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TRADE FLOWS AND FISCAL MULTIPLIERS

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ABSTRACT

We present novel insights on the role of international trade following unanticipated government spending and income tax changes in a flexible exchange rate environment. In a simple two-country, two-good model, we show analytically that fiscal multipliers can be larger in economies more open to trade, even when fiscal expansions imply a trade deficit. Cross-country comovement can be positive or negative. Three factors determine how trade linkages affect fiscal multipliers: the relative import share of public and private goods, how the government finances its budget, and the currency invoicing of exports. A Bayesian prior-predictive analysis shows a quantitative international business-cycle model bears the same predictions. Estimating the model on Canadian and U.S. data, we find support for larger multipliers relative to a counterfactually closed economy and positive cross-country spillovers.

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A data appendix is available at http://www.nber.org/data-appendix/w27652

1 Introduction

Since the onset of the Great Recession, debates over a need for globally-coordinated fiscal stimulus feature prominently in policy discourse (e.g., the 2009 G-20 London Summit and G-20 Brisbane meeting in November 2014). Discussions stem from varying perceptions on the sign of fiscal spillovers and the domestic effectiveness of a fiscal stimulus in open economies. In the policy narrative, incentives to coordinate fiscal policy interventions depend on trade balance dynamics (e.g., Frankel, 2016), implying the issue ultimately centers around a key question: How do trade linkages affect the transmission of fiscal policy? Conventional wisdom dictates real exchange rate appreciation and/or rising aggregate income lowers net exports, mitigating the domestic effectiveness of fiscal policy by shifting stimulus abroad.[1] In this conventional view, net export crowding out is the dominant, negative force through which international trade affects fiscal multipliers and incentives to coordinate fiscal interventions across countries.[2]

This paper shows this view offers only a partial characterization of the effects of trade linkages on the transmission of fiscal policy. We show following unanticipated government spending and income tax changes, multipliers can be larger in economies more open to trade, even when fiscal expansions imply a trade deficit. Cross-country spillovers can be positive or negative. Domestic multipliers can be larger since private consumption and investment can increase (i.e., can be crowded-in) relative to less open economies. Moreover, the total trade-to-GDP ratio does not intrinsically determine these results. Holding the trade share and trade elasticity constant, we show countries can have higher or lower fiscal multipliers with stronger trade linkages depending on 1) the private-sector import intensity relative to the public-sector, 2) how the government finances fiscal expansions, and 3) the invoicing of import and export prices.

[1] See Frenkel and Mussa (1981) and Chinn (2013) for a more formal discussion.

[2] In this paper, we define a fiscal multiplier as measuring the change in GDP relative to the change in a fiscal instrument, e.g., public spending or tax revenue.

We first demonstrate these results analytically in a simple two-good, two-country model. Then, using a Bayesian prior-predictive analysis, we show a quantitative international business-cycle model bears the same agnostic predictions. Estimating the model with likelihood-based methods on Canadian and U.S. data, we find support for larger domestic multipliers relative to a counterfactually closed economy and positive cross-country spillovers.

We illustrate the core intuition about the role of trade linkages in a simple open-economy variant of Woodford (2011) with endogenous physical capital. Analytical solutions show the effects of trade linkages on fiscal multipliers depend on the relative price of domestic to imported goods, which we define as the domestic terms of consumption. This measure coincides with the terms of trade under complete exchange rate pass-through, whereas it features a markup-adjustment otherwise.[3] When fiscal policy induces an appreciation of the domestic terms of consumption—e.g., following an increase in government spending that raises world demand for domestic goods—trade linkages increase domestic multipliers provided the positive wealth effect stemming from the favorable relative price movement more than offsets its negative substitution effect.[4] Importantly, larger domestic multipliers can coexist with a trade deficit and positive cross-country comovement. Alternatively, when fiscal policy induces a deterioration of the domestic terms of consumption—e.g., following a decrease in the income tax rate that raises the relative supply of the domestic good—the positive substitution effect must more than offset the negative wealth effect.

Analytical solutions demonstrate the relative import share of public and private goods, the financing of the government budget, and the currency invoicing of trade shape terms-of-consumption dynamics, for a given trade elasticity. To build intuition, consider an increase in government spending under flexible prices. Provided higher public expenditure raises the world demand for domestic goods, domestic prices increase relative to the rest of the

[3]With incomplete exchange rate pass-through, the domestic terms of consumption equals the terms of trade multiplied by the ratio of domestic to export markups.

[4]The positive wealth effect occurs since domestic households give up fewer imports to consume one unit of the domestic good when the domestic terms of consumption increase. The negative substitution effect occurs as households switch to cheaper imports.

world. The resulting domestic terms-of-consumption appreciation (which coincides with an appreciation of the terms of trade with flexible prices) can lead to higher fiscal multipliers in more open economies depending on the relative import shares of the private and public sectors. Other things equal, a higher private import share implies that domestic households benefit more from the positive wealth effect of a terms-of-consumption appreciation, boosting private demand. In contrast, a higher public import share implies the increase in public demand falls more on imported goods, all else constant, raising the trade deficit.[5]

Distortionary financing can increase the likelihood that trade linkages enhance fiscal multipliers. When public expenditures are financed with higher income taxes, the appreciation of the domestic terms of consumption implied by higher taxes can partly offset the decline in the domestic labor and capital supply, raising multipliers relative to a closed economy. When an income tax cut is financed with lower public spending, multipliers can be higher since part of the reduction in public demand falls on trading partners. Nevertheless, consistent with the literature, distortionary financing worsens the domestic effectiveness of a fiscal stimulus relative to lump-sum financing, for a given trade openness.

Finally, the currency denomination of export prices also affects the dynamics of the domestic terms of consumption, and in turn, fiscal multipliers. For instance, in the limiting case of fully rigid prices, the domestic terms of consumption is tied to the response of the real exchange rate under local currency pricing (LCP, i.e., export prices sticky in the destination-market currency). In contrast, in the more empirically-relevant scenario of dominant currency pricing (DCP, i.e., export prices sticky everywhere in the dominant currency), what matters is the relative price of domestic to imported goods, despite the terms of trade being constant. In turn, when a fiscal expansion increases the real price of Home goods relative to Foreign goods—e.g., with an increase in government spending—multipliers are more likely to be larger under DCP relative to LCP, for a given response of the real exchange rate.

[5] Blanchard et al. (2016) and Erceg et al. (2005) also show that increasing the public sector import share decreases the domestic effectiveness of higher public spending.

Equipped with these analytical predictions, we then assess and quantify how trade linkages shape fiscal multipliers in a state-of-the-art international business-cycle model that includes additional, competing forces for the fiscal transmission—wage-setting frictions, intertemporal trade in assets, and complementarity between private and public consumption.[6] We employ a Bayesian prior-predictive analysis, as in Geweke (2010), to first uncover the full range of fiscal outcomes implied by the model structure. This exercise shows the model does not restrict fiscal outcomes along any dimension a priori. In particular, the model is agnostic about the role of trade linkages for fiscal multipliers, as well as the sign and size of the responses of the terms of consumption, real exchange rate, and international macroeconomic spillovers following discretionary fiscal interventions. However, the probability of fiscal multipliers being larger in a more open economy remains tied to the dynamics of the terms of consumption and the trade balance, consistent with the analytical model.

To discern which predictions are favored by the data, we estimate the model for a well-studied country pair with a flexible exchange rate, Canada and the U.S. We focus on this country pair because of the strong trade linkages (from the perspective of Canada, the U.S. is a good approximation of the rest of the world) and the high quality of fiscal and trade data. Posterior estimates imply government spending multipliers are larger with stronger trade linkages. For every dollar spent by the Canadian government, GDP can be up to 15 cents higher than a counterfactually closed economy (around a 20% increase in the multiplier). In addition, both a U.S. public spending increase and a tax cut raise GDP in Canada.

Related Literature This paper is related to several strands of the literature. Seminal theoretical contributions focused on whether fiscal policies are beggar or prosper-thy-neighbor (e.g. Betts and Devereux, 2001, Corsetti and Pesenti, 2001, Mendoza and Tesar, 1998, and Obstfeld and Rogoff, 1995). In addition, a few early quantitative studies examine government spending and tax changes in flexible exchange-rate models (e.g. Baxter, 1995 and

[6]The literature has shown these features are key determinants of fiscal multipliers in closed economy models. See for instance Leeper et al. (2017), Uhlig (2010), and Woodford (2011).

Erceg et al., 2005). In contrast to these studies, we focus on the role of trade linkages for the domestic and international transmission of fiscal policy.

Our analysis does not consider the role of fixed exchange rates nor cross-country strategic interactions in the design of fiscal policy. Without addressing the specific role of trade linkages, recent work addresses how monetary and exchange rate policies affect the fiscal transmission (e.g., Beetsma and Jensen, 2005, Born et al., 2013, Corsetti et al., 2013, Erceg and Linde, 2012, Gali and Monacelli, 2008, and Muller, 2008). Farhi and Werning (2016) also compare analytically fiscal multipliers in open and closed economies but focus on a currency union in a liquidity trap. Mendoza et al. (2014) study the effects of tax adjustments in response to large public debt shocks, considering cooperative and non-cooperative equilibria.

A few recent empirical studies examine cross-country spillovers from expansionary fiscal policies (Auerbach and Gorodnichenko, 2013 and Faccini et al., 2016). Our estimates in favor of positive international spillovers are consistent with these studies. The role of trade openness for the domestic transmission of government spending has been explored in the context of structural panel vector autoregressions. For instance, Ilzetzki et al. (2013) find public spending multipliers are smaller on average in countries where the trade-to-GDP ratio exceeds 60%.[7] Our theoretical analysis shows that behind these average effects, there can be cross-sectional heterogeneity depending on the composition of private and public imports, the financing of the government's budget, the currency invoicing of trade, and the trade elasticity. In light of our results, an important consideration for future empirical work is to include time-varying controls along these dimensions. Moreover, our results suggest the effects of trade openness can vary across fiscal instruments.

Finally, the paper relates to likelihood-based analyses on fiscal policy in closed economies (e.g., Drautzburg and Uhlig, 2015 and Leeper et al., 2017) and the international transmission of business-cycles (e.g., Adolfson et al., 2005, Justiniano and Preston, 2010, and Lubik and Schorfheide, 2005). Our analysis focuses on the role of trade linkages for fiscal multipliers.

[7]While Canada and the U.S. are included in their analysis, both countries fall in the "closed" classification (less than 60% trade-to-GDP ratios).

2 Building Intuition: A Simple Model

To understand the core implications of trade linkages for fiscal multipliers, we study a benchmark two-country model. The closed-economy version adds physical capital into Woodford's (2011) model, whose dynamics have been extensively studied in the literature. We present the model details below and provide the full system of equilibrium conditions in Appendix A.1.

