L,t}B_{HL,t}$, and long-term foreign government bonds, $q^*_{L,t}B_{FL,t}$:

$$a_{L,t}(i) = \left[\gamma_L^{\frac{1}{\lambda_L}} \left(\frac{q_{L,t}B_{HL,t}(i)}{P_t} \right)^{\frac{\lambda_L - 1}{\lambda_L}} + (1-\gamma_L)^{\frac{1}{\lambda_L}} \left(\frac{e_t q^*_{L,t} B_{FL,t}(i)}{P_t} \right)^{\frac{\lambda_L - 1}{\lambda_L}} \right]^{\frac{\lambda_L}{\lambda_L - 1}}, \tag{4}$$

where $q_{L,t}$ and $q^*_{L,t}$ denote the relative prices of real domestic and foreign long-term bonds, respectively.[7] Note that long-term bonds are modeled as perpetuities that pay a coupon payment of 1 unit in the first period after issuance, and their coupon payments decay by a factor of κ in each period after that, as in Woodford (2001).[8] Thus, the nominal yields on the long-term bonds, $R_{L,t}$ and $R^*_{L,t}$, are related to the relative bond prices as

$$R_{L,t} = \frac{1}{q_{L,t}} + \kappa, \text{ and } R^*_{L,t} = \frac{1}{q^*_{L,t}} + \kappa. \tag{5}$$

In the long-term bond subportfolio, γ_L determines the share of domestic bonds and λ_L is the elasticity of substitution between domestic and foreign long-term bonds.

using a nested CES structure, as in Alpanda and Kabaca (2020). Valchev (2015) features portfolio adjustment costs with a CES specification that enter the budget constraint of households, while Chen et al. (2012a) use a segmented markets approach to generate imperfect substitutability between bonds. Alpanda and Kabaca (2020) show that these approaches yield similar dynamics with respect to a QE shock in a closed-economy setup. Our choice of using the "bonds-in-utility" approach is also partly for convenience, since a segmented markets approach in our model would require introducing multiple types of "restricted agents" in order to adequately capture the imperfect substitutability among the four types of government bonds available. See also Harrison (2011) and Chin et al. (2015), who capture imperfect asset substitutability in the objective function of portfolio managers who sell mutual fund shares backed by bonds to households, instead of within the utility function of households directly. Vitek (2014) follows a similar strategy to ours for capturing portfolio balance effects in households' utility but focuses on portfolio balancing between government bonds and equity.

[7] For the notation related to long-term bonds, we follow the convention in Chen et al. (2012a). In particular, the price and quantity of bonds are denoted by $q_{L,t}$ and $B_{L,t}$, respectively, where the former is a *relative* price while the latter is denoted in *nominal* terms. This is without loss of generality, and one can define the bond price in nominal terms and the quantity in real terms. See the online appendix of Alpanda and Kabaca (2020) for more on this issue.

[8] Note that there are no coupon payments in the period of the bonds' issuance, and the coupon payments in the subsequent periods occur *before* the bonds are traded among agents. Thus, the prices of long-term bonds in the model represent *ex coupon*, and not *cum coupon*, prices.

The unrestricted households' period budget constraint is given by

$$c_{U,t}\left(i\right)+q_t\left[k_t\left(i\right)-\left(1-\delta\right)k_{t-1}\left(i\right)\right]+\frac{B_{HS,t}\left(i\right)}{P_t}+\frac{e_tB_{FS,t}\left(i\right)}{P_t}+\frac{q_{L,t}B_{HL,t}\left(i\right)}{P_t}+\frac{e_tq^*_{L,t}B_{FL,t}\left(i\right)}{P_t} \tag{6}$$
$$\leq\left(1-\tau_n\right)\frac{W_{U,t}\left(i\right)}{P_t}n_{U,t}\left(i\right)+\left(1-\tau_k\right)r_{k,t}k_{t-1}\left(i\right)+\tau_k\delta k_{t-1}\left(i\right)+\frac{R_{t-1}B_{HS,t-1}\left(i\right)}{P_t}$$
$$+\frac{e_tR^*_{t-1}B_{FS,t-1}\left(i\right)}{P_t}+\frac{\left(1+\kappa q_{L,t}\right)B_{HL,t-1}\left(i\right)}{P_t}+\frac{e_t\left(1+\kappa q^*_{L,t}\right)B_{FL,t-1}\left(i\right)}{P_t}$$
$$+\frac{\Pi_{h,t}}{P_t}+\frac{\Pi_{f,t}}{P_t}+tr_{U,t}-\frac{\kappa_w}{2}\left(\frac{W_{U,t}\left(i\right)/W_{U,t-1}\left(i\right)}{\pi_{t-1}^{\varsigma_w}\pi^{1-\varsigma_w}}-1\right)^2\frac{W_{U,t}}{P_t}n_{U,t},$$

where k_t is the capital stock, q_t is the relative price of capital, $W_{U,t}$ is the nominal wage rate of unrestricted households, and $r_{k,t}$ is the rental rate of capital. τ_n and τ_k denote the tax rates on labor and capital income, where depreciation is deductible from the latter. Short-term domestic and foreign bonds pay pre-determined interest rates of R_{t-1} and R^*_{t-1}, respectively. Long-term bonds are tradable each period, which allows us to write them in a recursive format in the budget constraint above.[9] $\Pi_{h,t}$ and $\Pi_{f,t}$ denote the profits of monopolistically competitive domestic producers and importers, while $tr_{U,t}$ is real lump-sum transfers from the government to unrestricted households.

Unrestricted households possess market power in the labor market and supply heterogeneous labor services, which are aggregated into a homogeneous labor service by perfectly competitive labor intermediaries, who in turn rent these labor services to goods producers. Households face quadratic adjustment costs when changing nominal wages à la Rotemberg (1982), which introduces nominal wage stickiness into the model. In the wage adjustment cost specification described above (the last term in the budget constraint), κ_w is a scale parameter, $\pi_t = P_t/P_{t-1}$ refers to the aggregate inflation factor, and ς_w determines the degree of indexation of wage adjustments to past inflation. We provide further details on the model features regarding labor intermediaries and wage rigidities in Appendix A.

The unrestricted households' objective is to maximize utility subject to the budget constraint, the labor demand curve of labor intermediaries, and appropriate no-Ponzi conditions.

2.1.1 Term premium and long-term interest rates

The unrestricted agents' optimality conditions with respect to domestic short- and long-term bonds are given by

$$\lambda_{U,t}=\beta E_t\left[\lambda_{U,t+1}\frac{R_t}{\pi_{t+1}}\right]+\frac{\xi_a}{a_t}\frac{\partial a_t}{\partial a_{S,t}}\frac{\partial a_{S,t}}{\partial b_{HS,t}}, \tag{7}$$
$$q_{L,t}\lambda_{U,t}=\beta E_t\left[\lambda_{U,t+1}\frac{R_{L,t+1}q_{L,t+1}}{\pi_{t+1}}\right]+\frac{\xi_a}{a_t}\frac{\partial a_t}{\partial a_{L,t}}\frac{\partial a_{L,t}}{\partial b_{HL,t}}, \tag{8}$$

[9] See the online appendix of Alpanda and Kabaca (2020) for more on this issue.

where $\lambda_{U,t}$ is the Lagrange multiplier on the budget constraint and real domestic bond holdings are defined as $b_{HS,t} = B_{HS,t}/P_t$ and $b_{HL,t} = B_{HL,t}/P_t$. The corresponding optimality conditions for their foreign short- and long-term bond holdings are

$$rer_t \lambda_{U,t} = \beta E_t \left[\lambda_{U,t+1} rer_{t+1} \frac{R_t^*}{\pi_{t+1}^*} \right] + \frac{\xi_a}{a_t} \frac{\partial a_t}{\partial a_{S,t}} \frac{\partial a_{S,t}}{\partial b_{FS,t}}, \tag{9}$$

$$rer_t q_{L,t}^* \lambda_{U,t} = \beta E_t \left[\lambda_{U,t+1} rer_{t+1} \frac{1 + \kappa q_{L,t+1}^*}{\pi_{t+1}^*} \right] + \frac{\xi_a}{a_t} \frac{\partial a_t}{\partial a_{L,t}} \frac{\partial a_{L,t}}{\partial b_{FL,t}}, \tag{10}$$

where the real exchange rate is defined as $rer_t = e_t P_t^*/P_t$ and real foreign bonds are defined as $b_{FS,t} = B_{FS,t}/P_t^*$, and $b_{FL,t} = B_{FL,t}/P_t^*$.

The first two of these expressions above can be log-linearized and combined to generate a recursive expression for the yield on long-term bonds as

$$\widehat{R}_{L,t} = \frac{\kappa}{R_L} \widehat{R}_{L,t+1} + \left(1 - \frac{\kappa}{R_L}\right) \left(\widehat{R}_t + \widehat{T}_t\right), \tag{11}$$

where the term, $\widehat{T}_t$, is given by

$$\widehat{T}_t = \left(\frac{\pi}{\beta R} - 1\right) \left\{ \frac{1}{\lambda_a} \left(\widehat{a}_{L,t} - \widehat{a}_{S,t}\right) - \frac{1}{\lambda_L} \left[\widehat{a}_{L,t} - \left(\widehat{q}_{L,t} + \widehat{b}_{HL,t}\right)\right] + \frac{1}{\lambda_S} \left(\widehat{a}_{S,t} - \widehat{b}_{HS,t}\right) \right\}. \tag{12}$$

Iterating on (11), one can show that the yield on long-term bonds depends on current and expected future short-term rates (expectations hypothesis), plus a term premium component as

$$\widehat{R}_{L,t} = \left(1 - \frac{\kappa}{R_L}\right) E_t \sum_{s=0}^{\infty} \left(\frac{\kappa}{R_L}\right)^s \widehat{R}_{t+s} + \widehat{tp}_t, \tag{13}$$

where the term premium, $\widehat{tp}_t$, is given by

$$\widehat{tp}_t = \left(1 - \frac{\kappa}{R_L}\right) E_t \sum_{s=0}^{\infty} \left(\frac{\kappa}{R_L}\right)^s \widehat{T}_{t+s}. \tag{14}$$

Thus, within the context of our model, the term premium is the discounted sum of the $\widehat{T}_t$ terms, with the individual $\widehat{T}_t$'s capturing the contribution of each period's relative bond holdings to the overall term premium.[10]

The equations above imply that, even when the short rate is kept constant (e.g., at the ZLB), the long rate can be altered by changing the maturity composition of the bonds outstanding. In

[10] Note also that if the elasticity of substitution across the different assets are equal to each other (i.e., $\lambda_a = \lambda_S = \lambda_L$), the expression for the long-term bond in (13) reduces to

$$\widehat{R}_{L,t} = \left(1 - \frac{\kappa}{R_L}\right) E_t \sum_{s=0}^{\infty} \left(\frac{\kappa}{R_L}\right)^s \left[\widehat{R}_{t+s} + \left(\frac{\pi}{\beta R} - 1\right) \frac{1}{\lambda_a} \left(\widehat{q}_{L,t+s} + \widehat{b}_{HL,t+s} - \widehat{b}_{HS,t+s}\right)\right],$$

which is similar to the expression in the closed-economy setup of Chen et al. (2012a).

particular, long-term rates would tend to increase if expansionary fiscal policy is financed primarily through the issuance of long-term bonds, while they would decrease if fiscal policy is financed by short-term bond issuance.

How does the foreign term premium affect the domestic term premium? First, let us log-linearize and combine equations 9 and 10 to obtain a recursive expression for the foreign yield on long-term bonds:

$$\widehat{R}^*_{L,t} = \frac{\kappa}{R_L}\widehat{R}^*_{L,t+1} + \left(1 - \frac{\kappa}{R_L}\right)\left(\widehat{R}^*_t + \widehat{T}^*_t\right), \tag{15}$$

where the term, $\widehat{T}^*_t$, is given by

$$\widehat{T}^*_t = \left(\frac{\pi}{\beta R} - 1\right)\left\{\frac{1}{\lambda_a}\left(\widehat{a}_{L,t} - \widehat{a}_{S,t}\right) - \frac{1}{\lambda_L}\left[\widehat{a}_{L,t} - \left(\widehat{rer}_t + \widehat{q}^*_{L,t} + \widehat{b}_{FL,t}\right)\right] + \frac{1}{\lambda_S}\left(\widehat{a}_{S,t} - \left(\widehat{rer}_t + \widehat{b}_{FS,t}\right)\right)\right\}. \tag{16}$$

We can obtain a relationship between domestic and foreign premia by combining equations 12 and 16 as in the following:

$$\widehat{T}_t = \widehat{T}^*_t + \left(\frac{\pi}{\beta R} - 1\right)\left\{\frac{1}{\lambda_L}\left(\widehat{q}_{L,t} + \widehat{b}_{HL,t} - \left(\widehat{rer}_t + \widehat{q}^*_{L,t} + \widehat{b}_{FL,t}\right)\right) + \frac{1}{\lambda_S}\left(\widehat{b}_{HS,t} - \left(\widehat{rer}_t + \widehat{b}_{FS,t}\right)\right)\right\}. \tag{17}$$

The above equation suggests that term premium spillovers from foreign to domestic yields will depend on the substitution between home and foreign assets in both short- and long-term maturities. Domestic premium moves in-tandem with foreign premium when home and foreign bonds are perfectly substitutable in both maturities ($\lambda_S = \lambda_L = \infty$).

2.1.2 Exchange rate determination

The exchange rate is determined through arbitrage between home and foreign assets. Equations 7 and 9 can be log-linearized and combined to yield a short-term (modified) uncovered interest parity (UIP) condition:

$$\widehat{R}_t - \widehat{R}^*_t = E_t\widehat{d}_{t+1} + \left(\frac{\pi}{\beta R} - 1\right)\frac{1}{\lambda_S}\left[\widehat{b}_{HS,t} - \left(\widehat{rer}_t + \widehat{b}_{FS,t}\right)\right], \tag{18}$$

where $\widehat{d}_t = \widehat{e}_t - \widehat{e}_{t-1}$ denotes the nominal depreciation rate of the ROW currency. The above condition implies that the country risk premium is determined by the relative holdings of short-term domestic and foreign bonds. In the case of a fiscal shock financed by issuing long-term debt, this premium will not affect the exchange rate much as the short-term debt remains fixed. However, if the fiscal shock is financed by short-term debt, the country risk premium will have appreciationary pressures on the home currency as the stock of foreign bonds increases in portfolios relative to home bonds. We examine the difference in maturity of debt financing further in section 3.2.5.

Note that the exchange rate has to also hold between long-term home and foreign assets. We can combine the short-term UIP condition with equation 17 to obtain a long-term (modified) UIP condition:

$$\widehat{R}_t + \widehat{T}_t - \left(\widehat{R}^*_t + \widehat{T}^*_t\right) = E_t\widehat{d}_{t+1} + \left(\frac{\pi}{\beta R} - 1\right)\frac{1}{\lambda_S}\left[\widehat{q}_{L,t} + \widehat{b}_{HL,t} - \left(\widehat{rer}_t + \widehat{q}^*_{L,t} + \widehat{b}_{FL,t}\right)\right]. \tag{19}$$

The above equation implies that the one-period holding return differential between home and foreign long-term bonds has to be equal to the expected depreciation plus the premium that agents require depending on their relative holdings of these bonds.

2.1.3 Bond yields and consumption demand

Changes in long-term interest rates also affect consumption demand in our setup. To see this, observe that the unconstrained households' first-order conditions with respect to the four types of bonds can be log-linearized and combined to yield an *IS* curve equation of the form:

$$\widehat{\lambda}_{U,t} = \beta\frac{R}{\pi}\left(E_t\widehat{\lambda}_{U,t+1} + \widehat{R}^a_t - E_t\widehat{\pi}_{t+1}\right) - \left(1 - \beta\frac{R}{\pi}\right)\widehat{a}_t, \tag{20}$$

where $\widehat{R}^a_t$ is the return on the bond portfolio given by

$$\begin{aligned}\widehat{R}^a_t \equiv\ & \gamma_a\gamma_S\widehat{R}_t + (1-\gamma_a)\gamma_L\left(\widehat{R}_t + \widehat{T}_t\right) \\ & + \gamma_a(1-\gamma_S)\left(\widehat{R}^*_t + E_t\widehat{d}_{t+1}\right) + (1-\gamma_a)(1-\gamma_L)\left(\widehat{R}^*_t + \widehat{T}^*_t + E_t\widehat{d}_{t+1}\right),\end{aligned} \tag{21}$$

with the nominal depreciation rate defined as $\widehat{d}_t = \widehat{e}_t - \widehat{e}_{t-1}$. Note that in the absence of imperfect substitutability between the four types of bonds, we would have

$$\widehat{R}_t = \widehat{R}_t + \widehat{T}_t = \widehat{R}^*_t + E_t\widehat{d}_{t+1} = \widehat{R}^*_t + \widehat{T}^*_t + E_t\widehat{d}_{t+1}, \tag{22}$$

and thus, the *IS* curve would reduce to

$$\widehat{\lambda}_{U,t} = \beta\frac{R}{\pi}\left(E_t\widehat{\lambda}_{U,t+1} + \widehat{R}_t - E_t\widehat{\pi}_{t+1}\right) - \left(1 - \beta\frac{R}{\pi}\right)\widehat{a}_t, \tag{23}$$

with $\widehat{a}_t$ appearing in the *IS* curve as a result of the bonds-in-utility assumption.[11] With imperfect substitutability, however, the relevant interest rate in the *IS* equation is a function of not only the domestic short rate, but also of the domestic long rate and foreign interest rates. Furthermore, the importance of each interest rate for consumption demand is linked to the portfolio share of the related bonds.

As we outline in Section 4, an expansionary fiscal policy shock in the US economy results in an

[11] In the absence of utility benefits of bonds, the real interest rate at the steady state would be equal to $R/\pi = 1/\beta$, and the above expression would reduce to the standard *IS* curve in the New Keynesian literature. Since $R/\pi < 1/\beta$ in our model, signaling short-term interest rate changes in the future by the central bank does not affect current demand as much. Thus, this extra discounting generated by the bonds-in-utility specification can partly help solve the "forward guidance puzzle" (Michaillat and Saez, 2021).

increase in short-term interest rates because inflation and aggregate output increase, similar to a standard international DSGE setup *without* portfolio balance effects. But here, even when short-term interest rates are constrained at the ZLB, both US and ROW term premiums increase and the consumption demand of unconstrained agents is adversely affected when the fiscal expansion is financed primarily by long-term debt issuance. There is a moderating effect on consumption demand based on the net increase in the portfolio size, a_t, but this effect is relatively small since $1-\beta R/\pi$ is slightly above but very close to 0, given our calibration.

The expansionary fiscal shock also leads to currency appreciation for the US economy similar to a standard setup, which reduces US net exports. Despite these adverse effects from unrestricted households' consumption and net exports, the US aggregate output increases due to the direct impact of the expansionary government expenditure as well as the positive response of hand-to-mouth households' consumption. Unlike the standard setup, however, aggregate output in the ROW economy declines, since the increase in its net export demand is not enough to reverse the adverse effects of the shock on their consumption demand through short- and long-term interest rates.

2.2 Restricted households

The economy is also populated by a unit measure of infinitely lived restricted (i.e., hand-to-mouth) households, who do not own any bonds and whose intertemporal preferences over consumption, $c_{R,t}$, and labor supply, $n_{R,t}$, are described by the following expected utility function:

$$E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left(\log\left[c_{R,\tau}(i) - \zeta c_{R,\tau-1}\right] - \xi_n \frac{n_{R,\tau}(i)^{1+\vartheta}}{1+\vartheta} \right). \tag{24}$$

The restricted households' period budget constraint is given by

$$c_{R,t}(i) \leq (1-\tau_n) \frac{W_{R,t}(i)}{P_t} n_{R,t}(i) + tr_{R,t} - \frac{\kappa_w}{2} \left(\frac{W_{R,t}(i)/W_{R,t-1}(i)}{\pi_{t-1}^{\varsigma_w} \pi^{1-\varsigma_w}} - 1 \right)^2 \frac{W_{R,t}}{P_t} n_{R,t}, \tag{25}$$

where $W_{R,t}$ is the nominal wage rate of restricted households, $tr_{R,t}$ is their real lump-sum transfers from the government, and the last term is their quadratic wage adjustment costs. The first-order conditions of hand-to-mouth agents are standard, and are relegated to Appendix A.

2.3 Fiscal policy

Government expenditure, g_t, is composed of two components: $g_t = g_{c,t} + g_{i,t}$, where $g_{c,t}$ is government consumption and $g_{i,t}$ is government investment.[12] Both components are assumed to follow exogenous

[12] Without loss of generality, one can assume that government consumption enters households' utility in a separable manner and is treated as an externality by households.

AR(1) processes as

$$\log g_{c,t} = (1-\rho_{gc})\log g_c + \rho_{gc}\log g_{c,t-1} + \varepsilon_{gc,t}, \tag{26}$$

$$\log g_{i,t} = (1-\rho_{gi})\log g_i + \rho_{gi}\log g_{i,t-1} + \varepsilon_{gi,t}, \tag{27}$$

where ρ_{gc} and ρ_{gi} are persistence parameters and $\varepsilon_{gc,t}$ and $\varepsilon_{gi,t}$ are *i.i.d.* shock innovations.

The law of motion linking government investment to the stock of government capital, $k_{g,t}$, is given by

$$k_{g,t} = (1-\delta_g)\,k_{g,t-1} + g_{i,t}, \tag{28}$$

where δ_g is the depreciation rate for government capital. As explained further in Appendix A, the productivity term in the firms' production function is affected by the stock of government capital, as in Leeper et al. (2010). In particular, firm j's production function is given by

$$y_t(j) = \left(z_t k_{g,t-1}^{\Psi}\right)\left[u_t(j)\,k_{t-1}(j)\right]^{\alpha}\left[n_{H,t}(j)^{\Phi}\,n_{L,t}(j)^{1-\Phi}\right]^{1-\alpha} - f, \tag{29}$$

where the total factor productivity (TFP) term has two components: z_t, which follows an exogenous AR(1) process, and lagged government capital, $k_{g,t-1}$, which affects TFP, with parameter Ψ determining the strength of the impact of government capital on TFP.[13]

The (consolidated) government budget constraint is given by

$$\frac{P_{h,t}}{P_t}g_t + \frac{R_{t-1}}{\pi_t}b_{S,t-1} + \frac{R_{L,t}}{\pi_t}q_{L,t}b_{L,t-1} + tr_t = tax_t + b_{S,t} + q_{L,t}b_{L,t}, \tag{30}$$

where $P_{h,t}$ is the price of domestic goods, $tr_t = tr_{U,t} + tr_{R,t}$ denotes aggregate transfers from the government to households, and tax_t is aggregate taxes given by

$$tax_t = \tau_n\left(w_{U,t}n_{U,t} + w_{R,t}n_{R,t}\right) + \tau_k\left(r_{k,t}-\delta\right)k_{t-1}, \tag{31}$$

with real wages of each agent given by $w_{U,t} = W_{U,t}/P_t$ and $w_{R,t} = W_{R,t}/P_t$.

Transfers to the individual types of households are given by

$$tr_{m,t} = \Xi_m y\left(\frac{y_t}{y}\right)^{-\varrho_y}\left(\frac{b_{S,t-1}+q_{L,t-1}b_{L,t-1}}{b_S + q_L b_L}\right)^{-\varrho_b}\widetilde{\varepsilon}_{tr,t} \text{ for } m\in\{U,R\}, \tag{32}$$

where Ξ_U and Ξ_R determine the steady-state value of the transfers-to-output ratio for each household, $b_{S,t}$ and $b_{L,t}$ refer to the total amount of real government bonds outstanding (held by both domestic and foreign households), ϱ_y and ϱ_b are parameters regulating the elasticity of transfers with respect to the output gap and the government debt gap, respectively, and $\widetilde{\varepsilon}_{tr,t}$ is an exogenous

[13]The firm also uses private capital, k_{t-1}, and the labor services of the two types of agents, $n_{U,t}$ and $n_{R,t}$, as inputs in production, with α and Φ denoting share parameters. u_t denotes the utilization rate of capital, while f denotes the fixed costs in production. See Appendix A for more details on the production side of the model.

shock, which follows an AR(1) process.[14] In our baseline case, we let transfer shocks affect both types of households, but we also run an alternative scenario in the next section with transfer shocks being targeted to restricted households only.

