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ABSTRACT

Motivated by empirical evidence, we propose an open-economy New Keynesian model with financial integration that allows financial intermediaries to hold foreign long-term bonds. We find financial integration features an amplification for a domestic monetary policy shock and a negative spillover for a foreign shock. These results hold for conventional and unconventional monetary policies. Among various aspects of financial integration, the bond duration plays a major role, and our results cannot be replicated by a standard model of perfect risk sharing between households. Finally, we observe an important interaction between financial integration and trade openness, and demonstrate trade alone does not have an economically meaningful impact on monetary policy transmission.

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1 Introduction

The global financial landscape has shifted in the past few decades: the financial markets have become more interconnected internationally for many parts of the world, whereas the rest of the world remains relatively segregated. As significant a phenomenon as financial integration has become, its implications for the global economy and policymaking are far less clear. How does financial integration affect monetary policy transmission? What are the key features of financial integration? How do trade openness and financial market openness interact with each other? We build a two-country open-economy New Keynesian model to answer these questions.

The key innovation of our model is that the international financial markets are integrated. Specifically, motivated by empirical observations, financial intermediaries can hold long-term bonds issued in the foreign country. The backbone of the model is a two-country open-economy New Keynesian model, which features standard real and nominal frictions as in the medium-scale DSGE models and assumes producer currency pricing (PCP) to facilitate a comparison with the literature. The principal actors in each country include a household, a production sector, a labor market, a financial intermediary, and fiscal and monetary authorities.

Asset markets are segmented: households save via one-period risk-free deposits, and firms (governments) finance their investment (purchases) via issuing long-term bonds. Financial intermediaries perform maturity transformation by taking in deposits and holding long-term bonds. They face a costly enforcement constraint that results in excess returns of long-term bonds over the risk-free rate. Firms face a loan-in-advance constraint that propagates the financial friction into the real economy. This structure provides a unified framework for studying conventional monetary policy that uses the short-term nominal interest rate to target domestic inflation and output and quantitative easing (QE) that relaxes intermediaries' enforcement constraint by purchasing long-term bonds.

The novelty of our paper lies in the case of financial integration, where financial intermediaries can hold not only domestic but also foreign long-term bonds. For comparison, the alternative case of financial autarky ensures all financial assets are held domestically, and thus, each economy features a balanced trade. To highlight the role of financial integration in monetary policy transmission, we compare these two cases and find financial integration amplifies the effects of an expansionary domestic monetary policy shock, and this amplification is larger for QE than conventional monetary policy. This result operates through two channels. The differences in output and consumption are primarily driven by a consumption switching channel, where an appreciation (depreciation) of terms of trade leads households to switch to foreign (home) produced goods. Moreover, financial integration stimulates investment through the financial channel, where the holdings of long-term bonds adjust quickly due to the open financial market.

Interestingly, financial integration has a negative spillover effect that turns an expansionary foreign monetary policy shock into a contraction. This effect works primarily through the consumption switching channel that dominates the demand augmenting channel, which is expansionary by nature. The negative spillover effect is not an artifact of our model of financial integration, rather it is a function of the assumed pricing method between PCP and local currency pricing (LCP): PCP is associated with a negative spillover, which disappears with LCP.

Further, we relate our findings to the empirical literature. First, the consensus in the empirical literature is that a US monetary expansion leads to an appreciation of foreign currencies. This result is consistent with our baseline case of PCP. Second, the empirical literature finds mixed signs of the spillover effect for both conventional and unconventional monetary policies. Our discussion contributes to the debate in the literature.

Next, we inspect some key aspects of financial integration. First, we find the duration of long-term bonds plays a major role. Specifically, a longer duration yields a stronger effect of monetary policy shock, regardless of the origin of the shock. The difference in consumption is mainly driven by the consumption switching channel, whereas the difference in investment is driven by the financial channel. Output is a combination of the two. Second, when the enforcement constraint is not binding, the effects of conventional monetary policy shock are qualitatively similar but quantitatively smaller. However, the financial friction is crucial for a QE shock. Without this constraint, QE does not have any effects. Finally, we argue the effects of financial integration are economically meaningful, and it is not possible to approximate our model with the standard setting of perfect risk sharing between households.