We start with the stark assumptions of flexible prices, financial autarky, and full home bias in government spending. In this context, the response of the terms of trade summarizes the qualitative effects of trade linkages on fiscal multipliers. We then discuss how the composition of government spending, distortionary financing, net-export dynamics, and price stickiness affect the core intuition in this simple environment. The key message of this section is that trade linkages can increase fiscal multipliers either by crowding-in private demand relative to a closed economy (following an increase in government spending) or by inducing expenditure switching towards domestic goods (following a tax cut).

A Two-Country Model with Flexible Prices

Consider two symmetric countries, Home and Foreign. We use the subscript D to denote quantities and prices of a country's own tradable good consumed domestically, and the subscript X to denote quantities and prices of exports.

A representative agent at Home maximizes $E_0\left\{\sum_{t=0}^{\infty}\beta^t\left(\log C_t-\frac{L_t^{1+\omega}}{1+\omega}\right)\right\}$, where C_t is consumption and L_t denotes hours worked. The baseline analysis assumes a unitary Frisch elasticity ($\omega=1$). Consumption C_t aggregates Home and Foreign tradable consumption sub-baskets in Armington form with an exogenous elasticity of substitution $\phi>0$:

$$C_t=\left[(1-\alpha_X)^{\frac{1}{\phi}}\left(C_{D,t}\right)^{\frac{\phi-1}{\phi}}+\alpha_X^{\frac{1}{\phi}}\left(C^*_{X,t}\right)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}},\quad 0\leqslant\alpha_X\leqslant 1, \tag{1}$$

where $1-\alpha_X$ is the weight attached to the country's own good. The corresponding price index

is $P_t = \left[(1-\alpha_X)\left(P_{D,t}\right)^{1-\phi} + \alpha_X\left(P^*_{X,t}\right)^{1-\phi}\right]^{1/(1-\phi)}$. Foreign households derive utility from an analogous consumption bundle of domestic and imported consumption goods, $C^*_{D,t}$ and $C_{X,t}$. Let $\rho_{D,t} \equiv P_{D,t}/P_t$ and $\rho^*_{X,t} \equiv P^*_{X,t}/P_t$ respectively denote the real prices of the domestic and imported goods expressed in Home consumption units. Home private demands for domestic and exported goods are, respectively, $C_{D,t} = (1-\alpha_X)\,\rho^{-\phi}_{D,t} C_t$ and $C_{X,t} = \alpha_X \rho^{-\phi}_{X,t} C^*_t$.

Households accumulate physical capital, K_t, and rent it to producers in a competitive capital market. We make two assumptions that ensure analytical tractability without loss of generality: (i) full capital depreciation and (ii) no time-to-build delays. This implies the model is static: in each period capital is equal to investment, i.e., $I_t = K_t$.[8] Investment in physical capital, I_t, requires purchasing a bundle that has the same composition of final consumption C_t.[9] The demand for domestic and exported capital goods are given by $I_{D,t} = (1-\alpha_X)\,\rho^{-\phi}_{D,t} I_t$ and $I_{X,t} = \alpha_X \rho^{-\phi}_{X,t} I^*_t$.

The household's budget constraint is $C_t + I_t = (1-\tau_t)\left(w_t L_t + r_{K,t} K_t\right) + T_t$, where w_t denotes the real wage, $r_{K,t}$ is the rental rate of capital, τ_t is an exogenous income tax, and T_t is a lump-sum transfer from the government. The optimal labor supply implies $L^{\omega}_t = (1-\tau_t)\,w_t/C_t$. Optimality in investment requires $r_{K,t} = 1/(1-\tau_t)$.

Each country produces with a constant-returns to scale technology $Y_t = K^a_t L^{1-\alpha}_t$. Optimal demand for the factors of production requires $r_{K,t} = \alpha \rho_{D,t} Y_t/K_t$ and $w_t = (1-\alpha)\,\rho_{D,t} Y_t/L_t$. International trade is frictionless and the law of one price holds, implying: $\rho_{X,t} = \rho_{D,t}/Q_t$, where Q_t is the real exchange rate (in units of Home consumption per unit of Foreign consumption).

[8] In Appendix B.1, we show numerically the results hold with dynamic capital accumulation.

[9] In the quantitative model of the next section, we allow for the relative import shares of investment and consumption to differ, consistent with the data.

The Government The government uses income taxes and transfers to finance an exogenous level of public expenditures G_t, which depends on both domestic and imported goods:

$$G_t = \left[(1-\alpha_X^g)^{\frac{1}{\phi}} (G_{D,t})^{\frac{\phi-1}{\phi}} + (\alpha_X^g)^{\frac{1}{\phi}} \left(G_{X,t}^*\right)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}, \quad 0 \leqslant \alpha_X^g \leqslant 1, \tag{2}$$

where we allow the share of Foreign goods in government consumption, α_X^g, to vary from the private-demand import share. The corresponding price index is

$$P_{G,t} = \left[(1-\alpha_X^g) (P_{D,t})^{1-\phi} + \alpha_X^g (P_{X,t})^{1-\phi}\right]^{1/(1-\phi)}.$$

The government's demand for domestic and exported goods are:

$$G_{D,t} = (1-\alpha_X^g) \left(\frac{\rho_{D,t}}{\rho_{G,t}}\right)^{-\phi} G_t, \quad G_{X,t} = \alpha_X^g \left(\frac{\rho_{X,t}}{\rho_{G,t}^*}\right)^{-\phi} G_t^*,$$

where $\rho_{G,t} \equiv P_{G,t}/P_t$ denotes the Home price of government consumption relative to Home consumption. The Home government budget constraint is $\rho_{G,t} G_t + T_t = \tau_t(w_t L_t + r_{K,t} K_t)$. The aggregate resource constraint implies $Y_t = C_{D,t} + C_{X,t} + I_{D,t} + I_{X,t} + G_{D,t} + G_{X,t}$.

Fiscal Financing and International Asset Markets

We consider two alternative scenarios about the financing of the government's budget: (i) lump-sum transfer financing (through the instrument T_t) and (ii) distortionary financing (assuming $T_t = T$ in every period).

Concerning the structure of international asset markets, we also consider two different scenarios: (i) financial autarky and (ii) complete international asset markets. The latter case allows us to study how trade-balance dynamics affect fiscal multipliers. Financial autarky implies balanced trade in every period: $TB_t = 0$, where $TB_t \equiv Q_t \rho_{X,t} (C_{X,t} + I_{X,t} + G_{X,t}) - \rho_{X,t}^* \left(C_{X,t}^* + I_{X,t}^* + G_{X,t}^*\right)$ denotes the trade balance. Full risk-sharing implies that cross-country consumption levels are tied to the real exchange rate, $Q_t = C_t/C_t^*$, replacing the

balanced-trade condition presented above.

Additional Definitions

We focus on the effects of fiscal expansions on real GDP, defined in units of Home output $Y_t \equiv K_t^{\alpha} L_t^{1-\alpha} = \tilde{Y}_t/\rho_{D,t}$, where $\tilde{Y}_t \equiv C_t + I_t + \rho_{G,t} G_t$ is real GDP in units of Home consumption.[10] While the latter measure is identical to output in a closed economy (since $\rho_{D,t} = 1$), in the open economy the two can differ. As discussed in section 3, our quantitative results are even stronger when considering real GDP in consumption units, arguably a metric closer to welfare.

For future reference, we define the terms of trade as the Home price of exports relative to the price of imports (both expressed in Home currency): $TOT_t \equiv Q_t \rho_{X,t}/\rho^*_{X,t}$. With complete exchange-rate pass through, the terms of trade also are equal to the relative price of domestic and imported goods, i.e., $TOT_t = \rho_{D,t}/\left(\rho^*_{D,t} Q_t\right)$. Moreover, in the symmetric steady state (where $Q = 1$), the total trade-to-GDP ratio is given by

$$\text{trade/GDP} \equiv \frac{2\left[\rho_X \left(C_X + I_X\right) + \frac{\rho_X}{\rho_G} G_X\right]}{Y} = 2\left[\left(1 - s_G\right)\alpha_X + \alpha_X^g s_G\right],$$

where $s_G \equiv G/Y$ is the steady-state ratio of government spending to GDP. Consequently, trade openness increases monotonically in either α_X or α_X^g.

We log-linearize the equilibrium conditions and use the method of undetermined coefficients to solve the model.[11] In what follows, hats denote variables in percentage deviations from the steady state. We consider exogenous changes to either domestic government spending ($\hat{G}_t > 0$) or taxes ($\hat{\tau}_t < 0$), while holding foreign government spending and taxes constant, $\hat{G}^*_t = \hat{\tau}^*_t = 0$ for all t.

[10] To simplify the analytical exposition, we focus directly on the GDP response. Results are similar when considering GDP multipliers. The only caveat concerns tax multipliers. While output always increases following a tax cut, tax revenue can either rise or fall, depending on the position of the income tax rate on the Laffer curve.

[11] Appendix A.1 lists the complete set of log-linearized equilibrium conditions.

Analytical Results in the Closed Economy

In a closed economy, both private- and public-consumption import shares are zero, i.e., $\alpha_X = \alpha_X^g = 0$. The GDP response is given by:

$$\hat{Y}_t^{closed} = \frac{s_G}{1 + s_C - s_I}\hat{G}_t + \frac{(s_I - \alpha)\left[1 - s_G + \alpha\left(1 + s_C - s_I\right)\right]}{s_I\left(1 + s_C - s_I\right)(1 - \alpha)}\hat{\tau}_t,$$

where $s_C \equiv 1-\alpha(1-\tau)-s_G$ is the steady-state ratio of consumption to GDP and $s_I \equiv \alpha(1-\tau)$ is the steady-state ratio of investment to GDP. Notice in a log-linear approximation, τ_t affects the equilibrium conditions only when $\tau > 0$ in steady state—otherwise $s_I = \alpha$ in the expression above.

GDP rises following either an increase in government spending or a reduction in income taxes. For an increase in public spending, GDP increases less than one-for-one, reflecting the crowding-out of private consumption. Moreover, in this static model, investment increases following an increase in public spending. This happens since the rental rate of capital is constant absent changes in the tax rate, increasing the firm's demand for both production inputs.[12] Absent capital ($\alpha = 0$), labor and GDP still rise with an increase in public spending, while consumption still declines (see Woodford, 2011). Following an income tax cut, GDP increases, reflecting a higher after tax-return to labor and a lower cost of capital.

Analytical Results in the Open Economy

We start with the assumption of financial autarky. Under this assumption, we study the role of home bias in public and private demand and the implications of alternative types of fiscal financing. We then consider the role of international trade in assets.

[12] In the closed economy, $\hat{I}_t = \hat{L}_t = -\hat{C}_t$, as implied by the firm's first-order conditions, the labor supply equation, and the fact that $\hat{\rho}_{D,t} = 0$.