Note that the term that gets determined residually in the government budget constraint is the change in total government bonds; hence, budget deficits are debt financed in the model. However, the relative financing of deficits through short- versus long-term bond issuance is so far undetermined. In our baseline exercises, we assume that fiscal deficits are financed by long-term debt, which requires that short-term debt stays constant over time at its steady-state value:

$$b_{S,t} = \bar{b}_S. \tag{33}$$

The above equation ensures that the government budget constraint equation in (30) is satisfied on the margin by issuing long-term bonds only.

2.4 Monetary policy

The central bank targets the nominal short-term interest rate using a Taylor rule of the form

$$\log R_t = \rho \log R_{t-1} + (1-\rho)\left(\log R + r_\pi \log \frac{\pi_t}{\pi} + r_y \log \frac{y_t}{y}\right) + \varepsilon_{r,t}, \tag{34}$$

where R is the steady-state value of the (gross) nominal policy rate, y_t denotes domestic output, y is the steady-state level of output, and $\varepsilon_{r,t}$ is an *i.i.d.* monetary policy shock. ρ determines the extent of interest rate smoothing in the Taylor rule, while the parameters r_π and r_y determine the sensitivity of the interest rate to inflation and the output gap, respectively.

We do not explicitly model the balance sheet of the central bank and its holdings of government bonds, following Chen et al. (2012a) and Alpanda and Kabaca (2020); thus, the government bonds outstanding in the government's budget constraint in (30) refer to the quantity of bonds available to the general public (i.e., both domestic and foreign households in the model economy), net of purchases by the central bank.[15]

2.5 Production and market clearing conditions

The production side of the model is relatively standard and is described in more detail in Appendix A. The model features domestic producers and importers in each country, which produce differentiated products in monopolistically competitive markets. Both domestic producers and importers face adjustment costs when changing prices, and both index their price changes partly to trend inflation

[14] Lump-sum transfers adjust with the level of government debt to rule out a Ponzi scheme for the government.

[15] Note that we have denoted the government's budget constraint in (30) as the "consolidated budget constraint," implying that it can effectively be viewed as combining the flow constraints of both the fiscal and the monetary authorities, while treating the monetary base created by the central bank and the short-term bonds issued by the fiscal authority as perfectly substitutable. This consolidated representation of the flow constraints also captures the notion that the net cash flow of the central bank ultimately accrues to the fiscal authority in the real world.

and partly to their respective past inflation rates. These nominal rigidities result in non-neutralities in the effects of conventional monetary policy shocks and lead to partial pass-through from exchange rates to inflation, which are standard features in open-economy New Keynesian models (Adolfson et al., 2008; Justiniano and Preston, 2010).

The differentiated domestic and imported products are aggregated by final-goods producers, which operate in perfectly competitive markets. The domestically produced final goods, y_t, can be used as the "home" component of the consumption and investment aggregates, or as government expenditure or export goods, as

$$c_{h,t} + i_{h,t} + g_t + y^*_{f,t} = y_t, \tag{35}$$

where $c_{h,t}$ and $i_{h,t}$ denote the home components of the consumption and investment aggregates, while $y^*_{f,t}$ denotes the foreign country's imports, hence the domestic country's exports.[16] Similarly, the imported final goods in the domestic country, $y_{f,t}$, can be used as the "foreign" component of the consumption and investment aggregates:

$$c_{f,t} + i_{f,t} = y_{f,t}. \tag{36}$$

The final consumption and investment goods are then constructed as a CES aggregate of their respective home and foreign components described above.

The model also features perfectly competitive capital producers, who face adjustment costs in the change in investment levels, which helps generate a relative price between investment and consumption goods.[17] The market clearing conditions for short- and long-term bonds issued by the ROW economy are given by

$$\frac{B_{S,t}}{P_t} = \frac{B_{HS,t}}{P_t} + \frac{B^*_{FS,t}}{P_t}, \text{ and } \frac{q_{L,t}B_{L,t}}{P_t} = \frac{q_{L,t}B_{HL,t}}{P_t} + \frac{q_{L,t}B^*_{FL,t}}{P_t}, \tag{37}$$

where $B^*_{FS,t}$ and $B^*_{FL,t}$ refer to US holdings of ROW short- and long-term bonds, respectively.[18] The balance-of-payments identity in the model is given by

$$\left(\frac{e_t B_{FS,t}}{P_t} - \frac{e_t R^*_{t-1} B_{FS,t-1}}{P_t}\right) + \left(\frac{e_t q^*_{L,t} B_{FL,t}}{P_t} - \frac{e_t R^*_{L,t} q^*_{L,t} B_{FL,t-1}}{P_t}\right)$$
$$- \left(\frac{B^*_{FS,t}}{P_t} - \frac{R_{t-1} B^*_{FS,t-1}}{P_t}\right) - \left(\frac{q_{L,t} B^*_{FL,t}}{P_t} - \frac{R_{L,t} q_{L,t} B^*_{FL,t-1}}{P_t}\right) = \frac{P_{h,t}}{P_t} y^*_{f,t} - \frac{e_t P^*_{h,t}}{P_t} y_{f,t}, \tag{38}$$

where the right hand side denotes the trade balance, while the left hand side captures the corresponding change in bond holdings, net of interest payments, across borders. The model's equilibrium

[16]Note that all adjustment costs are assumed to accrue to households in lump-sum fashion and therefore do not enter the feasibility condition.

[17]Note that different import shares in the investment and consumption aggregates would also generate differences in the price of these final goods, although we assume equal import shares for both of these goods in our parameterization in Section 3.

[18]The F subscript denotes the fact that these are foreign bonds from the perspective of the US economy.

is defined as prices and allocations such that households maximize the discounted present value of utility, all firms maximize the discounted present value of profits, subject to their constraints, and all markets clear.

3 Quantitative Analysis Using the DSGE Model

In this section, we first describe the calibration of model parameters and then present impulse responses of key variables for the US and ROW economies to fiscal policy shocks originating in the US. In particular, we consider three types of fiscal shocks: (i) government consumption, (ii) government investment, and (iii) government transfers.

3.1 Calibration

Table 1 lists the parameter values used in our baseline calibration, while Table 2 presents the implied steady state of the model based on these parameters. In what follows, we describe the calibration of some of the key parameters of the model, including those related to fiscal policy and the bond portfolio, relegating the relatively standard parts of the calibration to Appendix B. Most parameter values are similar to those used in Alpanda and Kabaca (2020).

The steady-state level of the exogenous part of TFP in the US, z^*, is set to 1 without loss of generality, while the ROW's z is calibrated so that the steady-state output in the ROW economy is 2.5 times as large as the US economy, based on the average of the export-to-GDP and the import-to-GDP ratios in the US between 1990 and 2007 (12.1%) and the corresponding measure for the ROW economies (4.9%), similar to Sutherland (2005).

We set the share of unconstrained households in total composite labor, Φ, to 0.8, implying a hand-to-mouth share of 20%, similar to Campbell and Mankiw (1991). The steady-state government expenditure level is set to ensure that its share in output, g/y, is 20% in each country. The depreciation rate for government capital, δ_g, is set to 2% to match a government investment-to-GDP ratio of 5%, while government consumption-to-GDP ratio is 15%. The elasticity of government capital to TFP, Ψ, is set to 0.1, close to estimates in Leeper et al. (2010). The tax rates on labor and capital income, τ_n and τ_k, are set to 0.3 and 0.2, respectively. The elasticity of transfers to output gap and government debt gap, τ_y and τ_b, are set to 1, and Ξ_R is set to 0.01 in both countries, while the steady-state transfer level parameter for unconstrained agents in the two countries, Ξ_U and Ξ_U^*, are set to ensure that each government's budget constraint is satisfied given the bond ratios and interest rates at the steady state.

To calibrate the portfolio share parameters for the US and the ROW, we combine data targets on the supply of short- and long-term bonds in each economy, as well as data on foreign bond holdings provided by the Treasury International Capital (TIC) database of the US Treasury. For the US, the short- and long-term government bonds outstanding relative to annual GDP are 0.114 and 0.186, respectively, over the 2001-2007 period. The corresponding government bond supply-to-GDP ratios for the ROW economy are given by 0.127 and 0.353 when we consider the sample of countries we used to construct a ROW measure.[19] These constitute our bond supply targets.[20] For bond holdings, TIC data indicate that the foreign holdings of short- and long-term US Treasuries, as a ratio to world GDP excluding the US, are given by 0.017 and 0.044, respectively, for the 2001-2007 period.[21] TIC data also indicate that US residents' holdings of short- and long-term foreign government bonds, as a ratio to US GDP, are given by 0.002 and 0.025, respectively. These constitute our targets for the foreign holdings of each bond. The differences in the bond supplies and these figures can then be used to construct data targets for domestic holdings of these bonds.

We calibrate the portfolio share parameters in the CES aggregates to match the bond supply and bond holding data targets mentioned above. In particular, we set the share of short-term bond portfolio in the US portfolio, γ_a^*, to 0.42, while the shares of domestic bonds in the US short- and long-term portfolios, γ_S^* and γ_L^*, are set to 0.98 and 0.75, respectively. Similarly, for the ROW portfolio, the share of short-term bonds, γ_a, is set to 0.27, while the shares of domestic bonds in their short- and long-term portfolios, γ_S and γ_L, are 0.88 and 0.89. For both countries, the elasticity of substitution between short- and long-term bonds, λ_a, is set to 1.5, while the elasticity of substitution between domestic and foreign bonds in the short and long subportfolios, λ_S and λ_L, are relatively higher at 12.5 and 4.5, respectively.

3.2 Results

In this section, we start off by describing the effects of fiscal shocks in the US on both the US and the ROW economies. We then analyze how these baseline results would be different under alternative scenarios, such as the absence of portfolio rebalancing effects. For these, we focus more on the government consumption shock and defer the results for the other fiscal shocks to Appendix C.

3.2.1 Impact of fiscal shocks on the US and the ROW

We start by considering the impulse responses of the US and ROW economies to fiscal shocks originating in the US. We consider all three fiscal shocks, namely, government consumption, government investment, and transfers. All three shocks are assumed to have a persistence of 0.9, and the size of the shocks is scaled to 1% of the steady-state annual US output.

Figure 1 shows the impulse responses of US variables after each of the three fiscal policy shocks originating in the US. Similar to a standard setup, government consumption shocks act as expansionary demand shocks, leading to an increase in both output and inflation, while the central bank raises the short-term interest rate given its Taylor rule. The US long-term rate increases as well,

[19] The aggregate ROW series are constructed using the weighted average of data from Australia, Canada, China, the Euro Area, Japan, Norway, Sweden, Switzerland, and the United Kingdom, as in Alpanda and Kabaca (2020).

[20] The short-term bond supply series are constructed as the sum of the monetary base and government bonds with a maturity of less than one year at issuance. The measure for the US long-term bonds includes only Treasury bonds, and not debt issued by government-sponsored enterprises.

[21] The figure for the short-term holdings also includes foreign holdings of US currency, reported by the Flow of Funds of the Federal Reserve Bank. In general, our short-term bond measures include the monetary base, since it is a close substitute for short-term government bonds when the policy rate is at the ZLB or when the central bank pays interest on reserves.

due to both the expectations hypothesis and the increase in the term premium component. In particular, due to imperfect substitution between short- and long-term bonds, the term premium on long-term rates in the US increases by about 25 basis points (bps). Note that unconstrained agents increase their holdings of US (and foreign) long-term bonds relatively more than their US (and foreign) short-term bond holdings. The fiscal shock crowds out not only private investment, but also consumption of unconstrained agents. Aggregate consumption increases, however, due to the response of hand-to-mouth agents, who increase their labor supply and consumption as a result of the increased aggregate demand in the economy. On the trade side, the fiscal expansion leads to an appreciation of the US currency, which results in a decline in US exports and an increase in US imports. Thus, the fiscal expansion also crowds out the net export component of demand. Nevertheless, the government consumption shock overall acts as a standard expansionary demand shock in the economy.

The effects of an expansionary government investment shock on the US economy are similar to those from a government consumption shock, except for the former's effects on inflation and interest rates. In particular, government investment increases the stock of government capital and acts similar to a positive productivity shock given the externality effect of government capital on private production. The higher levels of supply then increase overall output and curb inflation. The latter effect is associated with a decline in the short-term rate via the central bank's Taylor rule, which also leads to a decline in the long-term rate through the expectations hypothesis despite the increase in the term premium component. The decline in interest rates also moderates the appreciation effects on the US currency, which mitigates trade effects relative to government consumption. Also, the increase in effective productivity incentivizes private investment, which recovers much faster than it does after a government consumption shock. As a result, the expansionary impact on US output is higher with government investment relative to government consumption.

The baseline results with transfer shocks are also similar to those from a government consumption shock, except consumption and imports increase relatively more with transfer shocks. This is because the transmission of transfer shocks to the economy is primarily through households' consumption, and consumption goods require imported intermediate goods in their production process, unlike government consumption goods, which only require domestically produced intermediates. As a result of higher spending on imported goods, output also increases less than under government consumption or investment shock.

Note that the appreciation of the US dollar following those fiscal shocks is consistent with the short-term UIP condition (see equation 18). Fiscal stimulus in the US generates a short-term rate differential, appreciating the currency. In addition, the portfolio term in the short-term UIP condition does not have a significant impact on the currency since the fiscal stimulus does not move short-term debt supply. The appreciation of the US dollar is also consistent with the long-term UIP condition (see equation 19). Here, the term premium differential generates additional appreciation pressures on the dollar, which is then offset by increased US long-term debt. The latter is because the fiscal stimulus is financed by issuing long-term debt, increasing the holdings of US long-term bonds in portfolios. And higher US debt in long-term portfolios generates depreciation pressures on the dollar.

Figure 2 plots the corresponding impulse responses for ROW variables to the expansionary fiscal shocks originating in the US. The spillover effects of US government consumption shocks on ROW output is, on net, negative. We observe that the inflation rate picks up due to the depreciation of the ROW currency, and this causes short-term interest rates to rise. The increase in the US term premium partially passes through to the ROW term premium as ROW agents increase their holdings of US long-term bonds and reallocate their portfolios away from local long-term bonds. This causes a further increase in long-term interest rates, depressing consumption demand in the ROW economy. Coupled with the reduction in private investment, aggregate output falls despite the positive impact of the currency depreciation on ROW net exports.

The spillover effects of US government investment and transfer shocks to the ROW economy are by and large similar. As noted, the transfer shock in the US leads to a larger positive impact on ROW net exports, which results in ROW output to slightly increase on impact rather than decrease. Figures C.4 and C.5 in Appendix C repeat the transfer experiment described above, but allocate the transfers only to hand-to-mouth agents (instead of both types of agents as in the baseline case). These results illustrate that both the expansionary impact of transfers on the US economy as well as the positive spillover effects on the ROW economy are rendered significantly larger if the transfers are targeted towards the hand-to-mouth agents, which have a much larger marginal propensity to consume.

In Appendix C, Figures C.1 and C.2 repeat the above exercises in the absence of hand-to-mouth agents in both countries. The results for both the US and ROW economies are virtually the same except for the response of the aggregate consumption variable in the US, which now becomes negative at impact for government consumption and investment shocks. As a result, the stimulatory impact of these fiscal shocks on aggregate output is also slightly less positive in the US. These results are consistent with the literature and one of the main reasons why hand-to-mouth agents are now routinely added in models considering the effects of fiscal shocks (Campbell and Mankiw, 1991).[22]

3.2.2 The case without portfolio balancing

Portfolio balancing is a key mechanism in our model that drives the spillover of US fiscal policy to the ROW economy. To identify the contribution of this mechanism more precisely, we shut off the mechanism and compare the degree of spillover to the baseline scenario with portfolio balancing. Figure 3 illustrates this comparison. To shut off the mechanism, we set all the elasticity parameters in the portfolio specification, λ_a, λ_S, and λ_L, to infinity. Figure 3 plots the impulses for government consumption shocks only, while the corresponding figures for government investment and transfer

[22] Unlike government consumption and investment shocks, we observe an increase in aggregate consumption following the transfer shock. The main reason why consumption increases following the transfer shock is because the exchange rate appreciation increases imports more in the case of the transfer shock relative to other fiscal shocks. When we assume the economy is closed, the consumption demand no longer depends on the exchange rate, and the transfer shock does not move the aggregate demand, as in the stylized New Keynesian models with Ricardian equivalence.

shocks are deferred to Appendix C.

In the absence of portfolio rebalancing effects, the term premium stays constant in response to a government consumption shock, resulting in a smaller increase in the long-term rate in the US. The expansionary shock, therefore, generates a slightly higher increase in output and inflation. While short-term rates increase in response to higher inflation, long-term rates in the US increase less than they do under the baseline calibration given the non-responsiveness of the term premium component.

For the ROW economy, both output and inflation is higher in the absence of portfolio rebalancing effects. The term premium does not change in this case, implying a lower portfolio return in real terms and higher spending. The higher level of spending in turn fuels inflation despite the lower degree of depreciation in the ROW currency, demonstrating that the impact of lower import prices is dominated by higher domestic-good prices in determining total inflation. Finally, the higher inflation rates lead to higher short-term rates through the Taylor rule. As a result, long-term rates increase despite a stable term premium.

Figures C.6 and C.7 in Appendix C present the corresponding impulse responses from government investment and transfer shocks, respectively. The results are qualitatively similar to those from the government consumption shocks described above. In particular, US and ROW inflation rates increase by more and the level of ROW output is higher in the absence of portfolio rebalancing.

Here we should note that while the level of ROW GDP is higher in the absence of portfolio balancing, it still falls following a positive US fiscal policy shock. This is at odds with the standard textbook description of the positive fiscal spillovers to foreign GDP through trade. The reason why GDP falls in our model even in the absence of portfolio balancing effects is because monetary policy responds to higher inflation, increasing the real short-term rates. We should, however, mention that it is possible for foreign monetary authorities to keep policy rates unchanged if they perceive the rise in import prices and depreciation of their currency as a temporary response. It is also possible that the ROW might face constraints on monetary policy such as ZLB, as was the case at the beginning of the Covid-19 pandemic. Figure 4 shows the results when ROW monetary policy does not respond to higher inflation over eight quarters for either of the two reasons mentioned above. In the absence of portfolio balancing effects, GDP spillovers are now positive due to positive trade effects. This highlights the importance of ROW monetary policy reaction, or the lack thereof, for the spillovers from US fiscal policy.

3.2.3 Trade openness and fiscal spillovers

We now investigate how trade openness affects the domestic and international spillover impact of fiscal shocks. In particular, we consider a case where we increase the degree of international trade openness by considering $\gamma_i^* = \gamma_c^* = 0.3$, implying a home bias for goods in the foreign economy closer to its country size. While doing this, we keep the steady-state portfolio ratios the same as in our baseline case.[23] The results for government consumption shocks are presented in Figure 5. Figures C.8 and C.9 in Appendix C present the corresponding impulse responses from government investment and transfer shocks, respectively.

The results show that the domestic and international GDP spillover effects of fiscal shocks are not highly sensitive to import shares. On the other hand, inflation is sensitive to import shares as the contribution of import prices to headline inflation increases. In particular, higher import shares results in US inflation falling despite a lower degree of US dollar appreciation. Lower inflation also prompts a lower level of US short-term and long-term rates relative to the baseline scenario. In the ROW economy, however, the positive response of inflation is larger in magnitude. This surge in inflation, despite a small increase in the term premium, generates higher short- and long-term interest rate responses in the ROW. Thus, both rate differentials across regions become smaller, consistent with a lower degree of US dollar appreciation.

The insensitivity of GDP spillovers are mainly an outcome of offsetting effects on GDP through domestic demand and trade. On the positive side, higher trade volumes increase the contribution of exports to ROW GDP, making US fiscal policy shocks appealing from the ROW perspective. However, a lower degree of depreciation offsets this positive trade spillover. In addition, higher policy rates as a reaction to higher inflation have contractionary effects on ROW domestic demand. As a result, ROW GDP does not change much with higher trade openness. In order to identify the contribution of the monetary policy rule, we shut down the reaction function for eight quarters and recalculate the responses (displayed in Figure 6). Higher trade openness now implies positive spillovers to ROW GDP from the US fiscal shock without a prompt monetary policy reaction. Similar to the findings in the previous subsection, this highlights the important influence of ROW monetary policies on the spillover effects from the US fiscal policy.

3.2.4 Financial openness and fiscal spillovers

We next analyze the sensitivity of our baseline results to financial openness. In particular, we consider a case where we increase the degree of international financial openness by considering $\gamma_S^* = \gamma_L^* = 0.3$, implying a home bias for bonds in the foreign economy closer to its country size.[24] Again, the results for government consumption shocks are presented in the main text in Figure 7, while Figures C.10 and C.11 in Appendix C present the corresponding impulse responses from government investment and transfer shocks, respectively.

The effect of the US fiscal shock on the US term premium is smaller in this case because smaller home bias in portfolios mean term premiums are affected less by domestic factors such as asset supply. A lower term premium, in turn, implies slightly lower appreciation of the US dollar, which further amplifies the effect of the expansionary shock on inflation. As a result, policy rates increase more, leading to a stable long-term rate despite a lower term premium. With stable portfolio returns (lower term premium and higher real short rates), total aggregate spending does not move much,

[23] The portfolio ratios and the difference in country size implies $\gamma_i = \gamma_c = 0.72$ for the home region.

[24] The goods ratios and the difference in country size implies $\gamma_S = 0.74$ and $\gamma_L = 0.84$ for the home region.

leaving output unchanged in the US.

Higher financial openness, however, means the ROW term premium is affected more by external factors such as US asset supply. As a result, the same fiscal shock leads to a higher term premium, generating higher long-term rates resulting in a larger negative spillover effect on the ROW output from the US fiscal expansion. In addition, trade contributes to the negative spillovers here. As a result of a smaller term premium differential, the exchange rate depreciates slightly less, leading to a smaller gain from trade spillovers.

Both the term premium and exchange rate pulls down ROW output; however, quantitatively, the impact is small. This is mainly because policy rates increase less in the ROW, preventing a bigger recession. A smaller policy rate is mostly a reaction of a smaller exchange rate pass-through from a smaller depreciation. Similar to what we did in previous subsections, to identify the contribution of the monetary policy rule, we shut down the reaction function for eight quarters and recalculate the responses (displayed in Figure 8). The negative spillover effects from a higher term premium are more visible now without a prompt monetary policy reaction.

3.2.5 Maturity of debt financing and fiscal spillovers

We proceed by considering a US fiscal expansion financed by short-term debt and comparing the results with the baseline scenario (with funding through long-term debt). This is akin to the case of helicopter money under the assumption that money and short-term government bonds are perfectly substitutable. Figure 9 in the main text presents the related results for government consumption shocks, while Figures C.12 and C.13 in Appendix C present the corresponding results for government investment and transfer shocks, respectively.

Short-term financing of the fiscal shock, or equivalently a helicopter drop policy that combines a fiscal expansion financed by long-term debt with central bank purchases of long-term government bonds in exchange for bank reserves, increases the supply of US short-term bonds in the market. Due to imperfect substitutability, the higher amount of US short-term bonds decreases the demand for ROW short-term bonds and leads to a relative increase in the demand for both US and ROW long-term bonds. As a result, term premiums in both countries decline. The international spillover effects of the US fiscal shock are, therefore, smaller on the ROW output. In particular, the decrease in the term premium leads to a smaller increase in the long-term interest rate with less impact on ROW demand. Nevertheless, the US long-term rate increases by more relative to the baseline case given higher inflation and short-term interest rates.

4 Empirical Analysis

The DSGE model featured three distinct mechanisms of fiscal policy spillover. Specifically, US fiscal spending shocks were transmitted to the foreign economy through real exchange rates, trade and term premiums. Simulations of the model showed that the spillover effects feeding through exchange rates and the term premium dominated the trade effects so that an expansionary (contractionary)

US fiscal policy generated a decrease (an increase) in foreign output. In this section, we describe the methodology and data that we use to test whether these mechanisms and predictions are consistent with the data. We discuss our main results and those obtained from various sensitivity tests.

