PRODUCTIVE MISALLOCATION AND INTERNATIONAL TRANSMISSION OF CREDIT SHOCKS*

BY YUKO IMURA AND JULIA K. THOMAS[1]

Bank of Canada, Canada; Ohio State University and NBER, U.S.A.

We study the role of international trade in cross-country financial shock transmission using an equilibrium business cycle model calibrated to the United States and Canada. Heterogeneous firms have differing needs for external finance and face occasionally binding collateral constraints hindering their investments, while input-output linkages drive trade in final goods and intermediate inputs. Transmission of a U.S. financial shock recession into Canada's economy is qualitatively different from productivity shock transmission and asymmetric. We trace the first result to a unique investment channel operating through persistent trade balance adjustments and the second to differences in the two countries' exposure to trade.

Running head title: INTERNATIONAL TRANSMISSION OF CREDIT SHOCKS
JEL codes: D25, E22, F44
Keywords: capital misallocation, credit crisis, cross-country shock propagation

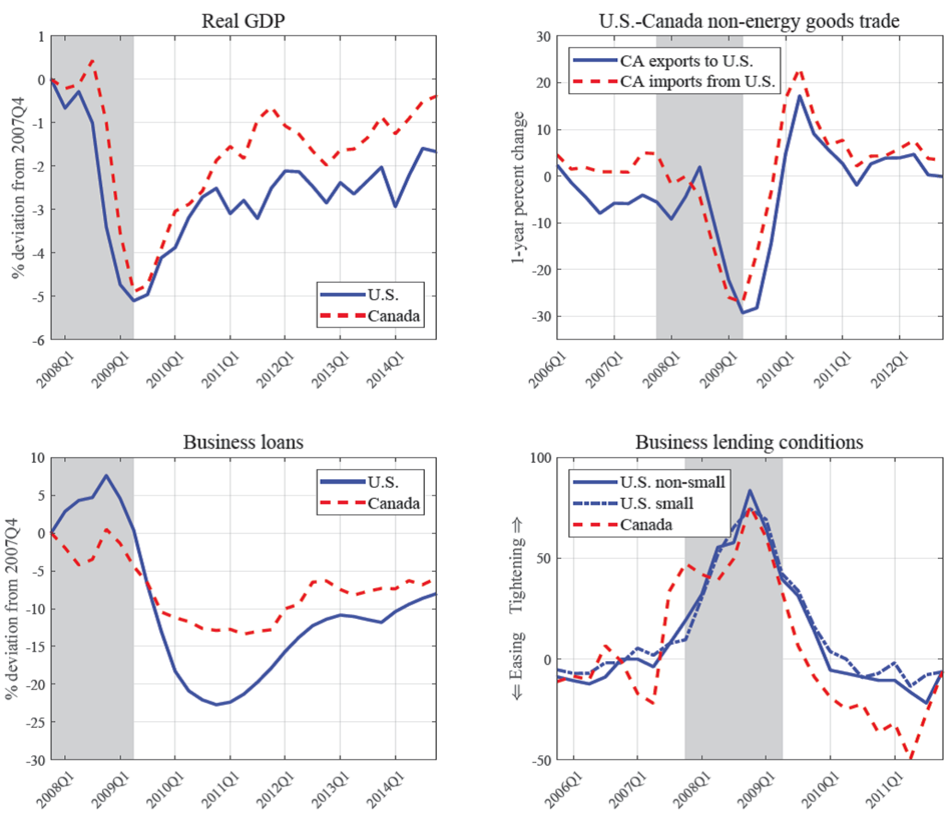
*Manuscript received March 2022; revised August 2024.

[1] We thank the editor, Iourii Manovskii, and four anonymous referees for insightful suggestions that have sharpened the quality and clarity of this work. We also thank Paul Beaudry, Yan Bai, Jonathan Heathcote, Aubhik Khan and session participants in the 2022 Canadian Economics Association and 2023 Midwest Macro Meetings for useful comments. The views expressed here are our own and do not represent the views of the Bank of Canada.

1 Introduction

United States credit market disruptions spread rapidly over the 2007 financial crisis, triggering financial market turmoil and sharp contractions in real activity around the world; meanwhile, international trade experienced an abrupt collapse that some empirical studies have linked to the global financial crisis.[2] Figure 1 demonstrates these events using Canada, the United States' leading trade partner at the time. The lower panels show Canada's decline in business lending was roughly coincident with that in the U.S., as was its tightening of loan standards; the upper panels show the two countries' recessions were similar in magnitude and timing, and bilateral trade between them contracted sharply and coincidentally. Studies related to the lower panels argue that financial linkages were important in propagating the global recession; others related to the upper right panel suggest that international trade also may have had a role.

FIGURE 1. U.S. AND CANADA OVER THE GLOBAL FINANCIAL CRISIS



NOTE.– Real GDP series drawn from U.S. Bureau of Economic Analysis and Statistics Canada GDP tables; gray bars reflect U.S. 2007 recession dates. Bilateral trade series are Canada-U.S. nominal merchandise exports and imports of non-energy products deflated by export and import price indices, from Statistics Canada. Real business loans series constructed from United States Board of Governors data on commercial and industrial loans at all commercial banks and Bank of Canada data on loans to non-financial corporations and unincorporated businesses by chartered banks. Quantity series are in logs, detrended using an HP filter with weight 1600. Lending conditions series are net percentage of banks reporting tightened loan standards in the U.S. Board of Governors' Senior Loan Officer Opinion Survey on Bank Lending Practices and the Bank of Canada's Senior Loan Officer Survey.

[2]See Kollmann, Enders and Müller (2011), Ueda (2012), and Perri and Quadrini (2018) for evidence of synchronization in real and financial aggregates between the U.S. and other advanced economies during the global financial crisis. Bems, Johnson and Yi (2013) offer an excellent survey of work examining the unprecedented contraction in international trade. They ascribe the trade collapse to large reductions in expenditures on traded goods, as do Eaton et al. (2016) and Bussière et al. (2013).

This paper develops an international business cycle model to explore how a financial disturbance in a large open economy like the U.S. affects the real economies of its trading partners through trade. Ours is unique among model-based studies of cross-country credit shock transmission in that it abandons the representative agent abstraction to derive a domestic downturn from increased productive misallocation. As a result, it delivers a financial-shock recession while maintaining consistency with evidence from U.S. Flow of Funds data that the average firm need not borrow to fund investment *and* evidence from U.S. Census and other microeconomic datasets that young, small and cash-poor firms suffered disproportionate contractions relative to other firms during the 2007 recession. These novel elements fundamentally shape international transmission of a credit shock, rendering it investment-led and highly nonmonotone. Given an anticipatory wealth effect implied by the gradual unraveling of real activity, misallocation-driven erosion in the return to domestic aggregate investment prompts a rise in net exports facilitating investment of *residual savings* abroad. Those capital flows drive an expansion in the recipient economy until domestic credit conditions improve; a long investment-led contraction and anemic recovery follow, as the unevenly-allocated capital build-up slowly reverses course. These unusual dynamics vanish if current account adjustments are prohibited or if the aggregate disturbance is real rather than financial.

We introduce Khan and Thomas' (2013) producers into an asymmetric two-country setting with a direct interdependency between production and trade, motivated by the prominence of cross-country production linkages in international business cycles.[3] The model features a roundabout structure whereby firms' output is used as both final goods and production inputs, at home and abroad, and its calibration captures the extent of intermediate inputs use relative to firms' value added and the share of imported content in these inputs. Firms differ in capital and financial position and face persistent idiosyncratic productivity shocks and occasionally binding borrowing limits; their investments are financed with internal funds and one-period debt, but debts are limited by a collateral constraint anchored on their existing capital stocks. Exogenous death and birth ensure there are always some cash-poor firms in each country that cannot borrow enough to undertake efficient investments consistent with their productivities. The resulting resource misallocation lowers the aggregate return to capital accumulation and aggregate productivity in ordinary times, and it is through this channel that a credit shock tightening collateral constraints causes a domestic recession.

We calibrate our model to the United States and Canada, replicating each country's trade shares and Canada's relative GDP. These countries' geographic proximity and strong trade relationship make them natural candidates for an analysis focused on the role of trade linkages in the transmission of financial shocks.[4] Their pairing also avoids some considerations absent from our model such as exchange rate policy, trade policy and transportation costs and lags, which themselves may have non-trivial effects on cross-country shock transmission. Our model reflects a sharp difference in trade reliance, with the U.S. having minimal exposure to the Canadian economy relative to its domestic production and Canada having substantially greater exposure to the U.S. economy, and this difference leads to asymmetric financial shock transmission.

We first examine responses to a credit crisis in the larger economy calibrated to the United States, setting the shock's size and persistence so the predicted debt path matches that of U.S. nonfinancial business debt over the financial crisis. As in Khan and Thomas (2013), the domestic result is a growing distortion to capital allocation that drives persistent declines in aggregate productivity and interest rates, gradually eroding aggregate investment, employment and production. We demonstrate that disruptions to young

[3] Input-output linkages are increasingly emphasized in the recent trade literature, as intermediate inputs now account for a sizeable share of trade; see, for example, Burstein, Kurz and Tesar (2008) and di Giovanni and Levchenko (2010).

[4] The World Bank's World Integrated Trade Solution data show Canada was the top destination for U.S. exports in 2007, accounting for 21.4 percent of total U.S. exports, and it was the second largest source of imports into the U.S. (15.7 percent), closely following China (16.9 percent). At the same time, 79 percent of Canadian exports went to the U.S., and the U.S. supplied 54.2 percent of Canada's imports.

cohorts' life-cycle growth lie at the heart of the nonmonotone aggregate response. Born comparatively small, young firms tend to be cash-poor and so more reliant on external funds than older firms. Tight credit increases the inefficiency in their investments and extends their maturing phases. With life-cycle growth protracted for each cohort born during the crisis, a growing subset of firms invests inefficiently, worsening overall misallocation with time. This distributional damage is slowly repaired after the restoration of credit conditions, so recoveries in aggregate investment and other series are gradual.

The financial shock is transmitted across borders through an investment channel because it persistently lowers the U.S. economy's return to aggregate capital accumulation. Responding to the wealth effect implied by their worsening recession, its households reduce their savings by less than the fall in domestic investment, achieving this with changes in net goods flows. Effectively, they relocate some savings abroad where financial conditions have in relative terms improved, a shift mirrored by a persistent rise in their country's trade balance and a temporary worsening in its terms of trade.

Those trade adjustments have a non-trivial impact on our smaller economy calibrated to Canada, where the external sector accounts for a sizable share of real activity. Through a markedly greater rise in investment than in its savings, Canada initially ramps up aggregate capital to accommodate an increasing demand for domestic production in anticipation of rising costs of imported goods. The result is a modest expansion lasting until the U.S. credit condition begins to improve. At that point, global production starts slowly shifting back towards the larger economy, and investment in the Canadian economy begins a correspondingly slow decline. This protracted reversal yields a long contraction, with investment reductions accounting for over 40 percent of the ultimate GDP losses, followed by a decidedly sluggish recovery.

Trade intensity matters. A financial shock to the Canadian economy induces investment relocations and net export dynamics qualitatively similar to those described above. However, given its larger productive scale and far more limited exposure to trade, the U.S. economy is almost entirely unaffected. This model prediction is consistent with findings in the empirical literature that business cycle synchronization correlates with the strength of trade linkages across countries.

The type of shock matters. Changes in investment are crucial to cross-country credit shock transmission; tight credit steadily erodes the return to domestic capital by disparately affecting cohorts needing it most, raising relative returns to investing abroad. By contrast, a persistent productivity shock scales domestic firms' production down both evenly and immediately. The domestic economy suffers no rising misallocation, and so no further erosion in TFP; thus, its trading partner faces an immediate rise in import prices and also enters recession right away. Expenditure shares of GDP in both countries are roughly unaltered by that shock, so changes in consumption account for the bulk of their GDP responses. In short, the model's responses to a real shock resemble those reported elsewhere in the international business cycle literature.

We also consider an exercise featuring direct credit shocks in both economies, calibrating the second shock to reproduce the fall in Canadian business debt over the global financial crisis. We find the smaller economy's financial recession is altered in three ways by its trading partner's recession, all traceable to the investment channel described above. Given a smaller shock and its greater exposure to trade, the Canadian economy receives infusions of savings from abroad at the start of the crisis, propping its investment up whilst growing misallocation is lowering the return to aggregate capital. Those infusions soften the initial downturn, appreciably delay the recession trough, and extend the half-life of the GDP recovery by more than a decade. Comparing these global financial crisis predictions to the actual U.S. - Canada experience, we see similarities in the coincident start of their downturns, Canada's small initial investment rise and sizeable declines in its trade balance with the U.S. starting in 2008, and the unusual sluggishness in both countries' economic recoveries. The greatest differences lie in the far larger magnitudes of decline in the data, and the fact that the Canadian recovery began alongside that in the United States and proceeded at a similar rate.

The remainder of the paper is organized as follows. Section 2 reviews the literature related to our study. We describe the model economy in Section 3 and discuss its calibration in section 4. Section 5 presents our results, and section 6 concludes.

2 Related literature

Our analysis of financial shock propagation builds on advancements in the closed-economy financial frictions literature born from the U.S. 2007 recession. We particularly draw on Khan and Thomas (2013), extending their collateral constraint model to a two-country setting with input-output linkages capturing international trade in both final goods and intermediate inputs.[5] Reconsidering mechanics underlying the nonmonotone domestic response to a credit shock, we show tight credit is particularly damaging to young firms' growth, so capital misallocation worsens as the number of affected cohorts rises, discouraging domestic investment.[6] We find the investment channel is also central to international transmission, given temporary rises in the relative return to aggregate capital in the economy experiencing no direct shock or a lesser one.

Our work complements studies with other mechanisms through which firms' financing needs propagate aggregate credit disturbances. One such mechanism operates through the labor demand channel. Arellano, Bai and Kehoe's (2019) firms use defaultable debt to finance their wage bills before observing idiosyncratic productivities, so an uncertainty shock raising default risk discourages hiring through raised loan interest rates. Jermann and Quadrini's (2012) firms face a binding enforcement constraint limiting working capital loans, so their effective labor cost rises when a shock tightens it.[7] Other authors emphasize the role of trade credit in transmitting financial shocks along production chains by disrupting inter-firm borrowing used to finance intermediate inputs. In Luo (2020) and Antinoglu (2021), firms borrow from banks and intermediate input suppliers to pay their wages and input costs before production, and the financial interdependency between firms amplifies the aggregate impact of shocks to bank lending costs or borrowing constraints. Bocola and Bornstein (2023) and Reischer (2024) endogenize the use of trade credit in multi-sector models, showing its disruption acted as a credit multiplier significantly amplifying the U.S. 2007 recession.

Our focus on financial shock transmission through international trade also complements a literature exploring financial contagion. Devereux and Sutherland (2011), Dedola and Lombardo (2012), Perri and Quadrini (2018), Yao (2019) and Devereux and Yu (2020) examine models where investors access foreign assets subject to financial frictions. Given direct exposure to foreign assets in these settings, a financial shock in one country worsens borrowing conditions abroad, inducing cross-country comovement in investment and production. Other studies allow an explicit role for global banks; see, for example, Mendoza and Quadrini (2010), Kollmann, Enders and Müller (2011), Ueda (2012) and Beaton, Lalonde and Snudden (2014).[8] We do not model financial contagion, but allow for it in our simultaneous shocks exercise. Comparing responses to a domestic credit tightening in isolation versus alongside a financial recession in its large trading partner, we find the trade channel reshapes our small open economy's financial recession in noteworthy ways.

[5] Collateral constraints have been adopted widely in the closed-economy financial frictions literature since Kiyotaki and Moore's (1997) theoretical work showing they propagate shocks to the value of collateral. A popular alternative, Bernanke, Gertler and Gilchrist's (1999) financial accelerator mechanism, derives from Townsend's (1979) costly state verification model where information asymmetries yield borrowing premia inversely related to net worth.

[6] Khan and Thomas (2013) argue this point based on disproportionate employment losses among small firms and the correlation between age and size. We establish it directly using moments from the firm age-size distribution.

[7] The credit-induced distortion in Buera and Moll (2015) may be an efficiency (TFP), investment or labor wedge depending on whether idiosyncratic shocks affect firms' productivities, investment costs or labor recruitment costs.

[8] See also Kalemli-Ozcan, Papaioannou and Perri (2013), Kamber and Thoenissen (2013) and Kollmann (2013). As in the closed-economy literature, earlier work by Gilchrist (2004), Iacoviello and Minetti (2006), Faia (2007), and Devereux and Yetman (2010) studies real and nominal shocks in two-country models with financial frictions.

More broadly, in contrasting financial versus real shock transmission in an asymmetric two-country model, this paper contributes to an extensive literature examining shock transmission in international business cycle models starting with Backus, Kehoe and Kydland (1992, 1994) and Baxter and Crucini (1995). While early work featured symmetric one-sector models driven by productivity shocks, more recent studies have replaced one or more of these assumptions to strengthen internal propagation and in other ways improve empirical performance. Kose and Yi (2006) develop a three-country IRBC model allowing differing Armington weights and productivity shock processes; they find it generates a positive relation between trade linkages and output comovement as in the data, albeit with a weaker implied elasticity. We do not quantify the relationship in our analysis, but our results complement theirs in demonstrating that an economy with greater exposure to international trade in proportion to its GDP is more affected by financial shocks abroad.

Miyamoto and Nguyen (2017) emphasize labor market responses to relative price changes as a key factor in business cycle transmission. Using a model estimated with U.S. and Canadian data, they show preferences implying a low wealth elasticity of labor supply, imported intermediate inputs and variable capital utilization each help boost transmission of permanent productivity shocks, and together deliver substantial cross-country comovement. Our U.S. and Canada model omits variable utilization; however, consistent with their findings, the other two elements strengthen its international transmission of a productivity shock recession.

Alessandria, Kaboski and Midrigan (2013) find the inclusion of inventories succeeds in addressing several deficiencies of the standard IRBC model. Adding a stockout-avoidance motive in their model's retail sector, they show stock adjustments amplify trade volatility following TFP shocks, and help generate countercyclical real net exports while reducing the consumption correlation across countries. We do not undertake stochastic simulations to compute business cycle moments from our model; however, its impulse responses show GDP and net exports co-move negatively in both countries when either experiences a financial shock. Where the countercyclicality of net exports is driven by procyclical inventory accumulation in Alessandria, Kaboski and Midrigan (2013), it instead reflects investment relocation from an economy experiencing temporarily heightened financial market distortions toward the raised relative return of its trading partner in our model.

Finally, our inclusion of input-output linkages is prompted by recent work emphasizing the importance of intermediate inputs trade, particularly in the trade collapse during the global financial crisis.[9] Embedding a vertically integrated production structure in their two-country IRBC model, Burstein, Kurz and Tesar (2008) find cross-country production linkages and complementarity in domestic and foreign inputs strengthen the relationship between trade and business cycle comovement. Johnson (2014) shows a multi-country model with production linkages predicts the strong correlation between trade linkages and output comovement only when shocks are correlated across countries. Alessandria and Choi (2014) find these linkages contribute to the gains from trade in a model where fixed costs influence firms' export market participation choices. Consistent with the results in these prior studies, we find allowing a realistic share for material inputs increases cross-country transmission of productivity shocks in our model; however, it adds nothing to financial shock transmission.