Full Home-Bias in Government Spending

We first consider the case of full home-bias in government spending, $\alpha_X^g = 0$, a simplifying assumption often adopted in the literature.[13] We also assume a unitary trade elasticity ϕ, another benchmark value in the literature. Under these knife-edge assumptions, terms-of-trade fluctuations ensure full international risk sharing (Cole and Obstfeld, 1991).

Proposition 1 *Let s_C and s_I denote, respectively, the steady-state shares of private consumption and investment relative to GDP. Assume a unitary trade elasticity ($\phi = 1$), full home bias in government spending ($\alpha_X^g = 0$), financial autarky, and lump-sum transfer financing. Following a fiscal expansion at Home:*

1. *The response of the terms of trade is given by:*

$$\widehat{TOT}_t = \frac{s_C - s_I}{\Omega_G}\hat{G}_t - \frac{s_I - \alpha}{\Omega_\tau}\hat{\tau}_t,$$

where $\Omega_G > 0$ and $\Omega_\tau > 0$. It follows that:

   (a) *For an increase in government spending, $\widehat{TOT}_t > 0$ provided $s_I < s_C$.*

   (b) *For a decrease in income taxes, $\widehat{TOT}_t < 0$, since $s_I \equiv \alpha(1-\tau) < \alpha$.*

2. *Provided $\widehat{TOT}_t > 0$, it follows that*

   (a) *In the Home economy, $\hat{Y}_t$, $\hat{C}_t$, and $\hat{I}_t$ are increasing in openness (α_X); $\hat{L}_t$ is decreasing in openness.*

   (b) *In the Foreign economy, $\hat{Y}_t^*$, $\hat{C}_t^*$, and $\hat{I}_t^*$ are decreasing in openness (α_X); L_t^* is increasing in openness.*

   (c) *The real exchange rate appreciates only when $\alpha_X < 0.5$.*

[13] See for instance Corsetti and Pesenti (2001), Erceg et al. (2005), Cook and Devereux (2013), and Farhi and Werning (2016).

Proposition 1 (proved in Appendix A.2) states the response of the terms of trade, TOT_t, determines whether or not stronger trade linkages imply a larger fiscal stimulus. In particular, when TOT_t improve, GDP in the open economy increases by more than GDP in the closed economy, i.e., $\hat{Y}_t > \hat{Y}_t^{closed}$. By contrast, Foreign GDP declines.

What is the intuition for the results in Proposition 1? Higher government expenditure raises the relative price of the Home good $\rho_{D,t}$, which, other things equal, crowds out private consumption (lowering demand for domestic goods). At the same time, as in the closed economy, investment rises, increasing private demand. Since a share of both investment and consumption goods are imported, import demand also changes. When $s_C > s_I$, imports fall relative to exports, and the terms of trade appreciate to maintain balanced trade. This favorable relative price movement induces a positive wealth effect for Home as more foreign goods are traded per domestic good. In turn, this allows domestic households to purchase more Home goods, increasing private consumption, investment, and output relative to the closed economy.[14] Foreign GDP and its components decline.

Proposition 1 also shows the labor response is decreasing in openness when the terms of trade appreciate. The lower (albeit positive) response of L_t relative to L_t^{closed} reflects lower hours supply given the positive wealth effect of the terms-of-trade appreciation. In equilibrium, the crowding-in of investment dominates and output increases. It is sufficient to consider preferences that eliminate the wealth effect on labor supply to generate $\hat{L}_t > \hat{L}_t^{closed}$ following a terms-of-trade appreciation. In Appendix B.3, we present the analytical results for the limiting case of a zero capital share α and also consider preferences as in Greenwood et al. (1988).

Contrary to GDP and its components, the terms-of-trade response is not a sufficient statistic for the real exchange rate response. For instance, when the terms of trade improve, the real exchange rate can still appreciate or depreciate, depending on the degree of Home

[14] If one interprets instantaneously adjustable capital as materials, the restriction $s_I < s_C$ is not empirically plausible. However, $\hat{Y}_t > \hat{Y}_t^{closed}$ can occur even when $s_I > s_C$ once the restriction of a unitary Frisch elasticity, ω, is relaxed. See Appendix B.2 for the derivations.

bias in private demand.

Under the knife-edge parameterization of Proposition 1, an income tax cut unambiguously depreciates the terms of trade. Following the tax cut, domestic households are willing to work more, leading to lower wages and domestic prices. Moreover, the rental rate of capital falls—since $\hat{r}_k = \tau/(1-\tau)\hat{\tau}_t$—increasing demand for capital. Both effects lead to a deterioration in the terms of trade, which results in a negative (positive) wealth effect domestically (abroad). In turn, this lowers the domestic effectiveness of the stimulus relative to the closed economy. At the same time, Foreign GDP and its components increase.

Generalizing the Composition of Government Spending

In practice, governments import goods. For instance, import shares for Australia, the U.K., and Canada are approximately 11% (see Corsetti and Muller, 2006). We now show the effectiveness of public spending depends on the *relative* size of public-private import shares and not on trade openness per se. Put differently, the relative composition of public and private imports and exports, $\nu \equiv \alpha_X^g/\alpha_X$ (and not α_X^g or α_X per se) is key for the effects of government spending.

We continue to assume a unitary trade elasticity.[15] To simplify the analytical results, we impose $\tau = 0$, $\nu \leq 1$, and $s_C > s_I$ (that is, the GDP consumption share is larger than the investment share), the latter being the restriction in Proposition 1 that ensures $\hat{Y}_t > \hat{Y}_t^{closed}$ following an increase in public spending. We then show numerically the results generalize when these restrictions are relaxed.

Proposition 2 *Let s_C, s_I, and s_G denote, respectively, the steady-state shares of private consumption, investment, and government spending relative to GDP. Let $\nu \equiv \alpha_X^g/\alpha_X$ be the ratio of public-to-private sector import shares. Assume a unitary trade elasticity ($\phi = 1$), zero income taxes ($\tau = 0$), $s_C > s_I$, $\nu \leqslant 1$, financial autarky, and lump-sum transfer financing.*

[15] When $\alpha_X^g > 0$, a unitary trade elasticity no longer implies perfect international risk sharing.

For an increase in Home government spending, there exists a threshold ν^*:

$$\nu^* \equiv \frac{1 - s_G - 2\alpha}{2 - s_G - 2\alpha},$$

such that for any $\nu < \nu^*$:

$$(i)\ \widehat{TOT}_t > 0; \quad (ii)\ \hat{Y}_t > \hat{Y}_t^{closed}, \quad and\ (iii)\ \hat{Y}_t^* < 0,$$

provided that $s_G < 1/2$.

Proposition 2 shows $\hat{Y}_t > \hat{Y}_t^{closed}$ even for countries with a non-zero public import share. As in Proposition 1, when the terms of trade improve, a higher private-sector import share (α_X) reduces consumption crowding out and increases investment, leading to higher GDP relative to the closed economy. In contrast, a higher public import share (α_X^g) lowers GDP. As the government consumes more Foreign goods, Foreign prices increase, dampening Home imports' demand. For a sufficiently high value of ν, the reduced private-import demand implies a reduction in Home total imports, resulting in a terms-of-trade depreciation to maintain balanced trade. In turn, the negative wealth effect generates more crowding out of domestic private demand relative to the closed economy.

Figure 1a demonstrates the robustness of proposition 2 for various combinations of ϕ and ν.[16] The figure depicts the Home and Foreign GDP responses as well as the terms-of-trade response following a 1% increase in government spending. We consider a grid for $\alpha_X^g \in [0, 0.35]$ and let α_X adjust to maintain a constant trade share equal to 0.5. In addition, we set $\alpha = 0.33$, $s_G = 0.2$, and $\tau = 0.25$. The plane in each panel plots the response in the closed economy. The relative size of public-private import shares continues to determine outcomes once relaxing the parametric restrictions on ϕ. Consistent with proposition 2, Home GDP responses decline in ν. Home GDP and the terms-of-trade responses also are

[16] In Appendix A.5, we present additional numerical results, computing the probability of $\hat{Y}_t > \hat{Y}_t^{closed}$ conditional on a range of values for ϕ, ν, and the inverse Frisch elasticity ω.

decreasing in ϕ, since a higher trade elasticity dampens the terms of trade appreciation.

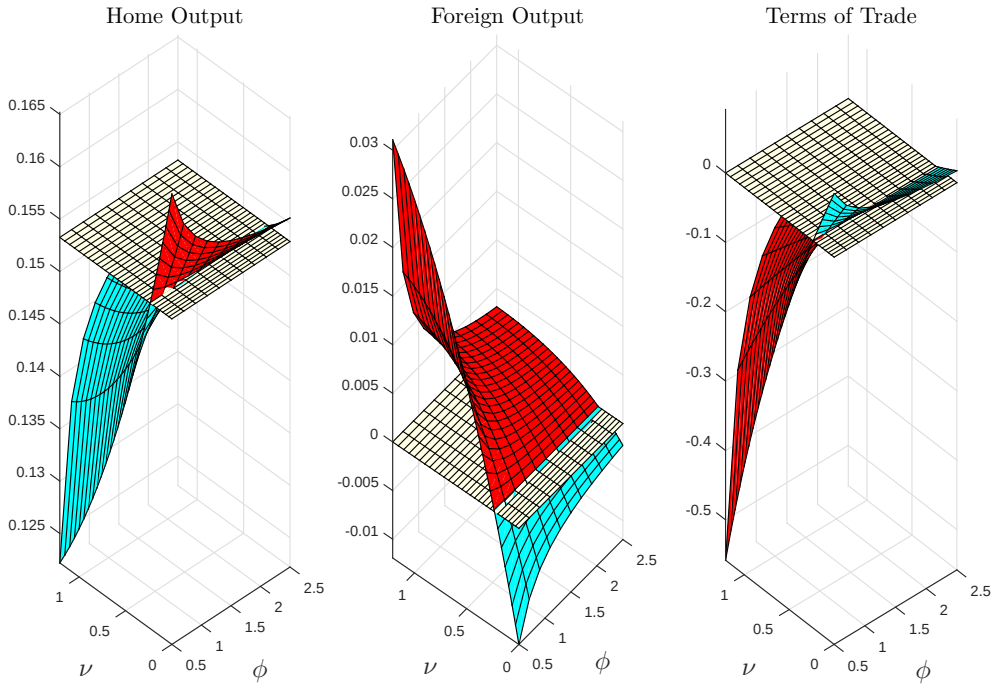
Distortionary Fiscal Financing

So far our analysis has assumed the government uses lump-sum transfers to finance its budget. Here we demonstrate distortionary financing can increase the likelihood that trade linkages enhance fiscal multipliers.