4.1 Methodology

We begin by investigating whether the three key mechanisms from our model are consistent with cross-country data. Specifically, we test whether a US fiscal policy expansion is consistent with a US dollar appreciation, an increase in countries' bilateral trade surplus with the US, and an increase in their term premium. To infer these relationships, we estimate different forms of the following model:

$$\begin{aligned} x_{i,t} = \beta^X x_{i,t-1} + \sum_{k=1}^{4} \beta_k^F g_{t-k}^{US} + \sum_{k=1}^{4} \beta^T bts\_y_{i,t-k} + \sum_{k=1}^{4} \beta^{TI} bts\_y_{i,t-k} * g_{t-k}^{US} \\ + \sum_{k=1}^{4} \beta^B bhs\_y_{i,t-k} + \sum_{k=1}^{4} \beta^{BI} bhs\_y_{i,t-k} * g_{t-k}^{US} + \beta^{TD} v_t + \beta^{CD} u_i + \varepsilon_{i,t}, \end{aligned} \tag{39}$$

where subscripts i and t index countries and time, respectively, and v_t and u_i are vectors of dummy variables that represent time and time-invariant country fixed effects, respectively. This equation, similar to our theoretical predictions, relates exchange rates, countries' trade balance, and their term premium (denoted by $x_{i,t}$) to US fiscal spending, g_{t-k}^{US}. In equation (39), $bts\_y_{i,t-k}$ and $bhs_{i,t-k}$ represent the growth rate of country i's bilateral trade surplus with the US and its US bond holdings as a share of its GDP, respectively. The former variable is approximated by the growth rate of the bilateral exports-to-GDP ratio minus the growth rate of the bilateral imports to GDP ratio. Incorporating these variables and their interaction with US fiscal spending into our empirical analysis allows us to test whether the strength and nature of the spillover mechanisms in our model depend on the direction of trade and the degree of financial integration through government bond holdings.

To estimate equation (39), we use a panel fixed effects estimator that accounts for both country and time fixed effects. In doing so, we use country clusters to account for the possibility that observations could be correlated within countries. The main reason we use a fixed effects approach over a dynamic panel estimator is that dynamic panel estimators such as Blundell and Bond (1998) are designed for panels with a large cross sectional dimension and short time dimension. In our panel, the number of time periods exceeds the number of countries. We should also point out here that we use four lags of the independent variables to account for the impact lags of fiscal policy. While there is no clear indication of the appropriate number of lags in the literature, especially in a panel setting (e.g., Alesina et al., 2012; Alesina and Adagna, 2013), there is evidence that the long-term effects of fiscal policy could be much smaller in magnitude compared with the short-term effects (see Gemmel et al., 2011). This is why we choose four quarters in our baseline specification.[25]

[25] We checked the robustness of our results to using 8- and 12-quarter lags. While the results were qualitatively similar, the fiscal policy coefficients were insignificant relatively more often.

4.2 Data

To estimate our empirical models, we use quarterly data from 19 of the G-20 economies that span the 2000:Q1-2020:Q4 period. Since we include the largest economies in the Euro Area, we exclude the EU as a bloc. The data are mainly obtained from four sources. Nominal and real exchange rates, seasonally adjusted real GDP growth rates, and the term premium variable, measured as the spread between government bond rates and deposit rates, are obtained from the International Financial Statistics database. The reason we use the two series to measure the term premium was that they were the only indicators of long-term and short-term interest rates that were available for every country and each period in our sample.

The statistics of the 18 countries' bilateral trade (imports and exports) with the US are from the Census Bureau. These data are in US dollars. To gauge the significance of US trade on the three dependent variables in our model, we first convert bilateral exports and imports to local currency and then we divide this by the nominal GDP of the given country. We then calculate the growth rates (growth over the previous period) of these ratios and subtract the growth of imports-to-GDP ratio from the growth rate of exports-to-GDP ratio. Including this measure of trade surplus/deficit growth then allows us to determine whether the spillover effects of US fiscal policy depend on countries' direction of trade with the US. Naturally, we exclude this variable when we are estimating the relationship between US fiscal policy and bilateral trade.

The holdings of US securities are obtained from the Treasury International Capital (TIC) System. The TIC data date back to 2000, and this is the reason why our sample starts from this year. The historical TIC data shows the stock of total US security holdings by country, and they are available at the monthly frequency. We convert these data to the quarterly frequency by taking averages.

To avoid endogeneity risks, we use a narrative measure to capture US government spending shocks. Specifically, we use the Ramey (2011) news shock series, a commonly used US fiscal shock variable in the literature that tracks the changes in the expectations of US government military/political spending.

4.3 Results

In this section, we report the results obtained from the estimation of equation (39). We investigate the relationship between US fiscal policy and foreign output. We determine if or how the spillover effects on output are altered at the ZLB. Finally we use a vector autoregression (VAR) analysis to investigate the foreign output responses to US fiscal policy.

4.3.1 Evidence for the three mechanisms

The results reported in Table 3 show the relationship between US fiscal policy shock and the three key variables in our model. Overall, the results, consistent with our model predictions, indicate that there is a real US dollar appreciation and an increase in the trade surplus (in bilateral trade with the US) and the term premiums of foreign economies when there is a US expansionary fiscal shock.

Interpreting the coefficient of the exchange rate variable is not straightforward given that the G-20 sample includes a diverse group of currencies and our baseline measure of fiscal spending is a generated regressor. Nevertheless, the coefficient value of 0.2782 in the first column implies that the real dollar exchange rate appreciates by roughly 0.5 standard deviations after a one standard deviation of US fiscal spending shock in the previous four quarters. Both the magnitude and the sign of the coefficient value are similar when we add the growth rate of countries' trade balance with the US as a share of their GDP (results in the second column) and its interaction with US fiscal policy. This is also true when we add countries' US bond holdings as a share of their GDP (results in the third column). The significant positive coefficients of bilateral trade balance and bond holdings suggest that the dollar tends to depreciate in real terms against currencies of countries that have a bilateral trade surplus with the US and hold large amounts of US bonds relative to their GDP.

The real appreciation of the dollar following a US fiscal expansion is consistent with the results displayed in column 4. Specifically, the results imply that countries experience an improvement (deterioration) in their bilateral trade balance with the US when there is a fiscal expansion (contraction). In these estimations, the dependent variable is the countries' trade balance with the US as a share of their GDP and hence the trade balance variable is not included on the right hand side. We similarly omit the bond holdings variable as trade balance directly affects the denominator of the bond holdings variable, US bond holding as a share of countries' GDP. The coefficient value of 0.0424 implies that countries' trade surpluses with the US relative to their GDP increase by roughly 4.2 percentage points when there is a 1% increase in US fiscal spending. More generally, the results in the first four columns are consistent with the trade mechanism in our model such that a real US dollar appreciation prompted by a US fiscal expansion can have spillover effects on other countries through trade.

Our model projected that an expansionary bond-financed US fiscal policy can increase term premiums and long-term rates in the US and abroad, which, in turn, would further depress foreign economic activity. In our estimations, reported in the last three columns of Table 3, we find a positive relationship between US fiscal policy and term premiums in foreign economies. Using our measure of term premiums as the dependent variables in equation (39), we find that a US fiscal spending shock is positively related to the change in foreign term premiums. The coefficient value of 0.3764 implies that there is roughly a 38-basis-points increase in the term premium of G-20 countries when there is a 1% change in US fiscal spending evenly spread cross four quarters. The positive significant coefficient of the interactive term in the last column suggests that this sensitivity to US fiscal policy is higher for countries that have a trade surplus with the US.

In the next section, we turn to the effects of US fiscal spending on foreign output. We follow the standard practice in the literature and primarily use a VAR analysis for identifying and measuring these effects. We note, however, that panel estimations of (39) with foreign output as the dependent variable also provide support for the negative relationship between US fiscal spending and foreign output in our DSGE model. We discuss these estimations and the corresponding results in Appendix D.

4.3.2 VAR evidence

In this section we use panel country-specific data in simple VAR models to investigate the response of foreign output to the changes in and shocks to US government spending. To do so, we first use a panel VAR model (PVAR) with three variables and a Cholesky ordering in which the three variables are ordered as follows: the Ramey government spending shock, country-specific real GDP growth rate, and the growth rate of the real US dollar exchange rate. Our sample similarly includes quarterly data from 2000:Q1 to 2020:Q4. To estimate the model, we use the first lags of the variables and we cluster standard errors by country.

The response of foreign output (orthogonalized impulse responses) to a US government spending shock in our estimated PVAR model is displayed at the top of Figure 10. Consistent with the main inference from our panel regressions, we find a negative response. Next, we use the updated Blanchard-Perotti (2002) fiscal spending series, a widely-used government shock series, as an alternative measure of US fiscal policy stance to check the robustness of the negative relationship mentioned above. The impulse responses to this alternative measure also reveal a negative relationship between US fiscal spending and foreign output. Unlike the initial result, however, the significant spillover effects of fiscal policy now appear to be more short-lived. The 90% level confidence bands indicate that this negative response is significant for the first seven quarters. The amplitude of the response implies that a one standard deviation US government spending shock generates roughly a 25-basis-point decrease in the growth rate of foreign real GDP. This one-to-four ratio is consistent with our panel regressions.

The VAR identification strategy that we have used so far assumes that foreign variables can affect US fiscal policy measures, albeit with a lag. As a final robustness check, we use a Panel Vector Autoregressive X (PVARX) model that incorporates US fiscal policy measures as exogenous variables. The model, therefore, allows US shocks to affect foreign variables (contemporaneously and with a lag) but not the other way around. Figure 10 displays the responses to the two US fiscal policy measures, the Ramey spending shock and the component of US fiscal spending that is orthogonal to US real GDP growth. Both responses, consistent with our baseline results, point to negative international spillover effects of US fiscal policy shocks.

As our final robustness check, we use the local projections methodology of Jorda (2005) to measure the output responses to the changes in US fiscal spending. The responses to a one standard deviation increase in the US government spending shock are also shown in Figure 10. The responses, though less persistent then the VAR model responses, demonstrate a negative relationship between US fiscal spending and foreign output in the first year after the shock.

We should also note that we find evidence for the negative relationship between US fiscal spending and foreign output at the country level. Specifically, when we estimate our VAR model separately for each country in our sample, the output responses to US fiscal spending shocks are negative for a majority of the countries. We discuss these estimations in Appendix D.

5 Conclusion

In this paper, we study the international spillover effects of fiscal policies in a calibrated two-country, open-economy model with portfolio balance effects. Portfolio balance effects arise from imperfect substitutability between short- and long-term bonds in portfolio preferences, which we introduce into an otherwise stylized two-country DSGE model with nominal and real rigidities. This imperfect substitution leads to higher long-term yields in the US economy as a response to a fiscal expansion financed by long-term bond issuance, which generates depreciation pressures on the ROW currency, but also leads to higher bond yields in the ROW. The latter spillover effect on the ROW long-term yields contracts the ROW economy despite the improvement in its trade balance.

Our model also suggests that the stimulatory effects of fiscal policy in the domestic economy can be attenuated if fiscal expansions are financed primarily through long-term bond issuance, given the increase in long-term interest rates. Similarly, the stimulatory effects of QE policies adopted by the central bank can also be attenuated if the government decides to take advantage of the resulting lower long-term interest rates and to bias its fiscal financing towards the issuance of long-term debt. This points to the importance of coordination between central banks and governments in deep recessions, which require large fiscal stimuli by governments and/or large-scale asset purchases by central banks. Finally, our model indicates that a helicopter drop type of policy, which combines a fiscal expansion financed by long-term debt with central bank purchases of long-term government bonds, can have more robust effects on the economy. The spillover effects of a helicopter drop policy is also more expansionary on the ROW economy as the crowding out effects of the portfolio rebalancing channel are muted.

In the second half of the paper, we provide empirical evidence supporting the key mechanisms in our model and indicating that US fiscal expansions can be contractionary for ROW economies. Specifically, we use panel estimations and find that countries' trade surpluses with the US grow, their currencies depreciate in real terms, and their term premiums increase when there is a US fiscal expansionary shock. Investigating the relationship between foreign output and US fiscal policy, we infer that domestic demand effects through higher term premiums could be more important than trade effects as we find that US fiscal expansions are contractionary abroad.

While our empirical analysis provides suggestive evidence, future research could corroborate our findings by investigating the behavior of bondholders (by using entity-level data) in response to a US fiscal policy shock. This research could identify and measure the significance of portfolio balancing effects associated with US fiscal policies.

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Table 1: Parameter values

Parameter	Value	Parameter	Value
Portfolio		*Preferences*	
Home share (short), γ_S, γ_S^*	0.88, 0.98	Discount factor, β	0.99
Home share (long), γ_L, γ_L^*	0.89, 0.75	Cons. habit, ζ	0.70
Short share, γ_a, γ_a^*	0.27, 0.42	Labor elasticity (inverse), ϑ	2
Elasticity, λ_a	1.5	Portfolio coeff., ξ_a, ξ_a^*	0.08, 0.03
Elasticity, λ_S, λ_L	4.5, 12	Labor coefficient, ξ_n, ξ_n^*	85.23, 86.00
Coupon, κ	0.98		
Technology		*Taylor Rule and Gov't*	
Home bias cons., γ_c, γ_c^*	0.94, 0.85	R persistence, ρ	0.80
Home bias inv., γ_i, γ_i^*	0.94, 0.85	Inflation sensitivity, r_π	1.5
Elas. H and F cons., λ_c	1	Output gap sensitivity, r_y	0.125
Elas. H and F inv., λ_i	1	Tax coefficient (unconstrained), Ξ_U, Ξ_U^*	0.03, 0.02
Mark-up, θ_w, θ_h, θ_f	1.25	Tax coefficient (constrained), Ξ_R	0.01
Indexation, ς_w, ς_h, ς_f	0.50	Elasticities in tax policy, τ_y,τ_b	1
Calvo rigidity, κ_{ph}^{est}, κ_{pf}^{est}, κ_w^{est}	0.90	Tax rate (labor income), τ_n	0.30
Private capital exponent, α	0.34	Tax rate (capital income), τ_k	0.20
Gov't capital exponent, Ψ	0.10	Fiscal shock persistence, ρ_b	0.90
Share of unconstrained, Φ	0.80		
Depreciation rate, δ, δ_g	0.02		
Inv. adj. cost, φ	5		
Utilization elasticity, ϖ	1		

Notes: The parameter values are equal across regions, unless otherwise noted.

Table 2: Model steady-state ratios

(relative to output)	Symbol	ROW	US
Consumption	c/y	0.606	0.602
Investment	i/y	0.195	0.195
Gov't expenditure	g/y	0.20	0.20
Gov't consumption	g_c/y	0.15	0.15
Gov't investment	g_i/y	0.05	0.05
Transfers	tr/y	0.038	0.034
Tax revenue	tax/y	0.227	0.227
Exports[a]	y_f^*/y	0.048	0.122
Imports[a]	y_f/y	0.049	0.120
Wage share in income	$1-\alpha$	0.66	0.66
Priv. capital stock / GDP (ann.)	k/y	2.5	2.5
Gov't capital stock / GDP (ann.)	k_g/y	0.6	0.6
Bond supply / GDP (ann.)			
short	b_S/y	0.1270	0.1139
long	$q_L b_L/y$	0.3530	0.1864
Bond holdings / GDP (ann.)			
short home	b_{HS}/y	0.1264	0.0724
long home	$q_L b_{HL}/y$	0.3428	0.0764
short foreign	b_{FS}/y	0.0166	0.0016
long foreign	$q_L^* b_{FL}/y$	0.0440	0.0254

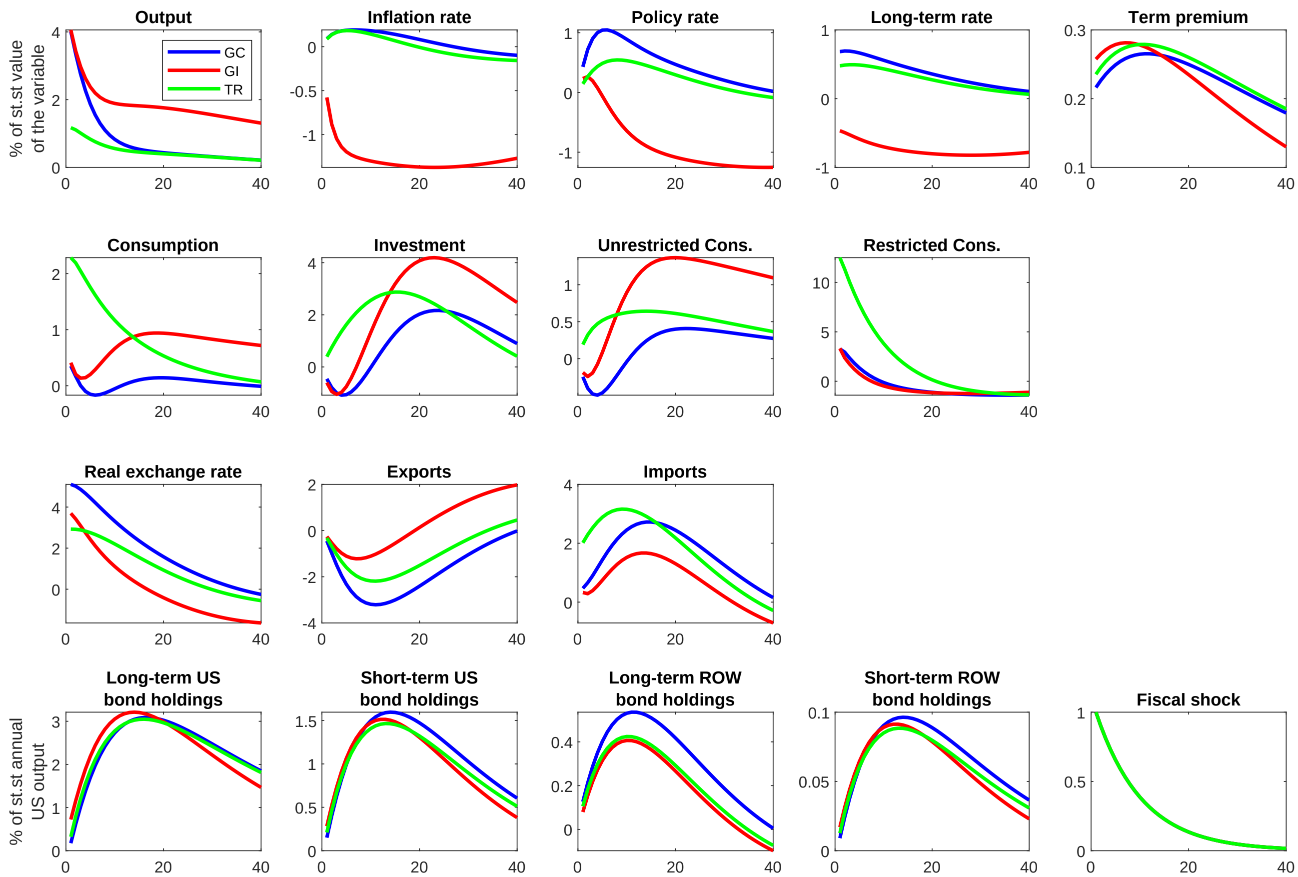
Notes: (a) In the model, ROW exports is equal to US imports, and ROW imports is equal to US exports by construction. The differences in the figures above reflect the relative size of the two economies at the steady state (i.e., $y/y^* = 2.5$).

Table 3: US fiscal policy, exchange rates, term premium, and trade

	Real exchange rates			Bilateral Trade Balance	Term premium		
	(1)	(2)	(3)	(1)	(1)	(2)	(3)
U.S. fiscal policy stance	-0.2782	-0.2736	-0.3880	0.0424	0.3764	1.1092	0.5679
	(0.001)***	(0.002)***	(0.027)**	(0.051)*	(0.012)**	(0.022)**	(0.033)**
Bilateral trade balance		0.0009	0.4191				-0.0206
		(0.221)	(0.003)***				(0.681)
Bilateral trade balance* U.S. fiscal policy stance		-0.2904	-0.7426				0.2642
		(0.599)	0.2838				(0.000)***
Bond holdings			0.2371			-2.1121	-2.1466
			(0.333)			(0.075)**	(0.001)***
Bond holdings * U.S. fiscal policy stance			0.0300			-0.4927	-0.4704
			(0.011)**			(0.017)**	(0.013)**
Dependent variable lag	0.001	0.001	0.145	-0.250	0.0002	0.012	-0.070
	(0.048)**	(0.037)***	(0.042)**	(0.000)***	(0.689)	(0.887)	(0.265)
# of observations	756	973	529	761	430	278	278
Adj-R2	0.071	0.052	0.154	0.046	0.095	0.025	0.088

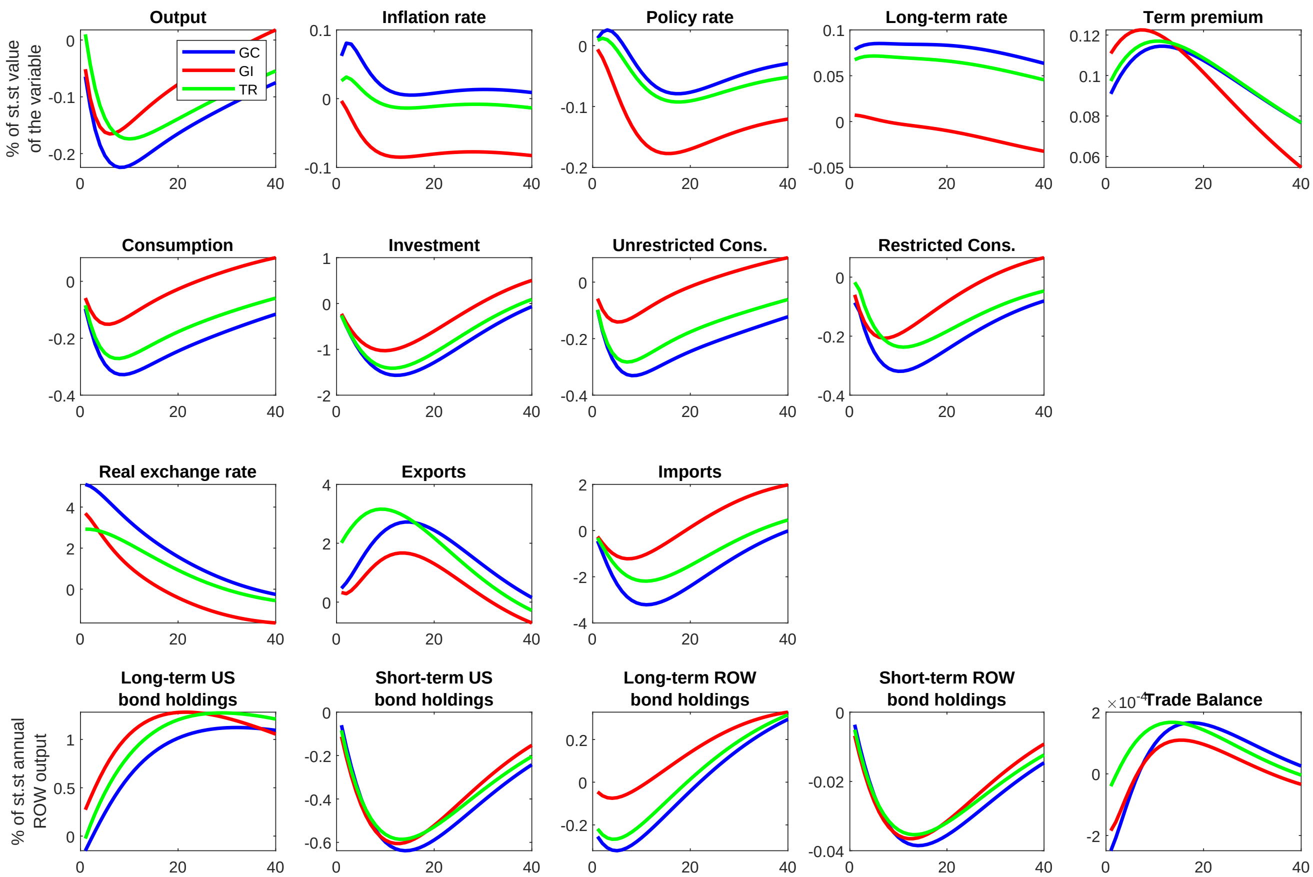
Notes: This table reports the results obtained from a fixed effects estimation of equation (39). The growth rates of the real exchange rate, the bilateral trade surplus with the US, and the term premium are the dependent variables for the estimation results displayed in the first three columns, the fourth column, and the last three columns, respectively. US fiscal policy stance is represented by the updated Ramey (2011) fiscal shock series. *, **, *** show significance levels at 10%, 5%, and 1%, respectively. The numbers reported in parentheses are F statistics for all variables except the lagged dependent variable.