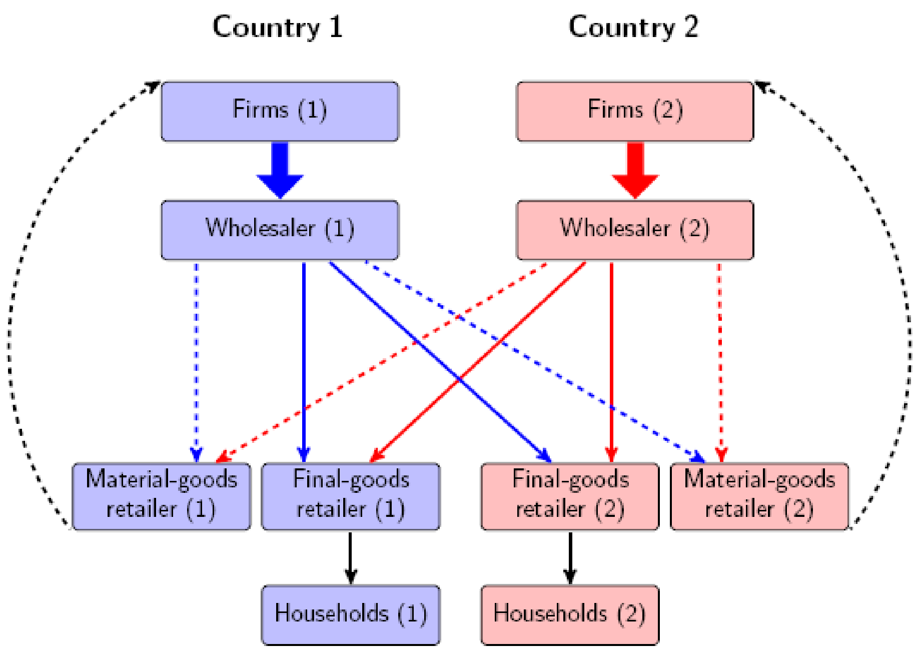
3 Model

We study two countries, $c = 1, 2$, distinguished in size by their constant measures of households, Ψ_c. The countries are symmetric in most other respects, though their differing home biases in materials and final goods production will yield large differences in international trade exposure in our calibration. All markets are perfectly competitive, prices are flexible, and we assume complete international financial markets.

[9] Bems, Johnson and Yi (2011) report that trade in intermediate inputs accounted for over 40 percent of the fall in total trade during this episode. Levchenko, Lewis and Tesar (2010) and Bems, Johnson and Yi (2010) also demonstrate the empirically important role of intermediate inputs in the trade collapse following the global downturn.

Within each country, households are identical and infinitely-lived, with access to state-contingent nominal bonds. The production structure features input-output linkages within and across countries depicted in figure 2. A representative final goods retailer combines domestic and imported inputs to produce the good used for home consumption and capital investment. A wholesaler intermediates the sale of domestic firms' output to final goods retailers at home and abroad, and to domestic and foreign material goods retailers that, in turn, supply materials to domestic firms. Each country has a time-invariant measure of heterogeneous firms matching its household population size, and each firm uses capital, labor and materials in its production.

FIGURE 2. MARKET INTERACTIONS



Firms produce a common domestic good; they face persistent country-specific aggregate productivity shocks and persistent idiosyncratic productivity shocks. They hire labor from domestic households, purchase materials from the domestic material goods retailer and maintain their own capital stocks. Each invests goods bought from the domestic final goods retailer to augment its stock for next period, and each can use one-period loans to help fund that. A country-specific collateralized borrowing constraint limits the debt a firm can take on as a function of its current capital stock, and firms cannot circumvent the constraint by paying negative dividends. A constant exogenous exit and entry rate each period prevents all firms effectively outgrowing financial frictions in the long run, while maintaining a fixed measure of firms over time.

The aggregate state is A, where $A \equiv (S, Z)$ and $Z \equiv [z_1, z_2, \zeta_1, \zeta_2]$ is the exogenous state vector including an aggregate productivity shock, z_c, and the credit state ζ_c, in each country, $c = 1, 2$. Each country's ζ_c anchors the collateral constraint limiting firms' debt in proportion to their capital. All exogenous state variables follow Markov chains; z takes one of N_z values, ζ takes one of N_ζ values, and the joint transition matrix Π^Z has elements $\{\pi^Z_{lm}\}$ representing $pr\{Z'_m | Z_l\}$ for $l, m = 1, \ldots, N_Z$, where $N_Z = N_z N_\zeta$.

Our model yields a time-varying distribution of firms over capital, ($k \in \mathbf{K} \subset \mathbf{R}_+$), debt ($b \in \mathbf{B} \subset \mathbf{R}$) and firm-specific productivity ($\varepsilon \in \mathbf{E}$) in each country. We summarize the distribution of firms at the start of a period in country c using the probability measure μ_c defined on the Borel algebra $\mathcal{S}$ generated by the open subsets of the product space, $\mathbf{S} = \mathbf{K} \times \mathbf{B} \times \mathbf{E}$ for each $c = 1, 2$. The model's endogenous aggregate state vector comprises these distributions; $S \equiv [\mu_1, \mu_2]$.[10] All agents take as given the laws of motion determining Z' given Z, as well as the evolution of the endogenous state according to an equilibrium mapping $S' = \Gamma(A)$. We describe the preferences, technologies and optimization problems in each country c and its trading partner $\widetilde{c} \neq c$ below, specifying country 1 or country 2 where necessary for clarity or in defining notation.

3.1 Households

Each of Ψ_c identical households in a country is endowed one unit of time per period, values consumption and labor supply by a utility function $u(C, N)$ and discounts future utility by the subjective discount factor $\beta \in (0, 1)$. Household wealth is composed of one-period shares in domestic firms, identified by the measures ξ_c, noncontingent real bonds corresponding to the debts of domestic firms, denoted by ϕ_c, and aggregate state-contingent nominal bonds. The aggregate bond is denominated in units of country-1 currency, and $B_c(A)$ denotes country c per-capita nominal bonds redeemed in the current period given aggregate state A.

Each household in country 1 chooses its consumption, C_1, labor hours supplied to domestic firms, N_1, shares in firms of each type with which to begin the next period, $\xi_1'(k', b', \varepsilon')$, and noncontingent real bonds for next period, ϕ_1'. The household also decides its purchases of state-contingent nominal bonds for next period, $B_1(A')$, each guaranteeing one unit of country-1 currency if state A' is realized. Let $\varrho(A'; A)$ be the real price of one such bond in units of country-1 final goods, and define $\widetilde{\rho}_1(k, b, \varepsilon; A)$ as the dividend-inclusive values of current firm shares and $\rho_1(k', b', \varepsilon'; A)$ as the ex-dividend prices of new shares in a given firm type.

The country-1 real wage and aggregate price level are $w_1(A)$ and $P_1(A)$, respectively, and each real bond therein costs domestic households $q_1(A)$ units of consumption. Finally, let $G(A'|A)$ represent the conditional probability of realizing a given state A' next period, which is determined by $S' = \Gamma(A)$ and the exogenous transition probabilities for the elements of Z. Each country-1 household's expected lifetime utility maximization problem then can be written as follows.

$$V_1^h(\xi_1, \phi_1, B_1(A); A) = \max_{C_1, N_1, \xi_1', \phi_1', B_1(A')} u(C_1, N_1) + \beta \int V_1^h(\xi_1', \phi_1', B_1(A'); A') G(dA'|A) \tag{1}$$

subject to:

$$\int \widetilde{\rho}_1 (k, b, \varepsilon; A)\, \xi_1 (d[k \times b \times \varepsilon]) + \phi_1 + \frac{B_1(A)}{P_1(A)} + w_1(A) N_1 \geq$$
$$C_1 + \int \rho_1 (k', b', \varepsilon'; A)\, \xi_1' (d[k' \times b' \times \varepsilon']) + q_1(A)\phi_1' + \int \varrho(A'; A) B_1(A') dA'$$

Let $\lambda_1(A) = D_1 u(C_1, N_1)$ be the Lagrange multiplier on the budget constraint. Household efficiency conditions with respect to hours worked, shares and real bonds imply restrictions on the country-1 real wage, firm share prices and inverse loan price listed in (2) - (4). Efficiency conditions with respect to state-contingent nominal bonds yield the additional restrictions in equation 5.

$$w_1(A) = -D_2 u(C_1, N_1)/\lambda_1(A) \tag{2}$$

$$\rho_1 (k', b', \varepsilon'; A) = \int \frac{\beta \lambda_1(A')}{\lambda_1(A)} \widetilde{\rho}_1 (k', b', \varepsilon'; A')\, G(dA'|A) \tag{3}$$

$$q_1(A) = \int \frac{\beta \lambda_1(A')}{\lambda_1(A)} G(dA'|A) \tag{4}$$

$$\varrho(A'; A) = \frac{\beta \lambda_1(A')}{\lambda_1(A)} \frac{1}{P_1(A')} G(A'|A) \tag{5}$$

[10] Households' state-contingent bond holdings, $[B_1, B_2]$, are indeterminate in equilibrium.

Households in country 2 solve a similar problem adjusted to reflect that state-contingent nominal bonds are denominated in country-1 currency. Let $Q(A)$ represent the real exchange rate, the price of country-2 final goods in units of country-1 final goods. Each such bond held at the start of the period returns $\frac{1}{P_1(A)}$ units of country-1 final goods, each worth $\frac{1}{Q(A)}$ units of country-2 final goods. Similarly, a bond for next period state A' costs $\varrho(A';A)$ country-1 final goods, each worth $Q(A)^{-1}$ units of country-2 consumption.

$$V_2^h(\xi_2,\phi_2,B_2(A);A)=\max_{C_2,N_2,\xi_2',\phi_2',B_2(A')} u(C_2,N_2)+\beta\int V_2^h(\xi_2',\phi_2',B_2(A');A')G(dA'|A) \tag{6}$$

subject to:

$$\int \widetilde{\rho}_2\left(k,b,\varepsilon;A\right)\xi_2\left(d\left[k\times b\times\varepsilon\right]\right)+\phi_2+\frac{B_2(A)}{P_1(A)Q(A)}+w_2(A)N_2\geq$$
$$C_2+\int \rho_2\left(k',b',\varepsilon';A\right)\xi_2'\left(d\left[k'\times b'\times\varepsilon'\right]\right)+q_2(A)\phi_2'+\int\frac{\varrho(A';A)}{Q(A)}B_2(A')dA'$$

Country-2 households' efficiency conditions imply restrictions on $w_2(A)$, $\rho_2\left(k',b',\varepsilon';A\right)$ and $q_2(A)$ mirroring (2) - (4), with $\lambda_2(A)=D_1u(C_2,N_2)$, and restrict bond prices to satisfy (7).

$$\varrho(A'|A)=\frac{\beta\lambda_2(A')}{\lambda_2(A)}\frac{Q(A)}{P_1(A')Q(A')}G(A'|A) \tag{7}$$

Equations (5) and (7) combine to determine the evolution of the real exchange rate across each date and state: $Q(A')=\frac{\lambda_2(A')}{\lambda_1(A')}\frac{\lambda_1(A)Q(A)}{\lambda_2(A)}$. Assuming an initial date zero wherein $\frac{\lambda_1(A^0)Q(A^0)}{\lambda_2(A^0)}=1$, each period's real exchange rate is a ratio of the marginal utility of consumption in country 2 versus 1.

$$Q(A)=\lambda_2(A)/\lambda_1(A) \tag{8}$$

3.2 Retailers and international trade

Each country has two representative retailers. One uses the outputs of domestic and foreign firms to make final goods; the other uses domestic and imported goods to make materials used by domestic firms. This roundabout technology implies direct concurrent effects of international trade on final goods output and upstream in the supply chain. We summarize the problems of retailers in each country $c=1,2$ below, again using the notation $\widetilde{c}$ to represent the country's trade partner.

3.2.1 Final goods retailers

The final goods retailer in country c combines per-capita domestic inputs, h^{Dc}, and exports from country $\widetilde{c}$, $h^{X\widetilde{c}}$, in a CES technology to make per-capita final goods, H_c:

$$H_c(h^{Dc},h^{X\widetilde{c}})=\left[\theta_{hc}\left(h^{Dc}\right)^{\frac{\rho-1}{\rho}}+(1-\theta_{hc})\left(h^{X\widetilde{c}}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}, \tag{9}$$

where ρ is the (Armington) elasticity of substitution between domestic and foreign inputs, and θ_{hc} is a country-specific relative weight on domestic inputs (home bias). It sells its output at price $P_c(A)$ to domestic households for consumption and domestic firms for investment.

Traded goods are denominated in the currency of the country where they are sold. Let $P_h^{Dc}(A)$ and $P_h^{X\widetilde{c}}(A)$ be the nominal prices the country c final goods retailer pays for its domestic and foreign inputs, hereafter termed *h-goods*. In real terms, the country c retailer pays $P_h^{Dc}(A)/P_c(A)$ and $P_h^{X\widetilde{c}}(A)/P_c(A)$ domestic final goods for each unit of domestic and foreign h-goods it uses.

The country-c final goods retailer solves (10) given its technology, (9). The resulting per-capita conditional factor demands in (11) combine with (9) to deliver the aggregate price level in (12).[11]

$$\max_{h^{Dc},h^{X\tilde{c}}} \ \Psi_c[P_c(A)H_c(h^{Dc},h^{X\tilde{c}}) - P_h^{Dc}(A)h^{Dc} - P^{X\tilde{c}}(A)h^{X\tilde{c}}] \tag{10}$$

$$h^{Dc} = (\theta_{hc})^{\rho}\left(P_h^{Dc}/P_c\right)^{-\rho} H_c \ \text{ and } \ h^{X\tilde{c}} = (1-\theta_{hc})^{\rho}\left(P_h^{X\tilde{c}}/P_c\right)^{-\rho} H_c \tag{11}$$

$$P_c(A) = \left[(\theta_{hc})^{\rho}\left(P_h^{Dc}(A)\right)^{1-\rho} + (1-\theta_{hc})^{\rho}\left(P_h^{X\tilde{c}}(A)\right)^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{12}$$

3.2.2 Material goods retailers

Production and trade in the material goods sector is as in the final goods sector, though the home bias parameters may differ there. The material goods retailer in country c uses per-capita domestic inputs, m^{Dc}, and exports from country $\tilde{c}$, $m^{X\tilde{c}}$, in the production function below to produce per-capita materials, M_c.

$$M_c(m^{Dc},m^{X\tilde{c}}) = \left[\theta_{mc}\left(m^{Dc}\right)^{\frac{\rho-1}{\rho}} + (1-\theta_{mc})\left(m^{X\tilde{c}}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \tag{13}$$

It sells materials at price $P_c^M(A)$ to local firms and pays $P_m^{Dc}(A)$ and $P_m^{X\tilde{c}}(A)$, respectively, for its domestic and foreign inputs (hereafter, *m-goods*). Given these prices and its technology, it solves the problem in (14).

$$\max_{m^{Dc},m^{X\tilde{c}}} \ \Psi_c[P_c^M(A)M_c(m^{Dc},m^{X\tilde{c}}) - P_m^{Dc}(A)m^{Dc} - P_m^{X\tilde{c}}(A)m^{X\tilde{c}}] \tag{14}$$

Combining the resulting per-capita conditional factor demands in (15) with (13), we obtain the nominal price of materials in (16).

$$m^{Dc} = (\theta_{mc})^{\rho}\left(P_m^{Dc}/P_c^M\right)^{-\rho} M_c \ \text{ and } \ m^{X\tilde{c}} = (1-\theta_{mc})^{\rho}\left(P_m^{X\tilde{c}}/P_c^M\right)^{-\rho} M_c \tag{15}$$

$$P_c^M(A) = \left[(\theta_{mc})^{\rho}\left(P_m^{Dc}(A)\right)^{1-\rho} + (1-\theta_{mc})^{\rho}\left(P_m^{X\tilde{c}}(A)\right)^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{16}$$

3.2.3 Trade

Recalling the real exchange rate Q, we assume the *law of one price* prevails: $\frac{P_i^{X1}Q}{P_2} = \frac{P_i^{D1}}{P_1}$ and $\frac{P_i^{X2}}{P_1 Q} = \frac{P_i^{D2}}{P_2}$ for $i = h, m$. Thus, we may express country c's real exports of h-goods as $\frac{P_h^{Dc}}{P_c}\Psi_{\tilde{c}}h^{Xc}$ in units of domestic final goods, and its real exports of m-goods as $\frac{P_m^{Dc}}{P_c}\Psi_{\tilde{c}}m^{Xc}$. Similarly, its real imports of h-goods and m-goods are $\frac{P_h^{X\tilde{c}}}{P_c}\Psi_c h^{X\tilde{c}}$ and $\frac{P_m^{X\tilde{c}}}{P_c}\Psi_c m^{X\tilde{c}}$, respectively. Equation 17 combines these trade aggregates to obtain per-capita net exports for use in each country's real GDP accounts.

$$NX_c = \frac{\Psi_{\tilde{c}}}{\Psi_c}\left(\frac{P_h^{Dc}}{P_c}h^{Xc} + \frac{P_m^{Dc}}{P_c}m^{Xc}\right) - \left(\frac{P_h^{X\tilde{c}}}{P_c}h^{X\tilde{c}} + \frac{P_m^{X\tilde{c}}}{P_c}m^{X\tilde{c}}\right) \tag{17}$$

3.3 Wholesalers

We include a representative wholesaler in each country c purely for expositional convenience. This zero-profit intermediary buys domestic firms' output at real price $\omega_c(A)$ to supply h-goods and m-goods to the two retail sectors in each country. It is indifferent between selling at home and abroad in light of the law of one price assumption above.

[11] We suppress the state arguments of the pricing functions in (11) and elsewhere below to simplify the equations.

Denoting its per-capita supply of h-goods and m-goods by W_{hc} and W_{mc}, the wholesaler's budget constraint is: $W_{hc} + W_{mc} \leq Y_c$, where Y_c is the total per-capita output it purchases from domestic firms. The first order conditions arising from its static optimization problem in (18) immediately imply a common real price, ω_c, for domestic h-goods and m-goods. Combining this observation with those from section 3.2.3, we arrive at the equilibrium price restrictions listed in equation 19.

$$\max_{W_{hc},\, W_{mc}} \left[\Psi_c W_{hc}\right]\left(\frac{P_h^{Dc}}{P_c} - \omega_c\right) + \left[\Psi_c W_{mc}\right]\left(\frac{P_m^{Dc}}{P_c} - \omega_c\right) \tag{18}$$

$$\frac{P_i^{D1}}{P_1} = \frac{P_i^{X1}Q}{P_2} = \omega_1 \text{ and } \frac{P_i^{X2}}{P_1 Q} = \frac{P_i^{D2}}{P_2} = \omega_2, \text{ for } i = h, m \tag{19}$$

Each country's terms of trade is defined as the ratio of its real price of imports relative to the real price of its exports. Using the results in equation 19, these are: $ToT_1 = \frac{\omega_2 Q}{\omega_1}$ and $ToT_2 = \frac{\omega_1}{\omega_2 Q}$.