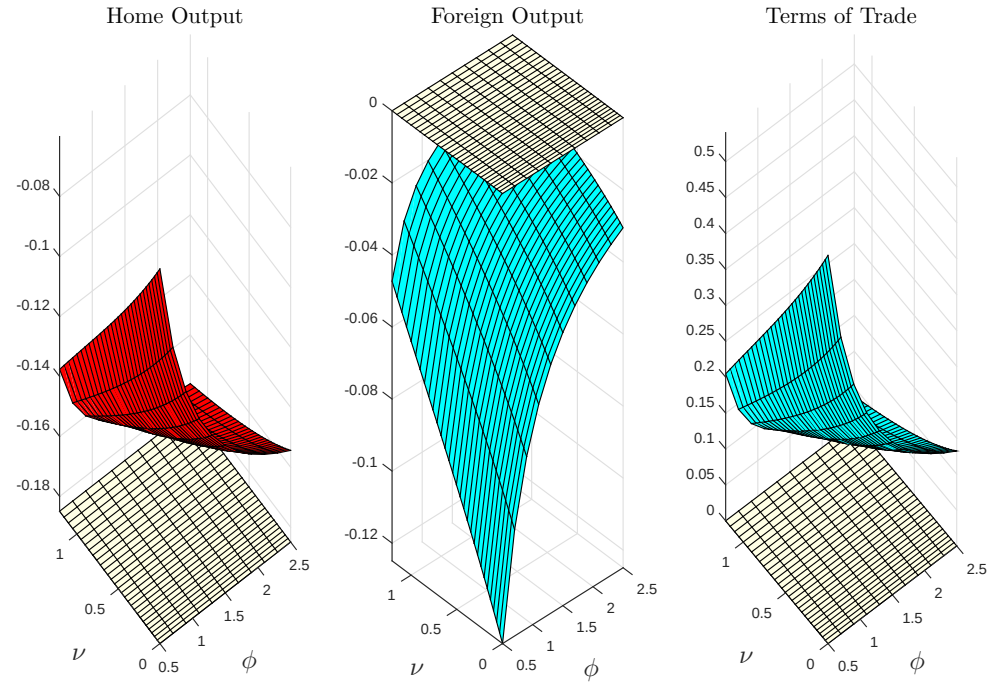
To assess the role of distortionary financing, we must resort to numerical simulations.[17] Figure 1b repeats the numerical analysis of figure 1a assuming income taxes finance the government budget (i.e., lump-sum transfers remain constant). The plane in each panel plots the response in the closed economy. Absent trade linkages, Home GDP falls when government spending increases, due to the negative effect of higher taxes on the supply of capital and labor. Trade linkages reduce this effect for all combinations of the trade elasticity ϕ and the relative share of public and private imports ν—the GDP response is above the closed economy in all cases. Other things equal, the increase in the income tax rate raises the terms of trade, and this additional wealth effect partly offsets the negative response of the supply of capital and labor. As explained before, the terms-of-trade appreciation is stronger for lower ν and ϕ combinations.

When an income tax cut is financed by lower government expenditures, again the relative share of public and private imports, ν, determines the size of GDP responses. As shown in Appendix A.3, less home bias in public goods (i.e., a higher ν) raises domestic responses since the reduction in public demand affects more heavily the Foreign economy. Provided the decrease in government spending falls sufficiently on Foreign imports, the terms of trade can improve in equilibrium, boosting Home GDP relative to the closed economy.

[17] Analytical solutions are only possible under the knife-edge assumptions of Proposition 1, preventing us from analyzing the central role of $\nu \equiv \alpha_X^g/\alpha_X$ for distortionary financing.



(a) Government Spending Increase Financed by Lump-Sum Transfers; $Pr(\hat{Y} > \hat{Y}^{\text{closed}}) = 0.3$.



(b) Government Spending Increase Financed by Income Taxes; $Pr(\hat{Y} > \hat{Y}^{\text{closed}}) = 1.0$.

Figure 1. Impact response of GDP (Home and Foreign) and the terms of trade under financial autarky following a 1% increase in government spending for different combinations of ν and ϕ. The plane in each panel denotes the response in the closed economy. In all cases, $\alpha = 0.33$, $s_G = 0.2$, $\tau = 0.25$, and the trade share $= 0.5$.

International Trade in Financial Assets

We now relax the assumption of financial autarky and consider the role of trade balance dynamics. To obtain analytical results under complete asset markets, we impose $\alpha_X^g = 0$ and the following simplifying assumptions: $\tau = 0$ following an increase in public spending and $s_G = 0$ following an income tax cut. In Appendix A.4, we show numerically the results generalize when relaxing these restrictions.

Proposition 3 *Let ϕ denote the trade elasticity; α_X and α_X^g respectively denote the private- and public-sector home bias; τ is the income tax rate; and s_G is the share of government spending to GDP. Assume complete international asset markets, lump-sum transfer financing, and $\alpha_X^g = 0$. Following a fiscal expansion, trade linkages can increase domestic output even when net exports decline.*

1. *Assuming $\tau = 0$, following an increase in Home government spending:*

   (a) *The terms of trade increase ($\widehat{TOT}_t > 0$).*

   (b) *$\hat{Y}_t > \hat{Y}_t^{closed}$ if α_X and ϕ are sufficiently small ($\alpha_X < \tilde{\alpha}_X$ and $\phi < \tilde{\phi}$).*

   (c) *Given $\hat{Y}_t > \hat{Y}_t^{closed}$, net exports decline when α_X and ϕ are sufficiently large ($\bar{\alpha}_X < \alpha_X < \tilde{\alpha}_X$ and $\bar{\phi} < \phi < \tilde{\phi}$).*

2. *Assuming $s_G = 0$, following a decrease in Home income taxes:*

   (a) *The terms of trade decline ($\widehat{TOT}_t < 0$).*

   (b) *$\hat{Y}_t > \hat{Y}_t^{closed}$ if trade is sufficiently price elastic, i.e., $\phi > \overline{\overline{\phi}}$.*

   (c) *Given $\hat{Y}_t > \hat{Y}_t^{closed}$, net exports always increase.*

See Appendix A.4 for the definitions of the cut-off values $\tilde{\alpha}_X$, $\bar{\alpha}_X$, $\tilde{\phi}$, $\bar{\phi}$, and $\overline{\overline{\phi}}$. Proposition 3 shows even with net export crowding out, trade linkages can increase domestic GDP responses. Following an increase in government spending, output is higher than in the closed

economy when private-sector home bias and the trade elasticity are below threshold values. Intuitively, trade linkages increase domestic output when the positive wealth effect stemming from the appreciation of the terms of trade more than offsets its negative substitution effect through net exports. In contrast, for a decrease in income taxes, output is higher than in the closed economy when the trade elasticity is higher than a threshold value. In this case, the increase in net exports is sufficient to offset the negative wealth effect implied by the terms-of-trade depreciation. Appendix A.4 shows the qualitative responses of Home and Foreign GDP remain consistent with Proposition 3 once relaxing the parametric restrictions on τ, s_G, and α_X^g. Moreover, consistent with Proposition 2, the response of GDP continues to depend on the relative share of public and private imports, ν.

Nominal Rigidities and The Role of International Pricing

Finally, we discuss the role of price-setting frictions. In the presence of nominal rigidities, there are three scenarios depending on the invoicing of export prices: (i) producer currency pricing (PCP), in which both domestic and export prices are sticky in the domestic currency; (ii) local currency pricing (LCP), in which export prices are sticky in the foreign currency; and (iii) dominant currency pricing (DCP), in which export prices are sticky everywhere in the Foreign currency (the dominant currency).

In order to derive analytical solutions, we make the following assumptions: (i) complete price stickiness and (ii) financial autarky. We present the analytical derivations for the three alternative export pricing scenarios in Appendix A.6. Here we highlight two main insights.

First, incomplete exchange-rate pass-through (e.g., LCP and DCP) creates a wedge between terms-of-trade fluctuations and cross-country wealth effects. For instance, with fixed prices, the terms of trade are constant under DCP ($TOT_t = \bar{P}_X/\bar{P}_D^*$). Nevertheless, trade linkages affect fiscal multipliers. Independent of export invoicing, the markup-adjusted terms of trade,

$$TOC_t \equiv TOT_t \frac{\mu_{D,t}/\mu_{D,t}^*}{\mu_{X,t}/\mu_{X,t}^*} = \frac{\rho_{D,t}}{Q_t \rho_{D,t}^*},$$

summarize the domestic effects of trade linkages following a fiscal expansion (see Appendix A.6 for the proof). We refer to this relative price as the domestic terms of consumption. Intuitively, when export prices are sticky in a foreign currency, lack of markup synchronization affects domestic wealth even if the terms of trade are constant, since a unit of export revenue does not yield one unit of domestic consumption once expressed in the same consumption units. Mirroring the intuition of the flexible price model (where $TOC_t = TOT_t$), an increase in TOC_t implies that Home agents can consume more Foreign goods per unit of the Home good. Other things equal, this positive wealth effect reduces the crowding out of private demand relative to a closed economy.

Second, the currency invoicing of imports and exports affects the behavior of the domestic terms of consumption. For instance, with complete price stickiness, $TOC_t = 1/Q_t$ under LCP, whereas $TOC_t = \rho_{D,t}/\rho^*_{X,t}$ under DCP. Thus, while under LCP the effects of a fiscal expansion are simply tied to the response of the real exchange rate, under DCP what matters is the relative price of domestic to imported goods (since in this case the aggregate price indices P_t and P^*_t are not constant). In turn, when a fiscal expansion increases the real price of Home goods relative to Foreign goods—e.g., with an increase in government spending—trade linkages are more likely to strengthen the response of GDP under DCP for a given response of the real exchange rate. We explore the quantitative significance of price-setting frictions and the invoicing of export prices when studying the quantitative model presented in the next section.

3 The Quantitative Model

In this section, we use a Bayesian prior-predictive analysis to show a benchmark, international business-cycle model preserves the key insights from section 2. In the next section, we estimate the model for a well-studied country pair with a flexible exchange rate, Canada and the U.S.

Towards this goal, we introduce additional competing forces for the fiscal transmission

absent in the analytical model. First, we consider a rich fiscal environment, including government debt, public spending, and consumption and income taxes. Second, we include features proven to be important for the transmission of fiscal shocks in a closed economy—non-separable utility between public and private consumption and wage-setting frictions. Third, we introduce intertemporal investment dynamics and incomplete international asset markets, thus allowing fiscal shocks to affect the current account position of trading partners without imposing complete international risk sharing.

We consider a small open economy that trades with the rest of the world, since in our empirical application we focus on Canada and the U.S.—the latter being a good approximation of the rest of the world for Canada. We follow the standard approach in the literature and model two countries in which one (the small open economy, Home henceforth) is of measure zero relative to the other (the rest of the world, Foreign henceforth). Consistent with recent empirical evidence (e.g., Goldberg and Tille, 2008 and Gopinath, 2015), we assume export prices are sticky in the Foreign currency (the dominant currency). The small open economy's terms of trade fluctuate endogenously due to firms' monopoly power.