Finally, we study financial integration together with trade openness. Conditioning on a degree of trade openness, the output response to an expansionary domestic monetary policy shock is larger when the economy is more open financially. Similarly, conditioning on a degree of financial integration, the output response is larger when the real economy is more open. Next, we illustrate an important interaction between financial integration and trade openness. Although intuitively, higher degrees of trade openness and financial market openness together contribute to higher demand for home goods and higher inflation, this result is primarily driven by the degree of financial integration. Moreover, when we compare the importance of financial integration and trade openness in terms of monetary policy transmission, we find trade alone does not make an economically meaningful difference. These results highlight the importance of our new channel.

Related Literature Our paper builds on the vast literature on the New Open Economy Macroeconomics model, dating back to Obstfeld and Rogoff (1995). For surveys, see Engel (2014) and Corsetti et al. (2014). Our setup, especially related to the households, is closest to Benigno and Benigno (2003) and De Paoli (2009). Different from this literature, our model incorporates investment and an adjustment cost in producing new capital as in medium-scale (closed-economy) DSGE models. Further, we model asset market segmentation in terms of both maturity and origin.

Our financial markets are similar to Gertler and Karadi (2011, 2013), Sims and Wu (2021), and Sims et al. (2022).[1] These papers work with a closed economy. For a survey of

[1]Sims et al. (forthcoming) and Wu and Xie (2022) feature a similar financial sector but work with a

segmented markets in open economies, see Maggiori (2022). Different from the literature, our paper allows intermediaries to hold foreign bonds and enables us to study the role of international financial integration.

Our paper contributes to the literature that studies international monetary policy transmission and spillovers. Rey (2015), Han and Wei (2018), Kalemli-Özcan (2019), and Gopinath et al. (2020), among many others, investigate the transmission of conventional monetary policy, whereas Alpanda and Kabaca (2020) and Kolasa and Wesołowski (2020) focus on unconventional monetary policy. Different from the literature, we micro-found segmented financial markets, and more importantly, we emphasize the role of financial integration in shock transmissions.

Finally, our paper is also related to the literature that studies international risk sharing by allowing agents to hold foreign assets; see, for example, Corsetti et al. (2008), Bai and Zhang (2012), and Fanelli (2017). The literature focuses on households holding foreign deposits, whereas our model has a full-blown financial sector and intermediaries can hold foreign long-term bonds, which is motivated by empirical observations.

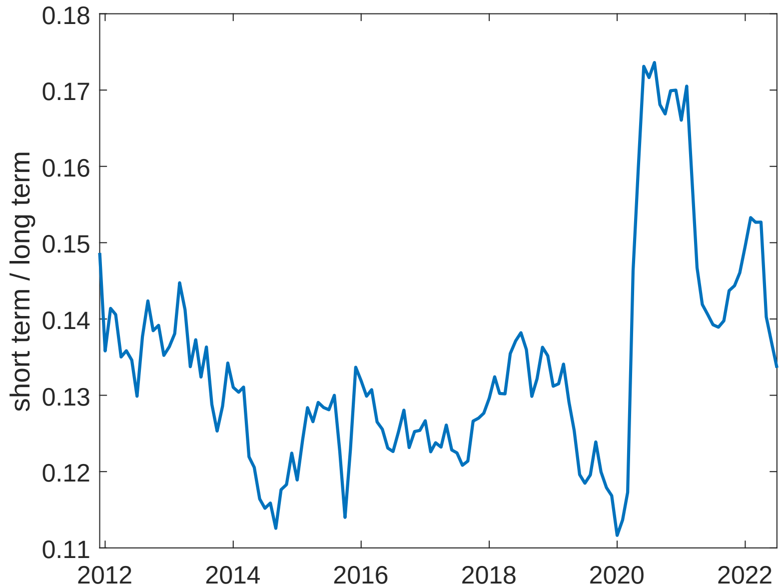
The rest of the paper proceeds as follows. Section 2 presents some empirical observations to motivate our model, which is described in Section 3. Section 4 compares impulse responses of monetary policy shocks under financial autarky and financial integration. Section 5 inspects the key aspects of our model and compare it with a standard model of household risk sharing. Section 6 compares financial integration with trade openness and studies their interaction. Finally, Section 7 concludes.