3.4 Firms

Reviewing notation above, country c firms receive real price $\omega_c(A)$ for their output, and pay real wage $w_c(A)$ for labor and real price $\frac{P_c^M(A)}{P_c(A)}$ for materials. Each firm enters a period identified by $s \equiv (k, b, \varepsilon)$, where k and b are the capital and debt levels it selected at the end of last period, and ε is its current persistent idiosyncratic productivity. Positive values of b represent debt; negative values are financial savings. The firm repays its debt (or recoups its savings) and produces with capital, labor and materials in a decreasing returns to scale Cobb-Douglas production function:

$$y(n, m; k, \varepsilon) = z_c \varepsilon k^\alpha n^\nu m^\gamma, \tag{20}$$

where z_c is the aggregate productivity shock in its country, $\alpha \in (0,1)$, $\nu \in (0,1)$, $\gamma \in (0,1)$, and $\alpha+\nu+\gamma < 1$. Like aggregate productivity, firm-specific productivity ε follows a Markov chain; it has N_ε realizations and evolves according to transition probabilities $\varphi_{ij}^{\varepsilon} = pr(\varepsilon' = \varepsilon_j \mid \varepsilon = \varepsilon_i)$.

After production, each firm realizes the outcome of a state-invariant, exogenous exit shock, and fraction $\chi \in (0,1)$ of firms exit the economy with $k' = b' = 0$. Each exiting firm undertakes a negative investment of size $(1-\delta)k$ and returns its cash as dividends to domestic households as it departs. Continuing incumbent firms choose their future capital stocks and debt ($b' > 0$) or financial savings ($b' \leq 0$) subject to a collateral constraint and non-negative dividends. Exiting firms are replaced at the start of the next period by an equal number of new firms that each begin with capital stock k_{0c}, debt b_{0c} and a productivity drawn from the ergodic distribution of ε; thus the total investment in new firms each period is χk_{0c}.

3.4.1 Static choices, profits and cash

Given its capital and productivity, the domestic real wage, real materials cost and relative price of its output, each firm chooses its labor and materials inputs to solve the following static problem, subject to the production technology in (20).

$$\max_{n,m} \omega_c(A) y(n, m; k, \varepsilon) - w_c(A) n - \frac{P_c^M(A)}{P_c(A)} m \tag{21}$$

The firm's labor and materials decision rules, and thus its output supply, follow immediately. That in turn recovers its static profits, $\pi_c(k, \varepsilon; A) = (1-\nu-\gamma)\omega_c y_c(k, \varepsilon; A)$, the real value of sales less flow input costs.

Note that each of these is independent of its financial position.

$$n_c\left(k,\varepsilon;A\right) \;=\; \left[\gamma z_c \varepsilon \omega_c \left(\frac{\nu}{\gamma w_c}\right)^{1-\gamma}\left(\frac{P_c^M}{P_c}\right)^{-\gamma} k^{\alpha}\right]^{\frac{1}{1-\nu-\gamma}} \tag{22}$$

$$m_c\left(k,\varepsilon;A\right) \;=\; \gamma w_c \left(\nu \frac{P_c^M}{P_c}\right)^{-1} n_c\left(k,\varepsilon;A\right) \tag{23}$$

Given its static decision rules in (22) - (23), we can write the firm's profits as a multiplicative function of individual versus aggregate states in (24). This will be useful for determining its capital decision rule below.

$$\pi_c(k,\varepsilon;A) \;=\; (1-\nu-\gamma)\left[\varepsilon k^{\alpha}\right]^{\frac{1}{1-\nu-\gamma}}\,\Omega_c(A) \tag{24}$$

$$\text{where } \Omega_c(A) \;\equiv\; \left[z_c \omega_c(A)\gamma^{\gamma}\left(\frac{P_c^M(A)}{P_c(A)}\right)^{-\gamma}\left(\frac{\nu}{w_c(A)}\right)^{\nu}\right]^{\frac{1}{1-\nu-\gamma}} \tag{25}$$

We define x as the (k,b,ε) firm's real cash-on-hand, the sum of its static profit and non-depreciated capital net of outstanding debt:

$$x_c(k,b,\varepsilon;A) \equiv \pi_c(k,\varepsilon;A) + (1-\delta)k - b. \tag{26}$$

Exiting firms return their x to households as they leave the economy; continuing firms use it to finance capital investment and/or dividends, solving the intertemporal problem below.

3.4.2 Intertemporal choices

A continuing firm receives $q_c(A)$ units of domestic final goods in the current period for each unit of debt it incurs; thus, a debt with face value b' delivers a real loan of size $q_c(A)b'$. Capital accumulation is one period time-to-build; $k' = (1-\delta)k + i$, where i is investment. The firm's choices of k', b' and current dividends, D, are thus restricted by the budget constraint:

$$x_c(k,b,\varepsilon;A) + q_c(A)b' \geq D + k'. \tag{27}$$

We assume the firm cannot issue new equity to finance its investment, $D \geq 0$, and the debt it takes on is limited in proportion to its existing capital by the collateral constraint: $b' \leq \zeta_c(A)k$, where $\zeta_c \geq 0$ is the exogenous state variable reflecting the current availability of credit in country c.

Continuing firms make decisions taking as given the equilibrium evolution of the endogenous aggregate state, $S' = \Gamma(S,Z)$, and the transition probabilities π^Z_{lm} governing the evolution of the exogenous aggregate state Z. There are no real frictions impeding capital adjustments, so we can use the profit function (24) to explicitly solve for *target capitals* $k^*_c(\varepsilon;A)$ selected in absence of financial constraints. These ε-specific targets will facilitate our solution for firms' capital decisions.

We impose state-contingent discounting consistent with equilibrium in the market for shares (section 3.1) in stating firms' intertemporal problem. Let $\Lambda_c(A)$ be the value a country c firm ascribes to dividends, where $A = (S,Z)$, and assume firms discount their future value by the household discount factor β. In equilibrium, $\Lambda_c(A)$ is the domestic household marginal utility of consumption, so we are simply expressing the firm value function in units of marginal utility.

Let v^e_c represent the value of a country c firm just prior to the realization of the exit shock:

$$v^e_c(k,b,\varepsilon;A) = \chi\Lambda_c(A)x_c(k,b,\varepsilon;A) + (1-\chi)v_c(k,b,\varepsilon;A), \tag{28}$$

where v_c is the expected discounted value conditional on continuing to the next period. Because the dividends of a continuing firm are immediate as a function of its k', b' choice from the binding budget constraint (27), we can write the problem of a continuing firm of type (k, b, ε_i) as follows.

$$v_c(k, b, \varepsilon_i; S, Z_l) = \max_{k',b'} \Big[\Lambda_c(S, Z_l)[x_c(k, b, \varepsilon; S, Z_l) + q_c(S, Z_l)b' - k'] + \beta \sum_{m=1}^{N_Z} \sum_{j=1}^{N_\varepsilon} \pi_{lm}^Z \varphi_{ij}^\varepsilon v_c^e(k', b', \varepsilon_j; S', Z_m) \Big] \tag{29}$$

$$\text{subject to:} \quad b' \leq \zeta_c(A)k \quad \text{and} \quad x_c(k, b, \varepsilon; A) + q_c(A)b' - k' \geq 0 \tag{30}$$

The second constraint in (30) prevents the firm from using negative dividends to evade the first.

The problem (29) - (30) is simplified further by the following observations. In equilibrium, no continuing firm can strictly raise its value by paying positive dividends, since it borrows and lends at the same price its owners face, and $\Lambda_c(A) = \lambda_c(A)$. If a firm has amassed sufficient cash to prevent its investment ever again being hindered by inadequate funds, its shadow value of retained earnings matches the household valuation of dividends. Any such *impervious* firm invests efficiently and is indifferent about paying dividends. Conversely, for a firm lacking adequate cash to preclude the possibility that the collateral constraint (30) may bind in some future state, the per-unit valuation of retained earnings exceeds the domestic household's dividend valuation. Any such financially *exposed* firm sets $D = 0$ to maximize its value, and its investment may be affected by its cash. With this classification, it is straightforward to recover the firm decision rules below.

Capital decision rules: As no *real* frictions impede capital adjustment, an impervious firm maximizes its value by adopting the efficient (target) capital $k_c^*(\varepsilon_i; S, Z_l)$ satisfying:

$$\Lambda_c(S, Z_l) = \beta \sum_{m=1}^{N_Z} \pi_{lm}^Z \Lambda_c(S', Z_m) \left[1 + \delta + \sum_{j=1}^{N_\varepsilon} \varphi_{ij}^\varepsilon \partial \pi_c(k', \varepsilon_j; S', Z_m)/\partial k' \right].$$

Efficient capital choices for $i = 1, \ldots, N_\varepsilon$ are listed in (31), given $\Omega_c(A)$ in (25) and $S' = \Gamma(A)$, and the impervious firm capital rule is $k_c^*(\varepsilon_i; A)$.

$$k_c^*(\varepsilon_i; S, Z_l) = \left[\frac{\alpha}{1 - (1-\delta)q_c(S, Z_l)} \sum_{m=1}^{N_Z} \pi_{lm}^Z \frac{\beta \Lambda_c(S', Z_m)}{\Lambda_c(S, Z_l)} \Omega_c(S', Z_m) \sum_{j=1}^{N_\varepsilon} \varphi_{ij}^\varepsilon \varepsilon_j^{\frac{1}{1-\nu-\gamma}} \right]^{\frac{1-\nu-\gamma}{1-\alpha-\nu-\gamma}} \tag{31}$$

An exposed firm also maximizes its value by adopting $k_c^*(\varepsilon_i; A)$ *if* its cash permits. The collateral constraint (30) limits its b' and so bounds its affordable capital at $x_c(k, b, \varepsilon; A) + q_c(A)\zeta_c(A)k$. Given the strictly concave profit function, it adopts $k_c^*(\varepsilon; A)$ or the nearest k' not violating this bound. Thus, its capital rule is $g_c(k, b, \varepsilon; A) = \min\{k_c^*(\varepsilon; A), x_c(k, b, \varepsilon; A) + q_c(A)\zeta_c(A)k\}$. Note that g_c also captures an impervious firm's capital rule; its accumulated cash simply ensures a slack bound.

Debt decision rules: An *exposed* firm always sets $D = 0$, so its capital choice implies its debt through the binding budget constraint (27). Thus, it adopts $b' = [g_c(k, b, \varepsilon; A) - x_c(k, b, \varepsilon; A)]/q_c(A)$. By contrast, an impervious firm is financially indifferent, and we can choose how to resolve that indeterminacy so long as we ensure it remains so. One natural approach is to follow Khan and Thomas (2013) in assigning any such firm a *minimum savings* debt policy $B_c(\varepsilon_i; S, Z_l)$ ensuring it will have sufficient funds to invest efficiently without borrowing more than (30) allows in all possible future dates and states, and then retrieve its dividends from the budget constraint. In dynamic stochastic general equilibrium, $B_c(\varepsilon_i; S, Z_l)$ solves (32) - (33), where

$\widetilde{B}_c\left(k_c^*(\varepsilon_i;S,Z_l),\varepsilon_j;S',Z_m\right)$ is the greatest debt a firm can hold, alongside capital $k_c^*(\varepsilon_i;S,Z_l)$, and still be impervious if next period's exogenous state is (ε_j,Z_m). The minimum $\widetilde{B}_c(\cdot)$ over all possible (ε_j,Z_m) is the greatest debt with which the firm can exit *this* period and know it will be impervious next period, $B_c(\varepsilon_i;A)$.

$$B_c(\varepsilon_i;S,Z_l)=\min_{\{\varepsilon_j|\varphi_{ij}^{\varepsilon}>0 \text{ and } Z_m|\pi_{lm}^Z>0\}}\widetilde{B}_c\Big(k_c^*(\varepsilon_i;S,Z_l),\varepsilon_j;\Gamma(S,Z_l),Z_m\Big) \tag{32}$$

$$\widetilde{B}_c(k,\varepsilon;A)=\pi_c\left(k,\varepsilon;A\right)+(1-\delta)k-k_c^*(\varepsilon;A)+q_c(A)\min\{B_c(\varepsilon;A),\zeta_c(A)k\} \tag{33}$$

Equation 33 identifies the maximum debt a firm can repay while adopting its target capital and a debt not exceeding that dictated by the minimum savings policy; this is the b implying $D=0$ when impervious firm rules are adopted. The minimum operator imposes the collateral constraint while identifying a firm borrowing $\zeta_c(A)k<B_c^I(\varepsilon;A)$ as impervious if it has adequate cash to finance its investment. Any firm that can adopt $k'=k_c^*(\varepsilon;A)$ and $b'=\min\{B_c(\varepsilon;A),\zeta_c(A)k\}$ while paying non-negative dividends, $x_c(k,b,\varepsilon;A)-k_c^*(\varepsilon;A)+q_c(A)\min\{B_c(\varepsilon;A),\zeta_c(A)k\}\geq 0$, is impervious and remains so forever by adopting these policies.

Given the large aggregate state vector and number of relative price functions in our model, we study transitional dynamics following aggregate shocks rather than its stochastic solution. This imposes ignorance of aggregate shocks in steady state, artificially restricting the information set for the minimum savings policy. We can ensure this alters no real results by recovering the minimum savings policy $B_c(\varepsilon_i;S_t,Z_t|Z_{t+1})$ date-by-date over the transition presuming knowledge of future exogenous aggregate states, then verifying that all firms identified as impervious in the steady state adopt their target capitals in every date of the impulse. Alternatively, we can assign impervious firms a zero-dividend policy $D_c^Z(k,b,\varepsilon;A)=0$ so they can never regret their debt decisions. We adopt the second approach, taking care to allow a sufficiently negative lower bound for the distribution of debt so that the fraction of firms there never exceeds 0.1 percent and those there can always adopt their target capitals. One advantage of this is that we need not track which firms are impervious, since every firm's capital rule can be written as $g_c(k,b,\varepsilon;A)=\min\{k_c^*(\varepsilon;A),x_c(k,b,\varepsilon;A)+q_c(A)\zeta_c(A)k\}$, and every firm's debt rule is $f_c(k,b,\varepsilon;A)=[g_c(k,b,\varepsilon;A)-x_c(k,b,\varepsilon;A)]/q_c(A)$.

3.5 Recursive equilibrium

A *recursive competitive equilibrium* is a set of functions:

$$\varrho,Q,\{w_c,q_c,\rho_c,\widetilde{\rho}_c,P_c\}_{c=1,2},\ \{P_h^{Dc},P_h^{X\widetilde{c}},P_m^{Dc},P_m^{X\widetilde{c}},\omega_c\}_{c=1,2},\ \{V_c^h,C_c,N_c,\xi_c',\phi_c',B_c'\}_{c=1,2},$$
$$\{H_c,h^{Dc},h^{X\widetilde{c}},M_c,m^{Dc},m^{X\widetilde{c}}\}_{c=1,2},\ \{W_{hc},W_{mc},Y_c,\}_{c=1,2},\text{ and }\{n_c,m_c,y_c,g_c,f_c\}_{c=1,2}$$

that solve household, retailer and firm problems and clear the markets for assets, materials, final goods, labor, and firms' output in each country, as outlined by the following conditions.

(i) V_1^h solves (1) and V_2^h solves (6), with associated policy functions $(C_c,N_c,\xi_c',\phi_c',B_c')$ for $c=1,2$

(ii) final goods retailers solve (10), with policy functions $(H_c,h^{Dc},h^{X\widetilde{c}})$ for $c=1,2$

(iii) material goods retailers solve (14), with policy functions $(M_c,m^{Dc},m^{X\widetilde{c}})$ for $c=1,2$

(iv) wholesalers solve (18), with policy functions (W_{hc},W_{mc},Y_c) for $c=1,2$

(v) firms (k,b,ε) solve (21) with policy functions (n_c,m_c,y_c) for $c=1,2$

(vi) continuing firms solve (28) - (30) with associated policy functions (g_c,f_c), for $c=1,2$

(vii) $\xi_c'(k',b',\varepsilon_j,\xi_c,\phi_c,B_c;A)=\mu_c'(k',b',\varepsilon_j;A)$, for each $(k',b',\varepsilon_j)\in\mathcal{S}$ in country $c=1,2$

(viii) $\phi_c'(\xi_c, \phi_c, B_c; A) = \int f_c\left(k, b, \varepsilon; A\right) \mu_c(d\left[k \times b \times \varepsilon\right])$, for $c = 1, 2$

(ix) $\Psi_1 B_1'(A', \xi_1, \phi_1, B_1; A) + \Psi_2 B_2'(A', \xi_2, \phi_2, B_2; A) = 0$ for all $(A'; A)$

(x) $\Psi_c C_c(\xi_c, \phi_c, B_c; A) = \Psi_c H_c(A) - \Psi_c I_c(A)$, where:

$$\Psi_c I_c(A) \equiv \int [(1-\chi) g_c(k, b, \varepsilon; A) + \chi k_{0c} - (1-\delta) k] \mu_c(d\left[k \times b \times \varepsilon\right]), \text{ for } c = 1, 2$$

(xi) $\Psi_c N_c(\xi_c, \phi_c, B_c; A) = \int n_c(k, \varepsilon; A) \mu_c(d\left[k \times b \times \varepsilon\right])$, for $c = 1, 2$

(xii) $\Psi_c M_c(A) = \int m_c(k, \varepsilon; A) \mu_c(d\left[k \times b \times \varepsilon\right])$, for $c = 1, 2$

(xiii) $\Psi_c W_{hc}(A) = \Psi_c h^{Dc}(A) + \Psi_{\widetilde{c}} h^{X\widetilde{c}}(A)$, for $c = 1, 2$

(xiv) $\Psi_c W_{mc}(A) = \Psi_c m^{Dc}(A) + \Psi_{\widetilde{c}} m^{X\widetilde{c}}(A)$, for $c = 1, 2$

(xv) $\Psi_c\left[W_{hc}(A) + W_{mc}(A)\right] = \Psi_c Y_c(A)$, where:

$$\Psi_c Y_c(A) = \int y_c(k, b, \varepsilon; A) \mu_c(d\left[k \times b \times \varepsilon\right]), \text{ for } c = 1, 2$$

(xvi) $\mu_c'\left(\Upsilon, \varepsilon_j\right) = (1-\chi) \int\limits_{\{(k,b,\varepsilon_i)\ |\ (g_c(k,b,\varepsilon_i;A), b_c'(k,b,\varepsilon_i;A)) \in \Upsilon\}} \varphi_{ij}^{\varepsilon} \mu_c(d\left[k \times b \times \varepsilon_i\right]) + \chi \mathcal{J}(k_0) M(\varepsilon_j)$,

$$\forall\left(\Upsilon, \varepsilon_j\right) \in \mathcal{S}, \text{defines } \Gamma, \text{ where } \mathcal{J}(k_0) = \{1 \text{ if } (k_0, 0) \in \Upsilon \text{ and } 0 \text{ otherwise}\}, \text{ for } c = 1, 2$$

GDP: We end this section with each country's real per-capita GDP in units of its own final goods, starting from the expenditure side: $GDP_c = C_c + I_c + NX_c$. Using items (x) and (xv) above with equation 17 from section 3.2.3, price restrictions from section 3.3 and conditional factor demands from section 3.2, we can write this as a price-weighted function of total production less material inputs: $GDP_c = \omega_c Y_c - \frac{P_c^M}{P_c} M_c$. This collapses to $GDP_c = (1-\gamma)\omega_c Y_c$ after aggregating firms' static first order conditions in section 3.4.1.