Below, variables without a time subscript denote non-stochastic values along the balanced growth path. Unless otherwise specified, exogenous shocks follow a stationary autoregressive process in logs: $\log \bar{X}_t = \rho_{\bar{X}} \log \bar{X}_{t-1} + \varepsilon_{\bar{X}t}$ with $\varepsilon_{\bar{X}t} \overset{iid}{\sim} N\left(0, \sigma^2_{\bar{X}}\right)$, for any shock $\bar{X}_t$. We present the model details below, relegating to Appendix C standard first-order conditions. In Appendix D, we show our results are unchanged in a two large-country version of the model.

Households

The representative household, indexed by $j \in [0, 1]$, maximizes the expected intertemporal utility function

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \bar{\beta}_t \left[\log\left(\tilde{C}_{jt} - h_C \tilde{C}_{t-1} \right) - \bar{h}_t \frac{L_{jt}^{1+\omega}}{1+\omega} \right] \right\}, \tag{3}$$

where $\beta \in (0,1)$ is the discount factor, $\tilde{C}_{jt}$ is a consumption basket that consists of private and public consumption as described below, and L_{jt} is the number of hours worked. To introduce wage stickiness, we assume each household is a monopolistic supplier of a differentiated labor input L_{jt}. The household values consumption relative to a habit stock defined in terms of lagged aggregate consumption $h_C \tilde{C}_{t-1}$, where $h_C \in [0,1)$. $\bar{\beta}_t$ is an exogenous shock to the discount factor, while $\bar{h}_t$ is an exogenous shock to the marginal disutility of hours worked. Consumption utility is logarithmic to ensure balanced growth in the presence of non-stationary technological progress.

To allow for an agnostic response of private consumption following a government spending shock, we follow Fève et al. (2013) and Leeper et al. (2017), assuming non-separable preferences between private and public consumption. Total consumption, $\tilde{C}_{jt}$, is the sum of private and public consumption goods, $\tilde{C}_{jt} = C_{jt} + \omega_G G_t$. When $\omega_G < 0$, private and public consumption are complements; when $\omega_G > 0$, the goods are substitutes.

Market consumption C_t aggregates Home and Foreign consumption sub-baskets as described by equation (1) in the previous section. We allow for exogenous fluctuations in the elasticity of substitution between Home and Foreign baskets, $\bar{\phi}_t$, capturing in reduced form fluctuations in the relative price of imported goods (Mukhin and Itskhoki, 2016 and Pavlova and Rigobon, 2007).

The sub-basket $C_{D,t}$ aggregates domestic differentiated consumption varieties $C_{D,t}(i)$: $C_{D,t} = \left[\int_0^1 C_{D,t}(i)^{(\bar{\theta}_t - 1)/\bar{\theta}_t} di\right]^{\bar{\theta}_t/(\bar{\theta}_t - 1)}$, where $\bar{\theta}_t > 1$ is the exogenous elasticity of substitution across domestic goods, capturing price-markup shocks. A similar basket describes consumption of Foreign goods: $C^*_{X,t} = \left[\int_0^1 C^*_{X,t}(i)^{(\bar{\theta}^*_t - 1)/\bar{\theta}^*_t} di\right]^{\bar{\theta}^*_t/(\bar{\theta}^*_t - 1)}$.

International asset markets are incomplete, as a non-contingent nominal bond denominated in Foreign currency is the only internationally traded asset. We denote Home holdings with A^j_t. To ensure a determinate steady-state equilibrium and stationary responses to aggregate shocks, we assume that there is a premium on the Home holdings of Foreign bonds (e.g. Schmitt-Grohe and Uribe, 2003 and Adolfson et al., 2005): $\Gamma_t \equiv \exp\left\{-\gamma \frac{Q_t A_t}{Y_t}\right\} \bar{\Lambda}_{at}$,

where $\gamma > 0$, and Q_t is the real exchange rate. The risk premium increases with the economy's aggregate level of debt ($-A_t$) as a share of GDP (Y_t, defined below). The term $\bar{\Lambda}_{at}$ captures exogenous fluctuations in the risk-premium as in Mukhin and Itskhoki (2016).

Households also have access to one-period, riskless nominal domestic government bonds B_t^j.[18] Moreover, the household accumulates physical capital and rents it to intermediate input producers in a competitive market. Investment aggregates domestic and imported investment goods $I_{D,t}$ and $I_{X,t}$ in Armington form:

$$I_t = \left[(1-\alpha_X^I)^{1/\bar{\phi}_t} (I_{D,t})^{(\bar{\phi}_t-1)/\bar{\phi}_t} + (\alpha_X^I)^{1/\bar{\phi}_t} (I_{X,t}^*)^{(\bar{\phi}_t-1)/\bar{\phi}_t} \right]^{\bar{\phi}_t/(\bar{\phi}_t-1)},$$

where $1-\alpha_X^I$ is the weight attached to the country's own investment good. The investment sub-baskets $I_{D,t}$ and $I_{X,t}^*$ have the same composition as the private consumption sub-baskets $C_{D,t}$ and $C_{X,t}^*$.

We introduce convex adjustment costs in physical investment and variable capital utilization. Effective capital rented to firms, K_t^j, is the product of physical capital, $\tilde{K}_t^j$, and the utilization rate, $u_{K,t}^j$: $K_t^j = u_{K,t}^j \tilde{K}_t^j$. Utilization incurs a cost of $\Psi(u_{K,t}^j)$ per unit of physical capital. In steady state, $u_K = 1$ and $\Psi(1) = 0$. We define the parameter $\psi \in [0,1)$ such that $\Psi''(1)/\Psi'(1) \equiv \psi/(1-\psi)$. Physical capital, $\tilde{K}_t$, obeys a standard law of motion:

$$\tilde{K}_{t+1}^j = (1-\delta_K)\tilde{K}_t^j + \bar{P}_{K,t}\left[1 - \frac{\nu_K}{2}\left(\frac{I_t^j}{I_{t-1}^j} - \bar{z}\right)^2\right] I_t^j, \tag{4}$$

where $\nu_K > 0$ is a scale parameter, $\bar{P}_{K,t}$ is an exogenous investment specific shock, and $\bar{z}$ is the growth rate of productivity along the balanced growth path.

Household's income (the sum of rental capital and labor income) is taxed at the rate τ_t^I. Moreover, the household pays consumption taxes τ_t^C. The household's period budget

[18] We assume all government debt is issued in domestic currency and held by domestic households. See Broner et al. (2018) and Priftis and Zimic (2018) for a discussion of how foreign debt holdings affect fiscal multipliers.

constraint is:

$$B_t^j + \varepsilon_t A_t^j + P_t C_t^j \left(1+\tau_t^C\right) + P_t^I I_t^j + \Psi(u_{K,t}^j) P_t \tilde{K}_t^j - P_t \left(T_t^j + T_{G,t}^j\right)$$
$$= (1+i_{t-1}) B_{t-1}^j + (1+i_{t-1}^*)\Gamma_{t-1} A_{t-1}^j \varepsilon_t + \left(1 - \tau_t^I - \frac{\nu_w}{2}\Delta_{W,t}^2\right) w_{jt}^n L_{jt} + \left(1-\tau_t^I\right) P_t r_{K,t} K_t^j, \tag{5}$$

where i_t and i_t^* are, respectively, the nominal interest rates on Home and Foreign bond holdings between $t-1$ and t, known with certainty as of $t-1$, and ε_t is the nominal exchange rate (in units of Home currency per unit of Foreign currency). T_t^j is a lump-sum rebate of producer profits, while $T_{G,t}^j$ is a lump-sum transfer from the government. Finally, the household sets the nominal wage w_{jt}^n subject to a quadratic adjustment cost $\nu_w/2\Delta_{W,t}^2$, where

$$\Delta_{W,t} \equiv \left[\frac{1}{\bar{z}} \frac{w_{jt}^n}{w_{jt-1}^n} \left(1+\pi_{C,t-1}\right)^{-\iota_w} - 1\right].$$

Households index wage changes to past CPI inflation, $1+\pi_{C,t} \equiv P_t/P_t$.

The household maximizes its expected intertemporal utility subject to (4) and (5). In Appendix C, we report the first-order conditions for L_{jt}, w_{jt}^n, $\tilde{K}_{t+1}^j$, $u_{K,t}^j$, I_t^j, C_t^j, and bond holdings.

Production

In each country, there are two vertically integrated production stages. At the upstream level, perfectly competitive firms use capital and labor to produce a non-tradable intermediate input. At the downstream level, monopolistically competitive firms use the intermediate input to produce tradable final consumption goods.

Homogeneous Intermediate Input Production The representative intermediate firm produces output $Y_t^I = K_t^\alpha \left(\bar{Z}_t L_t\right)^{1-\alpha}$, where $\bar{Z}_t$ is exogenous productivity, K_t is physical capital, and L_t is a bundle of the labor inputs supplied by individual households. $\bar{Z}_t$ and

$\bar{Z}_t^*$ are non-stationary and cointegrated stochastic processes.[19] The growth rate of Foreign productivity $\bar{z}_t^* \equiv \bar{Z}_t^*/\bar{Z}_{t-1}^*$ follows a stationary AR(1) process in logs. Home productivity $\bar{Z}_t$ features the same stochastic trend up to a stationary stochastic disturbance, $\bar{\zeta}_t \equiv \bar{Z}_t^*/\bar{Z}_t$, which also follows a stationary AR(1) process in logs. As a result, the growth rate of Home productivity $\bar{z}_t \equiv \bar{Z}_t/\bar{Z}_{t-1}$ evolves according to $\log \bar{z}_t = \log \bar{z}_t^* + \log \bar{\zeta}_{t-1} - \log \bar{\zeta}_t$.

The composite labor input aggregates in Dixit-Stiglitz form the differentiated labor inputs provided by domestic households: $L_t \equiv \left[\int_0^1 (L_{jt})^{(\eta-1)/\eta}\, dj\right]^{\eta/(\eta-1)}$ where $\eta > 0$ is the elasticity of substitution, and L_{jt} denotes the labor hired from household j. Let φ_t be the real price (in units of final consumption) of the intermediate input. The Home firm chooses L_t and K_t to maximize the value of per-period profit: $\varphi_t Y_t^I - (w_t^n/P_t)\, L_t - r_{K,t} K_t$. Appendix C presents the first-order conditions.

Final Producers A continuum of symmetric firms produce tradable consumption varieties indexed by $j \in (0,1)$. Final producers pay a quadratic adjustment cost when changing domestic and export prices.[20] Final producers index domestic and export prices to past CPI inflation in each respective market. The cost of adjusting the domestic price is

$$\frac{\upsilon_p}{2}\left[\frac{P_{D,t}^j}{P_{D,t-1}^j}\left(1+\pi_{C,t-1}\right)^{-\iota_p} - 1\right]^2 P_{D,t}^j Y_{D,t}^j,$$

where $\upsilon_p \geq 0$ is the size of the adjustment costs, and $Y_{D,t}^j$ denotes aggregate domestic demand. The cost (in Home currency) of adjusting the export price is

$$\frac{\upsilon_p}{2}\left[\frac{P_{X,t}^j}{P_{X,t-1}^j}\left(1+\pi_{C,t-1}^*\right)^{-\iota_p} - 1\right]^2 \varepsilon_t P_{X,t}^j Y_{X,t}^j,$$

[19] Rabanal and Rubio-Ramirez (2015) and Rabanal et al. (2011) show this specification for TFP helps match properties of real exchange rate data.