2 Empirical Motivation

In this section, we highlight two empirical observations regarding cross-country bond holdings to motivate our research question. First, we show among debt that is issued internationally or held by foreigners, the majority is long-term debt. This observation calls for a model

small-scale model.

Figure 1: **Maturity Breakdown of Foreign Holdings of U.S. Treasury Securities**



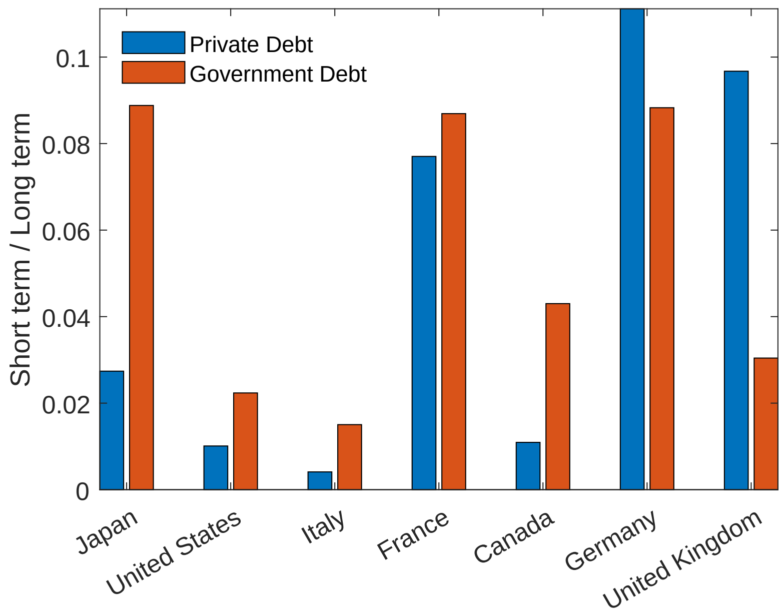
Notes: This figure shows the ratio of short-term versus long-term foreign holdings of U.S. Treasury Securities. Short-term securities include Treasury bills, whereas long-term securities include Treasury bonds and notes. All data are in face value. Data source: the Treasury International Capital System, available at https://home.treasury.gov/data/treasury-international-capital-tic-system-home-page/tic-forms-instructions/securities-b-portfolio-holdings-of-us-and-foreign-securities.

that allows cross-holdings of long-term bonds and motivates our modeling choice. Second, we show the fraction of debt that is issued internationally exhibits a wide range among both developed and developing economies. Together with our model implication that financial integration alters how monetary policy shocks transmit both domestically and cross borders, this observation has important policy implications on capital flow intervention.

Short-Term vs. Long-Term Debt The theoretical literature discusses capital flow and financial integration by primarily focusing on short-term debt. For example, see Farhi and Werning (2012, 2014), Gabaix and Maggiori (2015), Amador et al. (2020), and Fanelli and Straub (2021), who feature financial constrained intermediaries or incomplete international financial markets and study their consequences on exchange rate and capital flow fluctuations.