4 Calibration

The length of a period in our model is one quarter. We normalize country 1's population to 1 and calibrate its parameters using annualized moments drawn from postwar U.S. data. The only parameters differing in country 2 are those associated with its size and trade shares. We select these to reflect Canada's relative size and trading shares with the United States, as described below.[12]

We assume household period utility is $u(C, N) = \frac{1}{1-\phi}\left(\left[C - \frac{\kappa}{\eta} N^{\eta}\right]^{1-\phi} - 1\right)$, adopting the preferences of Greenwood, Hercowitz and Huffman (1988). This specification is widely used in international business cycle models because it removes consumption from the intra-temporal marginal rate of substitution, thus eliminating wealth effects on labor supply.[13] We set the household discount factor β to obtain a long-run annual real interest rate of 4 percent consistent with measurement in Gomme, Ravikumar and Rupert (2011). We fix $\eta = 1.25$ to imply a labor supply elasticity of 4, and set the coefficient of relative risk aversion at $\phi = 2$ as in Backus, Kehoe and Kydland (1994), Kehoe and Perri (2002) and Alessandria and Choi (2007).

[12] Our choice to pattern country 2 on Canada is prompted by its strong and relatively unhindered trade relationship with the U.S., as noted in section 1; we discuss other advantages of the choice in the next section.

[13] See Devereux, Gregory and Smith (1992), Schmitt-Grohé and Uribe (2003), and Alessandria, Kaboski and Midrigan (2013). Raffo (2008) shows it helps deliver the observed countercyclical net flow of goods across countries in a standard IRBC model.

The capital depreciation rate δ is set to yield an average annual aggregate investment-to-capital ratio at 7.1 percent, consistent with that for the private capital stock between 1954 and 2002 in the U.S. Fixed Asset Tables, controlling for growth. We choose χ so that 9 percent of firms exit each year, guided by the 8.76 percent average among firms in the Bureau of Labor Statistics' Business Dynamics Statistics database (BDS) over 1980 - 2006. The materials share parameter γ is set at 0.43 to match the average materials share of manufacturing in the U.S. input-output tables from the World Input-Output Database over 2000-2014.[14]

The remaining model parameters in table 1 are jointly calibrated, though we link them with the targets they most influence in this discussion. We set the capital share parameter α to reproduce the 2.34 average annual private capital-to-GDP ratio in the U.S. over 1954-2017, and the labor share parameter ν to imply a 60 percent labor share of GDP, as in Khan and Thomas (2013) and Perri and Quadrini (2018).[15] Next, we set the labor disutility parameter κ and country 1's steady-state exogenous productivity z_1^* so that its steady state GDP is 1, with households each working one-third of available time.

TABLE 1. PARAMETER VALUES

(a) Population and preferences, retail sectors, mean exogenous aggregate TFP and credit states												
Ψ_2	β	ϕ	η	κ	ρ	θ_{h1}	θ_{m1}	θ_{h2}	θ_{m2}	z_1^*	z_2^*	ζ^*
0.070	0.99	2	1.25	2.367	0.9	0.995	0.989	0.907	0.896	2.119	2.856	0.505
(b) Production, death and birth, depreciation and idiosyncratic TFP shocks												
	α	ν	γ		χ	k_{01}	b_{01}	k_{02}	b_{02}	δ	ρ_ε	σ_ε
	0.164	0.342	0.43		0.023	1.451	0.580	1.447	0.579	0.018	0.901	0.029

NOTE.– Quarterly frequency; all parameter values rounded to nearest 0.001.

Country 2's relative population size Ψ_2 and steady-state exogenous TFP z_2^* are taken to ensure its GDP averages 8.8 percent that in country 1, the average Canada-to-U.S. ratio over 1994-2007, while its per-capita labor hours match those in country 1. Turning to trade-related parameters, we set the elasticity of substitution between domestic and imported goods ρ at 0.9, as estimated by Heathcote and Perri (2002).[16] Next, we choose the four parameters reflecting home bias in each country's materials and final goods sectors, $\{\theta_{mc}, \theta_{hc}\}_{c=1,2}$, so that our model's steady state reproduces average U.S. imports from Canada relative to GDP (0.021) and Canadian imports from the U.S. relative to GDP (0.207) over 1994-2007 from the International Monetary Fund's Direction of Trade Statistics, alongside average U.S. materials inputs imported from Canada relative to total U.S. materials inputs use (0.017) and Canadian materials inputs imported from the U.S. relative to total Canadian materials inputs use (0.127) over 2000-2007.[17]

We turn now to idiosyncratic productivity, ordinary credit conditions, and new firms' initial states. Productivities are drawn from a log-normal distribution with persistence ρ_ε and standard deviation σ_ε, discretized using $N_\varepsilon = 7$ values. We set ρ_ε to imply a 0.659 annual persistence as in Khan and Thomas (2013), while σ_ε ensures that a comparable sample of mature firms in our model's steady state reproduces the 0.337 average cross-sectional standard deviation of annual investment rates reported by Cooper and Haltiwanger (2006) using panel data from the Longitudinal Research Database. Finally, we calibrate a common steady-state value for the collateral constraint anchor, ζ^*, and new firms' initial stocks $\{k_{0c}, b_{0c}\}_{c=1,2}$

[14] Our average reflects all sectors other than agriculture and commodities and is similar to that for Canada, 0.48.

[15] A prior version of the model had a constant returns wholesale sector with labor's share set to reproduce the U.S. wholesale trade value added share of GDP, 5.97 percent. Given its size and frictionless design, the sector was quantitatively irrelevant.

[16] Corsetti et al. (2008) estimate a 0.85 elasticity of substitution between home and foreign tradeables using a symmetric two-country model calibrated to the U.S. and a trade-weighted aggregate of Canada, Japan and EU-15.

[17] The North American Free Trade Agreement took effect in 1994; hence our choice in computing average import shares. Our source for materials input shares, The World Input-Output Tables database, is available from 2000.

so the debt-to-asset ratio of new firms in each country is 40 percent (Kauffman Firm Survey) and new and 1-year-old firms' average employment sizes relative to incumbent firms' match those in the BDS over 1990-2006, 27 and 37.1 percent, respectively. While not targeted in the calibration, our model's average employment share of young firms (aged 0 - 5 years) is 19.4 percent, versus 17.1 percent in the data.

5 Results

We use our model to explore how a financial recession in a large, developed country like the United States affects its trading partners through international trade. We have selected Canada as our second country despite its small size, motivated by its proximity to the U.S. in both geographic and development terms, the fact that it is a leading trading partner for the U.S. and the fact that the U.S. is by far its most important trading partner. An advantage of this choice is that the great disparity in size implies minimal feedback effects from the small economy to the large one, allowing us an unobstructed look at the direct transmission of a U.S. credit shock to its neighbor.

The computational burden of solving stochastic simulations is great, given the two 3-dimensional distributions in our model's aggregate state vector and the large number of equilibrium pricing and forecasting functions involved. Thus, we study perfect-foresight transitions following unforeseeable aggregate shocks. While the approach is not without loss of generality, we have minimized its consequences for the misallocative effects of a credit tightening by imposing a zero-dividend rule for financially indifferent firms, ensuring no firm regrets financial decisions made in steady state.

We first examine responses when country 1 (U.S.) experiences a credit shock absent any shock in country 2 (Canada). Investigating the channel through which country 1's recession is transmitted abroad, we isolate the importance of trade balance adjustments in propagating the shock through investment reallocation across the two economies. Next, we highlight the aspects unique to this reallocative disturbance by contrasting our results to those following a country-1 productivity shock. Finally, we study a global credit crisis featuring calibrated shocks in both countries, there using a set of comparisons to disentangle how country 2's financial recession is reshaped, through trade, by the financial recession of its large trading partner.

5.1 Transmission of a financial shock

We explore the repercussions of a country-1 credit shock by forcing the collateral constraint parameter ζ_1 below its steady state value, setting the shock's size and persistence so that the dynamic path of country-1 firms' aggregate debt resembles that of U.S. real commercial and industrial loans beginning in 2007. We fix ζ_1 at 69.29 percent of its steady-state value for 8 quarters, and then gradually return it to normal via an AR(1) process with persistence 0.935; this drives a 25.9 percent peak-to-trough decline in country-1 debt over 9 quarters and ensures the series is still 20.9 percent below its starting point one year later (in quarter 13), as observed in the United States.

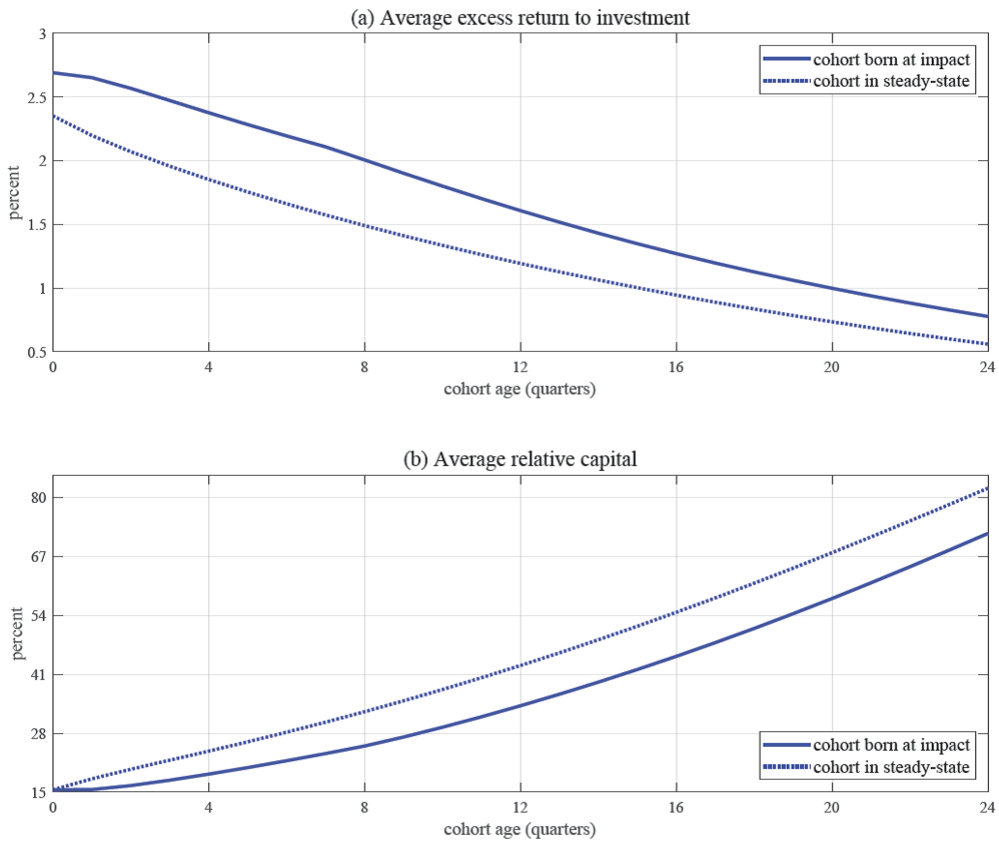
All firms are subject to collateral constraints, but a domestic credit tightening sharply curtails some firms' investments while indirectly raising some others'. This uneven incidence distinguishes aggregate credit shocks from real ones, tilting the allocation of production further from the efficient one implied by firms' productivities.[18] The hardest hit firms are those most reliant on external funds, which tend to be the economy's youngest firms since entrants arrive with little capital and collateral constraints are backward-looking. Thus, disruptions to firms' life-cycle growth feature heavily in the paths of aggregate TFP and the

[18] Persistent idiosyncratic productivity shocks allow greater micro-level realism in our model, but are not essential to the misallocation channel described here. Figures establishing this are available on request.

return to domestic aggregate capital accumulation.

Figure 3 demonstrates this point directly by tracing how the shock alters life for a country-1 cohort arriving at its impact. Panel (a) plots the average excess return to investment (the gap between the expected discounted marginal value of adopted capital versus its unit purchase price) at each age, showing that firms born during a credit crisis have larger investment wedges than firms born in normal times. Though greatest in its earliest ages, this cohort's elevated inefficiency persists beyond its 8th year.

FIGURE 3. LIFE-CYCLE IMPLICATIONS OF A CREDIT SHOCK



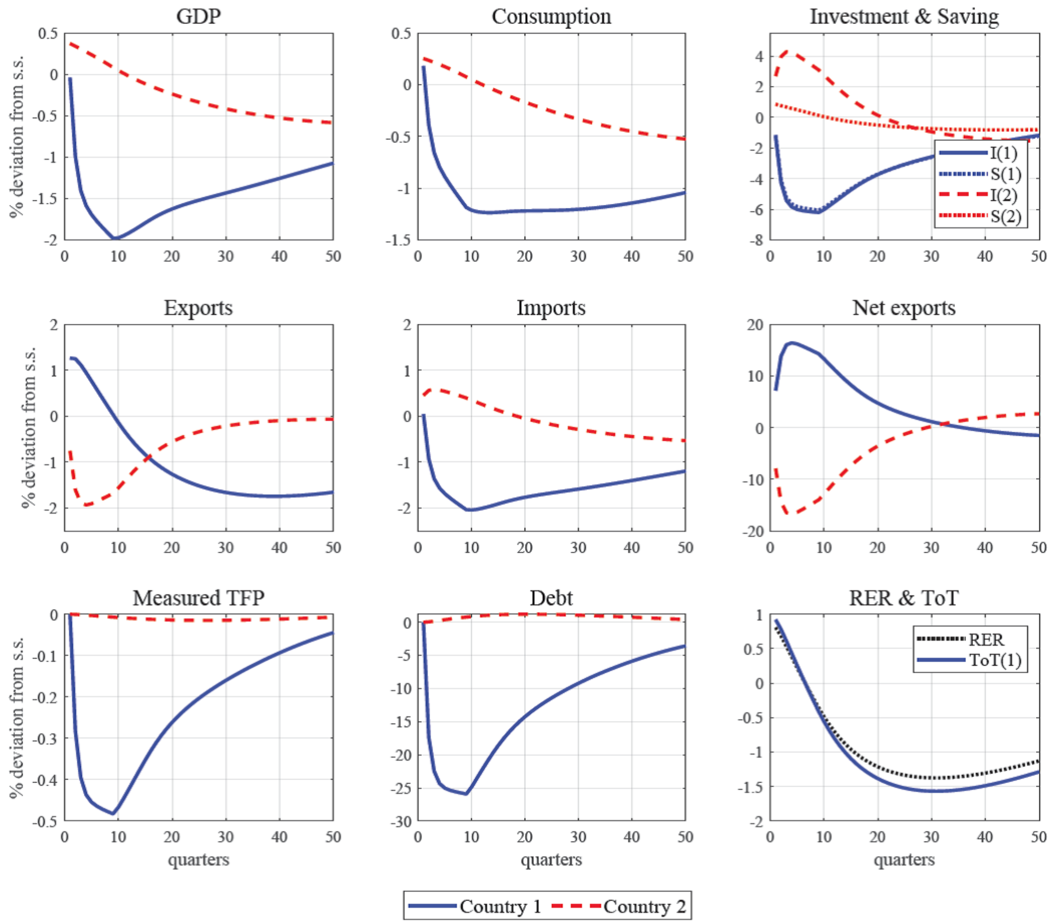
Panel (b) shows the cohort's average relative capital (per-member versus countrywide average capital) is persistently lower than had it arrived in steady state, confirming that firms born during the crisis are more affected than those predating it. Together, the two panels establish that (a) young firms suffer a disproportionate share of investment declines during a domestic financial recession, (b) their life-cycle growth phase is rendered unusually inefficient and thus protracted by it, and so (c) misallocation worsens with the birth of each new cohort, as more cohorts are affected and the fraction of firms investing inefficiently grows. Following such persistent disruptions to the growth phases of cumulated cohorts, country 1's distribution of capital is slow to recover its usual shape, as is evident from the path of measured TFP in our next figure.

Figure 4 presents both countries' aggregate responses to the country-1 credit shock. Recall that each country's GDP is a price-weighted function of its firms' total production; $GDP_c = (1 - \gamma)\omega_c Y_c$, for $c = 1, 2$. Given growing distortions in its capital allocation implied by our discussion above, country 1's aggregate TFP erosion discourages investment and hours worked, compounding the effects on GDP.[19] These three series

[19] Our declines in country-1 GDP and investment are smaller than in Khan and Thomas' (2013) closed-economy study for three reasons. First, our calibration implies entrants' capital stocks are 16 percent that of the average firm; Khan and Thomas'

reach their troughs after 8 quarters as credit conditions begin improving; consumption falls and recovers with a slight lag, after initially rising in anticipation of lowered returns to saving.[20]

FIGURE 4. GLOBAL RESPONSES TO COUNTRY-1 CREDIT SHOCK



NOTE.– Responses to an 8-quarter, 30.7 percent credit tightening in country 1 with AR(1) recovery.

In a closed-economy model, any decline in country-1 investment would be met by an equal fall in its aggregate saving, $S = GDP - C$. In our setting, however, country-1 households effectively relocate some savings abroad in response to the negative wealth effect implied by their worsening recession. The lesser reduction in their saving relative to firms' total investment, or *residual savings*, is mirrored in a persistent improvement of the country-1 trade balance, with the reduced demand for imports initially reinforcing a rise in exports and thereafter offsetting its decline. This trade balance adjustment is only a small fraction of GDP for country 1, as it is almost a closed economy in our calibration. However, it has a non-trivial impact on country 2, where international trade accounts for a larger share of the aggregate economy.

While no direct shock hits country 2, country 1's credit recession induces an immediate rise in its GDP followed by a far longer contraction. A small consumption rise accounts for some part, but the early phase of this response is mostly driven by rises in investment. With tight credit worsening the allocation of capital in country 1, and thus its aggregate return, some investment relocates to country 2. This is facilitated

entrants had 10 percent the average stock and so relied more on debt and for longer. Second, our exit rate is 1 percentage point lower, implying fewer firms in the maturing phase most affected by tight credit. Third, our credit shock is smaller and shorter, with a 16 (versus 88) percentage point reduction in ζ_1 in place for 2 (versus 4) years before mean reversion begins.

[20] Total hours worked responses closely resemble the paths of GDP in each country; we omit them for sake of space.