[20] Up to a first-order approximation and with zero trend inflation, Rotemberg and Calvo price adjustment yield identical dynamics.

where $Y^j_{X,t}$ denotes aggregate export demand. In the symmetric equilibrium, the domestic price of Home output is a time-varying markup, $\mu_{D,t}$, over the marginal cost φ_t: $\rho_{D,t} \equiv P_{D,t}/P_t = \mu_{D,t}\varphi_t$. The export price is a time-varying markup, $\mu_{X,t}$, over the marginal cost: $\rho_{X,t} \equiv P_{X,t}/P^*_t = \mu_{X,t}\varphi_t/Q_t$. We report the markups' derivations in Appendix C.

Monetary and Fiscal Policy

The monetary authority follows a Taylor rule in which the nominal interest rate responds to its lagged value, deviations of CPI inflation, and GDP from their long-run targets. We denote a variable in percentage deviations from steady state by a hat. The interest rate obeys

$$\hat{\imath}_t = \varrho_i \hat{\imath}_{t-1} + (1-\varrho_i)\left[\varrho_\pi \hat{\pi}_{C,t} + \varrho_Y \hat{Y}_t\right] + \varepsilon_{i,t}, \tag{6}$$

where $\varepsilon_{i,t}$ is an *i.i.d.* monetary shock. We define real GDP by evaluating expenditures at fixed (steady-state) relative prices (e.g., Laxton and Pesenti, 2003): $Y_t \equiv C_t + \rho_I I_t + \rho_G G_t + Q\rho_X Y_{X,t} - \rho^*_X Y^*_{X,t}$.

As in the one-period model of section 2, government consumption G_t aggregates Home and Foreign government consumption sub-baskets, $G_{D,t}$ and $G^*_{X,t}$. Fiscal choices satisfy the government's per-period budget constraint:

$$B_t + \tau^I_t \left(r_{K,t} P_t K_t + w^n_t L_t\right) + P_t \tau^C_t C_t = (1+i_{t-1})B_{t-1} + P_{G,t} G_t + P_t T_{G,t}.$$

Fiscal rules dictate the evolution of policy instruments, $X = \left\{G, \tau^C, \tau^L\right\}$. We assume $\hat{X}_t = \varrho_X \hat{X}_{t-1} - (1-\varrho_X)\gamma_X \hat{S}_{t-1} + \varepsilon_{X,t}$, where $\varepsilon_X \overset{iid}{\sim} N(0, \sigma^2_X)$. We include an autoregressive term to allow for serial correlation and a response to the debt-to-GDP ratio, $S_t \equiv B_t/(P_t Y_t)$, to ensure policies stabilize debt. Lump-sum transfers, $T_{G,t}$, capture all movements in government debt that are not explained by the model nor the government spending and tax processes. $T_{G,t}$ follows an AR(1) process.

Net Foreign Assets

Home net foreign assets are determined by: $Q_t a_{*,t} = a_{*,t-1} Q_t \left(1 + i^*_{t-1}\right) \Gamma_{t-1} / \left(1 + \pi^*_{C,t}\right) + TB_t$, where $a_{*,t} \equiv A_t / P^*_t$ denotes real holdings of Foreign bonds (in units of Foreign consumption) and $TB_t \equiv Q_t \rho_{X,t} Y_{X,t} - \rho^*_{X,t} Y^*_{X,t}$ is the trade balance. The change in net foreign assets is determined by the current account, $Q_t \left(a_{*,t} - \frac{a_{*,t-1}}{1+\pi^*_{C,t}}\right) = CA_t \equiv Q_t r_t a_{*,t-1} + TB_t$, where $\pi^*_{C,t} \equiv P^*_t / P^*_{t-1} - 1$ and $r_t \equiv \left[\left(1 + i^*_{t-1}\right) \Gamma_{t-1} - 1\right] / \left(1 + \pi^*_{C,t}\right)$ denotes the real interest rate.

We present additional details of the symmetric equilibrium and the determination of Foreign variables in Appendix C. We rewrite the model in terms of detrended variables and compute the log-linear approximation around the non-stochastic steady state.

Model Predictions

We employ a prior-predictive analysis to uncover the full range of fiscal outcomes implied by the model structure before confronting the data (see Geweke, 2010). To do so, we propose independent prior density functions for structural parameters, take draws from these priors, and calculate model-implied present-value fiscal multipliers, defined below. This exercise serves two purposes. First, the analysis shows the model does not restrict fiscal outcomes along any dimension a priori. In particular, the model is agnostic about the role of trade linkages for fiscal multipliers, as well as the sign and size of the responses of the terms of consumption, real exchange rate, and international macroeconomic spillovers following discretionary fiscal interventions. Second, the analysis confirms the central wisdom of section 2 is preserved in a quantitative version of the model. The effects of trade linkages on fiscal multipliers are tied to the dynamics of the terms of consumption and the trade balance.

Priors

We impose dogmatic priors for a few parameters. We set the discount factor β equal to 0.99, the share of capital in the Cobb-Douglas production function α equal to 0.33, and the capital

depreciation rate δ_K equal to 0.025. We set the elasticity of substitution of differentiated varieties θ equal to 6 to generate a 20 percent steady-state markup. We set the elasticity of substitution of labor inputs η to 11 to generate a 10 percent steady-state wage markup. For the remaining parameters, we specify independent prior density functions.

We choose conventional prior distributions for the parameters that are standard in the Bayesian estimation literature (e.g., Smets and Wouters, 2007). We discuss these priors in Appendix D. Concerning less-standard parameters, we employ the following approach. We adopt a uniform distribution for the elasticity of substitution between Home and Foreign goods (ϕ) over the interval 0.05 to 6. A uniform prior ensures the data fully inform the parameter's estimate. Likewise, we adopt a uniform prior for the elasticity of substitution between public and private goods (ω_G). For the parameter governing the endogenous risk premium (γ), we adopt an inverse gamma distribution for $10 \times \gamma$ with a mean of 0.75 and standard deviation of 1.5. The low mean reflects the low values of this parameter found in the literature (e.g., Lane and Milesi-Ferretti, 2002). The inverse gamma distribution allows for a long right tail encompassing higher estimates in the literature (e.g., Adolfson et al., 2007). We adopt uniform distributions encompassing empirically-relevant ranges for the following parameters: the steady-state trade-to-GDP ratio follows $U(0.25, 0.75)$; the import intensities of public consumption and private investment relative to private consumption are such that $\alpha_X^g/\alpha_X \sim U(0.1, 0.4)$ and $\alpha_X^I/\alpha_X \sim U(0.75, 1.40)$; the steady-state public spending share is $G/Y \sim U(0.10, 0.35)$; the annualized debt-to-GDP ratio is $B/(4 \times Y) \sim U(0.40, 0.80)$; and the tax rates are such that $\tau^I \sim U(0.15, 0.35)$, and $\tau^C \sim U(0.05, 0.20)$.

Prior-Predictive Analysis

We take 10,000 draws from our priors and calculate present-value multipliers for various variables of interest X (i.e., GDP, consumption or investment). Formally, the multiplier for

a variable X is:

$$M_X \equiv \frac{E_t \sum_{j=0}^{k} \left[\prod_{i=0}^{k}(1+r)^{-1}\right] \Delta P_{t+j} X_{t+j}}{E_t \sum_{j=0}^{k} \left[\prod_{i=0}^{k}(1+r)^{-1}\right] \Delta P_{t+j} F_{t+j}}, \tag{7}$$

where k is the time horizon, r is the steady-state real interest rate, and F denotes government spending or income tax revenue. All values are expressed in constant-price units. Additionally, we report GDP multipliers expressed in CPI units, $\tilde{Y}_t = C_t + \rho_{I,t} I_t + \rho_{G,t} G_t + TB_t$.[21] These present-value multipliers measure the present value change over the k-horizon in the variable of interest when government spending or income tax revenue increases in present value by one unit over the same horizon.[22]

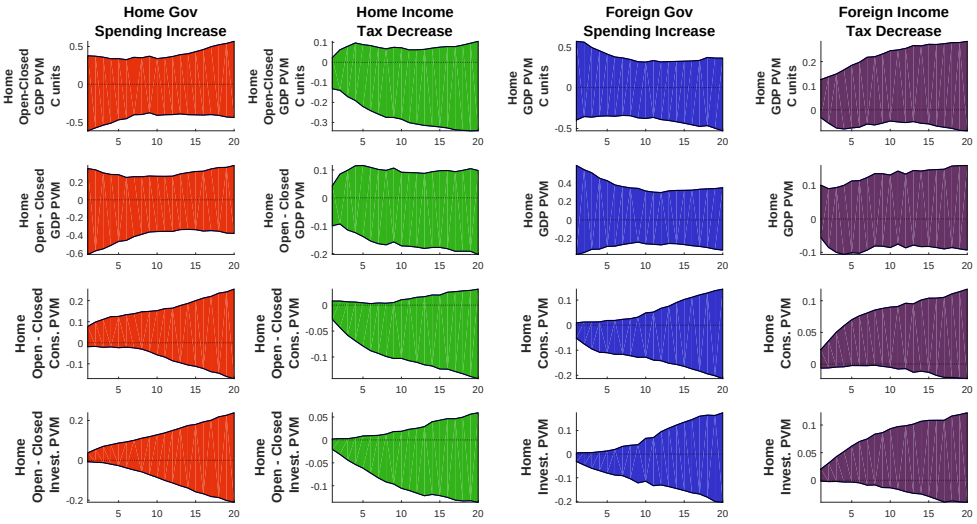
The prior-predictive analysis allows one to assess the range within which fiscal multipliers vary in an open vs. closed economy. In addition, it allows one to verify whether the model systematically restricts fiscal outcomes a priori. Figure 2a plots 90-percent confidence bands for the difference between open- and closed-economy multipliers following either a Home or Foreign fiscal shock. This multiplier difference subtracts the Home multiplier in a counterfactually closed economy (formally defined as $\alpha_X = \alpha_X^g = \alpha_X^I = 0$) from the Home multiplier in the open economy. Figure 2a shows large differences in open- vs. closed-economy multipliers following Home fiscal shocks, encompassing both positive and negative values. In addition, there is a wide range of spillovers from Foreign fiscal shocks to the Home economy.