However, data highlight the importance of long-term instead of short-term bonds for

Figure 2: **Maturity Breakdown of Internationally Issued Debt Securities across Countries**



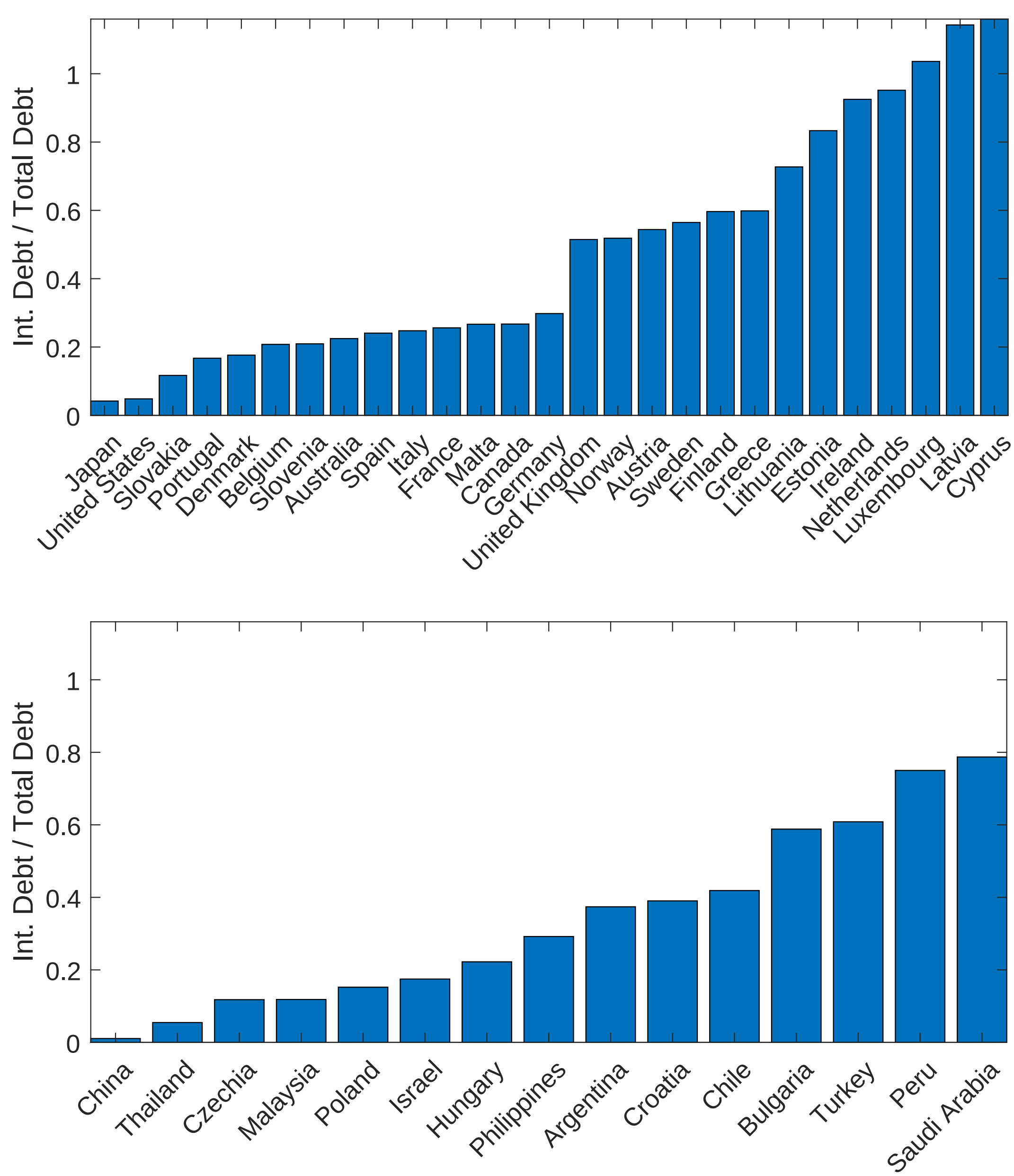
Notes: This figure shows the ratio of short-term versus long-term internationally issued debt securities for G7 countries in 2022Q1. The numbers shown are based on securities issued outside the local market of the country in which the borrower resides. Blue bars represent private debt, while red bars represent government debt. Data source: the Bank for International Settlements (BIS) debt securities statistics, available at `https://stats.bis.org/statx/toc/SEC.html` (Table C3).