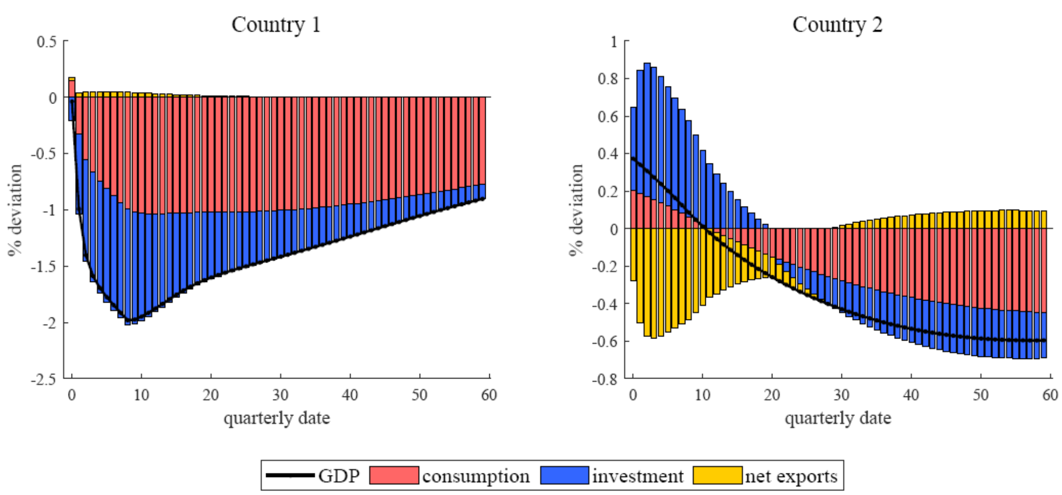
by country-2 households' borrowing from international financial markets, as reflected in country 2's trade balance deterioration and negative residual savings.

Understanding their real cost of imports will rise as country 1's misallocation problem grows, country 2's retailers prepare to start raising the domestic share of their productive input mix in coming dates. Large rises in investment put additional capital in place to help offset the persistently high domestic marginal costs this shift will imply. Those in turn are achieved by a temporary cheap-imports windfall alongside increased hours worked. With no rise in exogenous TFP to help fuel the expansion, there is no direct substitution effect reinforcing savings incentives. Instead, capital grows least among young, cash-poor firms that on average need it most, so TFP falls as the aggregate stock grows, thereby encouraging early-date rises in consumption.

Over time, as the country-1 credit state gradually recovers, country 2's investment boom fades and its initial capital accumulation is reversed thereafter. While slow for reasons explained above, country 1's steady recovery in aggregate productivity starting in quarter 10 gradually shifts global production back in its direction. The demand for country 2's exports is persistently depressed in this episode, and ultimately so is its domestic demand for investment. There follows a long contraction in country 2 as 'excess' capital gradually relocates and the disruption to its own productive distribution is slowly repaired. GDP reaches its trough in quarter 58, and the subsequent recovery is gradual.

If figure 4 suggested that investment is central to domestic *and* international transmission of country 1's financial shock, figure 5 reinforces the message. Here, we decompose the two GDP responses to consider the contributions of their expenditure-side components. Over the 8-quarter downturn in country 1, declines in investment account for on average 59 percent of its GDP losses, while net exports has almost no role given country 1's small trade shares. During the many subsequent quarters of the recovery phase, investment comes back fairly steadily while consumption increasingly offsets that recovery, holding GDP down.

FIGURE 5. COUNTRY-1 CREDIT SHOCK: GDP RESPONSE DECOMPOSITIONS

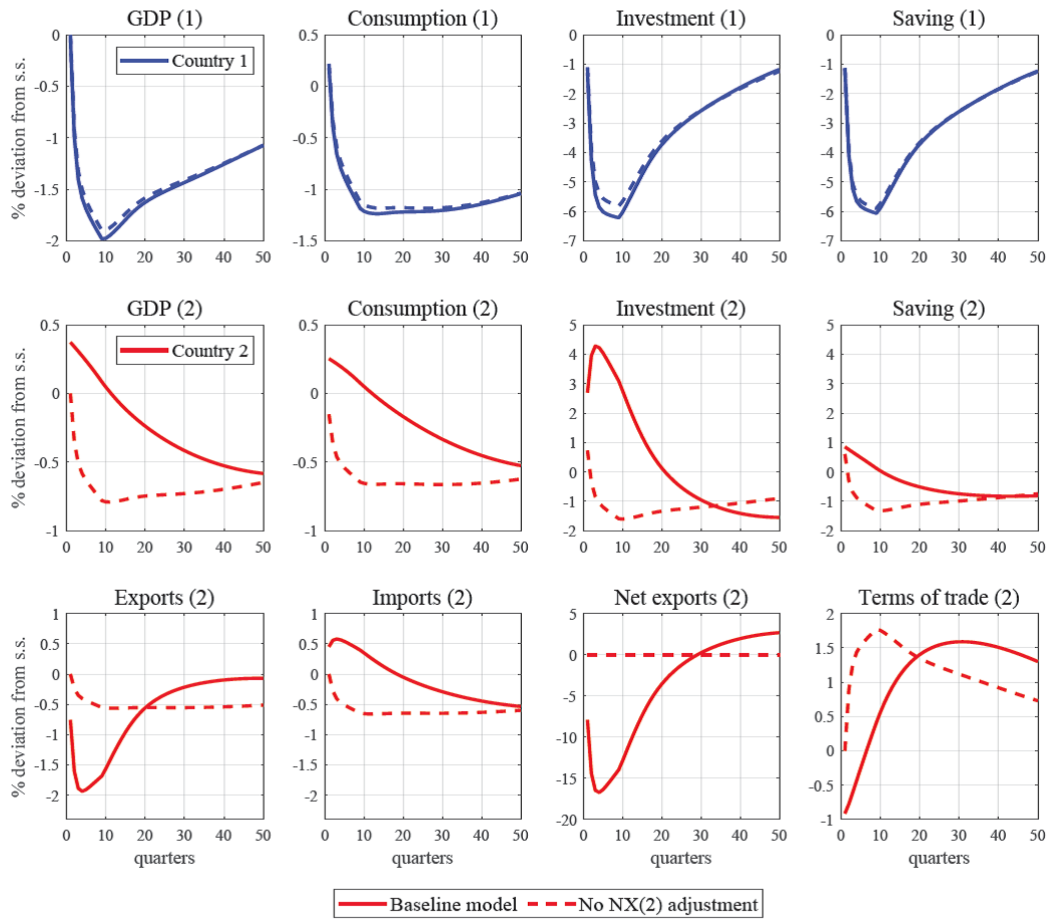


Looking rightward, we see investment also has an outsized role in transmitting the shock's effects to country 2. There, the initial rise in consumption and far greater rises in investment together more than offset the fall in net exports that accompanies the reduced demand for its exports we discussed above. When country 1 starts its recovery, country 2's long contraction begins. There onward, til its GDP trough 49 quarters later, investment has an increasingly prominent role in depressing economic activity and ultimately contributes more than 40 percent to the contraction.[21]

[21] The appendix demonstrates that all aspects emphasized in our discussion of figures 4 - 5 are stronger in a model specification

Figure 6 confirms the key role changes in the trade balance have in the transmission mechanics discussed above by studying what happens in their near-absence, fixing country 2's net exports at its marginally positive steady-state level via changes in the real exchange rate. In essence, this exercise prevents additional international borrowing and lending in response to the country-1 financial shock.[22] The modification alters little for country 1 (row 1) beyond the underlying trade-related variables, as net exports are such a small fraction of its GDP, though investment naturally falls slightly less than in the baseline (solid line) response.

FIGURE 6. COUNTRY-1 CREDIT SHOCK: ROLE OF NET EXPORT CHANGES



By contrast, country 2's responses (rows 2 and 3) are substantially altered when the sizeable per-capita net inflow of country-1 goods is suppressed. In this case, the decline in country-2 exports must be met by an equal fall in its imports, unlike the (solid line) rise of the baseline response, and its terms of trade immediately begin depreciating. Raised investment in preparation for the coming long episode of high import prices is sharply curtailed, at just 0.73 percent above normal, and it lasts only one quarter. With the investment boom eliminated by prohibiting its households raising additional funds from international capital markets, country 2's contraction begins immediately and is deeper than in the baseline model. Though the recovery starts 47 quarters sooner, shortly after that in country 1, its half-life is 89 quarters (versus the baseline 75).

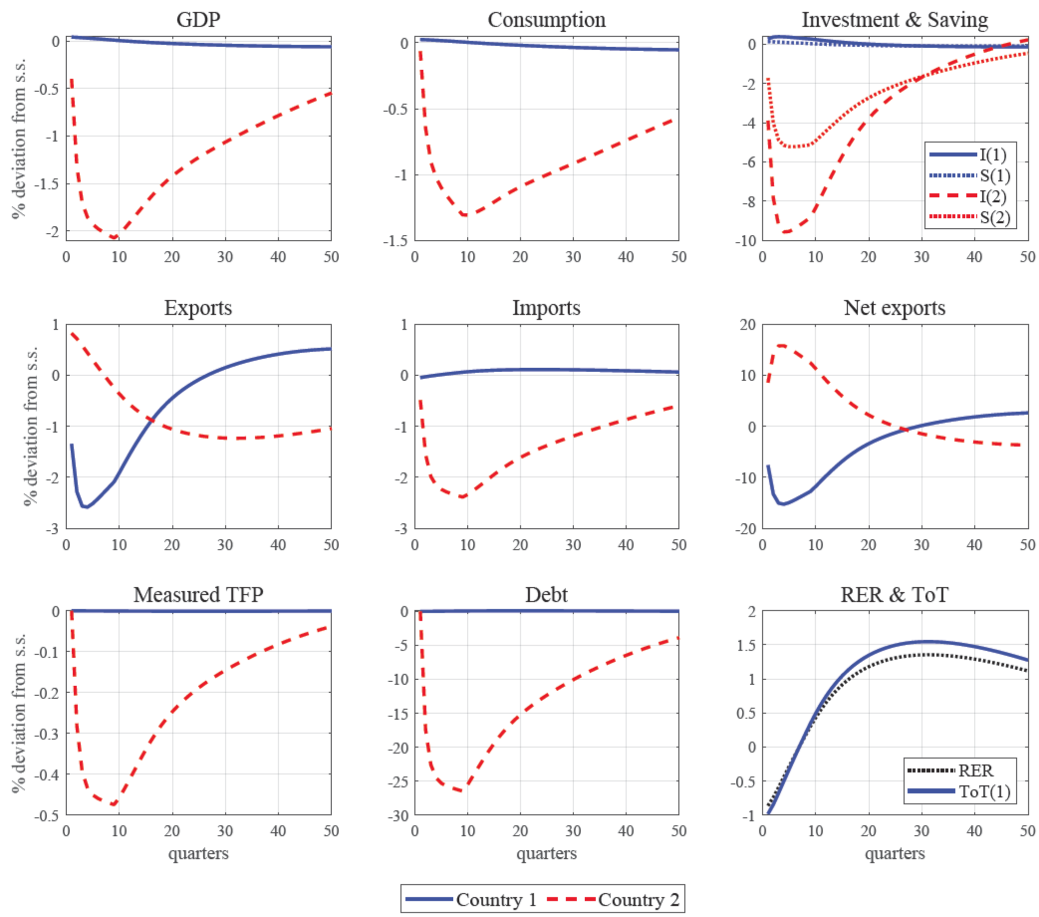
Throughout the discussion above, we have focused on the transmission of a financial shock from a large economy to a small open economy. We close this subsection by emphasizing that the mechanics of that

where traded goods are not complements, but substitutes (section A.1) and robust to the removal of both cross-country population differences (section A.2) and input-output linkages in production (section A.3).

[22] We thank an anonymous referee for suggesting this exercise linking the current and capital account adjustments.

transmission do not apply in reverse when the smaller economy instead directly experiences the shock. Figure 7 presents our model's responses to a country-2 credit shock of exactly the same size and persistence as country 1 experienced in figure 4. It shows the asymmetries between these economies matter enormously for the cross-country transmission of an aggregate shock.[23]

FIGURE 7. GLOBAL RESPONSES TO COUNTRY-2 CREDIT SHOCK



Country 2's financial recession looks much like country 1's in figure 4, with the same domestic transmission playing out. Despite similar (reversed) net export dynamics, the implications of these changes for country 1 bear little resemblance to country 2's responses in our earlier figure. Recall that country 2's GDP is 8.8 percent that of country 1 and imports from country 2 amount to only 2.1 percent of country 1's GDP, given our U.S. - Canada calibration. Here, the rise in country-2 exports largely reflects real exchange rate movement and shows up imperceptibly in country 1's imports. Given its limited exposure to trade, country 1's GDP, consumption and investment are almost entirely unaffected by the country-2 credit shock.

5.2 Transmission of a real shock

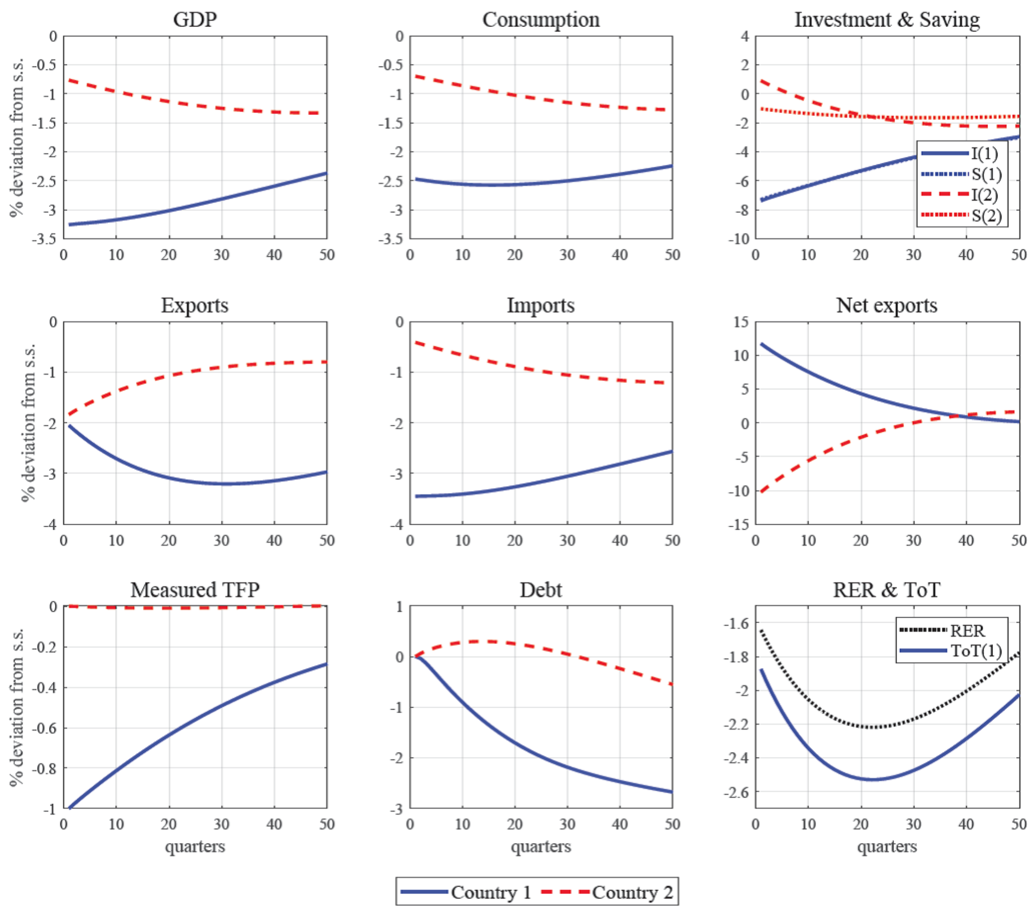
Our analysis of the transmission of financial shocks isolated investment's central role in propagating a shock both domestically and abroad. This offers new insights to the international real business cycle

[23] This is also evident in our model's responses to TFP shocks; figures available on request. Appendix section A2 shows that the key factor influencing transmission is the overall share of the external sector in the recipient economy.

literature, wherein the majority of analysis has been confined to real shocks such as aggregate productivity shocks. For sake of comparison, we next examine the transmission of a negative TFP shock in our model, considering how its channels relate to those emphasized above.

Figure 8 presents global responses to a 1-percent productivity shock in country 1 followed by AR(1) recovery with persistence 0.977. Unlike the domestic results of the financial shock in figures 3 and 4, where tight credit amplified misallocation by disproportionately depressing young, growing firms' investments, the TFP shock scales country-1 firms' investments down evenly in proportion to their usual productive shares. This mirrors Khan and Thomas' (2013) closed-economy finding; with no change in the allocation of production, the aggregate productivity response coincides with the shock, so other domestic responses resemble those in a frictionless representative firm model.

FIGURE 8. GLOBAL RESPONSES TO COUNTRY-1 PRODUCTIVITY SHOCK



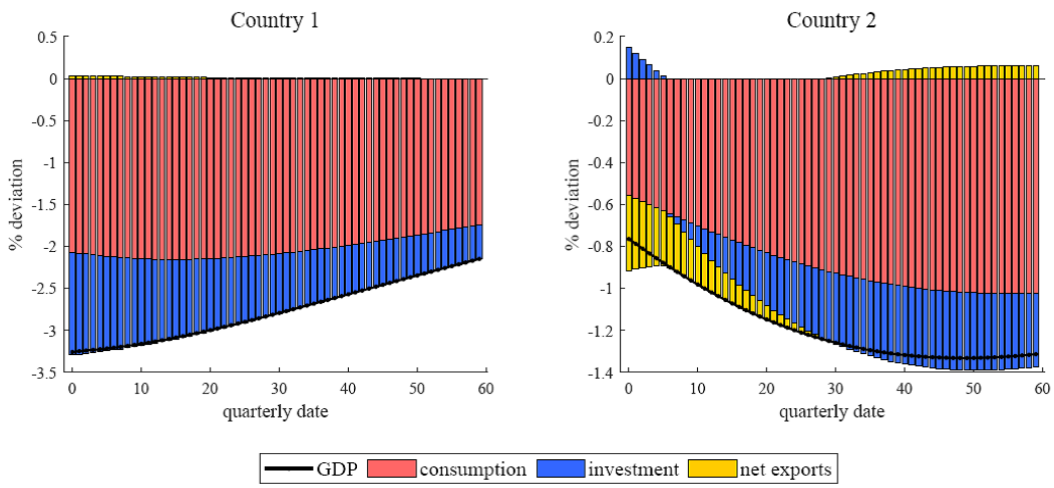
Unlike the case of a country-1 financial shock, there are no cheap-imports windfalls to fuel an initial investment-led expansion in country 2 in response to this shock. Country 1's abrupt fall in productivity leads it to lower (not raise) its exports and immediately (not gradually) lower its imports. Meanwhile, its sharp drop in production worsens the terms of trade for country 2; by contrast, country 2's terms of trade initially appreciated in figure 4 to accommodate a sizeable inflow of goods. These events lead country-2 households to work less, absent wealth effects in their supply decisions, and GDP immediately contracts.[24]

[24] Miyamoto and Nguyen (2017) analyze the transmission of a permanent productivity shock in an IRBC model similar to ours in its inclusion of imported intermediate inputs and weak wealth effects on labor supply.

Investment rises temporarily (far less than in figure 4) to get a bit more capital in place towards shifting retailers' production mix in favor of domestic goods, but none of this rise is financed by country-1 households. Country-2 households soften the immediate fall in their consumption by lowering (not raising) their savings, so the forces underlying the fall in the current account differ from those following country 1's credit shock.

We close this subsection with the novel observation that the distinctions in how financial versus real shocks operate within a country extend to how these shocks affect its trading partners. Figure 9 decomposes each country's GDP response into its expenditure-side components following country 1's TFP shock for comparison with those in figure 5 following its credit shock. Whereas investment played a central role in propagating the financial shock domestically and abroad in figure 5, here, we see the majority of both GDP responses to the real shock can be attributed to consumption.