Figure 2b shows the model also is agnostic about the sign and size of key international variables including the real exchange rate, the trade balance, and the domestic terms of consumption following any fiscal shock. In particular, the real exchange rate can depreciate following an increase in government spending, and higher open-economy multipliers can coincide with a real depreciation.[23] The agnostic predictions about the real exchange-rate response depend on the presence of a debt-elastic risk premium (Bouakez and Eyquem,

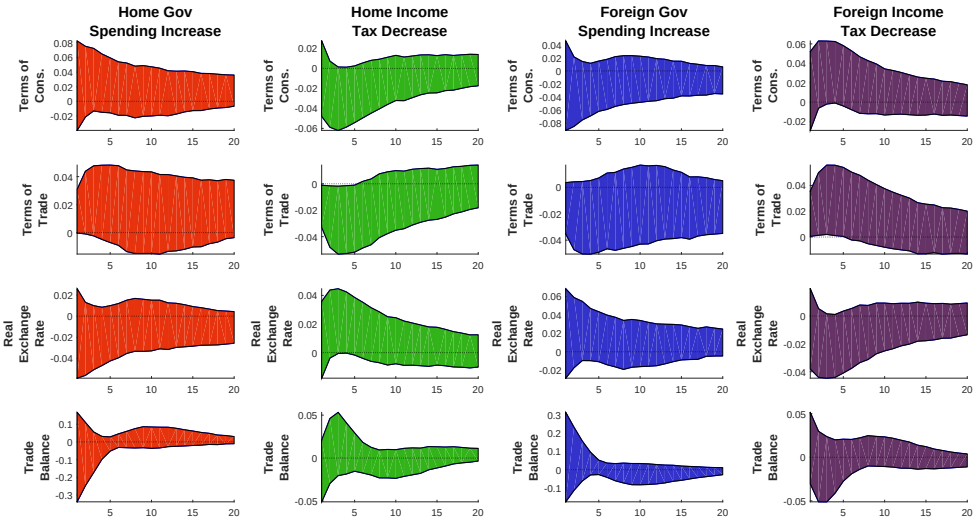
[21] Multipliers constructed using real variables in production units (Y_t^I) are similar (see Appendix D).

[22] When analyzing an income tax cut, we multiply the fiscal multipliers by -1, so that a positive GDP multiplier implies GDP increases, while a negative multiplier implies GDP declines. This favors comparability with the effects of a public spending increase.

[23] For instance, two years after an increase in government spending, GDP multipliers are higher relative to the closed economy in about 50% of the cases in which the real exchange rate depreciates.



(a) Present-Value Multipliers



(b) Select Impulse Responses

Figure 2. 90-percentile intervals implied by the prior-predictive analysis. X-axis denotes quarters.

2015), the diffuse prior for the trade elasticity encompassing both micro and macro estimates (Enders et al., 2011), and the diffuse prior for the degree of complementarity between public and private goods.[24] The latter shapes the response of private consumption following a public expenditure increase, affecting the real exchange rate through the uncovered interest parity condition. Finally, due to price stickiness, the responses of the terms of trade and terms of consumption can differ a priori (even qualitatively). Given the assumption of dollar currency pricing, the response of the terms of trade is always smaller in magnitude.

While the model is a priori agnostic about the effects of trade linkages, table 1 shows that whether fiscal multipliers are larger in an open economy depends on the responses of the terms of consumption and the trade balance, as highlighted in section 2. The left column of the table reports the unconditional probability of a larger multiplier in the open economy for each fiscal instrument, defined as $Pr\left(M_Y > M_Y^{\text{closed}}\right)$. Following an increase in government spending, $Pr\left(M_Y > M_Y^{\text{closed}}\right)$ is 36% on impact and 38% after one year. For a tax cut, the probabilities are 20% on impact and 47% after one year. Consistent with the intuition of the analytical results, table 1 also shows for a public spending increase, $\Pr\left(M_Y > M_Y^{\text{closed}}\right)$ is tied to the favorable wealth effect induced by the appreciation of the terms of consumption—e.g., after one year, the response of TOC is positive 99% of the time when $M_Y > M_Y^{\text{closed}}$. In contrast, for a tax cut, the beneficial effects of trade openness are tied to an increase of net exports—e.g., TB improves 98% of the time when $M_Y > M_Y^{\text{closed}}$ after one year. In this case, the terms of consumption depreciate, reflecting a lower domestic marginal cost, once again consistent with the analytical results.

The right column of table 1 plots probabilities of positive international spillovers. In this case, we compute the probability that a Foreign increase in public spending or a Foreign tax cut raises the Home GDP multiplier at a given time horizon. Following a Foreign government spending increase, $Pr\left(M_Y > 0\right) = 62\%$ after one year. The table shows the positive spillover stems from an increase in Home net exports, which happens in virtually all the cases (both on

[24] Ravn et al. (2012) show deep habits also can generate exchange rate depreciation, while Corsetti et al. (2012) focus on spending reversals.

impact and after one year). Moreover, the positive spillover occurs despite the depreciation of the Home terms of consumption. Following a Foreign income tax cut, $Pr\left(M_Y > 0\right) = 56\%$ after one year. The dominant force in this case is the appreciation of the terms of consumption, which occurs in 99% of the cases.

Summing up, the intuition from the analytical model is preserved in the quantitative framework. Theoretically the sign and size of the effects of trade linkages on fiscal multipliers are ambiguous. To discern which predictions are favored empirically, we now turn to the estimation of the model.

4 An Empirical Application: Canada & the U.S.

We estimate the model using data for Canada and the U.S. This country pair is particularly suited for the analysis, since 80% of Canadian trade occurs with the U.S., implying the latter provides a realistic characterization of the rest of the world for Canada. In Appendix F.3, we present results for an alternative country pair, the Euro Area and the U.S., and show the results are qualitatively similar to the U.S.-Canada application.

Table 1: Prior Probabilities for GDP Multipliers.

	Domestic Multiplier			**Int. Spillover**	
	Gov. Spending	*Income Taxes*		*Gov. Spending*	*Income Taxes*
Impact			*Impact*		
$\Pr\left(M_Y > M_Y^{closed}\right)$	36%	20%	$\Pr\left(M_Y > 0\right)$	63%	76%
$\Pr\left(\widehat{TOC} > 0 \vert M_Y > M_Y^{closed}\right)$	97%	6%	$\Pr\left(\widehat{TOC} > 0 \vert M_Y > 0\right)$	29%	60%
$\Pr\left(\widehat{TB} > 0 \vert M_Y > M_Y^{closed}\right)$	94.5%	83%	$\Pr\left(\widehat{TB} > 0 \vert M_Y > 0\right)$	99.9%	96%
After One Year			*After One Year*		
$\Pr\left(M_Y > M_Y^{closed}\right)$	38%	47%	$\Pr\left(M_Y > 0\right)$	62%	56%
$\Pr\left(\widehat{TOC} > 0 \vert M_Y > M_Y^{closed}\right)$	99.9%	1%	$\Pr\left(\widehat{TOC} > 0 \vert M_Y > 0\right)$	15%	99%
$\Pr\left(\widehat{TB} > 0 \vert M_Y > M_Y^{closed}\right)$	56%	98%	$\Pr\left(\widehat{TB} > 0 \vert M_Y > 0\right)$	94%	47%

Note: $M_Y \equiv$ Present Value Multiplier; $\widehat{TOC} \equiv$ terms of consumption; $\widehat{TB} \equiv$ Trade Balance. $\Pr(\cdot)$ denotes a probability.

We estimate the model using Bayesian methods over the period 1992-2007, including the following observables: consumption, investment, inflation, hours worked, the interest rate, and the ratios of government consumption to GDP, income tax revenue to GDP, consumption tax revenue to GDP, and the real market-value of government debt to GDP. In addition, we include the log first-difference of the bilateral real exchange rate between Canada and the U.S., U.S. bilateral exports in goods to Canada, and U.S. bilateral imports in goods from Canada. Details of the data construction, estimation procedure, posterior parameter estimates, as well as a comparison of model and data volatilities and correlograms are presented in Appendices E.1-E.4.[25]

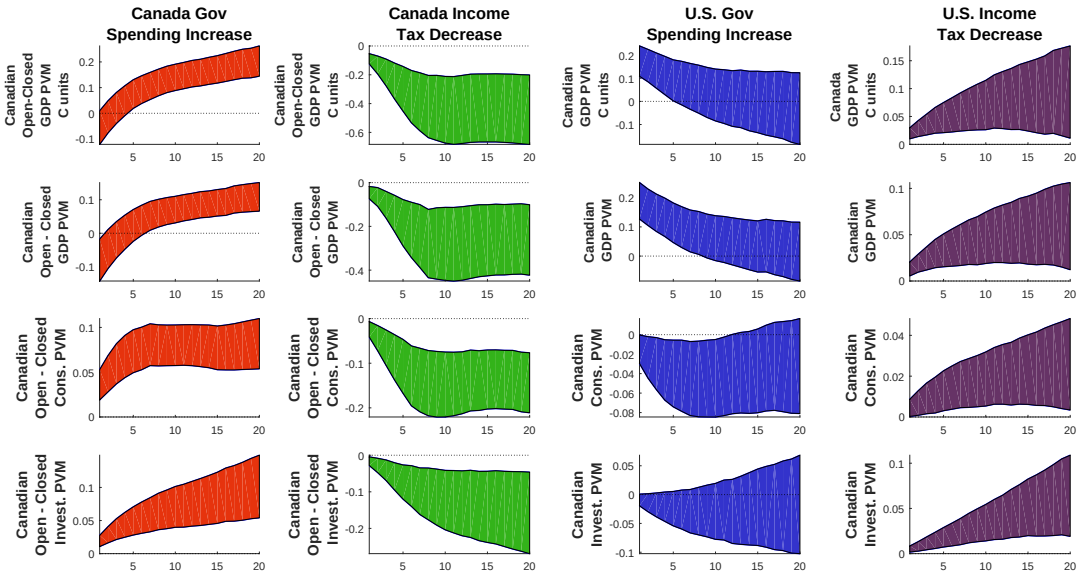
Figures 3a-3b display posterior 90-percent intervals for the difference in open- and closed-economy present-value multipliers and impulse responses for select variables. When calculating multipliers for a counterfactually closed Canadian economy we assume $\alpha_X = \alpha_X^g = \alpha_X^I = 0$.[26] Column 1 of figure 3 presents responses to a 1% increase in government spending in Canada. Despite the significantly persistent deterioration of the trade balance, the GDP multiplier is unambiguously larger relative to the counterfactually closed economy, and the positive difference materializes well before the reversal of the trade deficit. The effect is quantitatively notable: 6-15 cents higher after 20 quarters (i.e., approximately 20% higher than the closed economy) and 14-26 cents higher when GDP is measured in consumption units. In line with the intuition of the analytical model in section 2, the larger open-economy multiplier reflects the persistent appreciation of the domestic terms of consumption and terms of trade.[27] This appreciation crowds in private consumption and investment relative to the closed economy. Finally, there is an appreciation, albeit modest, of the real exchange rate.[28]

[25] In Appendix F.1, we show the robustness of our results to estimating with a longer sample period, 1992-2017, and in Appendix F.2 to the inclusion of an observable for the terms of consumption.