this purpose. Figure 1 visualizes the maturity breakdown of foreign holdings of outstanding U.S. Treasury Securities. Specifically, we plot the ratio between short-term and long-term securities. The sample covers the last decade. The ratio ranges from 11% to 17%; that is, foreign holdings are predominantly long-term bonds.

Figure 2 further provides evidence in the G7 countries by showing the maturity structure of debt securities that are issued internationally. Similar to Figure 1, we plot the ratio of outstanding short-term to long-term international debt. Blue bars are private debt, and red bars are government debt. They range from 0% to 11%.

Both figures point to the fact that cross-country holdings of debt securities are predominantly long term in nature. This finding contradicts the modeling assumption in existing theoretical work and calls for a model that can accommodate cross-country holdings of long-term bonds. We propose such a model in Section 3.

Figure 3: **Fraction of Internationally Issued Debt Securities**



Notes: This figure plots the fraction of debt securities that are issued internationally for developed and developing countries in 2022Q1. The top panel plots developed countries, and the bottom panel shows developing countries. The numbers shown are based on securities issued outside the local market of the country in which the borrower resides. Data source: the BIS debt securities statistics, available at `https://stats.bis.org/statx/toc/SEC.html` (Table C1).

Variations in Cross-Country Bond Holdings Figure 3 plots the fraction of debt securities that are issued internationally across countries in 2022Q1. The top panel plots developed countries, and the bottom panel shows developing countries. Figure 3 suggests both developed countries and developing countries exhibit a wide range for this fraction, implying significant heterogeneity in cross-country bond holdings.[2]

3 Model

In this section, we build a two-country open-economy New Keynesian model with a financial market that could potentially be integrated internationally. The world economy is populated with a continuum of agents of unit mass that belong to two countries. The principal actors in each country include a representative household, a labor market, a production sector, a financial intermediary, and fiscal and monetary authorities.

The backbone is a two-country open-economy New Keynesian model, similar to Benigno and Benigno (2003), De Paoli (2009), and Corsetti et al. (2014). Each country is specialized in a representative final good that is a composite of differentiated tradable goods. Firms face monopolistic competition and nominal rigidity in the form of Calvo (1983). They set prices in domestic currency or PCP. Households supply labor to domestic production and consume both domestically produced goods and imported goods. Different from the above-mentioned references in the international literature, we also introduce some standard features from closed-economy medium-scale DSGE models (e.g., Christiano et al., 2005; Smets and Wouters, 2007), which include investment, an adjustment cost that occurs when transforming output into new capital, and wage rigidity in the labor market.

Financial markets are similar to Gertler and Karadi (2011) and Sims and Wu (2021), in which the asset markets are segmented: households save via one-period riskless deposits, and the wholesale firms borrow via issuing long-term bonds to finance their investment. The financial intermediaries perform maturity transformation by taking in deposits and holding long-term bonds. The financial intermediaries face a costly enforcement constraint, which

[2]For some countries, the fraction is larger than one, because the numerators and denominators are collected from two separate data sources when the BIS constructs the statistics table.

results in excess returns of long-term assets over short-term bonds. The wholesale firms face a loan-in-advance constraint, which propagates financial frictions into the real economy.

Unique in our paper, the financial intermediaries can hold not only domestic but also foreign bonds, which allows us to study the role of financial integration. We consider two alternative scenarios: financial autarky and financial integration. For the former, all financial assets are held domestically, and thus, each economy features a balanced trade. In the latter case, intermediaries could hold both domestic and foreign-issued long-term bonds. For both cases, short-term bonds (i.e., deposits) cannot be traded internationally. For comparison, we also consider the case in which households can share risk perfectly; see more detailed discussion in Section 5.3.