Figure 1: US responses to a 1% fiscal shock in the United States as a fraction of steady-state annual US output



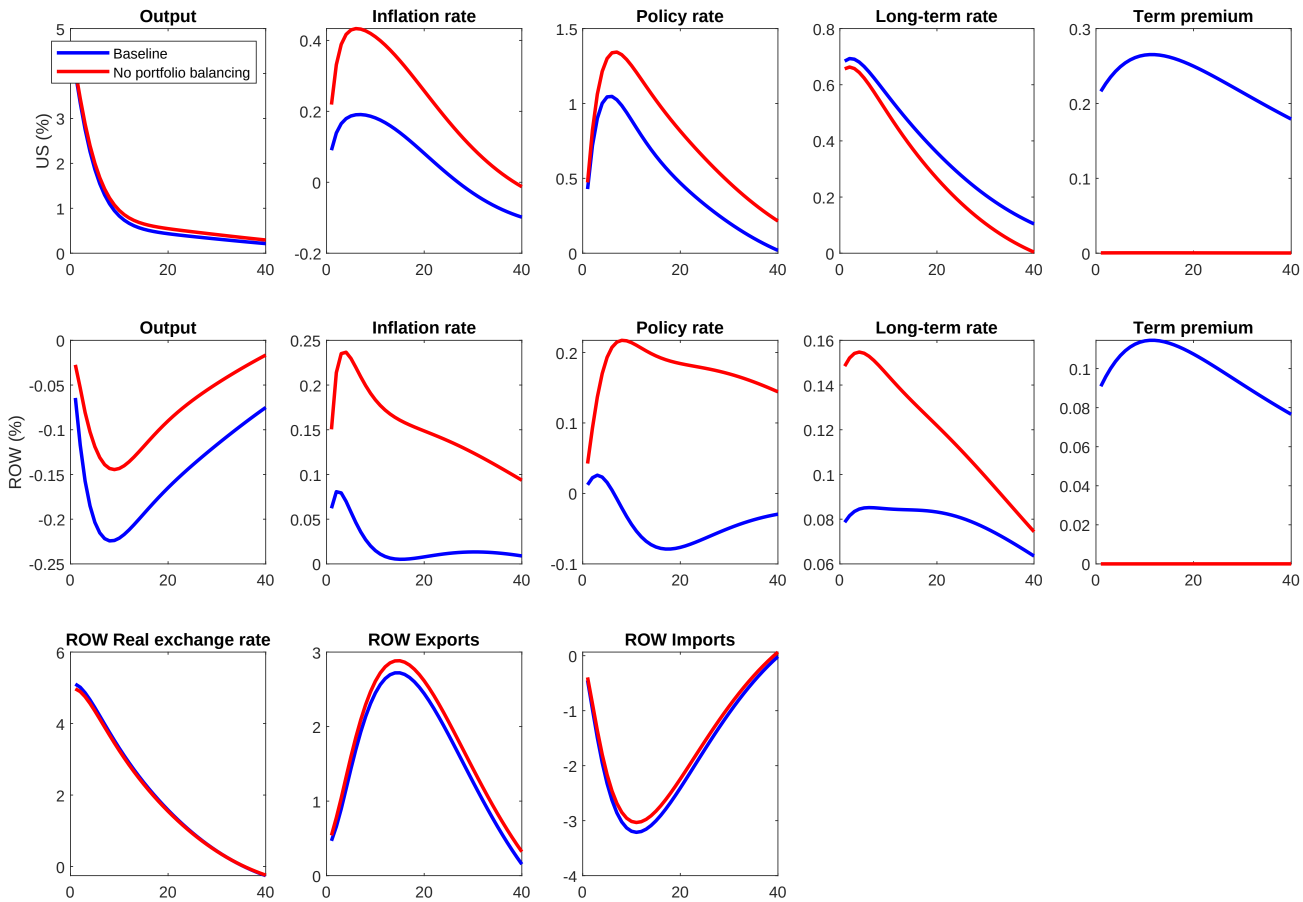
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except inflation, policy rate, long-term rate, term premium, and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure 2: ROW responses to 1% fiscal shock in the United States as a fraction of steady-state annual US output



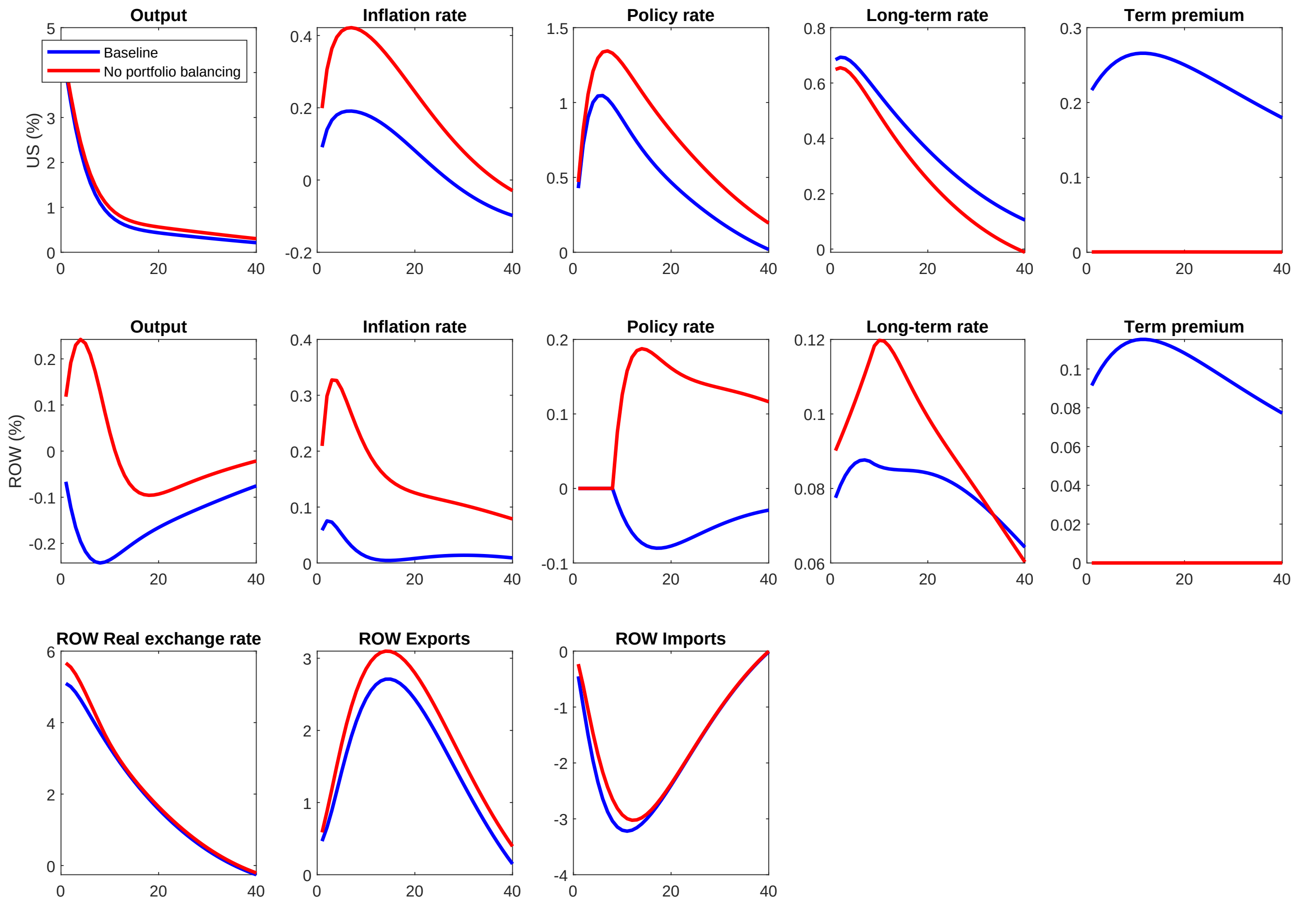
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except inflation, policy rate, long-term rate, term premium, and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure 3: Fiscal spillovers in the absence of portfolio balancing



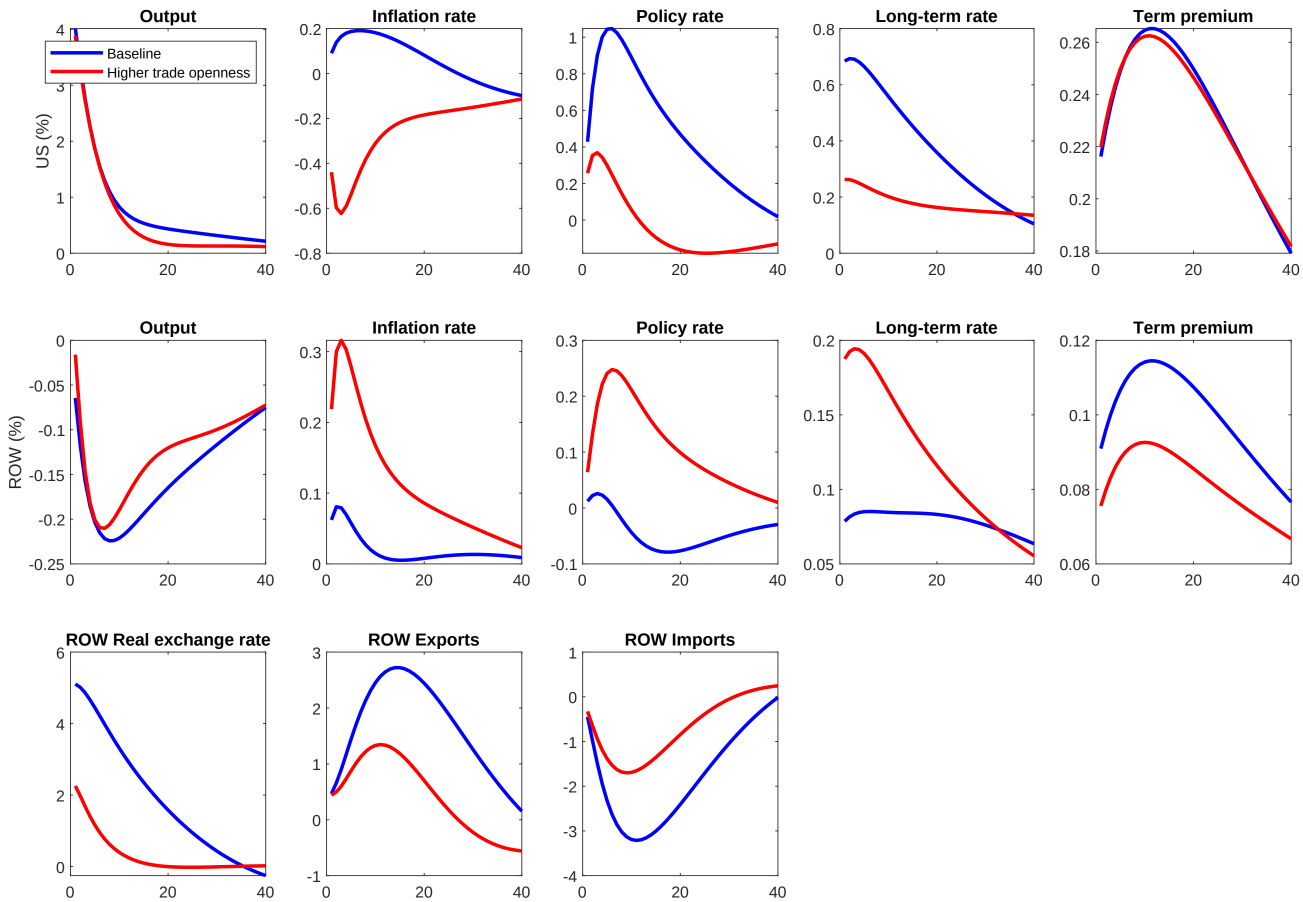
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except inflation, policy rate, long-term rate, term premium, and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure 4: Fiscal spillovers in the absence of portfolio balancing - No monetary policy reaction over eight quarters at ROW



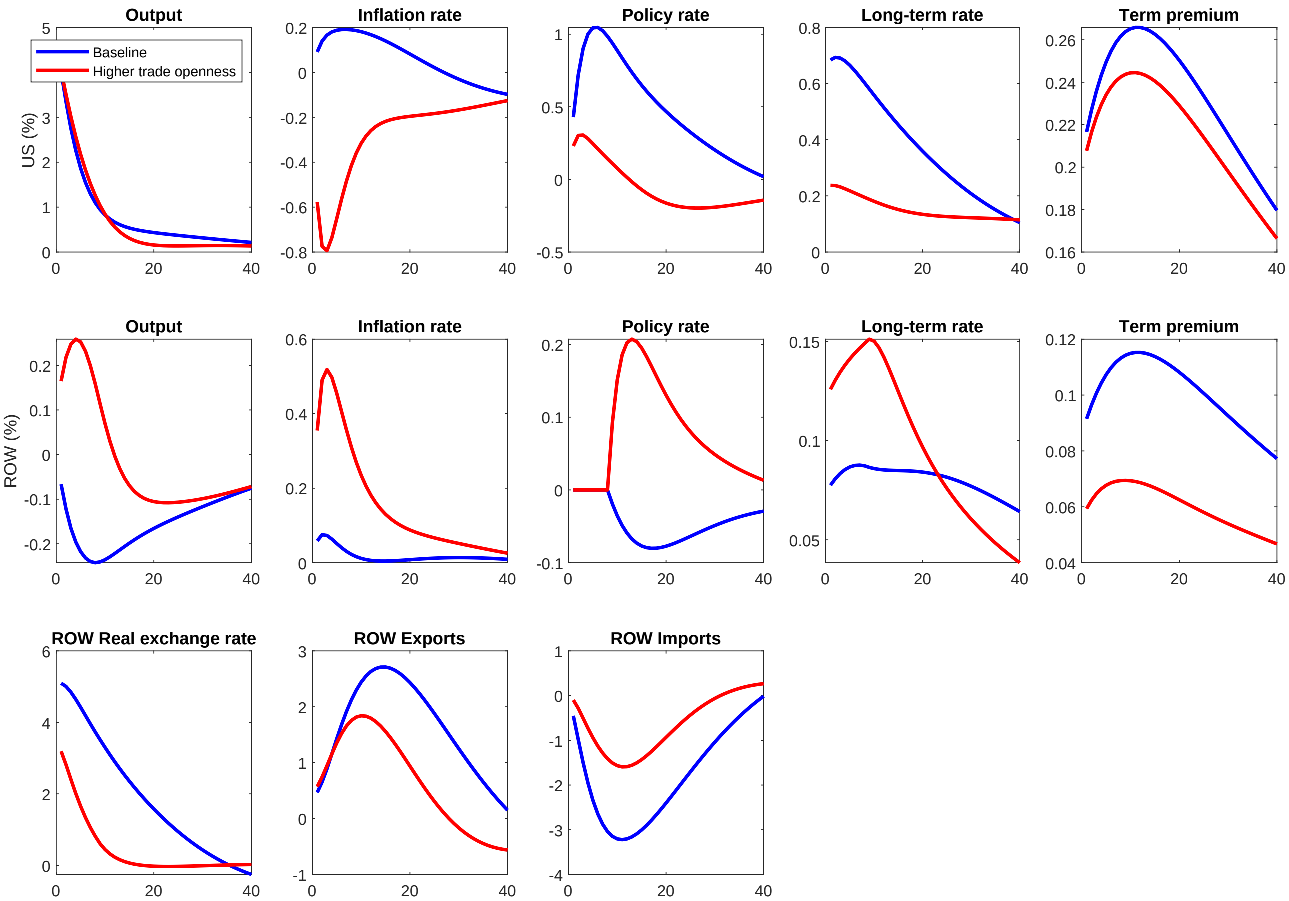
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except inflation, policy rate, long-term rate, term premium, and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure 5: Fiscal spillovers under higher trade openness



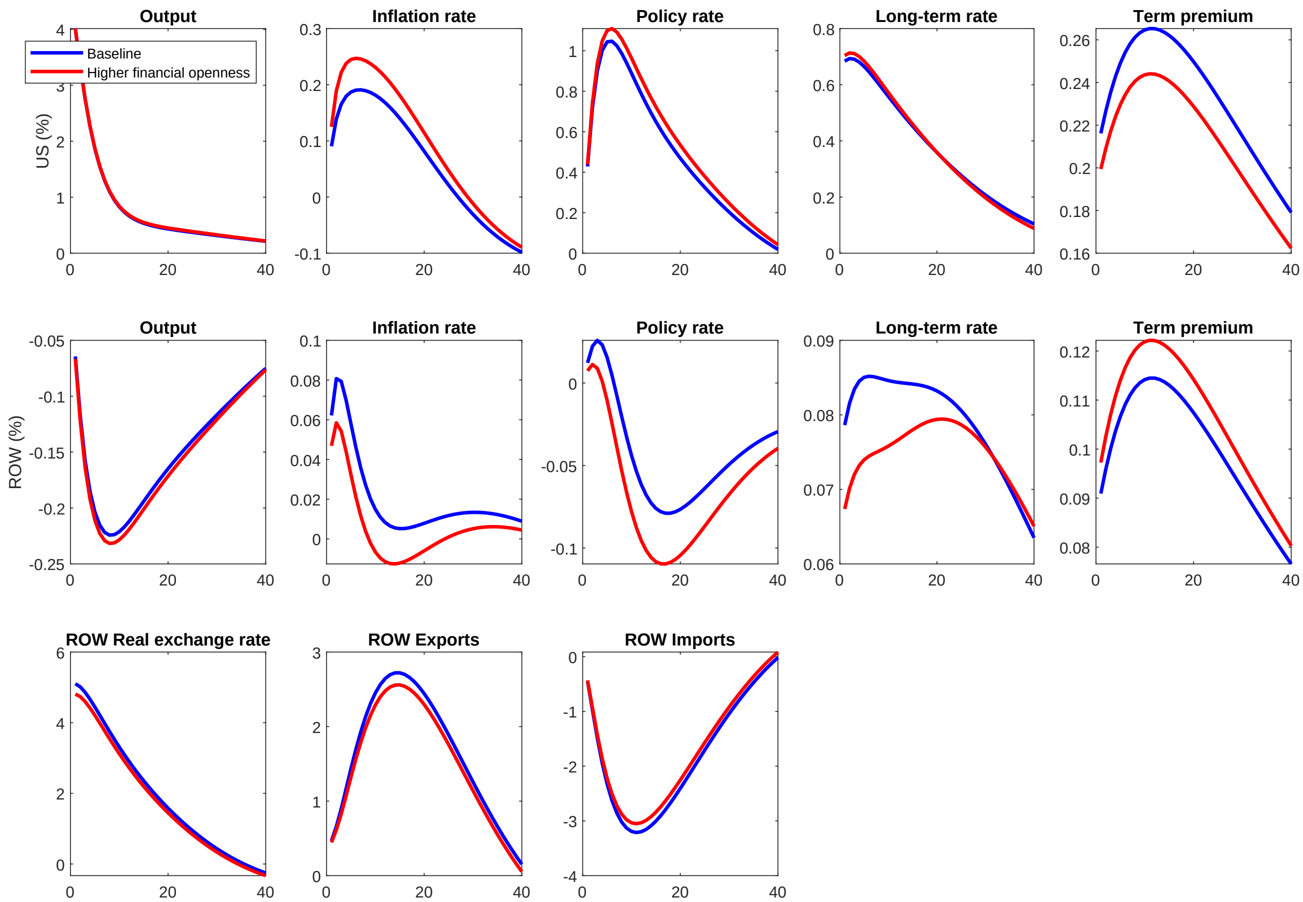
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except inflation, policy rate, long-term rate, term premium, and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure 6: Fiscal spillovers under higher trade openness - No monetary policy reaction over eight quarters at ROW



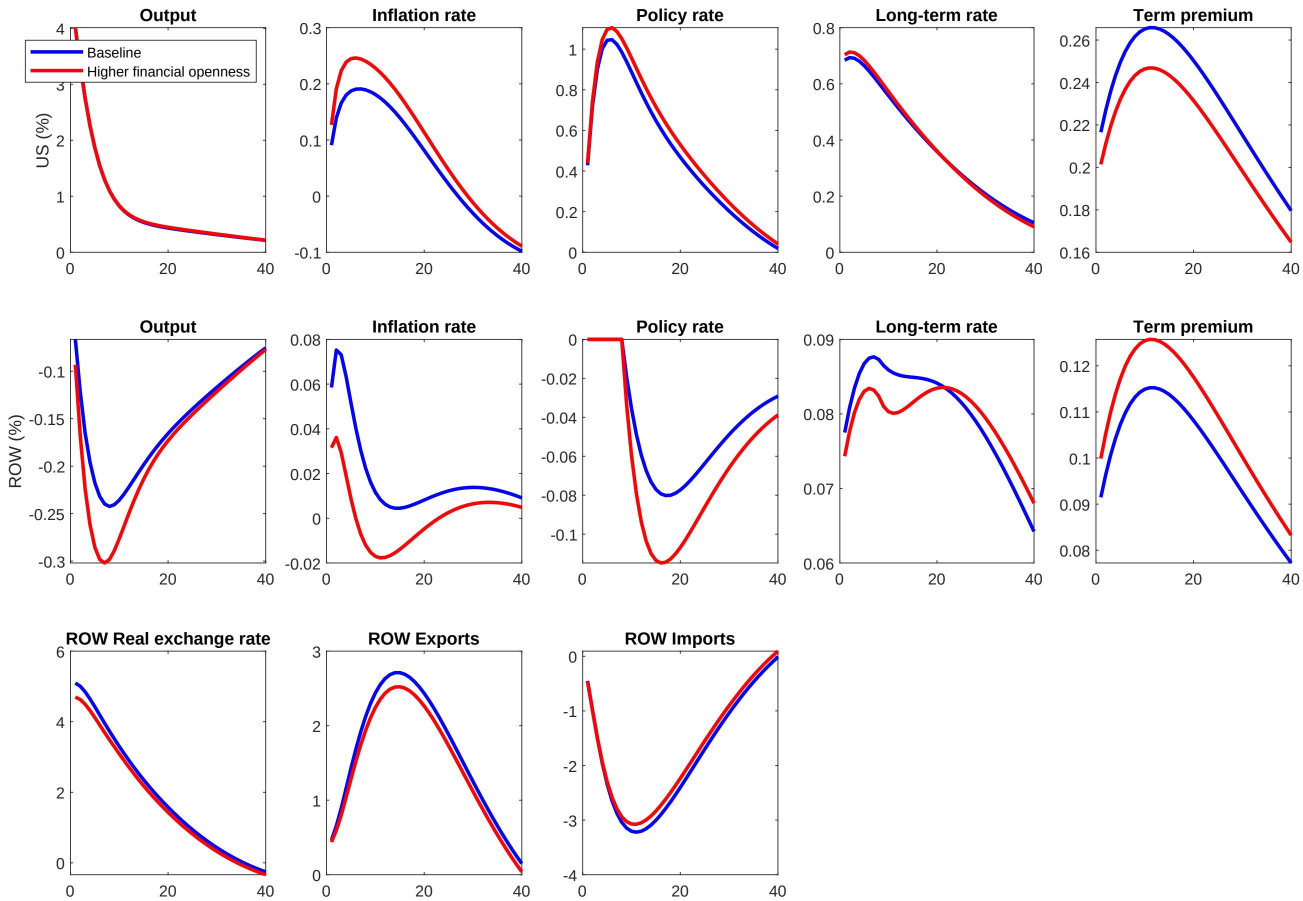
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except inflation, policy rate, long-term rate, term premium, and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure 7: Fiscal spillovers under higher financial openness