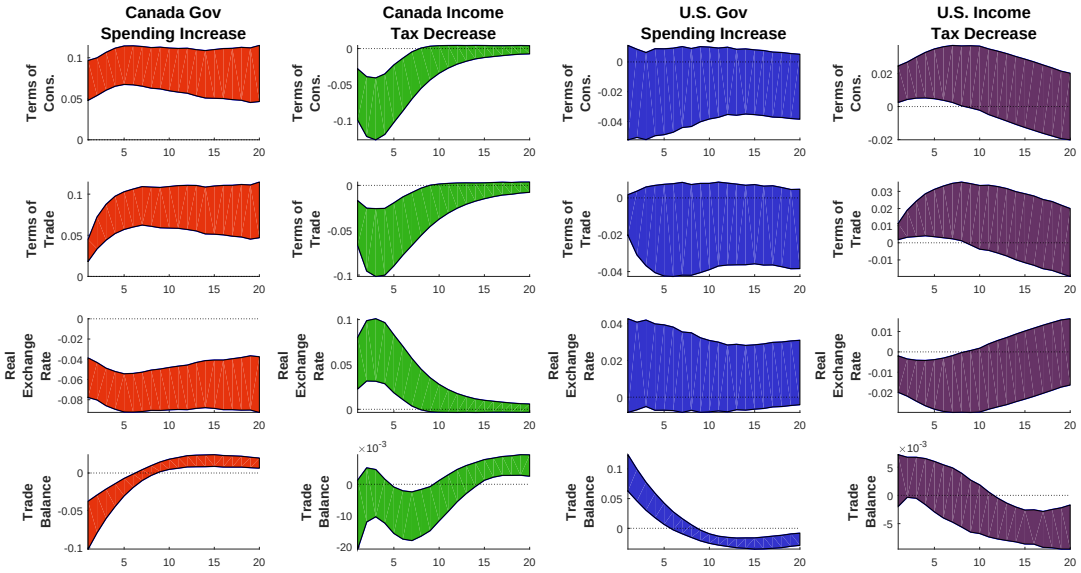
[26] An alternative approach is to measure the effects of trade linkages by assuming Canada trades with a symmetric trading partner, i.e., directly comparing Home and Foreign multipliers assuming both countries feature Canadian posterior estimates. Appendix E.5 presents the results for this case, demonstrating the asymmetries in parameter estimates between Canada and the U.S. play a modest role for the results.

[27] Basu and Kollmann (2013) show increases in government investment can lead to a deterioration in the terms of trade, akin to an increase in total factor productivity. Over our sample, government investment is only 14% of total government purchases in Canada and 21% in the U.S.

[28] For Canada, there is VAR evidence supporting a real appreciation following an increase in government



(a) Present-Value Multipliers



(b) Select Impulse Responses

Figure 3. 90-percentile intervals implied by the posterior estimates. X-axis denotes quarters.

Column 2 plots the responses following a reduction in the Canadian income tax rate. In contrast to the effects of a public spending increase, trade linkages reduce the effectiveness of a tax stimulus at all horizons. Cumulative GDP multipliers are lower than in the counterfactually closed economy, consistent with the deterioration of the domestic terms of consumption which crowds out private consumption and investment.

Turning to the spillover effects of U.S. policy, a 1% increase in U.S. public spending (column 3) and a 1% cut in U.S. income taxes (column 4) induce a positive spillover on Canadian GDP. This positive spillover is quantitatively stronger, albeit shorter lived, for the increase in U.S. public spending.

Key Transmission Channels

We consider alternative counterfactual scenarios to disentangle how competing international linkages affect Canadian present-value GDP multipliers. We consider three counterfactuals. The first one holds constant the terms of consumption in response to fiscal shocks. The other two address how the relative import share of public and private goods, the financing of the government budget, and the currency invoicing of trade shape terms-of-consumption dynamics. In all experiments, we condition the model on the posterior mean estimates.

The top row of figure 4 considers Canadian government spending and tax shocks; the bottom row considers U.S. fiscal shocks. In each quadrant, each line plots the Canadian GDP multiplier relative to a counterfactually closed economy (defined as $\alpha_X = \alpha_X^g = \alpha_X^I = 0$) under different counterfactual scenarios. For comparability, in each panel we also report this difference at the posterior mean estimates (the solid squared line).

We first consider the effects of Canadian fiscal shocks (top row of figure 4). Following the insights of the analytical model, we consider a counterfactual economy where the domestic terms of consumption are constant (solid-plus lines). We induce this outcome by assuming

spending. For example, Kim (2010) finds the real exchange rate appreciates significantly, while Canada is the only country for which Monacelli and Perotti (2010) do not find depreciation of the exchange rate. While there is no direct evidence on the response of the terms of consumption, Monacelli and Perotti (2008) and Muller (2008) find the terms of trade appreciates with an increase in public spending.

U.S. firms receive a per-period, lump-sum export subsidy such that the price adjustment leaves the domestic terms of consumption unchanged. Absent the appreciation of domestic prices relative to import prices, the domestic effectiveness of an increase in public spending is smaller than in the closed economy at all horizons. At the same time, absent the depreciation of the terms of consumption, trade linkages would not reduce the GDP multiplier following an income tax cut. These results confirm the insight from the analytical model.

We then assess the importance of direct trade linkages related to government expenditures by considering full home bias in public goods, i.e. $\alpha_X^g = 0$ (the solid-starred lines of figure 4). As in the analytical model, lowering the public-to-private import ratio ν to zero increases government-spending multipliers relative to the closed economy—with full home bias, trade linkages induce an additional increase in GDP multipliers equal to 15 cents after two years. Also consistent with the results of section 2, the public-to-private import share, ν, affects income tax multipliers. With full home bias in public goods, trade linkages result in a much smaller income-tax GDP multiplier relative to the closed economy (30 cents lower after two years), since $\alpha_X^g = 0$ implies a larger reduction in government spending on domestic goods to finance the tax cut over time. In turn, lower domestic demand results in a stronger deterioration of the domestic terms of consumption, leading to a more pronounced negative wealth effect.

Finally, we address the role of price setting frictions by considering local currency pricing, i.e. LCP (the solid-diamond lines of figure 4). Once again, following the insights from the analytical model, under LCP the terms of consumption respond less to fiscal shocks. In turn, the beneficial effects of trade for government spending multipliers and the detrimental effects on income tax multipliers are both reduced.

The bottom row of figure 4 repeats the same counterfactuals as the top row for U.S. fiscal shocks. Following a U.S. public spending increase, lack of depreciation in the Canadian terms of consumption (solid-plus line) would result in a longer-lasting positive spillover. Turning to a U.S. income tax cut, the appreciation in the Canadian terms of consumption

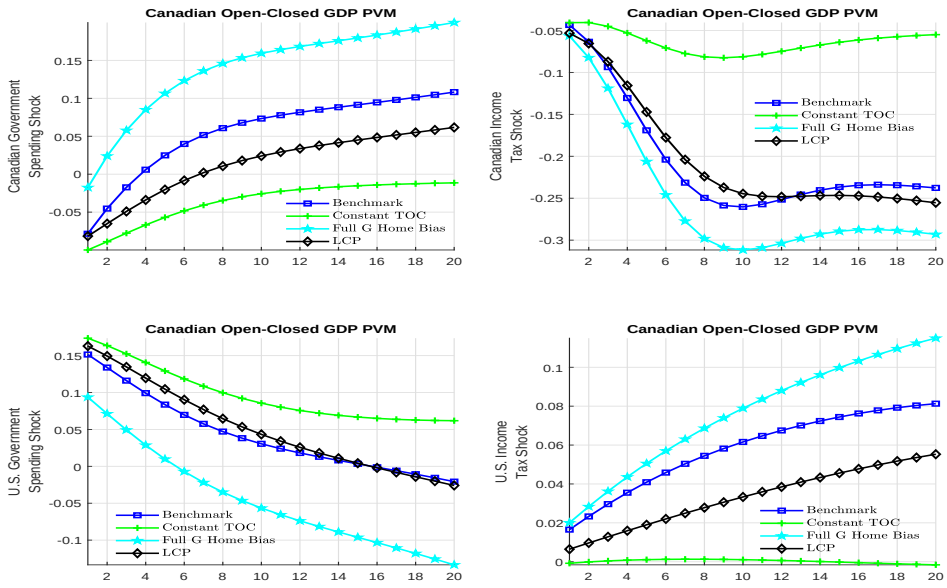


Figure 4. *First row*: increase in Canadian government spending and Canadian tax cut; *Second row*: increase in U.S. government spending and U.S. tax cut. Benchmark response at posterior mean denoted by blue solid lines in all panels, while counterfactuals vary parameter/model structure as described in the legends. X-axis measures quarters.

is essential for generating the positive, long-lasting comovement between U.S. and Canadian GDP. The solid-plus line shows without the appreciation, the spillover is virtually zero at all horizons. To understand this result, note that a U.S. income tax cut generates two opposing forces for Canada. On the one hand, the increased after-tax return in the U.S. encourages capital to shift from Canada to the U.S. Other things equal, this lowers Canadian GDP, generating a negative spillover (see Mendoza et al., 2014 for a discussion of this mechanism in a model of the Euro Area). At the same time, the decrease in U.S. income taxes leads to an appreciation of the Canadian domestic terms of consumption. The positive wealth effect from the appreciation encourages more consumption and investment in Canada, raising Canadian GDP. Given our estimate of the trade elasticity, the terms-of-consumption effect dominates in equilibrium and is essential for generating positive co-movement, as seen from the counterfactual with constant terms of consumption (solid-plus line).

5 Conclusion

This paper shows fiscal multipliers can be larger in economies more open to trade, even when fiscal expansions imply a trade deficit. Holding the trade share and trade elasticity constant, countries can have higher or lower fiscal multipliers relative to a counterfactually closed economy depending on 1) the private sector import intensity relative to the public sector, 2) how the government finances fiscal expansions, and 3) the invoicing of import and export prices. We demonstrate these ambiguous effects analytically in a simple two-good, two-country model.

We then employ a Bayesian prior-predictive analysis to show the forces highlighted in the analytical model also determine fiscal outcomes in a quantitative international business-cycle model. That is, the effects of trade linkages on fiscal multipliers remain tied to the dynamics of the terms of consumption and net exports. An empirical application that conditions the model on Canadian and U.S. data implies Canadian government spending multipliers are higher than in a counterfactually closed economy. Income tax cuts generate lower domestic multipliers but are more effective in inducing persistent and positive cross-country comovement.

Our results have direct implications for the effectiveness of fiscal policy in the global economy, including incentives for international fiscal policy coordination and fiscal consolidations. Moreover, our analysis suggests important considerations for future empirical work on the transmission of fiscal policy.

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