FIGURE 9. COUNTRY-1 TFP SHOCK: GDP RESPONSE DECOMPOSITIONS



Starting on the left with country 1, consumption losses contribute roughly two-thirds of the initial GDP decline, and that share grows with time. Meantime, country-2 investment rises for a few quarters in response to the immediate rise in its relative productivity. Unlike the investment boom following country 1's credit shock in figure 5, these rises are modest, short-lived, and dwarfed by declines in consumption. Investment's share of GDP never moves far from its usual 16.6 percent, and the contraction in consumption is the dominant factor throughout the GDP response. In sum, our analysis reveals that a financial shock propagates through a very different channel in comparison with the real shock transmission commonly studied in the literature.

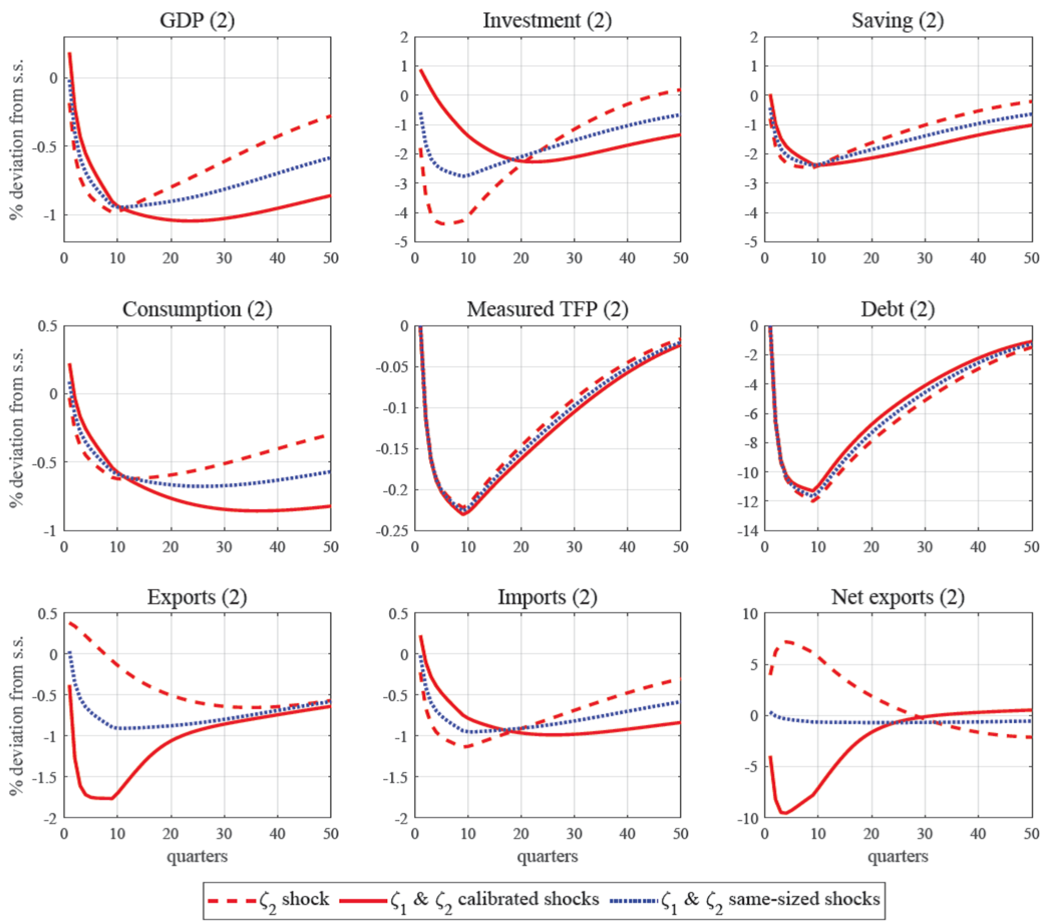
5.3 Global financial shocks

We have confined attention so far to the transmission of one aggregate shock, with emphasis on the consequences of a country-1 credit shock calibrated to the United States 2007-2009 experience. As discussed in section 1, however, there is ample evidence indicating that the U.S. financial crisis spilled into a global financial crisis affecting many advanced economies. The tightening of bank lending standards and subsequent fall in Canadian business loans suggests that Canada was among them, though its recession was less severe and shorter than in most other G7 countries.

Here, we allow for financial contagion by examining simultaneous credit shocks in our model counterparts to the U.S. and Canada, and highlight how international trade alters the consequences of the domestic financial shock for Canada. Retaining the calibrated country-1 shock above, we drop country 2's collateral constraint parameter, ζ_2, to 86.18 percent of its steady-state value so that its peak-to-trough debt decline matches that of real loans to Canadian non-financial corporations and unincorporated businesses, at 11.4 percent. The credit recovery path starting in quarter 9 follows the same AR(1) process as in country 1, and implies that country 2's debt series is still 9.33 percent below normal one year later, as happened in Canada.

Figure 10 compares three sets of impulse responses to isolate how our small open economy's financial recession is altered through international trade by the fact that its large trading partner is experiencing a deep financial recession. The dashed series in each panel are country 2's responses to its domestic credit shock absent any country-1 shock, dotted series are its responses if country 1 experiences the same shock, while solid series are its responses when country 1 is hit by the calibrated ζ_1 shock. The gaps between the solid and dashed responses reflect the consequences of country 1's credit crisis transmitted to country 2 through trade, the channel explored in isolation above in figure 4; the gaps between the dotted and dashed responses show what that channel would have contributed had country 1's financial recession been less severe.

FIGURE 10. COUNTRY-2 RESPONSES TO GLOBAL FINANCIAL SHOCKS



NOTE.– Country-2 responses to an 8-quarter 13.8 percent credit shock accompanied by: no country-1 shock, the same shock in country 1, or the calibrated U.S. shock in country 1.

Considering solid versus dashed series, we see that country 2's recession is altered in three notable ways by the recession in country 1. First, the early phase of the downturn is softened by an investment rise effectively financed by country-1 households, where investment otherwise should have fallen about 2 percent right away; the GDP contraction in quarter 2 is roughly half what it would be without the net inflow of goods reflected in country 2's trade balance. Although dampened by the presence of the ζ_1 shock, note that the ultimate fall in investment is still 12 times the ultimate 0.23 percent fall in aggregate productivity; whereas, country-2 investment falls 8.16 percent in response to a direct 1 percent productivity shock.

Second, given the countervailing force of the resulting stock accumulation, the recession lasts more than twice as long as it otherwise would, with GDP reaching its trough in quarter 24 versus 9. Third, and most strikingly, the recovery is greatly protracted by the slow relocation of 'excess' capital back to country 1, and by the fact that its arrival at a time of heightened financial distortions implies greater distributional disruption to be repaired later. Investment is still 1.5 percent below normal 11.5 years out, where it would have recovered fully absent the country-1 financial recession; meanwhile, measuring from their respective trough dates, the half-life of the GDP response is extended by more than a decade, from 7 to 17.5 years.

Examining the dotted versus dashed responses, notice country 1's recession would moderate country 2's initial GDP downturn even if its source was the same credit shock as in country 2, though less so. In that case, country 1's recession would merely soften country 2's investment decline, rather than raising investment above normal for several quarters, and so would not delay the GDP trough. Nonetheless, country 2's failure to repurpose as much capital as it otherwise should still would extend the half-life of its recovery by 13 years. These observations suggest that the size of the country-1 financial recession is not so critical in reshaping the country-2 financial recession as is country 2's exposure to trade with its large neighbor.

5.4 Connections to the U.S. - Canada experience

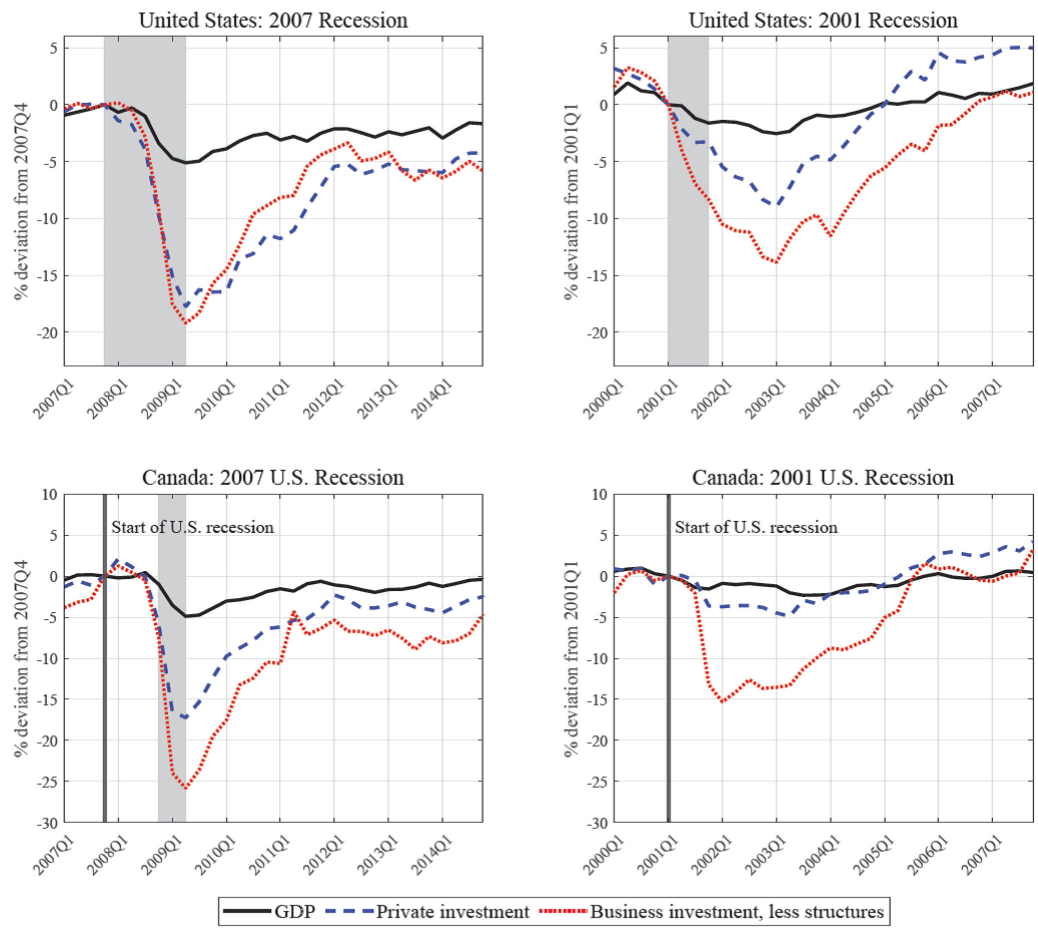
As discussed in section 1 and elsewhere in the literature, the onset of the U.S. financial crisis was followed by large, synchronized contractions across many advanced and emerging market economies, with Canada among them. Taking as given that financial contagion was critical in driving the business cycle synchronization over this episode, our model's predictions in section 5.3 suggest that international trade also may have had a role in transmitting the effects of the U.S. shock to its trading partners, especially ones with comparatively large exposure to trade. Those results in conjunction with the analysis from section 5.1 indicate that the dynamics of investment and the changes in the underlying distributions of firms that prompt them are central in propagating financial market disturbances within and across countries.

In response to synchronized credit shocks, our model predicts investment contractions of considerable size relative to the declines in aggregate productivity. Because young, growing firms are disproportionately affected, both countries' firm distributions are persistently disrupted, slowing aggregate investment and TFP reversion and thus the recoveries in aggregate capital and GDP. Country 2's recovery is further gradualized by the extra stock and added distributional disruption implied by initial investment infusions from country-1 households. These results are broadly consistent with the prolonged stagnation of investment seen in the United States and Canada following the global financial crisis, to which we now turn.

Figure 11 presents log, HP-filtered real GDP, private investment, and business fixed investment less structures in the U.S. and Canada in dates surrounding the U.S. 2007 (left panels) and 2001 recessions, with each series demeaned to its value at the start of the U.S. recession. Canada had no banking crisis per se, and its recession beginning in 2008Q4 was less severe than those in many other advanced economies; Bordo, Redish and Rockoff (2011) credit tighter financial sector regulation for its lack of bank failures and government bailouts during the global financial crisis. Canada also experienced only about half the percentage decline in real C&I loans as happened in the United States, recalling figure 1 from section 1. These observations notwithstanding, the size of its GDP contraction and that in the U.S. are a near perfect match. This is at odds with the predictions of our model, which translates a roughly half-sized fall in business lending into a roughly half-sized fall in GDP; however, some of the discrepancy might be explained by a real shock affecting Canada around this time omitted from our analysis, a notion we will return to below.

Canadian investment rose in early 2008, but private investment began a steep decline in 2008Q3 fueled by that in business investment. Model counterparts in figure 10 agree qualitatively with these observations, but the predicted investment decline is far smaller and more gradual. Whereas the empirical investment trough dates coincide in the 2007 recession episode, our model reproduces that coincidence only if we reduce the size of the country-1 credit shock to that in country 2. Over the recovery, United States and Canadian investment came back fairly steadily between mid-2009 and mid-2011 and then stagnated over several years.[25]

FIGURE 11. RECESSIONS IN THE U.S. AND CANADA



NOTE.– Real GDP, private investment and business fixed investment series from the U.S. Bureau of Economic Analysis and Statistics Canada GDP tables. Private investment includes consumer durables and residential investment. All series are in logs, detrended using a Hodrick-Prescott filter with weight 1600. U.S. filter is constructed using 1954Q1 - 2015Q2 data; Canadian filter uses 1961Q1 - 2015Q2 data.

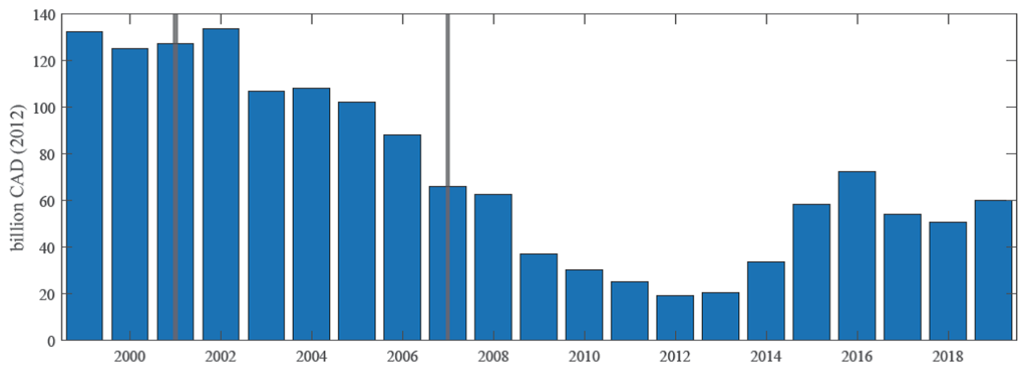
Our calibrated financial shocks imply both countries' credit states are low for two years and then slowly revert to normal. Given these shock paths, it is perhaps unsurprising that our model predicts GDP trough dates well after those in the data. Its predictions of a considerably later trough date and far slower recovery in Canada than in the U.S. are more problematic. However, it may be worth noting that the Canadian

[25] Note the contrast between these observations and the investment dynamics surrounding the U.S. 2001 recession. While both countries' detrended private and business investment series fell well below their 2001Q1 levels, the declines were small in comparison with those in the left panel, they were more gradual, and the subsequent recoveries in these series were more sustained. Moreover, Canada experienced no recession in the 2001 episode.

economy was buffeted by sharp declines in commodity prices and exports from mid-2008 through early 2009. Furthermore, monetary and fiscal stimulus packages helped hasten the actual economy's subsequent recovery. These factors absent from our analysis presumably contribute to the differences in timing.

Our model's key trade-related prediction underlying the strong influence of country 1's recession on that in country 2 is a large, persistent fall in country 2's trade balance. Figure 12 shows Canada's real surplus in non-energy goods trade with the U.S. fell during the global crisis. While in decline since the early 2000s, reductions in this series starting in 2008 were more pronounced and persisted for several years. These observations are consistent with predictions in figure 10. At the same time, we must acknowledge that the country-2 export decline there is far smaller than its empirical counterpart in figure 1, and the coincident rise in country 1's exports is at odds with that figure.

FIGURE 12. CANADA'S REAL TRADE BALANCE WITH THE U.S.

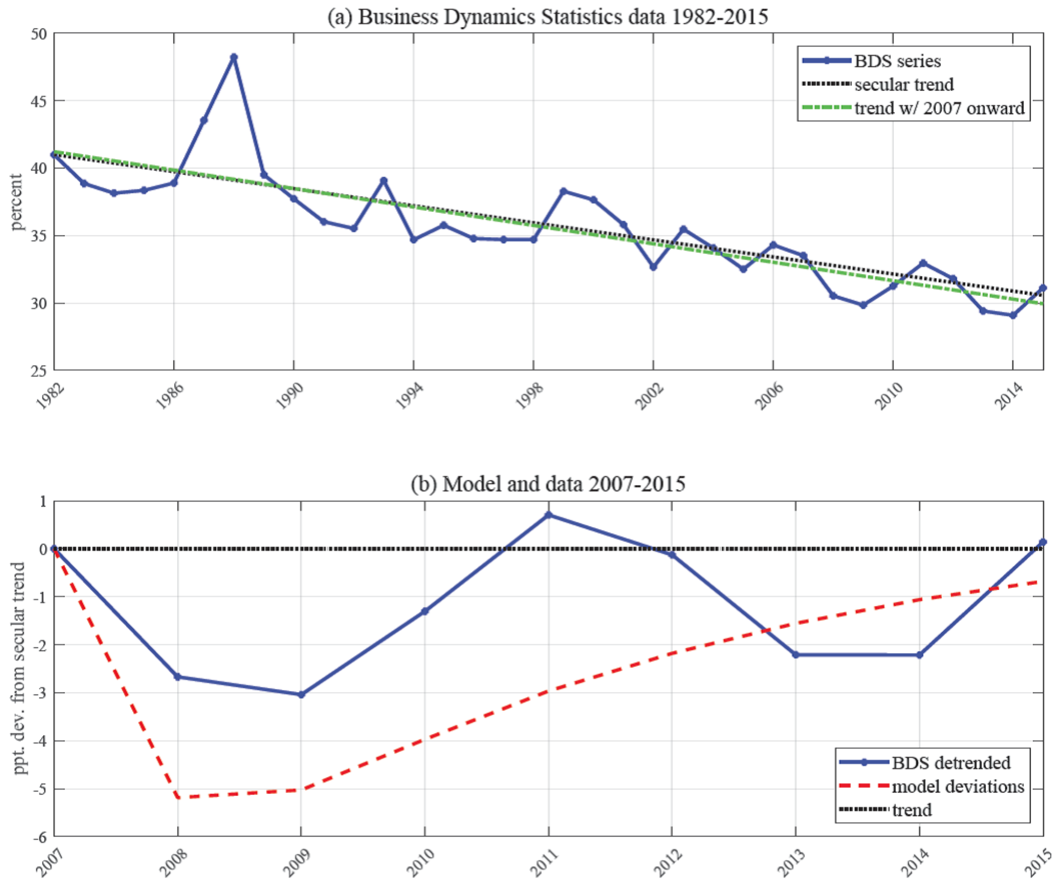


NOTE.– Real trade balance for goods excluding energy products; nominal exports and imports deflated using export and import price indices. Data source: Statistics Canada.