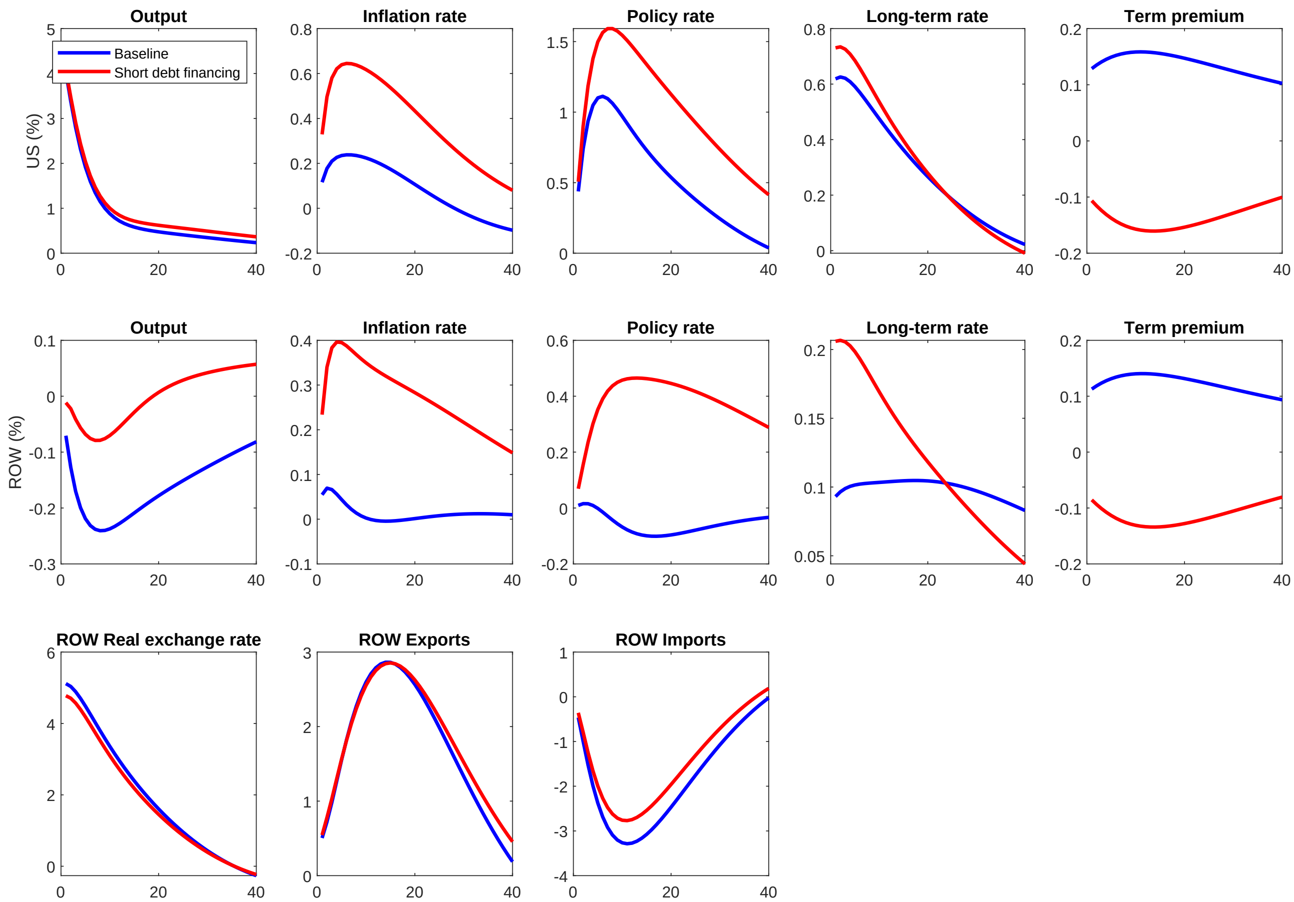
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except inflation, policy rate, long-term rate, term premium, and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure 8: Fiscal spillovers under higher financial openness - No monetary policy reaction over eight quarters at ROW



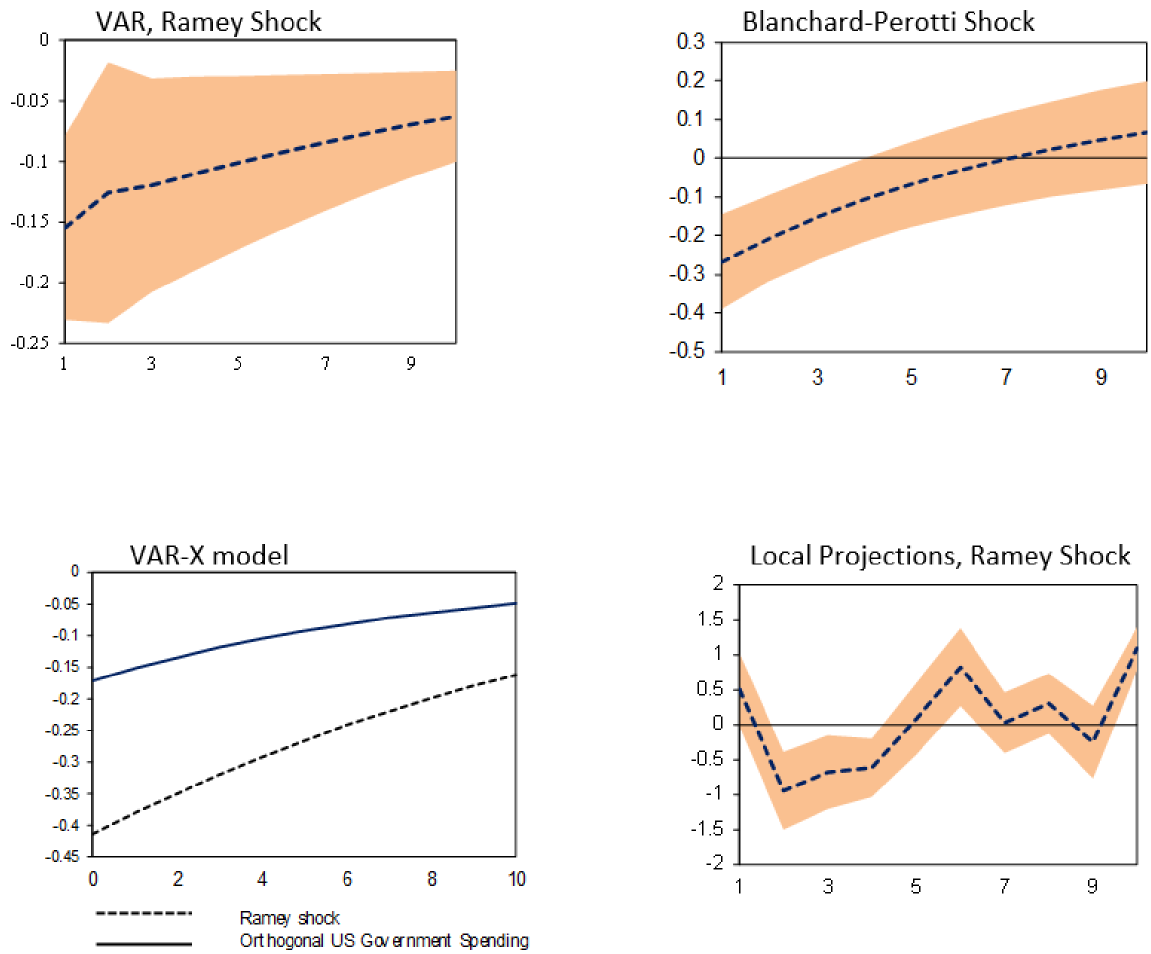
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except inflation, policy rate, long-term rate, term premium, and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure 9: Fiscal spillovers in the case of short-term debt financing



Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except inflation, policy rate, long-term rate, term premium, and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure 10: Foreign output responses to US fiscal policy



Notes: The figure displays the real GDP growth responses to three US fiscal policy shocks obtained from a panel VAR model estimated using G-20 data. The confidence intervals are at the 90% level. In the VAR-X model, US fiscal policy measures are incorporated as exogenous variables.

A Details on the DSGE Model

In this appendix, we describe in more detail some of the model features that were only briefly described in the main text.

A.1 Unrestricted households

The labor services supplied are heterogeneous across households and are aggregated into a homogeneous labor service by perfectly competitive labor intermediaries, who in turn rent these labor services to goods producers. The labor intermediaries use a standard Dixit-Stiglitz aggregator; therefore, the labor demand curve facing each household is given by

$$n_t(i) = \left(\frac{W_t(i)}{W_t}\right)^{-\Theta_n} n_t, \tag{40}$$

where W_t and n_t are the aggregate nominal wage rate and labor services of households, respectively, and Θ_n is the elasticity of substitution between the differentiated labor services.

The first-order conditions of unrestricted households with respect to consumption and capital are, respectively, given by

$$\frac{1}{c_{U,t} - \zeta c_{U,t-1}} = \lambda_{U,t}, \tag{41}$$

$$q_t \lambda_{U,t} = \beta E_t \left[\lambda_{U,t+1}\left((1-\delta) q_{t+1} + r_{k,t+1}\right)\right]. \tag{42}$$

The optimality conditions with respect to labor and wages can be combined to derive a New Keynesian Phillips curve for wages, which after log-linearization can be written as

$$\widehat{\pi}_{wU,t} - \varsigma_w \widehat{\pi}_{t-1} = \beta E_t\left[\widehat{\pi}_{wU,t+1} - \varsigma_w \widehat{\pi}_t\right] - \frac{(\eta_n - 1)(1-\tau_n)}{\kappa_w}\left(\widehat{w}_{U,t} - \frac{1}{1-\zeta}\left(\widehat{c}_{U,t} - \zeta \widehat{c}_{U,t-1}\right) - \vartheta \widehat{n}_{U,t}\right), \tag{43}$$

where the nominal wage inflation, $\widehat{\pi}_{wU,t}$, and the real wage rate, $\widehat{w}_{U,t}$, of unrestricted households are related as

$$\widehat{\pi}_{wU,t} - \widehat{\pi}_t = \widehat{w}_{U,t} - \widehat{w}_{U,t-1}. \tag{44}$$

A.2 Restricted households

The restricted (hand-to-mouth) households' first-order condition with respect to consumption is given by

$$\frac{1}{c_{R,t} - \zeta c_{R,t-1}} = \lambda_{R,t}.$$

Similar to unrestricted agents, the optimality conditions of restricted households with respect to labor and wages can also be combined to derive a New Keynesian Phillips curve for their wages, which after log-linearization can be written as

$$\widehat{\pi}_{wR,t}-\varsigma_w\widehat{\pi}_{t-1}=\beta E_t\left[\widehat{\pi}_{wR,t+1}-\varsigma_w\widehat{\pi}_t\right]-\frac{(\eta_n-1)(1-\tau_n)}{\kappa_w}\left(\widehat{w}_{R,t}-\frac{1}{1-\zeta}\left(\widehat{c}_{R,t}-\zeta\widehat{c}_{R,t-1}\right)-\vartheta\widehat{n}_{R,t}\right),\tag{45}$$

where the nominal wage inflation, $\widehat{\pi}_{wR,t}$, and the real wage rate, $\widehat{w}_{R,t}$, of restricted households are related as

$$\widehat{\pi}_{wR,t}-\widehat{\pi}_t=\widehat{w}_{R,t}-\widehat{w}_{R,t-1}.\tag{46}$$

A.3 Final-goods aggregators

There are two types of final-goods aggregators; for consumption goods, c_t, and for investment goods, i_t. In what follows, we mainly describe the consumption-goods aggregators, but investment-goods aggregators are modeled in an analogous fashion.

Consumption aggregators are perfectly competitive, and they produce the final goods as a CES aggregate of home and foreign goods, $c_{h,t}$ and $c_{f,t}$:

$$c_t=\left[\gamma_c^{\frac{1}{\lambda_c}}c_{h,t}^{\frac{\lambda_c-1}{\lambda_c}}+(1-\gamma_c)^{\frac{1}{\lambda_c}}c_{f,t}^{\frac{\lambda_c-1}{\lambda_c}}\right]^{\frac{\lambda_c}{\lambda_c-1}},\tag{47}$$

where γ_c denotes the share of domestic goods and λ_c is the elasticity of substitution between home and foreign goods in the consumption aggregate. For any level of aggregate consumption, the aggregators' optimal demand for the domestic and imported consumption goods is given by

$$c_{h,t}=\left(\frac{P_{h,t}}{P_t}\right)^{-\lambda_c}\gamma_c c_t \text{ and } c_{f,t}=\left(\frac{P_{f,t}}{P_t}\right)^{-\lambda_c}(1-\gamma_c)\,c_t,\tag{48}$$

where $P_{h,t}$ and $P_{f,t}$ are the prices of the home and foreign goods, respectively. The aggregate price index for consumption goods is given by

$$P_t=\left[\gamma_c P_{h,t}^{1-\lambda_c}+(1-\gamma_c)\,P_{f,t}^{1-\lambda_c}\right]^{\frac{1}{1-\lambda_c}}.\tag{49}$$

The analogous expressions for investment goods aggregators are given by

$$i_t=\left[\gamma_i^{\frac{1}{\lambda_i}}i_{h,t}^{\frac{\lambda_i-1}{\lambda_i}}+(1-\gamma_i)^{\frac{1}{\lambda_i}}i_{f,t}^{\frac{\lambda_i-1}{\lambda_i}}\right]^{\frac{\lambda_i}{\lambda_i-1}},\tag{50}$$

$$i_{h,t}=\left(\frac{P_{h,t}}{P_{i,t}}\right)^{-\lambda_i}\gamma_i i_t \text{ and } i_{f,t}=\left(\frac{P_{f,t}}{P_{i,t}}\right)^{-\lambda_i}(1-\gamma_i)\,i_t,\tag{51}$$

$$P_{i,t}=\left[\gamma_i P_{h,t}^{1-\lambda_i}+(1-\gamma_i)\,P_{f,t}^{1-\lambda_i}\right]^{\frac{1}{1-\lambda_i}},\tag{52}$$

where $P_{i,t}$ denotes the price of the aggregate investment good.

A.4 Domestic intermediate goods firms

There exists a unit measure of monopolistically competitive domestic firms indexed by j. As noted in the main text, their technology is described by the following production function:

$$y_t(j) = \left(z_t k_{g,t-1}^{\Psi}\right)\left[u_t(j)\,k_{t-1}(j)\right]^{\alpha}\left[n_{H,t}(j)^{\Phi}\,n_{L,t}(j)^{1-\Phi}\right]^{1-\alpha} - f, \quad (53)$$

where z_t refers to the exogenous part of TFP and follows an exogenous AR(1) process. Note that we capture the relative economic size of the domestic versus the foreign economy by their relative levels of z_t.

Domestic goods produced are heterogeneous across firms and are aggregated into a homogeneous domestic good by perfectly competitive final-goods producers using a standard Dixit-Stiglitz aggregator. The demand curve facing each firm is given by

$$y_t(j) = \left(\frac{P_{h,t}(j)}{P_{h,t}}\right)^{-\Theta_h} y_t, \quad (54)$$

where y_t is the aggregate domestic output and Θ_h is the elasticity of substitution between the differentiated goods. Thus, $\theta_h = \Theta_h/(\Theta_h - 1)$ is the gross markup of price over marginal cost at the steady state.[26]

Firm j's profits at period t are given by

$$\begin{aligned}\frac{\Pi_{h,t}(j)}{P_t} &= \frac{P_{h,t}(j)}{P_t}y_t(j) - \frac{W_{U,t}}{P_t}n_{U,t}(j) - \frac{W_{R,t}}{P_t}n_{R,t}(j) - r_{k,t}k_{t-1}(j) \\ &\quad - \frac{\kappa_u}{1+\varpi}\left[u_t(j)^{1+\varpi} - 1\right]k_{t-1}(j) - \frac{\kappa_h}{2}\left(\frac{P_{h,t}(j)/P_{h,t-1}(j)}{\pi_{h,t-1}^{\varsigma_h}\pi^{1-\varsigma_h}} - 1\right)^2 \frac{P_{h,t}}{P_t}y_t, \end{aligned} \quad (55)$$

where κ_u and ϖ are the level and elasticity parameters for the utilization cost, respectively. Similar to wage stickiness, price stickiness is introduced via quadratic adjustment costs with level parameter κ_h, and ς_h captures the extent to which price adjustments are indexed to past inflation.

A domestic firm's objective is to choose the quantity of inputs and output and the price of its output each period to maximize the present value of profits (using the households' stochastic discount factor), subject to the demand function it is facing with respect to its individual output from the aggregators. The first-order conditions of the domestic intermediate goods firm with respect to the two types of labor and capital imply

$$\widehat{w}_{U,t} + \widehat{n}_{U,t} = \widehat{w}_{R,t} + \widehat{n}_{R,t} = \widehat{r}_{k,t} + \widehat{u}_t + \widehat{k}_{t-1}. \quad (56)$$

[26] The fixed-cost parameter f is set equal to $\theta_h - 1$ times the steady-state level of output to ensure that pure economic profits are zero at the steady state; hence, there is no incentive for firm entry and exit in the long run.

Similarly, the first-order conditions for capital and utilization can be combined to yield

$$\widehat{u}_t = \frac{1}{\varpi}\widehat{r}_{k,t}. \tag{57}$$

Finally, the first-order condition with respect to price yields the New Keynesian Phillips curve for domestic prices as

$$\begin{aligned}\widehat{\pi}_{h,t} - \varsigma_h \widehat{\pi}_{h,t-1} &= \beta E_t \left[\widehat{\pi}_{h,t+1} - \varsigma_h \widehat{\pi}_{h,t}\right] \\ &- \frac{\Theta_h - 1}{\kappa_h}\left(\widehat{p}_{h,t} + \widehat{z}_t + \Psi \widehat{k}_{g,t-1} + (1-\alpha)\left[\Phi \widehat{n}_{U,t} + (1-\Phi)\,\widehat{n}_{R,t} - \left(\widehat{u}_t + \widehat{k}_{t-1}\right)\right] - \widehat{r}_{k,t}\right),\end{aligned} \tag{58}$$

where $p_{h,t} = P_{h,t}/P_t$ is the relative price of home goods.

A.5 Importers

A unit measure also exists for monopolistically competitive importers and is indexed by j. They import foreign goods from abroad, differentiate them, and mark up their prices, and then sell these heterogeneous goods to perfectly competitive import aggregators, who aggregate them into a homogeneous import good using a standard Dixit-Stiglitz aggregator. The demand curve facing each importer is given by

$$y_{f,t}(j) = \left(\frac{P_{f,t}(j)}{P_{f,t}}\right)^{-\Theta_f} y_{f,t}, \tag{59}$$

where $y_{f,t}$ is the aggregate imports and Θ_f is the elasticity of substitution between the differentiated goods.

Importers maximize the present value of profits (using the households' stochastic discount factor), subject to the demand function they are facing from the aggregators with respect to their own output. The importer's profits at period t are given by

$$\frac{\Pi_{f,t}(j)}{P_t} = \frac{P_{f,t}(j)}{P_t} y_{f,t}(j) - \frac{e_t P^*_{h,t}}{P_t} y_{f,t}(j) - \frac{\kappa_f}{2}\left(\frac{P_{f,t}(j)/P_{f,t-1}(j)}{\pi_{f,t-1}^{\varsigma_f}\pi^{1-\varsigma_f}} - 1\right)^2 \frac{P_{f,t}}{P_t} y_{f,t}, \tag{60}$$

where κ_f and ς_f are the price adjustment cost and indexation parameters, respectively. These import price-stickiness features ensure that exchange rate movements do not immediately pass through to the domestic price of imported goods.

The first-order condition of importers with respect to price yields the import-price New Keynesian Phillips curve, which, after log-linearization, can be written as

$$\widehat{\pi}_{f,t} - \varsigma_f \widehat{\pi}_{f,t-1} = \beta E_t \left[\widehat{\pi}_{f,t+1} - \varsigma_f \widehat{\pi}_{f,t}\right] - \frac{\Theta_f - 1}{\kappa_f}\left(\widehat{p}_{f,t} - \widehat{rer}_t - \widehat{p}^*_{h,t}\right), \tag{61}$$

where $\pi_{f,t} = P_{f,t}/P_{f,t-1}$ is the import price inflation factor and $p_{f,t} = P_{f,t}/P_t$ is the relative price of imported goods.

A.6 Private capital producers

Private capital producers are perfectly competitive. After goods production takes place, these firms purchase the undepreciated part of the installed capital from entrepreneurs at a relative price of q_t and the new capital investment goods, i_t, from final-goods firms at a price of $P_{i,t}$, and produce the capital stock to be carried over to the next period. This production is subject to adjustment costs in the change in investment and is described by the following law of motion for capital:

$$k_t = (1-\delta)\, k_{t-1} + \left[1 - \frac{\varphi}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t, \tag{62}$$

where φ is the adjustment cost parameter.

After capital production, the end-of-period installed capital stock is sold back to entrepreneurs at the installed capital price of q_t. The capital producers' objective is thus to maximize

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[q_t k_t - q_t (1-\delta)\, k_{t-1} - \frac{P_{i,t}}{P_t} i_t\right], \tag{63}$$

subject to the law of motion for capital, where future profits are discounted using the unrestricted households' stochastic discount factor. The first-order condition of capital producers with respect to investment yields the following investment demand equation (after log-linearization):

$$\widehat{i}_t - \widehat{i}_{t-1} = \beta E_t \left[\widehat{i}_{t+1} - \widehat{i}_t\right] + \frac{1}{\varphi}\left(\widehat{q}_t - \widehat{p}_{i,t}\right), \tag{64}$$

where $p_{i,t} = P_{i,t}/P_t$ is the relative price of investment goods.

B Details on the Calibration

The trend inflation factor, π, is set to 1.005 in both countries, corresponding to 2% annual inflation. Following Chen et al. (2012a), the decay parameter for the coupon payments of long-term bonds, κ, is calibrated to imply a duration of 30 quarters, similar to the average duration in the secondary market for 10-year US Treasury bonds.

We calibrate the time discount factor, β, to match a target capital-output ratio of 10 (i.e., 2.5 with annualized output), using the optimality condition for household's capital decision at the steady state. Traditionally, the discount factor is calibrated to match the steady-state interest rate using the first-order condition on short-term bonds. We instead use this condition to calibrate the portfolio level coefficients, ξ_a and ξ_a^*, in preferences using the ratio of government bond holdings to GDP in each country, a/y and a^*/y^*; thus, we set the portfolio level coefficients to 0.03 and 0.08 in the US and ROW economies, respectively. The labor level parameters, ξ_n and ξ_n^*, are calibrated to match the working hours of the economically active population as a ratio of total non-sleeping hours of 32%. The habit parameter in the utility function, ζ, is set to 0.7, helping capture the high levels of persistence in the consumption data. ϑ is set to 2, implying that the labor supply elasticity is 0.5, largely consistent with the estimates presented in Blundell and MaCurdy (1999).

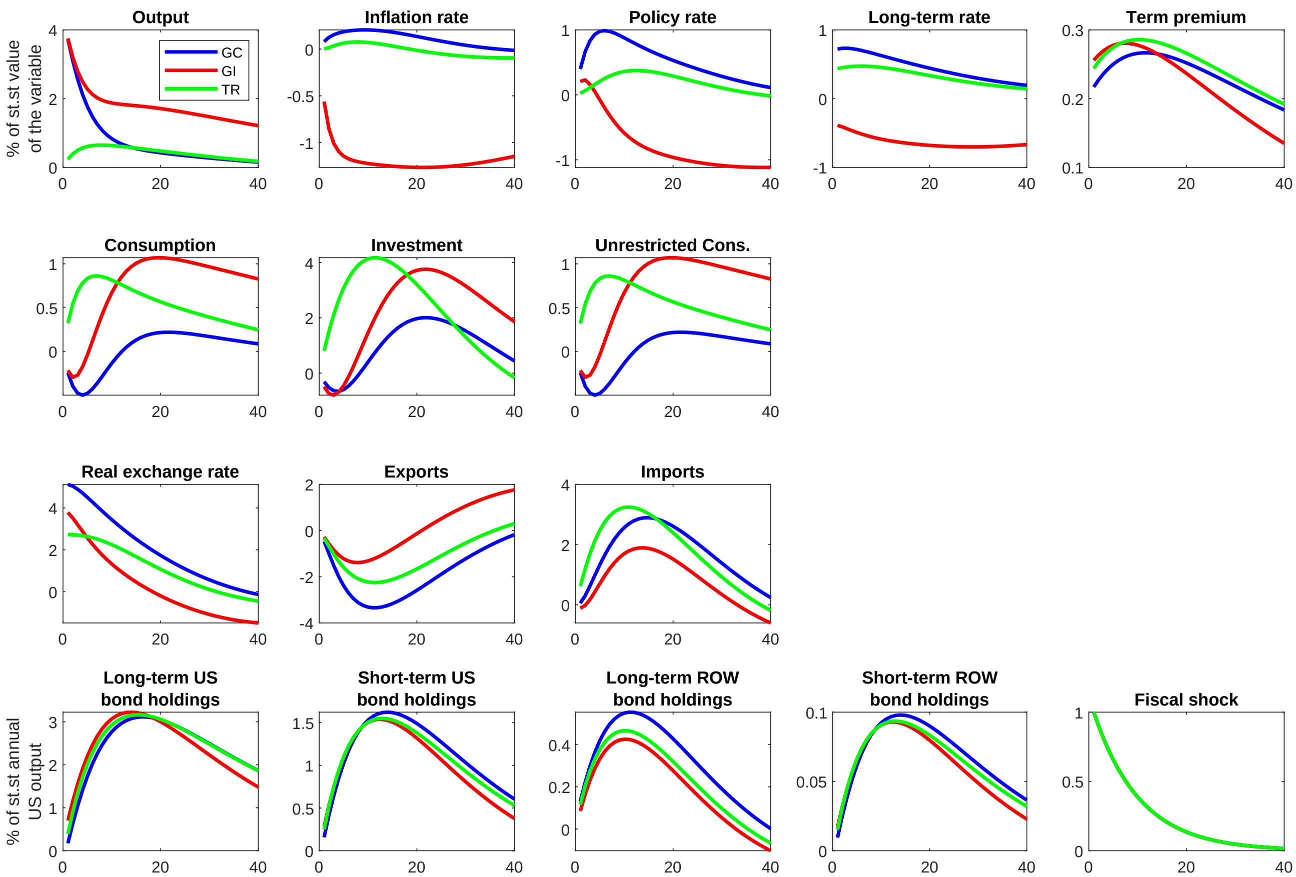
We calibrate the capital share in home-goods production, α, to 0.34 in both countries in order to match a labor income share of 66%. The depreciation rate of private capital, δ, is calibrated to 0.02 in both countries to match the investment-output ratio of 19.5%. The capital utilization cost level parameter, κ_u, is calibrated to imply, without loss of generality, a unit utilization rate at the steady state. Home-bias parameters in the consumption and investment aggregators in the US, γ_c^* and γ_i^*, are both set to 0.85, reflecting a 12% import share, while in the ROW, the corresponding parameters, γ_c and γ_i, are set to 0.94 given the size of 2.6 of the ROW economy relative to the US. ϖ is set to 1, implying a unit elasticity of capacity utilization with respect to the rental rate of capital, while the investment adjustment cost parameter, φ, is set to 5. The elasticity of substitution between domestic and imported goods in the consumption and investment aggregators, λ_c and λ_i, are set to 1.

The price and wage adjustment cost parameters, κ_h, κ_f and κ_w, are set to 90, corresponding to Calvo parameters of around 0.9 and indicating significant levels of price and wage stickiness, while the indexation parameters, ς_h, ς_f and ς_w, are set to 0.5. The markup parameters, θ_h, θ_f, and θ_w, are calibrated to reflect a 25% steady-state markup in prices and wages in both countries. Finally, the Taylor rule on the short-term interest rate is fairly persistent with ρ set to 0.8, while the long-run reaction coefficients, r_π and r_y, are set to 1.5 and 0.125, respectively, which are standard values in the literature.

C Details on the Sensitivity Analysis

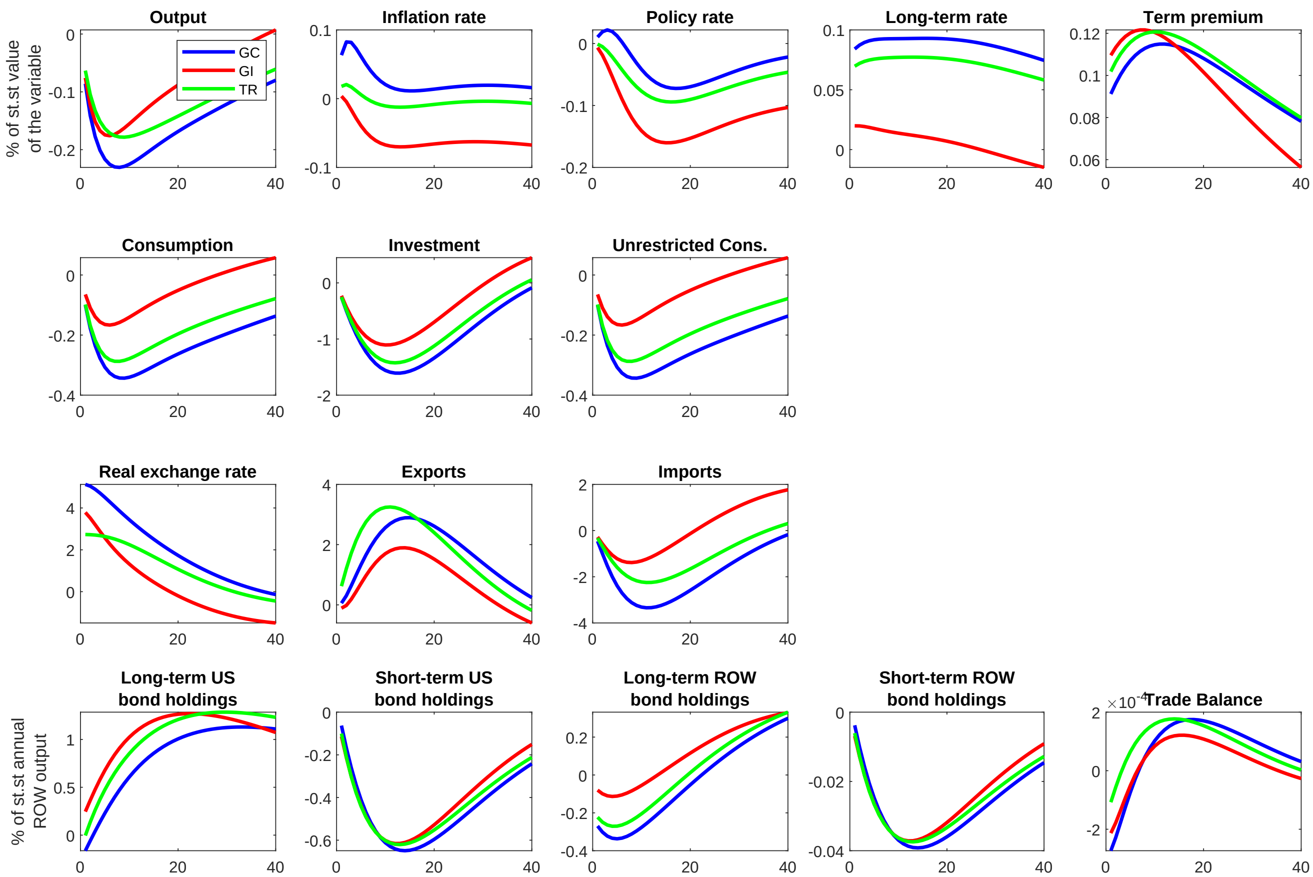
This section shows additional sensitivity analyses performed in the paper.

Figure C.1: US responses to a 1% fiscal shock in the United States as a fraction of steady-state annual US output: The case of no-restricted agents



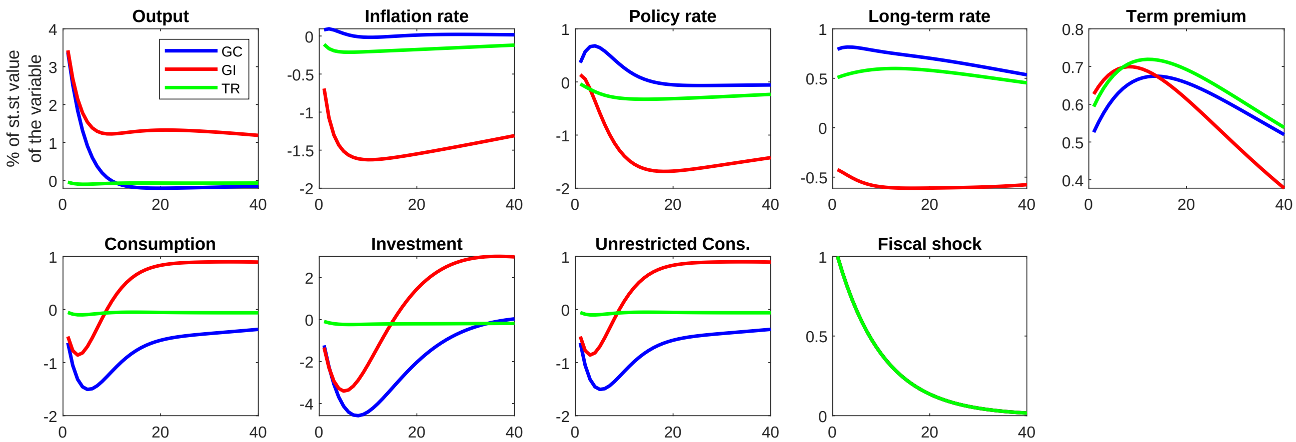
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.2: ROW responses to 1% fiscal shock in the United States as a fraction of steady-state annual US output: The case of no-restricted agents



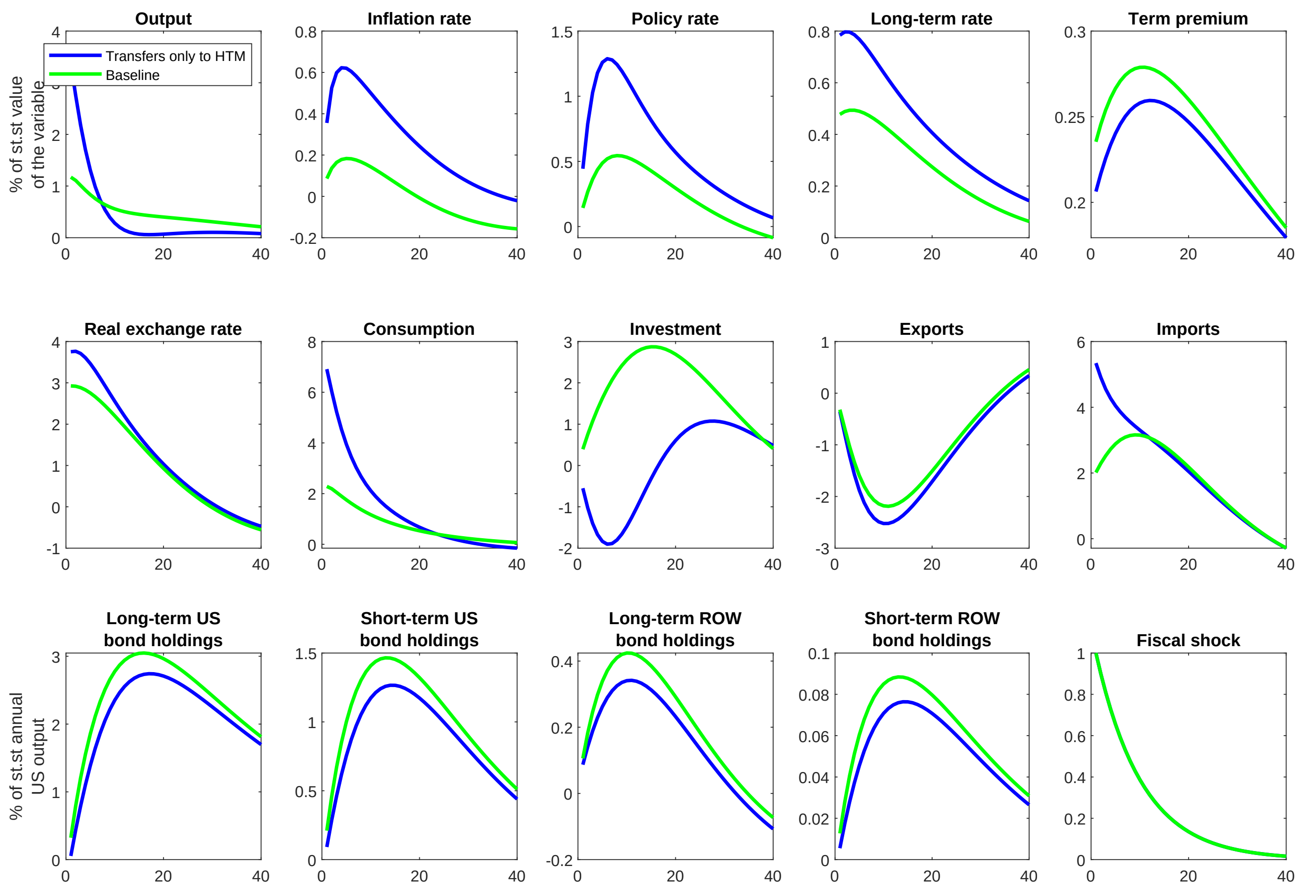
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.3: US responses to 1% fiscal shock in the United States as a fraction of steady-state annual US output: The case of no-restricted agents and closed-economy



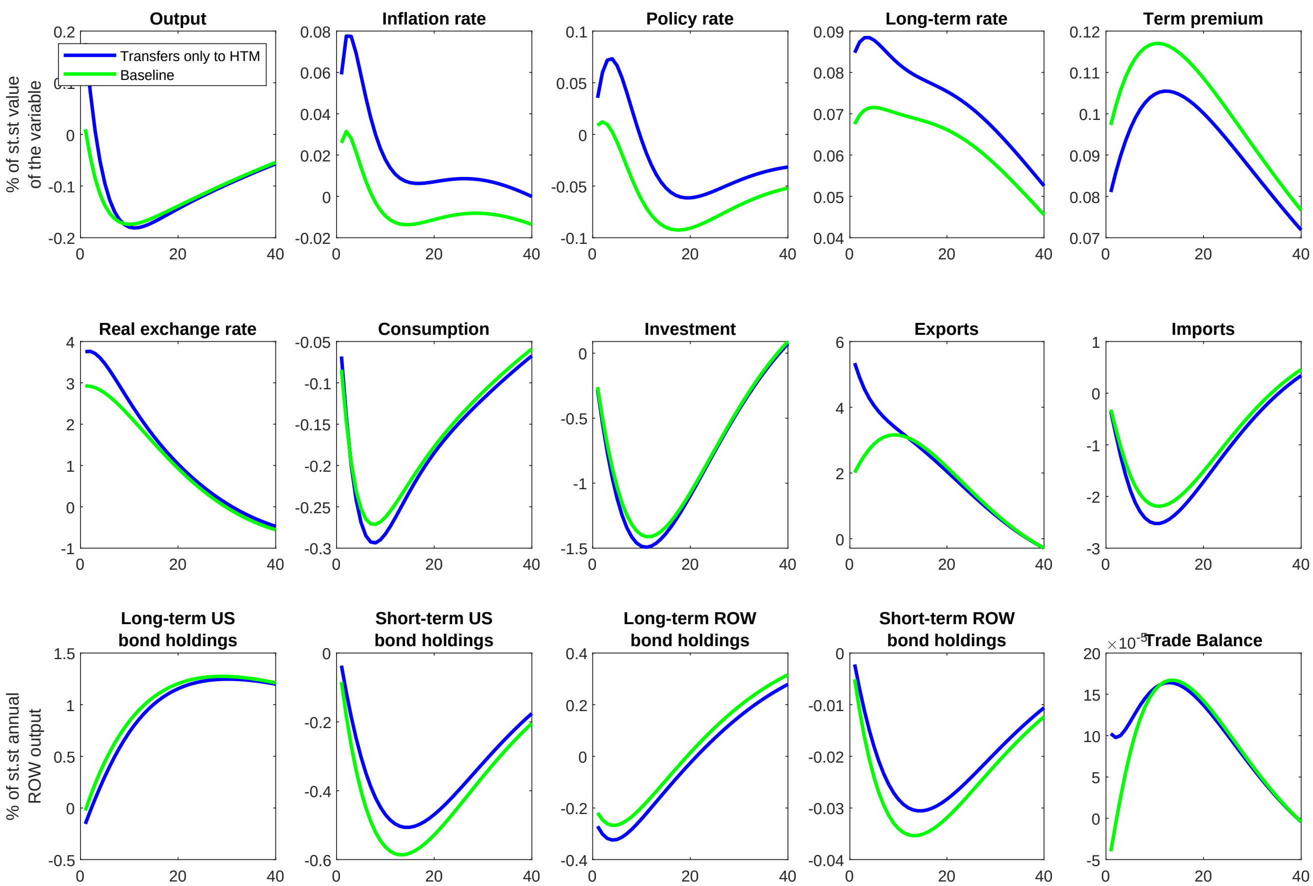
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.4: US responses to 1% fiscal shock in the United States as a fraction of steady-state annual US output: The case where transfers are sent only to restricted agents



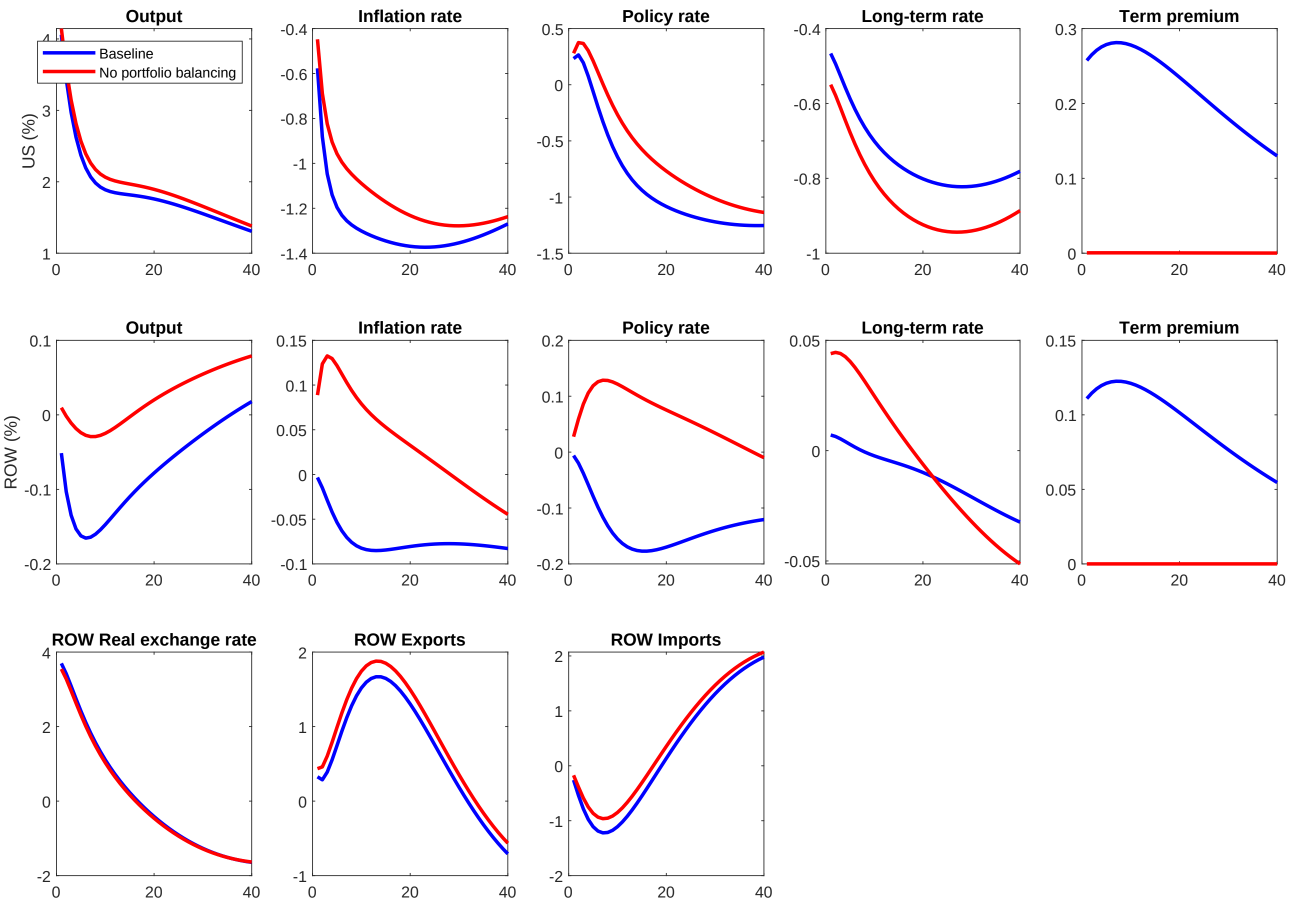
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.5: ROW responses to 1% fiscal shock in the United States as a fraction of steady-state annual US output: The case where transfers are sent only to restricted agents



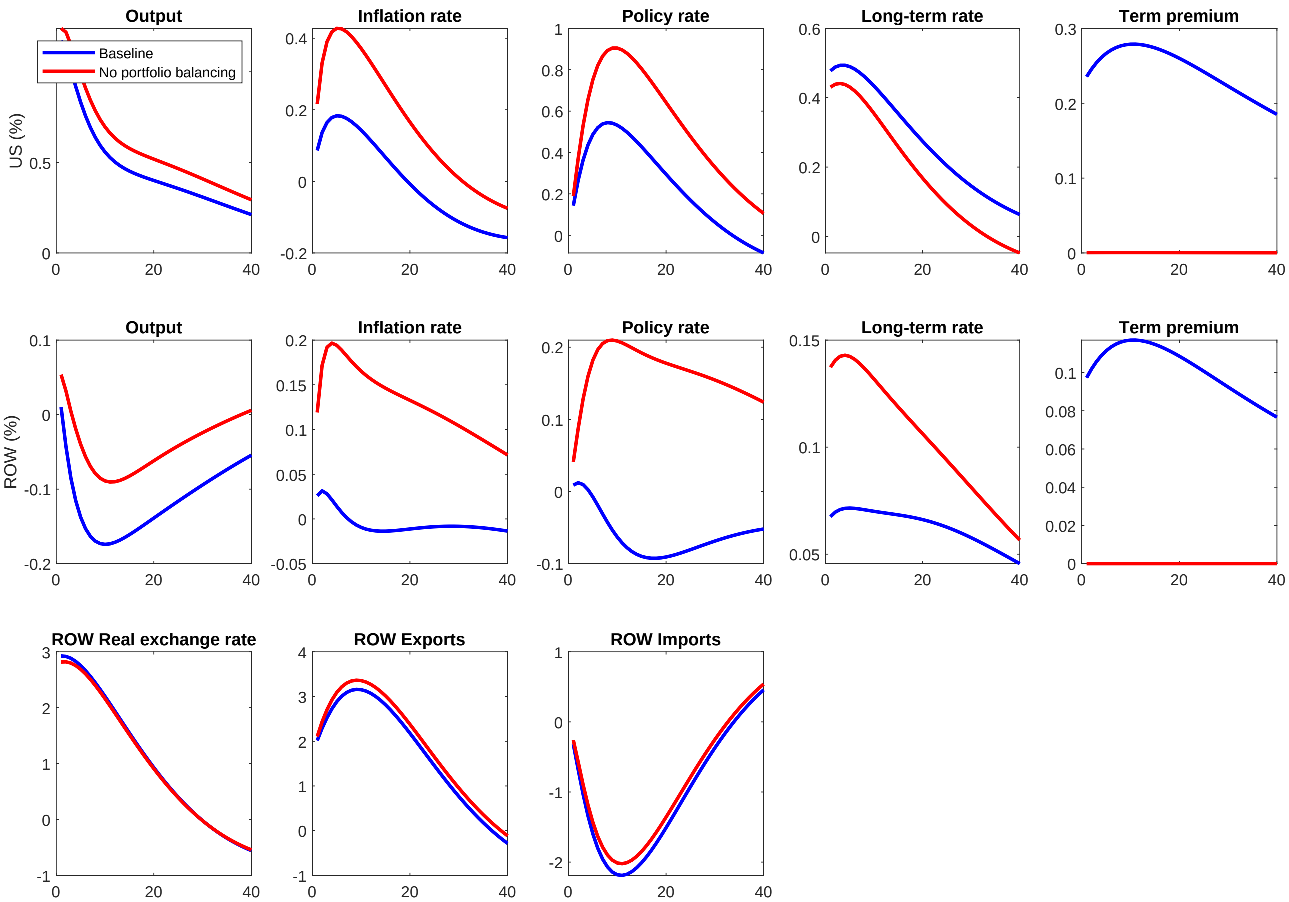
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.6: Fiscal spillovers in the absence of portfolio balancing: Government investment shock