We began this section by demonstrating that disruptions to young firms' life-cycle growth are central to credit-shock transmission in our model, so we close the discussion by considering how this prediction lines up with the 2007 recession episode. Absent publicly available data on Canada's age-size distribution, we compare the model's country-1 predictions with U.S. firm data from the Business Dynamics Statistics database. Annualizing our model-generated series for comparison with the BDS, we focus on the average relative size of age-1 firms at each year, since this series best reflects disproportionately increased inefficiencies in new firms' investments from the prior year.

The top panel of figure 13 plots age-1 U.S. firms' average relative size over 1982 - 2015 against a (dotted black) linear trend extrapolated from 1982 - 2006 data. This line serves as our reference in constructing empirical deviations from trend; the second trend is there only to show how subsequent events hastened the series' decline. The detrended series is demeaned to its 2007 value and plotted against model deviations from steady-state in the bottom panel. Although the relative employment contractions among the model's age-1 firms are greater and more persistent than what their counterparts in the BDS experienced, the paths of these series broadly agree from 2007 through 2011. Both show a sizeable initial decline lasting two years and, to differing degrees, gradualism in the recoveries of age-1 firms to their usual productive shares.

FIGURE 13. AVERAGE RELATIVE SIZE OF ONE-YEAR-OLD FIRMS



6 Concluding remarks

We have developed a two-country equilibrium business cycle model to study the transmission of financial shocks through international trade. Our model's persistent heterogeneity in firms' credit needs and access is central to its misallocation-driven domestic propagation of an aggregate credit tightening. Its inclusion of input-output linkages within and across countries accommodates an empirically valid role for trade in intermediate inputs. Finally, its calibration to the U.S. and Canada reflects an epicenter of the global financial crisis interacting with one of its leading trade partners, but at the same time reflects the interactions of a large economy relatively impervious to trade with a smaller economy highly reliant on its external sector.

Examining responses following a financial shock calibrated to the path of U.S. business loans in the 2007 crisis, we have seen that the unique mechanics translating aggregate credit disruptions into real ones in closed-economy settings extend across borders. Tight credit conditions in the large economy are most destructive to young firms' life-cycle growth, and so drive persistently worsened misallocation and lowered expected returns to domestic aggregate capital accumulation with the arrival of each new cohort. This explains investment's far larger share in a credit-induced GDP contraction compared with that induced by an aggregate TFP shock, and why the same pattern emerges for the trading partner suffering no direct shock.

A persistent trade balance adjustment facilitates shifts in the composition of world production whilst returns to investment are falling in the large economy. Local households reduce their savings by less than the fall in domestic investment and effectively invest the residual savings abroad through raised net exports. The resulting inflows are substantial relative to the small economy's usual productive scale, and help finance large rises in its investment to expand domestic production in anticipation of rising import prices. Over time, as credit conditions improve and the large economy's capital distribution slowly recovers its normal shape, world production shifts back in that direction, prompting persistent reversals in both countries' investment series and a prolonged GDP contraction in the small economy. Comparing these dynamics to the coincident consumption-led recessions in both countries following an aggregate TFP shock in the large economy, our results indicate that the dominant trade channel propagating an aggregate shock internationally is principally reflective of its domestic transmission channel.

Confronting the small economy with a credit shock reproducing the fall in Canadian business loans over the global financial crisis, we have seen its recession matters little to its large, comparatively closed trading partner. Conversely, through the mechanics reviewed above, the financial recession abroad reshapes the small economy's recession, delaying the start of its recovery phase and greatly extending it. Taking financial contagion as given, this suggests that international trade had a distinct, non-negligible role in the persistent stagnation of investment and slow economic recoveries following the global financial crisis. Some results from this exercise align well with U.S. - Canada evidence; those that do not indicate that a full Canadian calibration of the second economy and stochastic simulation with jointly estimated financial and real shocks would be necessary to confirm this prediction. We leave that investigation for future work.

Our analysis also might be extended to explore recent findings on the sources of the international trade collapse coinciding with the global financial crisis. Levchenko, Lewis and Tesar (2010) and Eaton, Kortum, Neiman and Romalis (2016) argue that the collapse came largely from declines in expenditures on durable goods, which are trade-intensive. In fact, the business cycle accounting decomposition undertaken by Eaton et al. (2016) attributes two-thirds of the decline in trade relative to GDP during that period to shocks affecting the efficiency of investment in durable manufactures. Because investment dynamics play the central role in propagating financial shocks in our model economy, a carefully calibrated extension including durable and nondurable goods sectors could be useful in tracing out the mechanisms underlying their result, thereby shedding further light on real-financial linkages through international trade.

A Appendix

This appendix considers how our model's predictions are affected by three key assumptions made in its development and calibration. We focus on its baseline responses to the country-1 credit shock from section 5.1, and consider how those results change if we remove: (i) complementarity between domestic and foreign goods, (ii) differences in country size and trade shares, or (iii) input-output linkages in production.

A.1 Complementarity

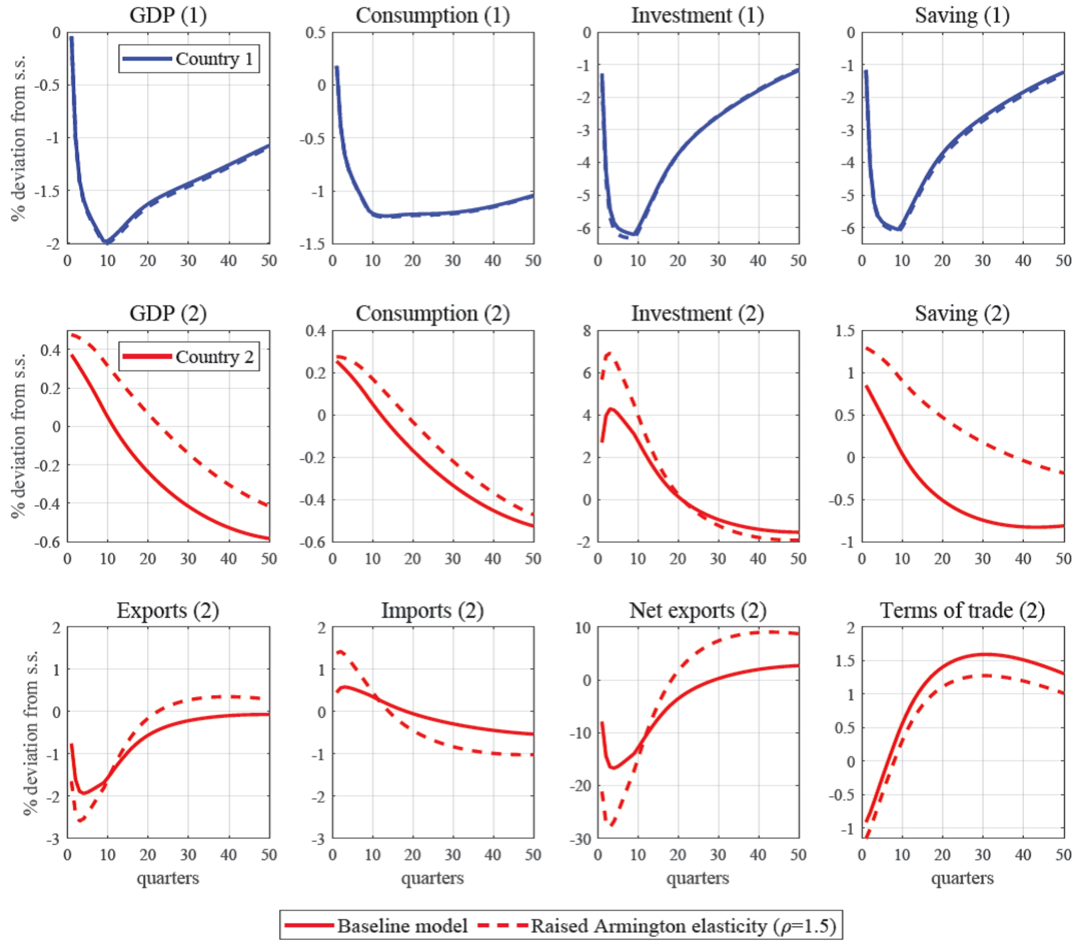
The Armington elasticity ρ is a critical parameter in quantitative analyses of open-economy models, as it determines the degree of substitutability between domestic and imported products. Our baseline calibration sets ρ at 0.9, implying domestic and imported products are complements. Many other studies follow Backus, Kehoe and Kydland (1994) in assuming imports are substitutes for domestic goods and setting $\rho = 1.5$. We reconsider our model under that alternative choice here. For comparability sake, we recalibrate its remaining parameters to maintain the fit to the calibration targets in section 4. This requires, at most, third decimal place changes in all but the following 6 parameters associated with the two countries' trade shares and GDP.

TABLE A1. ARMINGTON ELASTICITY: ALTERED PARAMETERS

ρ	θ_{h1}	θ_{m1}	θ_{h2}	θ_{m2}	z_1^*	z_2^*
1.5	0.962	0.941	0.787	0.774	2.268	3.256

Figure A1 compares our baseline results (solid lines) with those from the alternative model with $\rho = 1.5$ (dashed lines). There, we see that allowing greater substitutability between domestic and imported products amplifies the responses of exports and imports, and thus net exports, following the country-1 credit shock. These changes have a negligible impact on the aggregate responses in country 1 given the small calibrated share of trade in its GDP. For country 2, however, the larger adjustment in its trade balance is mirrored by a more pronounced initial investment rise. The repercussions of this moderate the country-2 GDP decline over many quarters, delaying its trough by 13 quarters; however, the ultimate fall in GDP differs by under 0.1 percent, and the half-life of the recovery is still 75 quarters. Thus, the main conclusions from section 5.1 are unaltered when we eliminate our complementarity assumption.

FIGURE A1. COUNTRY-1 CREDIT SHOCK WITHOUT COMPLEMENTARITY



A.2 Population and trade-share differences

We emphasized our countries' size disparity in discussing the transmission of country 1's credit shock to country 2 (figures 4 - 6), and the absence of transmission in the reverse direction (figure 7) in section 5.1. Identifying our model countries as the United States and Canada, the baseline calibration set country 2's relative population size at $\Psi_2 = 0.07$ to ensure its steady-state GDP is 8.8 percent that in country 1. We consider the importance of that assumption here, solving an alternative version of our model with $\Psi_2 = 1$.

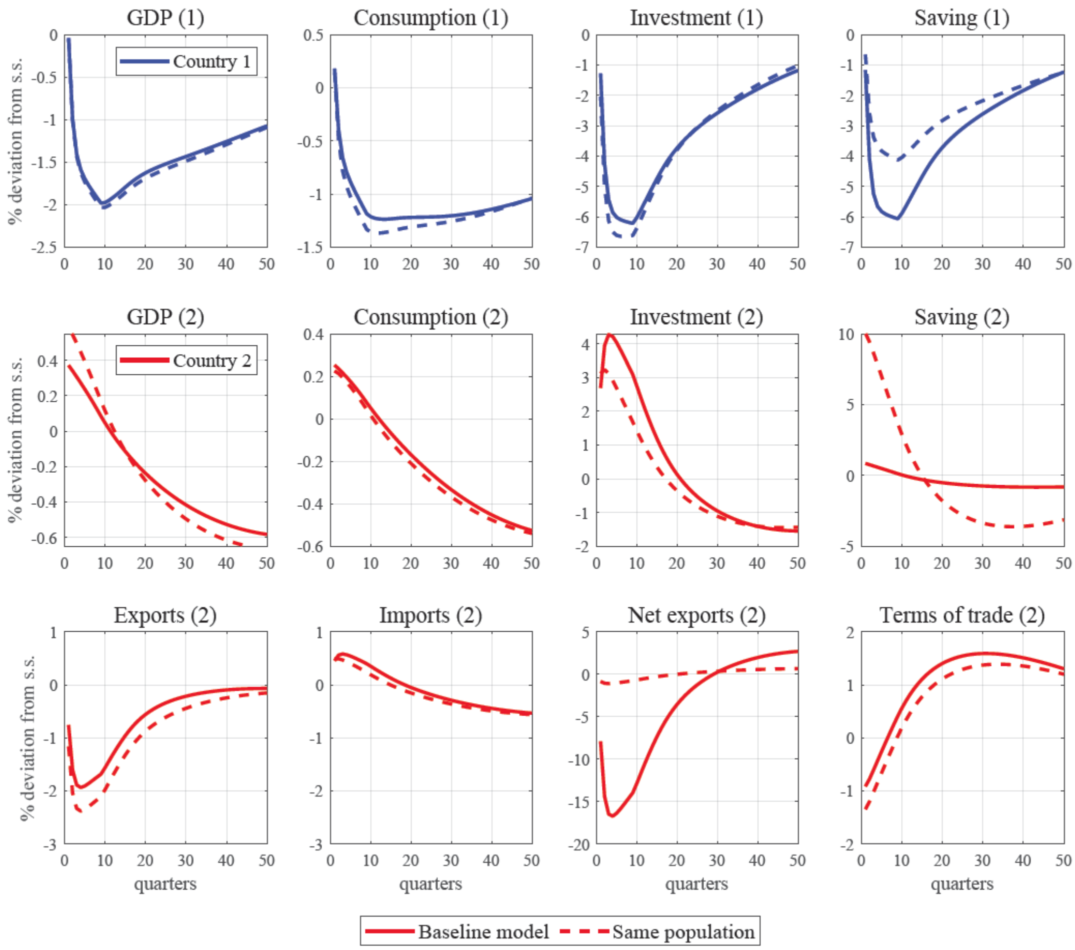
Given the substantial change to country 2's household and firm population size, recalibrating the model to our targets in section 4 implies large parameter adjustments confounding comparisons with the baseline results. Here, we hold remaining parameters unchanged, allowing the two countries' steady-state GDP and hours worked to move away from the calibration targets. Despite equal population sizes, country 2's steady-state GDP is still 42 percent that in country 1 in the alternative model, a result of its greater openness to international trade reflected in the calibrated trade shares.

Figure A2 compares our baseline results to those from the model with equal populations. The greatest change in country-1 outcomes is a lesser fall in aggregate savings, and so a greater flow of residual savings to country 2. With its comparatively open trade partner now of its size, country-1 households reduce their savings by less even as domestic investment contracts by more.[1] The ramifications of this for country-2

[1] Whereas country 1's trade balance is slightly negative (-0.003) in the baseline steady state, its greater preference for domestic goods than that in country 2 implies a small surplus, 0.089, in the model with equal populations.

investment are not so great as in the baseline model, however. These inflows are far smaller in relation to aggregates in the large country-2 economy; correspondingly, we see a smaller adjustment in its trade balance. Nonetheless, the rise in its relative return to investment is greater with more firms to spread the additional capital over. Measured productivity falls by less over the expansion, and the rise in investment now on its own offsets the fall in net exports. Effectively, its expanded size makes it easier for country 2 to take over a greater share of production while country-1's productivity is in decline; its GDP initially rises somewhat more, implying a greater contraction thereafter. While the path of country 1's recession and recovery is unaltered for reasons emphasized above, the gradualism in country 2's GDP responses lessens; its trough date arrives 1 year sooner, and the half-life of its recovery is 5 quarters shorter.

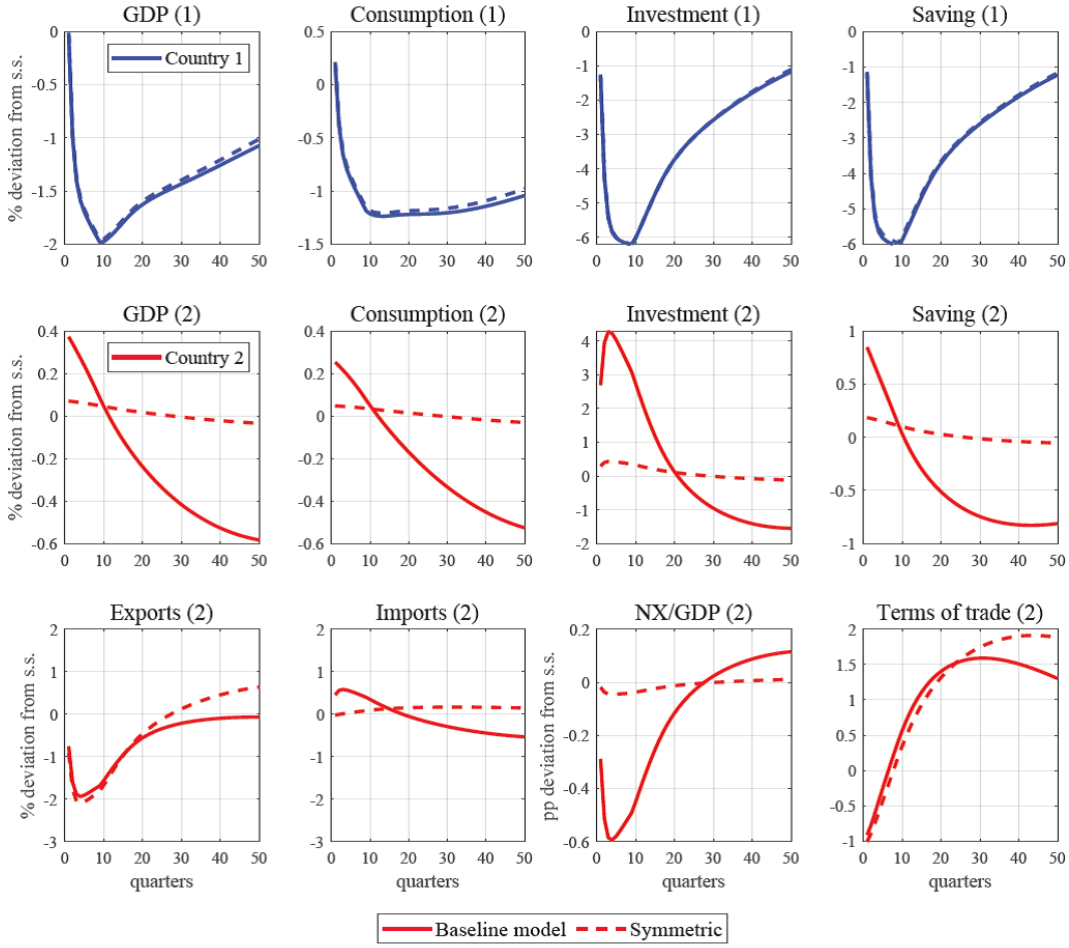
FIGURE A2. COUNTRY-1 CREDIT SHOCK WITHOUT POPULATION DIFFERENCES



On balance, figure A2 shows eliminating population differences alters the results in section 5.1 little; the investment channel remains central to cross-country financial shock transmission.[2] Country 2's small size matters little relative to the comparatively large importance of trade in its GDP. To see what happens when that asymmetry is eliminated, we reset the remaining country-2 parameters to country-1 values. Figure A3 presents responses in the resulting model where the U.S. trades with a twin economy. Not surprisingly, there is virtually no international transmission when country 2 is as nearly a closed economy as is country 1.