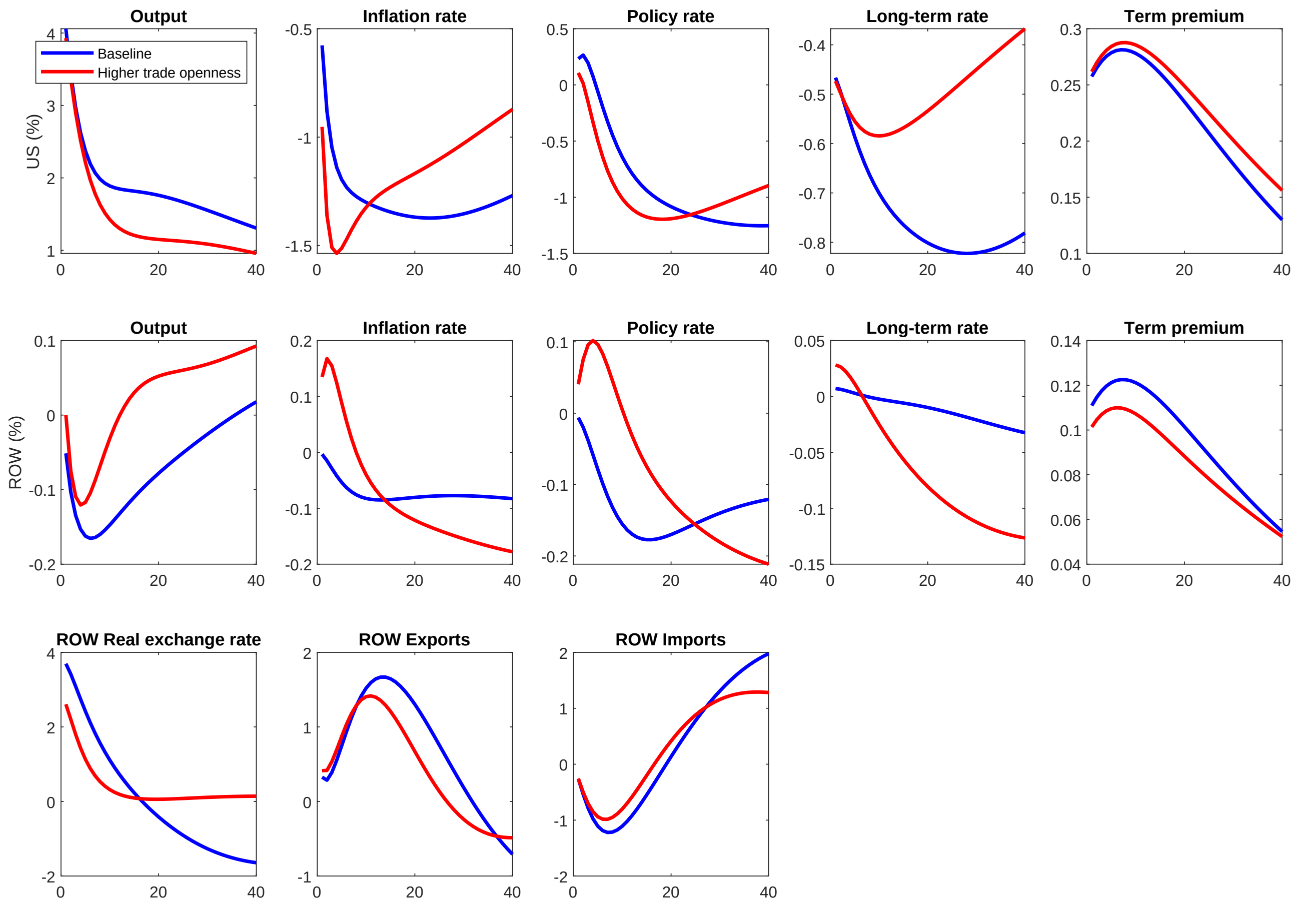
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.7: Fiscal spillovers in the absence of portfolio balancing: Transfer shock



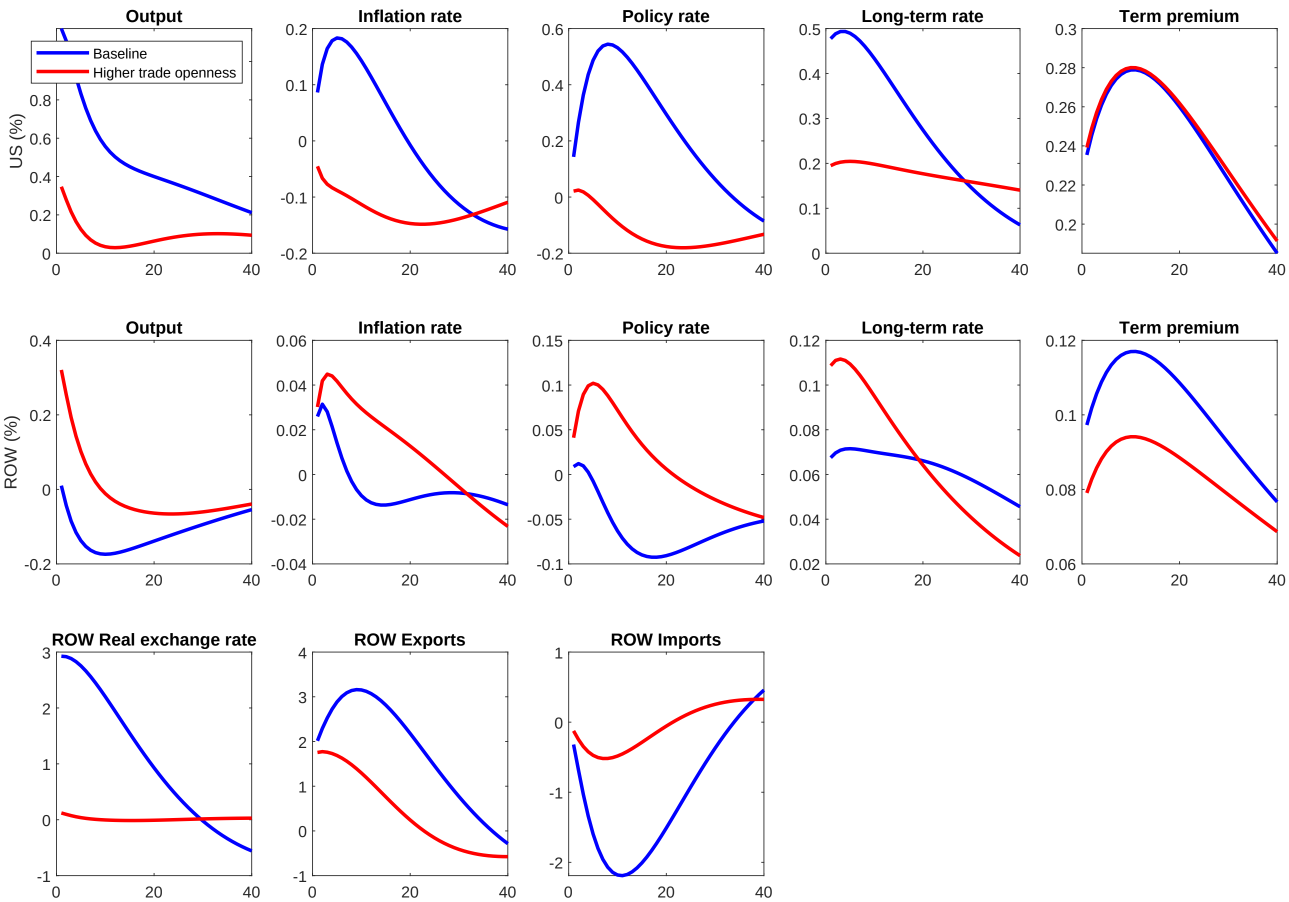
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.8: Fiscal spillovers under higher trade openness: Government investment shock



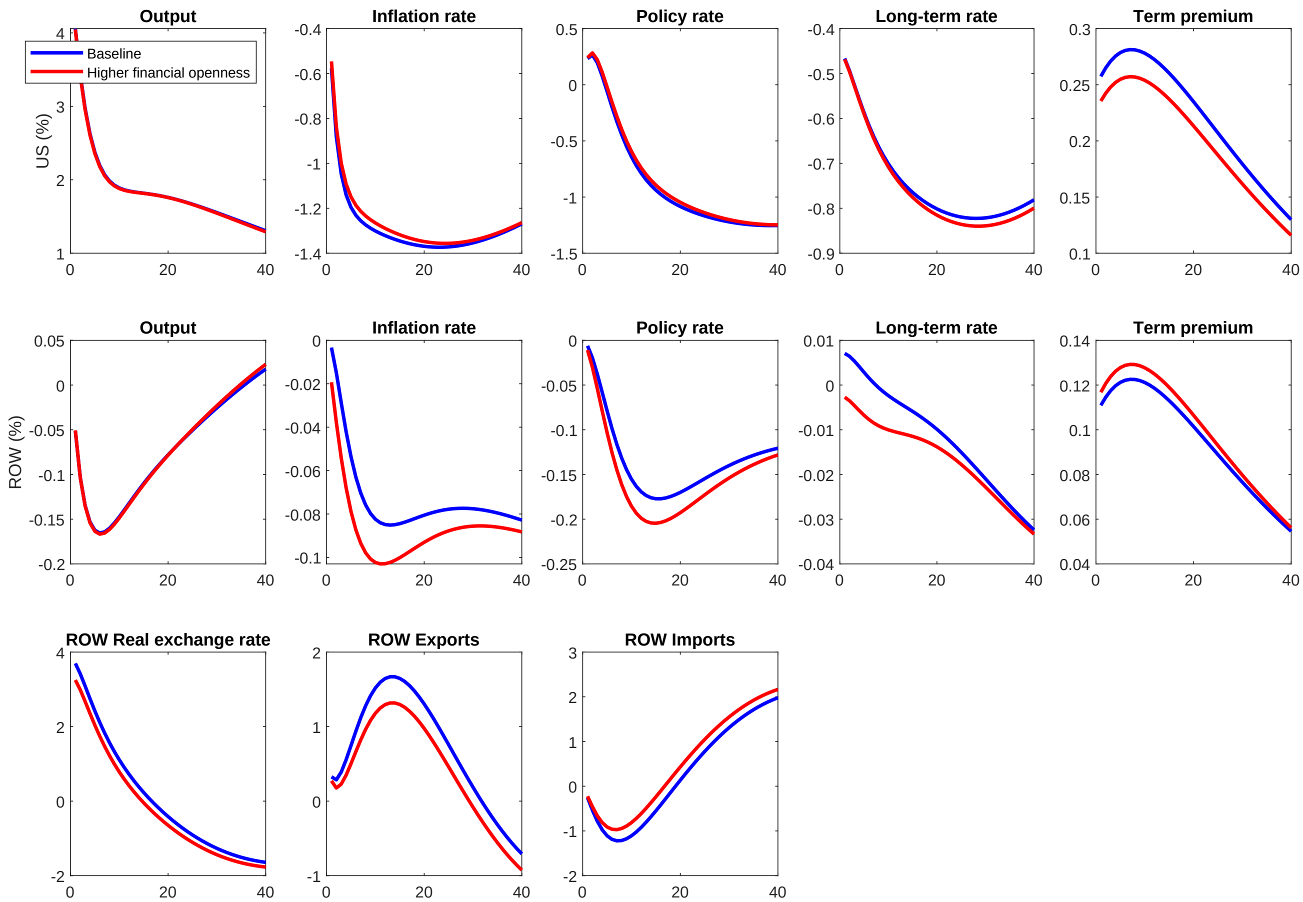
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.9: Fiscal spillovers under higher trade openness: Transfer shock



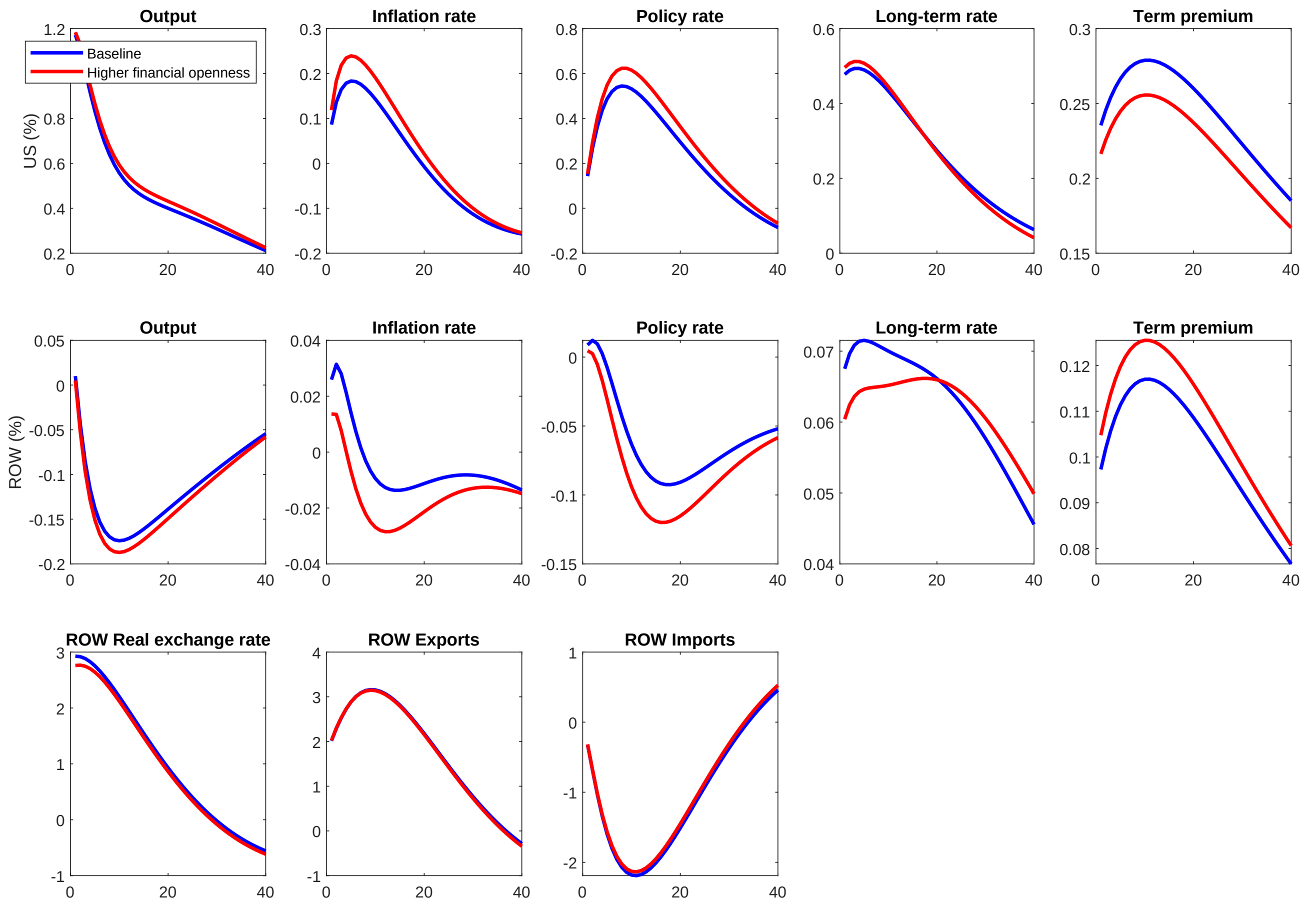
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.10: Fiscal spillovers under higher financial openness: Government investment shock



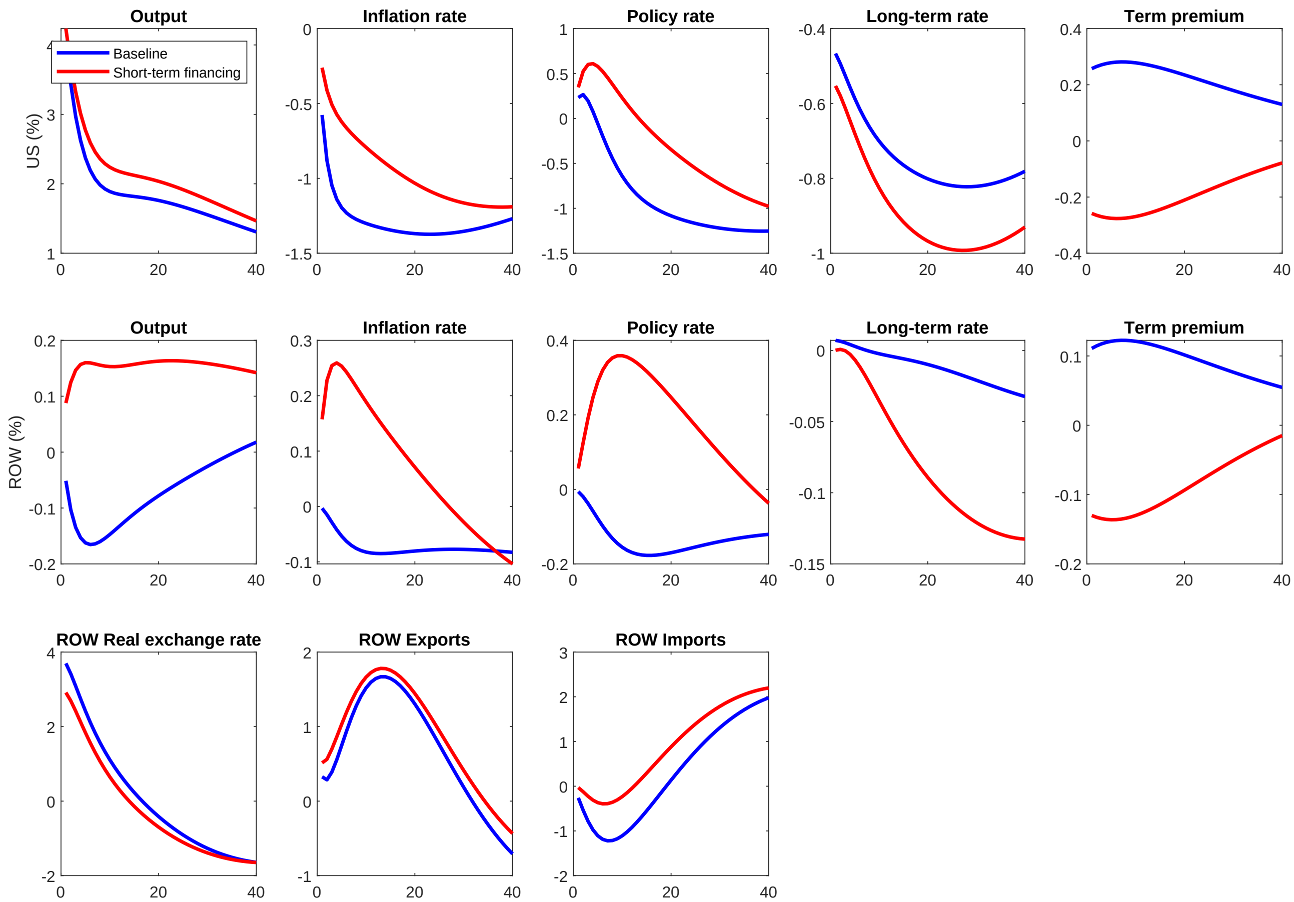
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.11: Fiscal spillovers under higher financial openness: Transfer shock



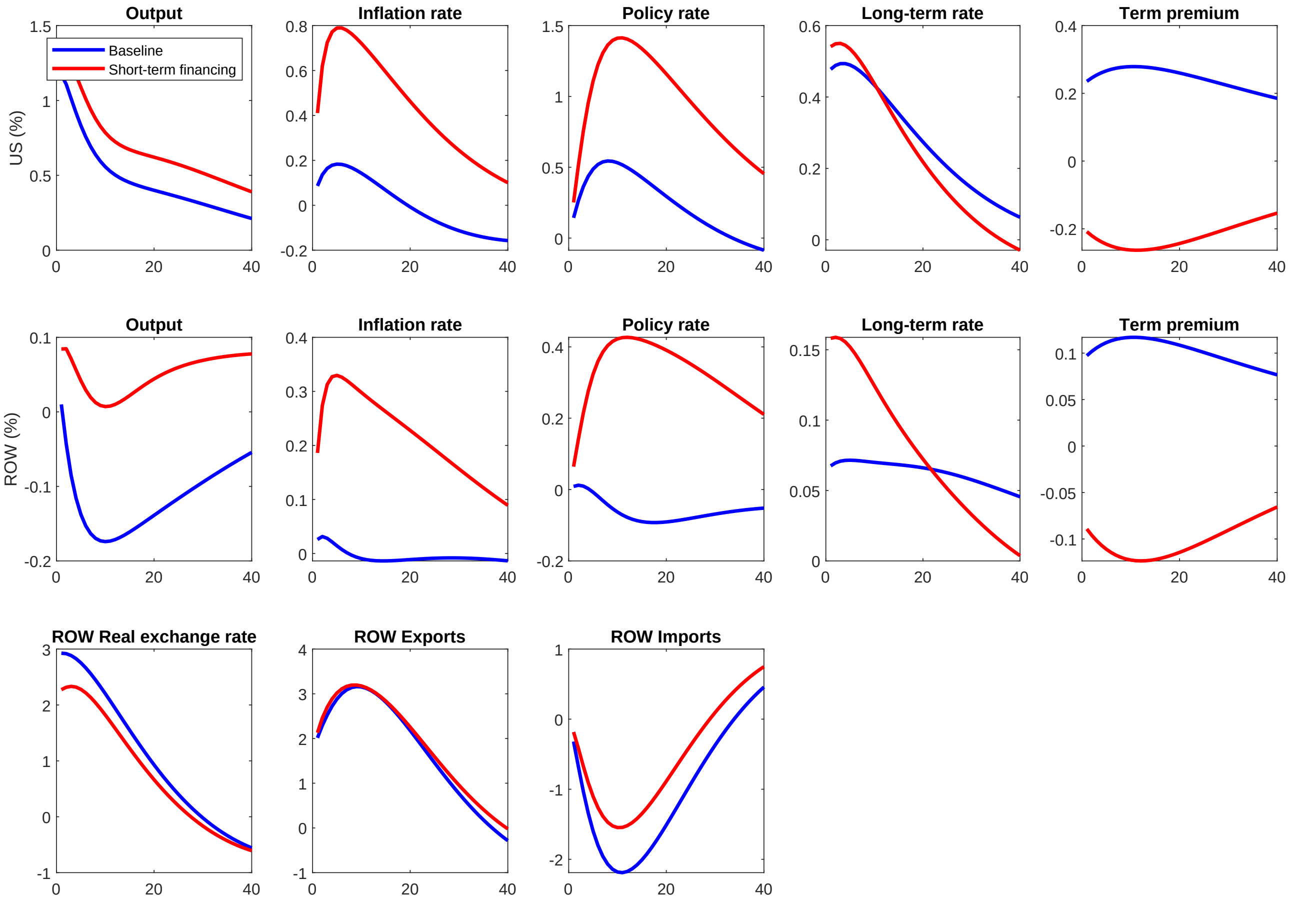
Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.12: Fiscal spillovers in the case of short-term debt financing: Government investment shock



Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

Figure C.13: Fiscal spillovers in the case of short-term debt financing: Transfer shock



Notes: Impulse responses are presented as percentage deviations (%) from the steady-state level for each variable except infation, policy rate, long-term rate, the term premium and bond holdings-to-GDP ratios, for which deviations are presented in percentage points.