[2]The same comparison following a country-1 TFP shock shows consumption remains dominant in transmitting real shocks. These figures, and additional figures from the credit shock exercise, are available on request.

FIGURE A3. COUNTRY-1 CREDIT SHOCK WITH SYMMETRIC COUNTRIES



A.3 Input-output linkages

Earlier studies have shown that input-output linkages in production amplify the transmission of nominal and real shocks.[3] Here, we explore the importance of those linkages in propagating a financial shock by considering a version of our model lacking them. Specifically, we eliminate the use of materials by resetting that productive share to $\gamma = 0$. Such a large shift from the calibrated value, 0.43, implies changes in our economies too great to avoid a complete recalibration. Table A2 reports resulting parameter values differing beyond the third decimal place from their baseline counterparts in table 1.

TABLE A2. INPUT-OUTPUT LINKAGES: ALTERED PARAMETERS

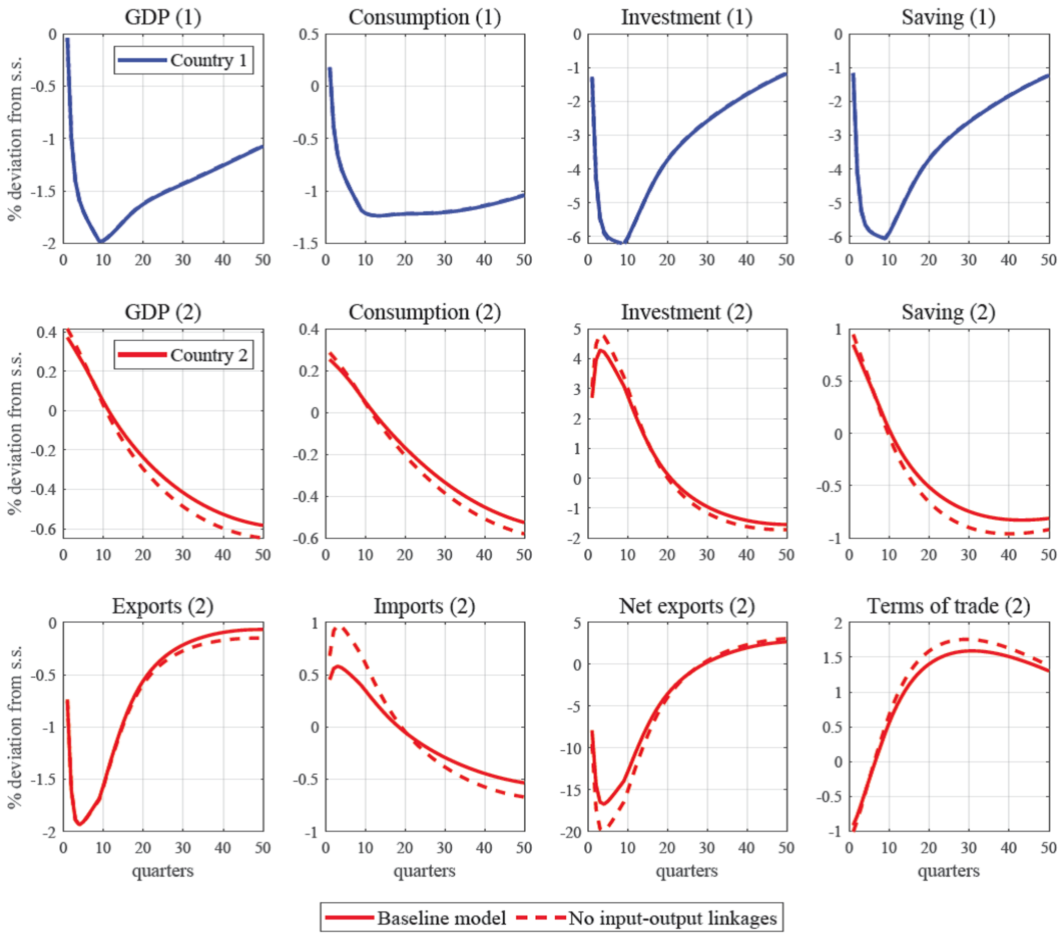
γ	α	ν	κ	θ_{h1}	θ_{h2}	z_1^*	z_2^*	σ_ε	k_{02}	b_{02}
0	0.287	0.60	2.396	0.986	0.814	1.122	1.815	0.052	1.479	0.512

Figure A4 compares our baseline model's (solid line) responses following the country-1 financial shock to those in the alternative model with $\gamma = 0$. In light of prior findings in the literature, the top row of

[3]See, for example, Alessandria and Choi (2014) for tariff changes, Luo and Villar (2023) for the price effects of demand and supply shocks, and Su (2023) for uncertainty shocks.

responses may come as a surprise. They indicate that roundabout production makes no difference to the domestic transmission of a credit shock in our large open economy. A more complete set of figures (available on request) shows country 1's measured TFP falls about twice as much in the alternate model, a natural consequence of our recalibration having raised the capital share parameter from 0.164 to 0.287; however, the only tangible consequence for country 1 is a greater rise in exports over dates where the TFP gap is wide.

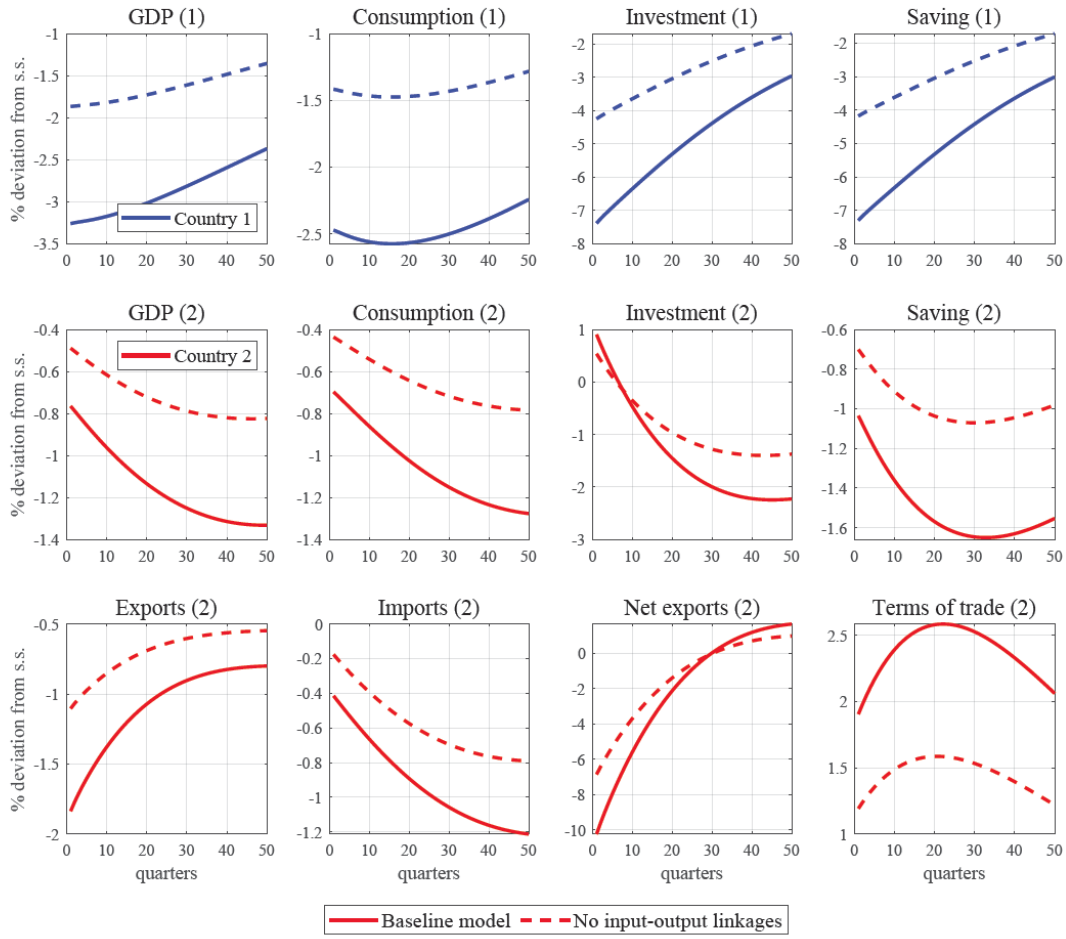
FIGURE A4. COUNTRY-1 CREDIT SHOCK WITHOUT INPUT-OUTPUT LINKAGES



The figure's remaining rows show that the implied boost to country-2 imports implies a larger adjustment in its trade balance and a correspondingly larger investment rise when input-output linkages are eliminated. Given the importance of early-date capital accumulation for the coming correction, its GDP subsequently falls by more and at a somewhat faster pace. Imported final goods are used directly for investment in our model, whereas imported intermediate inputs are further processed through domestic production. That processing is eliminated when only final goods are traded, facilitating the investment reallocation from country 1 to country 2 while country 1's credit-induced misallocation is worsening.

Finally, we confirm that the dynamic effects of production linkages in our model are consistent with the findings of prior studies when the source of fluctuations is a real shock. Figure A5 compares responses to a one-percent country-1 productivity shock in the same two economies as above. In contrast to the results in figure A4, we see here that the baseline model's roundabout production structure significantly amplifies its transmission of real shocks, both domestically and abroad.

FIGURE A5. COUNTRY-1 TFP SHOCK WITHOUT INPUT-OUTPUT LINKAGES



References

[1] Alessandria, George and Horag Choi, 2007. "Do Sunk Costs of Exporting Matter for Net Export Dynamics?" *Quarterly Journal of Economics* 122(1): 289-336.

[2] Alessandria, George and Horag Choi, 2014. "Establishment heterogeneity, exporter dynamics, and the effects of trade liberalization," *Journal of International Economics* 94: 207–23.

[3] Alessandria, George, Joseph Kaboski and Virgiliu Midrigan, 2013. "Trade wedges, inventories, and international business cycles," *Journal of Monetary Economics* 60: 1-20.

[4] Altinoglu, Levent, 2021. "The Origins of Aggregate Fluctuations in a Credit Network Economy," *Journal of Monetary Economics* 117: 316-34.

[5] Arellano, Cristina, Yan Bai and Patrick J. Kehoe, 2019. "Financial Frictions and Fluctuations in Volatility" *Journal of Political Economy* 127(5): 2039-2103.

[6] Backus, David K., Patrick J. Kehoe and Finn E. Kydland, 1992. "International Real Business Cycles," *Journal of Political Economy* 100: 745-75.

[7] Backus, D. K., P. J. Kehoe and Finn E. Kydland, 1994. "Dynamics of the Trade Balance and the Terms of Trade: The J-Curve?" *American Economic Review* 84(1): 84-103.

[8] Beaton, Kimberly, Rene Lalonde and Stephen Snudden, 2014. "The Propagation of U.S. Shocks to Canada: Understanding the Role of Real Financial Linkages," *Canadian Journal of Economics* 47(2): 466-93.

[9] Baxter, Marianne and Mario J. Crucini, 1995. "Business Cycles and the Asset Structure of Foreign Trade," *International Economic Review* 36: 821-54.

[10] Behrens, Kristian, Gregory Corcos and Giordano Mion, 2013. "Trade Crisis? What Trade Crisis?" *Review of Economics and Statistics* 95: 702-09.

[11] Bems, Rudolfs, Robert C. Johnson and Kei-Mu Yi, 2010. "Demand Spillovers and the Collapse of Trade in the Global Recession," *IMF Economic Review 58*: 295-326.

[12] Bems, Rudolfs, Robert C. Johnson and Kei-Mu Yi, 2011. "Vertical Linkages and the Collapse of Global Trade," *American Economic Review: Papers and Proceedings* 101: 308-12.

[13] Bems, Rudolfs, Robert C. Johnson and Kei-Mu Yi, 2013. "The Great Trade Collapse," *Annual Review of Economics* 5: 375-400.

[14] Bernanke, Ben S., Mark Gertler and Simon Gilchrist, 1999. "The financial accelerator in a quantitative business cycle framework." Chapter 21, 1341-93, in J. B. Taylor and M. Woodford (eds.) *Handbook of Macroeconomics*, Volume 1, Part 3, Elsevier.

[15] Bocola, Luca, and Gideon Bornstein, 2023. "The Macroeconomics of Trade Credit," working paper.

[16] Buera, Francisco J. and Benjamin Moll, 2015. "Aggregate Implications of a Credit Crunch: The Importance of Heterogeneity," *American Economic Journal: Macroeconomics* 7: 1-42.

[17] Burstein, Ariel, Christopher Kurz and Linda Tesar, 2008. "Trade, Production Sharing, and the International Transmission of Business Cycles," *Journal of Monetary Economics* 55: 775-95.

[18] Bussière, Matthieu, Giovanni Callegari, Fabio Ghironi, Giulia Sestieri and Norihiko Yamano, 2013. "Estimating Trade Elasticities: Demand Composition and the Trade Collapse of 2008-2009," *American Economic Journal: Macroeconomics* 5: 118-51.

[19] Corsetti, Giancarlo, Luca Dedola and Sylvain Leduc, 2008. "International Risk Sharing and the Transmission of Productivity Shocks" *Review of Economic Studies,* 75(2): 443-73.

[20] Dedola, Luca and Giovanni Lombardo, 2012. "Financial Frictions, Financial Integration and the International Propagation of Shocks," *Economic Policy* 27: 321-59.

[21] Devereux, Michael B., Allan W. Gregory and Gregor W. Smith, 1992. "Realistic cross-country consumption correlations in a two-country, equilibrium, business cycle model," *Journal of International Money and Finance* 11(1): 3-16.

[22] Devereux, Michael B. and Alan Sutherland, 2011. "Evaluating International Financial Integration under Leverage Constraints," *European Economic Review* 55: 427-42.

[23] Devereux, Michael B. and James Yetman, 2010. "Leverage Constraints and the International Transmission of Shocks," *Journal of Money, Credit and Banking* 42: 71-105.

[24] Devereux, Michael B. and Changhua Yu, 2020. "International Financial Integration and Crisis Contagion," *Review of Economic Studies* 87: 1174-1212.

[25] Eaton, Jonathan, Samuel Kortum, Brent Neiman and John Romalis, 2016. "Trade and the Global Recession," *American Economic Review* 106: 3401-38.

[26] Faia, Ester, 2007. "Finance and International Business Cycles," *Journal of Monetary Economics* 54: 1018-34.

[27] Gomme, Paul, B. Ravikumar and Peter Rupert, 2011. "The Return to Capital and the Business Cycle" *Review of Economic Dynamics* 14(2): 262-78.

[28] Greenwood, Jeremy, Zvi Hercowitz and Gregory W. Huffman, 1988. "Investment, Capacity Utilization, and the Real Business Cycle" *American Economic Review* 78(3): 402-17.

[29] Heathcote, Jonathan and Fabrizio Perri, 2002. "Financial Autarky and International Business Cycles" *Journal of Monetary Economics* 49(3): 601-27.

[30] Iacoviello, Matteo and Raoul Minetti, 2006. "International Business Cycles with Domestic and Foreign Lenders," *Journal of Monetary Economics* 53, 2267-82.

[31] Jermann, Urban and Vincenzo Quadrini, 2012. "Macroeconomic Effects of Financial Shocks," *American Economic Review* 102: 238-71.

[32] Johnson, Robert C., 2014. "Trade in Intermediate Inputs and Business Cycle Comovement," *American Economic Journal: Macroeconomics* 6: 39-83.

[33] Kalemli-Ozcan, Sebnem, Elias Papaioannou and Fabrizio Perri, 2013. "Global Banks and Crisis Transmission," *Journal of International Economics* 89: 495-510.

[34] Kamber, Güneş and Christoph Thoenissen, 2013. "Financial Exposure and the International Transmission of Financial Shocks," *Journal of Money, Credit and Banking* 45: 127-58.

[35] Kehoe, Patrick. J. and Fabrizio Perri, 2002. "International Business Cycles with Endogenous Incomplete Markets" *Econometrica*, 70(3): 907-28.

[36] Khan, Aubhik and Julia K. Thomas, 2013. "Credit Shocks and Aggregate Fluctuations in an Economy with Production Heterogeneity," *Journal of Political Economy* 121: 1055-1107.

[37] Kiyotaki, Nobuhiro and John Moore, 1997. "Credit Cycles," *Journal of Political Economy* 105: 211-48.

[38] Kollmann, Robert, 2013. "Global Banks, Financial Shocks, and International Business Cycles: Evidence from an Estimated Model," *Journal of Money, Credit and Banking* 45: 159-95.

[39] Kollmann, Robert, Zeno Enders and Gernot J. Müller, 2011. "Global Banking and International Business Cycles," *European Economic Review* 55: 407-26.

[40] Kose, M. Ayhan and Kei-Mu Yi, 2006. "Can the Standard International Business Cycle Model Explain the Relation between Trade and Comovement?" *Journal of International Economics* 68: 267-95.

[41] Levchenko, Andrei A., Logan Y. Lewis and Linda L. Tesar, 2010. "The Collapse of International Trade during the 2008-09 Crisis: In Search of the Smoking Gun," *IMF Economic Review* 58: 214-53.

[42] Luo, Shaowen, 2020. "Propagation of Financial Shocks in an Input-Output Economy with Trade and Financial Linkages of Firms," *Review of Economic Dynamics* 36: 246-69.

[43] Luo, Shaowen and Daniel Villar, 2023. "Propagation of Shocks in an Input-Output Economy: Evidence from Disaggregated Prices," *Journal of Monetary Economics* 137: 26-46.

[44] Mendoza, Enrique G. and Vincenzo Quadrini, 2010. "Financial Globalization, Financial Crises and Contagion," *Journal of Monetary Economics* 57: 24-39.

[45] Miyamoto, Wataru and Thuy Lan Nguyen, 2017. "Understanding the cross-country effects of U.S. technology shocks," *Journal of International Economics* 106: 143-64.

[46] Perri, Fabrizio and Vincenzo Quadrini, 2018. "International Recessions," *American Economic Review* 108: 935-84.

[47] Raffo, Andrea, 2008. "Net exports, consumption volatility and international business cycle models," *Journal of International Economics* 75(1): 14-29.

[48] Reischer, Margit, 2024. "Finance-thy-neighbor. Trade Credit Origins of Aggregate Fluctuations," working paper.

[49] Schmitt-Grohé, Stephanie and Martín Uribe, 2003. "Closing small open economy models," *Journal of International Economics* 61(1): 163-85.

[50] Su, Hsuan-Li. 2024. "Financial Frictions, Capital Misallocation, and Input-Output Linkages," *American Economic Journal: Macroeconomics* 16(2): 62-94.

[51] Townsend, Robert M., 1979. "Optimal contracts and competitive markets with costly state verification," *Journal of Economic Theory* 21: 265-93.

[52] Ueda, Kozo, 2012. "Banking Globalization and International Business Cycles: Cross-Border Chained Credit Contracts and Financial Accelerators," *Journal of International Economics* 86: 1-16.

[53] Yao, Wen, 2019. "International Business Cycles and Financial Frictions," *Journal of International Economics* 118: 283-91.