D Further empirical analysis

We use alternative measures of US fiscal spending to determine whether the relationships that we find in Table 3 are robust. Table D.1 reports these alternative measures of fiscal policy. The numbers (1), (2), and (3) in column 2 correspond to the specifications displayed in Table 3. The results in the first row of each panel, for example, correspond to the specification with only the lagged values of the fiscal policy measure and the dependent variable on the right hand side. To obtain the results in the first four columns, we use the growth rates of total government spending, government consumption spending, government investment spending and transfers as the independent variable in equation (39). The results in panel A, with the exception of column 3, support the relationship between real dollar exchange rates and US fiscal policy. We find that the relationship is reversed for investment. This finding is consistent with the DSGE model responses to government investment shocks as these shocks, similar to TFP shocks, generate a less negative and even positive response in exchange rates. These results are similar across the three specifications. The results reported in the first four columns of panel C also support our baseline findings that there is a positive link between US fiscal spending and foreign term premiums with the exception of government consumption spending and transfers in the first specification. By contrast, we do not detect a significant relationship between the four fiscal policy measures and bilateral trade balance as reported in the first four columns of panel B.

Next, we identify the components of real government consumption, investment, and transfer spending growth that are orthogonal to real GDP growth and use these as our measures of fiscal policy variable in equation (39). To do so, we first estimate a Vector Autoregressive (VAR) model, with real US government spending growth and real US GDP growth, ordered as such in a Cholesky decomposition to identify the component of US government spending that is orthogonal to US real GDP growth (hereafter referred to as orthogonal government spending). In this VAR estimation, we use 4 lags of the two variables. Using this measure also allows us to neutralize any automatic stabilizer features of fiscal policy as the main focus in our paper is on large-scale asset purchases that fund discretionary policies. The results in the last five columns of each panel display the results that correspond to these measures of fiscal policy. These results in panel A are qualitatively identical to the results in the first four columns. When the growth of the trade balance-to-GDP ratio is used as the dependent variable, the significant coefficients are now consistent with the earlier results. The coefficients of investment and transfers growth remain insignificant. Turning to panel C, we observe that all significant coefficients, consistent with the predictions of our model, are positive.

A key inference from the first part of the paper is that a US fiscal expansion, contrary to common wisdom, can have a negative effect on foreign output. In this section, we test whether this prediction of the model is consistent with data. To conduct the test, we use the real GDP growth rate of the G-20 economies as our dependent variable in equation (39). Since this variable is directly related to our baseline measures of bilateral trade and bond holdings, we reconfigure the two independent variables. For the trade variable, we add the bilateral exports and imports for a country and convert this trade volume statistic to local currency, and then express it as a share of total trade volume of US with the G-20 countries. We follow a similar approach and measure a country's US bond holdings as a share of all holdings by G-20 countries. Doing so allows us to test whether US fiscal policy has a bigger or smaller impact on its main trade partners and bondholders. We incorporate these variables and their interaction with US fiscal spending into equation (39). One caveat here is that some of the main trade partners of the US are also its main bondholders. To avoid multicollinearity, we therefore include our trade volume and bond holding variables in separate regressions. In doing so, we use all alternative measures of fiscal policy mentioned in the previous section.

The results obtained from the estimation of equation (39) with only the trade volume variables are reported in Table D.2. The main inference is that US fiscal spending is, in general, negatively related to foreign economic activity. A US fiscal expansion, for example, is associated with decline in the growth rate of G-20 economies. To visualize the quantitative significance of this negative sensitivity, suppose initially that a country, say country x, does not trade with the US nor does it hold US bonds. In addition, suppose that real US government expenditures increase 1% relative to the previous quarter for four consecutive quarters. The coefficient value of 1.0366 reported in the first column then implies that the real GDP of country x decreases by roughly 1 percentage point in the next quarter. The positive coefficient of transfers, by contrast to the other coefficients, indicates that a growth in US transfer payments is positively related to foreign economic activity. The negative coefficient of the interactive term does not change this inference as the mean value of the bilateral trade variable (countries' shares of US trade) is 0.034 in our sample.

The magnitude of the negative relationship mentioned above is not significantly altered by the degree of trade that country x has with the US, as the interactive variable coefficient is statistically insignificant throughout most estimations. The results do, however, show that the more important trade partners of the US grow slower relative to those who trade less with the US, although this relationship is not as strong as the relationship between US fiscal policy and foreign output growth. The coefficient value of -0.054 in column 1 implies that if country x's US trade as a share of its GDP goes up by 1 percentage point for four consecutive quarters, its GDP grows 0.054 percentage points slower in the ensuing quarter.

The remaining columns display the results that we obtained by using alternative measures for the stance of US fiscal policy. The results suggest that investment (measured as the growth rate of real government investment) is the component of government spending that is most negatively related to foreign economic activity. We note importantly that our results do not imply any causal relationships and that they only offer suggestive evidence to bring perspective to our model results.

The results in columns 5 to 8 also reveal a negative relationship, albeit smaller in magnitude, between orthogonal spending variables and foreign output growth. The positive relationship between growth in US transfer payments and foreign output growth is robust to using our alternative approach. The results displayed in the last column, which correspond to the Ramey (2011) news shock variable, similarly point to a negative relationship between US government spending and foreign output.

We proceed by estimating equation (39) with bond holding variables to determine whether holdings of US bonds change countries' sensitivity to US fiscal policy. Similar to our earlier results, the results displayed in Table D.3 demonstrate a significant and negative relationship between US government spending and foreign output for all variables except transfers. One noticeable difference is that the growth in total spending is not significantly related to foreign output in this model. Also, unlike earlier results, the coefficients of the interactive term are generally significant. The magnitude of these coefficients, however, are not large enough to change our main inference that US fiscal spending is negatively related to foreign output (the average share of US bond holdings across time and countries is 3.5% in our sample). It should be noted, however, that the negative effects of orthogonal government total spending, consumption, and investment are larger when countries hold a larger share of US bonds.

Sensitivity to US fiscal policy at the zero lower bound

Policy rates in some of the countries in our sample, especially in the second half of our sample period, are at the ZLB. It is well-known that output's sensitivity to changes in demand, whether fiscal in nature or not, is much higher at the ZLB. Any potential positive effects of US fiscal policy on the demand for foreign goods then would be stronger at this threshold. To check for this possibility, we estimate equation (39) by including a variable that captures the interaction between the US fiscal policy variables and the time periods characterized by ZLB. Specifically, we construct a dummy variable that takes the value 1 if short-term deposit rates are less than 0.5%, and 0 otherwise.[27] We then interact this variable with the measures of US fiscal policy and include it in equation (39). The results obtained from this estimation are reported in Table D.4. As indicated by the results in the first two rows, the relationship between US fiscal policy and foreign output is generally more positive (less negative) at the ZLB as all significant coefficients except those of orthogonal consumption and transfers are positive. The sign and significance of the fiscal policy measures are similar to those in our baseline results. The same can be said about the coefficients of lagged output and the bilateral trade variable, which are omitted for the sake of brevity.

Country-level VAR estimations

We proceed by using our VAR analysis to determine whether the negative relationship that we have uncovered so far is also observed at the country level. In doing so, we use the growth rate of real US government spending that is orthogonal to US output and the Ramey news shock as the two measures of fiscal policy. The orthogonalized output responses to a one standard deviation change in these variables are displayed in Figures D.1 and D.2, respectively. The responses generally support the negative relationship observed at the panel level. The responses, however, are less significant and there are countries, other than the US, for which a US fiscal expansion generates a positive output response. We should point out that the number of observations and the power of tests were significantly lower in our country-level analysis. The impulse responses, therefore, were less significant than those generated by our PVAR model. The output responses to US fiscal spending were still significant with one standard deviation confidence intervals for a majority of the countries

[27] We tried alternative thresholds and obtained qualitatively similar results.

in our sample.

Table D.1: Alternative measures of fiscal spending

		Government spending	Government consumption	Government investment	Government transfers	Orthogonal government spending	Orthogonal government consumption	Orthogonal government investment	Orthogonal government transfers	Ramey news shock
Panel A										
Real exchange rate	(1)	-1.155	-1.061	0.229	-0.144	-0.011	-0.017	0.020	-0.004	-0.278
		(0.019)**	(0.029)**	(0.020)**	(0.006)***	(0.0098)***	(0.002)***	(0.009)***	(0.002)***	(0.001)***
	(2)	-1.042	-1.008	0.308	-0.236	-0.010	-0.018	0.022	-0.007	-0.274
		(0.047)**	(0.023)**	(0.016)**	(0.008)***	(0.024)**	(0.002)***	(0.000)***	(0.003)***	(0.002)***
	(3)	-2.496	-2.329	-0.460	-0.401	-0.016	-0.022	0.019	-0.015	-0.388
		(0.004)***	(0.056)*	(0.452)	(0.000)***	(0.061)*	(0.008)***	(0.027)**	(0.001)***	(0.027)**
Panel B										
Trade balance	(1)	4.000	3.976	1.670	-1.611	0.025	0.023	0.022	-0.052	0.042
		(0.347)	(0.334)	(0.716)	(0.245)	(0.069)*	(0.043)**	(0.870)	(0.447)	(0.051)*
Panel C										
Term Premium	(1)	6.309	-3.757	1.104	-0.597	0.083	0.004	0.085	0.096	0.376
		(0.000)***	(0.000)***	(0.281)	(0.039)**	(0.000)***	(0.004)***	(0.077)*	(0.018)**	(0.012)**
	(2)	13.348	16.266	3.514	7.275	0.180	0.190	0.051	0.121	1.109
		(0.028)**	(0.076)*	(0.102)	(0.068)*	(0.018)**	(0.014)**	(0.761)	(0.498)	(0.022)**
	(3)	13.295	9.291	3.620	6.511	0.121	0.079	0.102	0.097	0.568
		(0.027)**	(0.007)***	(0.047)**	(0.062)*	(0.005)***	(0.011)**	(0.601)	(0.034)**	(0.033)**

Notes: This table reports the results obtained from a fixed effects estimation of equation (39). For the estimations reported in panels A, B and C, the growth rates of real exchange rate, the bilateral trade with the US, and term premium are the dependent variables, respectively. Column headers show the fiscal spending measures that are used as independent variables. *, **, and *** show significance levels at 10%, 5%, and 1%, respectively. The numbers reported in parentheses are F statistics for every variable except the lagged dependent variable.

Table D.2: Foreign output growth, US fiscal policy, and trade volume

	Government spending	Government consumption	Government investment	Government transfers	Orthogonal government spending	Orthogonal government consumption	Orthogonal government investment	Orthogonal government transfers	Ramey news shock
US fiscal policy stance	-1.037	-0.552	-1.472	0.818	-0.445	-0.079	-1.133	2.731	-0.029
	(0.084)*	(0.092)*	(0.000)***	(0.000)***	(0.259)	(0.004)***	(0.000)***	(0.000)***	(0.045)**
Bilateral trade	-0.054	-0.051	-0.054	0.004	-0.078	-0.080	-0.072	-0.032	0.007
	(0.017)**	(0.014)**	(0.057)*	(0.386)***	(0.026)**	(0.008)***	(0.035)**	(0.389)	(0.635)
Bilateral trade * US fiscal policy stance	-2.798	-3.194	-1.458	-2.022	-2.305	-1.634	-3.170	-5.407	0.743
	(0.593)	(0.47)	(0.368)	(0.456)***	(0.409)	(0.322)	(0.38)	(0.349)	(0.707)
Lag of GDP	-0.349	-0.345	-0.354	-0.310	-0.345	-0.346	-0.356	-0.311	-0.292
	(0.002)***	(0.003)***	(0.002)***	(0.01)***	(0.002)***	(0.002)***	(0.002)***	(0.009)***	(0.011)**
# of observations	1,213	1,213	1,213	1,213	1,213	1,213	1,213	1,213	914
Adj-R2	0.136	0.134	0.161	0.260	0.136	0.136	0.147	0.251	0.095

Notes: This table reports the results obtained from a fixed effects estimation of equation (39). For each estimation, real GDP growth rate is the dependent variable. *, **, and *** show significance levels at 10%, 5%, and 1%, respectively. The numbers reported in parentheses are F statistics for all variables except the lagged dependent variable.

Table D.3: Foreign output growth, US fiscal policy, and bond holdings

	Government spending	Government consumption	Government investment	Government transfers	Orthogonal government spending	Orthogonal government consumption	Orthogonal government investment	Orthogonal government transfers	Ramey news shock
US fiscal policy stance	-0.952	-0.554	-1.383	0.782	-0.506	-0.170	-1.053	2.488	-0.057
	(0.344)	(0.021)**	(0.000)***	(0.000)***	(0.729)	(0.000)***	(0.000)***	(0.000)***	(0.001)***
Bond holdings	-0.056	-0.056	-0.057	-0.012	-0.054	-0.051	-0.052	-0.046	-0.049
	(0.364)	(0.292)	(0.221)	(0.141)***	(0.464)	(0.367)	(0.347)	(0.159)	(0.035)**
Bond holdings * US fiscal policy stance	0.353	0.587	0.248	-1.648	-0.355	-0.230	-0.990	-3.030	0.977
	(0.137)	(0.074)*	(0.000)***	(0.219)***	(0.045)**	(0.046)**	(0.009)***	(0.066)*	(0.019)**
Lag of GDP	-0.422	-0.425	-0.421	-0.395	-0.418	-0.420	-0.422	-0.395	-0.373
	(0.001)***	(0.001)***	(0.001)***	(0.007)***	(0.001)***	(0.001)***	(0.001)***	(0.006)***	(0.007)***
# of observations	969	969	969	969	969	969	969	969	712
Adj-R2	0.180	0.177	0.206	0.311	0.179	0.180	0.191	0.305	0.161

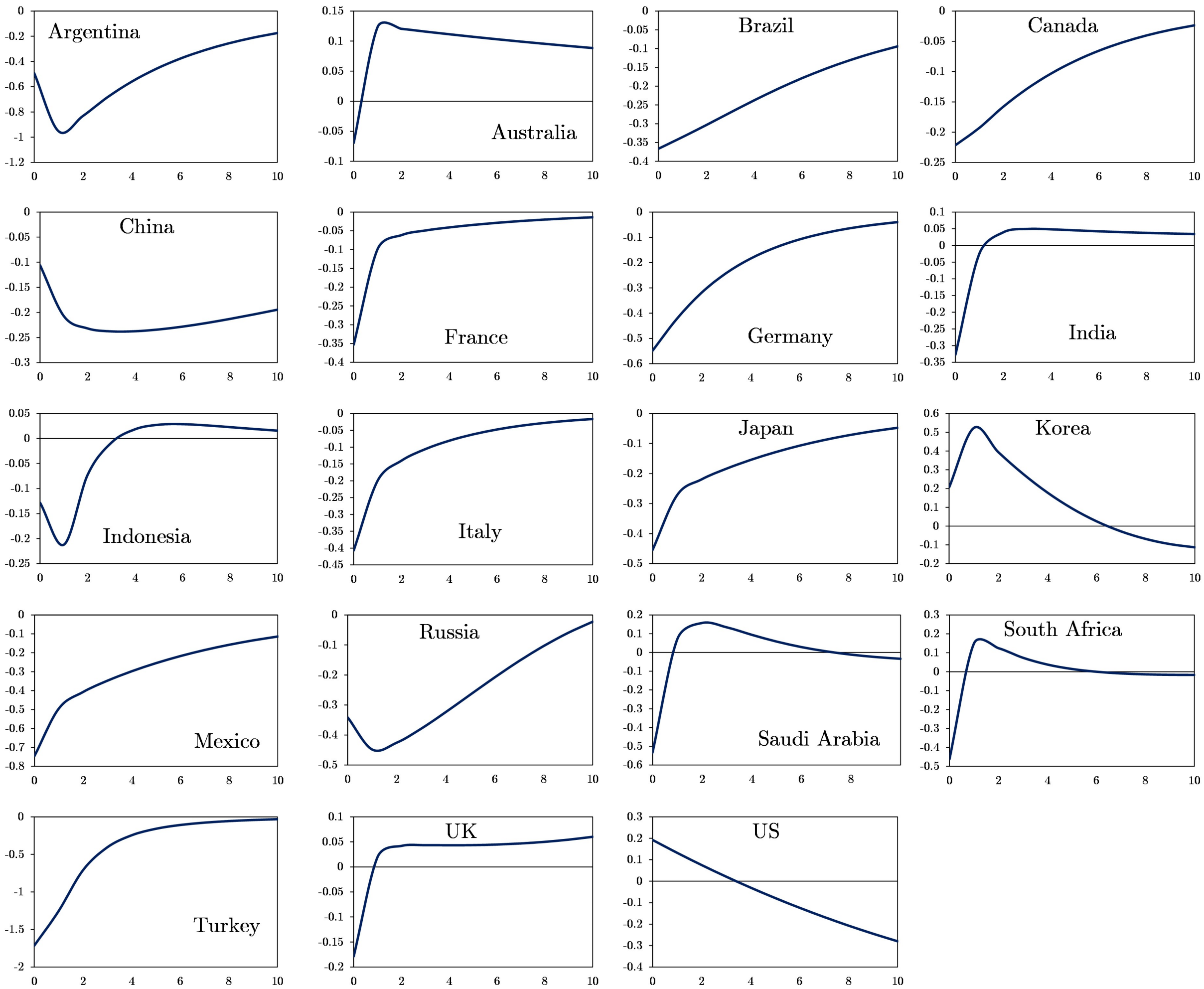
Notes: This table reports the results obtained from a fixed effects estimation of equation (39). For each estimation, real GDP growth rate is the dependent variable. *, **, and *** show significance levels at 10%, 5%, and 1%, respectively. The numbers reported in parentheses are F statistics for all variables except the lagged dependent variable.

Table D.4: Sensitivity to US fiscal policy at the zero lower bound

	Government spending	Government consumption	Government investment	Government transfers	Orthogonal government spending	Orthogonal government consumption	Orthogonal government investment	Orthogonal government transfers	Ramey news shock
ZLB * US fiscal policy stance	0.253	0.201	0.264	-0.055	0.085	-0.066	0.218	-0.068	0.206
	(0.000)***	(0.001)***	(0.004)***	(0.024)**	(0.001)***	(0.000)***	(0.006)***	(0.173)	(0.000)***
US fiscal policy stance	-1.040	-0.544	-1.480	0.820	-0.444	-0.073	-1.134	2.741	-0.034
	(0.065)*	(0.092)*	(0.006)***	(0.000)***	(0.241)	(0.004)***	(0.001)***	(0.000)***	(0.045)**
Bilateral trade * US fiscal policy stance	-2.932	-3.323	-1.489	-2.301	-0.024	-0.018	-0.034	-0.068	0.756
	(0.428)	(0.538)	(0.391)	(0.401)	(0.260)	(0.215)	(0.320)	(0.202)	(0.868)

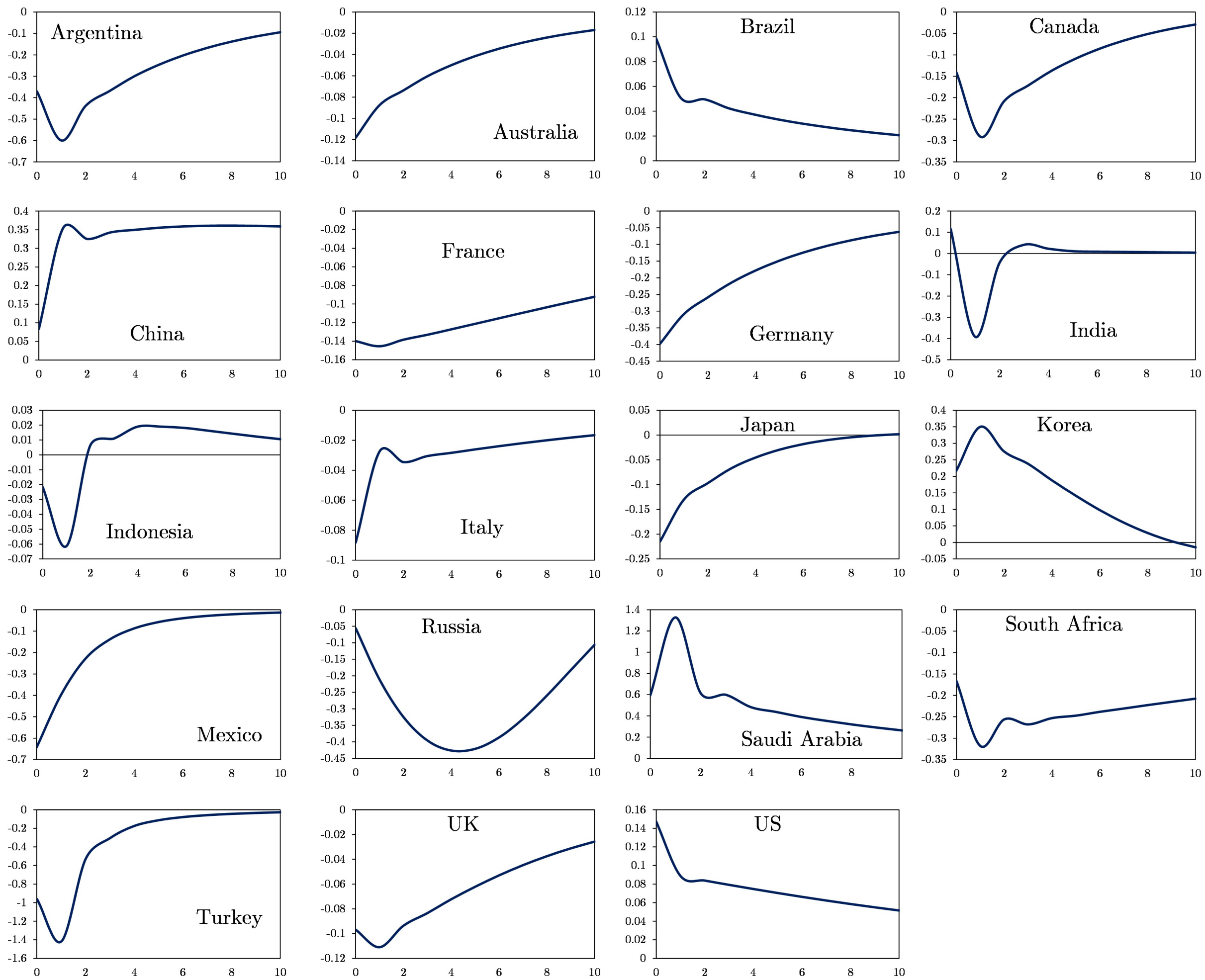
Notes: This table reports the results obtained from a fixed effects estimation of equation (39) when the interactive variable displayed in the first row is added as an additional independent variable. For each estimation, real GDP growth rate is the dependent variable. *, **, and *** show significance levels at 10%, 5%, and 1%, respectively. The numbers reported in parentheses are F statistics for all variables except the lagged dependent variable.

Figure D.1: Output responses in country-specific VAR models (responses to the changes in real US government spending)



Notes: The figure displays the real GDP growth responses to a one standard deviation change in real US government spending. The responses are obtained from country-specific VAR models.

Figure D.2: Output responses in country-specific VAR models (responses to changes in the orthogonal component of US government spending)



Notes: The figure displays the real GDP growth responses to a real US fiscal policy shock. The responses are obtained from country-specific VAR models. The policy shock in the estimations with the US is the Ramey fiscal shock.