Notations For the most part, we only describe the home economy. The foreign country is symmetric and we denote it with an asterisk *. Households consume goods produced in both countries; we use H to denote home production and F for foreign goods. Similarly, financial intermediaries can hold long-term bonds issued by both H and F countries.

3.1 Household

3.1.1 Consumption Composites and Price Indices

A representative household in the home country consumes C_t, which is a composite of the home-produced good $C_{H,t}$ and foreign-produced good $C_{F,t}$:

$$C_t \equiv \left[\nu^{\frac{1}{\vartheta}} C_{H,t}^{\frac{\vartheta-1}{\vartheta}} + (1-\nu)^{\frac{1}{\vartheta}} C_{F,t}^{\frac{\vartheta-1}{\vartheta}}\right]^{\frac{\vartheta}{\vartheta-1}}, \tag{3.1}$$

where ϑ is the elasticity of substitution between the two goods. $\nu = 1-(1-\gamma)\upsilon$ captures the household's preference for home goods, where $\gamma \in [0,1]$ measures the population size of the home country and $\upsilon \in [0,1]$ measures the degree of trade openness as in De Paoli (2009). The foreign country shares a similar preference as in (3.1), with a population size $1-\gamma$ and

$\nu^* = \gamma\upsilon$. When $\upsilon = 1$, no home bias exists as in Benigno and Benigno (2003), and $\upsilon < 1$ generates a bias toward home goods. When $\upsilon = 0$, the system reduces to a closed economy.

The home and foreign final goods are further composites of differentiated goods indexed by h and f, respectively:

$$C_{H,t} = \left[\left(\frac{1}{\gamma}\right)^{\frac{1}{\epsilon_p}} \int_0^\gamma C_t(h)^{\frac{\epsilon_p-1}{\epsilon_p}} dh\right]^{\frac{\epsilon_p}{\epsilon_p-1}}, \qquad C_{F,t} = \left[\left(\frac{1}{1-\gamma}\right)^{\frac{1}{\epsilon_p}} \int_\gamma^1 C_t(f)^{\frac{\epsilon_p-1}{\epsilon_p}} df\right]^{\frac{\epsilon_p}{\epsilon_p-1}},$$

where ϵ_p is the elasticity of substitution across goods produced within a country.

The household's cost-minimization problems imply the following demand functions:

$$C_{H,t} = \nu \left(\frac{P_{H,t}}{P_t}\right)^{-\vartheta} C_t, \tag{3.2}$$

$$C_{F,t} = (1-\nu) \left(\frac{P_{F,t}}{P_t}\right)^{-\vartheta} C_t, \tag{3.3}$$

$$C_{H,t}(h) = \frac{1}{\gamma} \left(\frac{P_t(h)}{P_{H,t}}\right)^{-\epsilon_p} C_{H,t}, \tag{3.4}$$

$$C_{F,t}(f) = \frac{1}{1-\gamma} \left(\frac{P_t(f)}{P_{F,t}}\right)^{-\epsilon_p} C_{F,t}. \tag{3.5}$$

The consumer price index (CPI) in the home country P_t is given by

$$P_t = \left[\nu P_{H,t}^{1-\vartheta} + (1-\nu) P_{F,t}^{1-\vartheta}\right]^{\frac{1}{1-\vartheta}}, \tag{3.6}$$

where $P_{H,t}$ and $P_{F,t}$ are producer price indexes (PPI) of home- and foreign-produced composites in the home-country currency, which are further aggregated as follows:

$$P_{H,t} = \left[\left(\frac{1}{\gamma}\right) \int_0^\gamma P_t(h)^{1-\epsilon_p} dh\right]^{\frac{1}{1-\epsilon_p}}, \qquad P_{F,t} = \left[\left(\frac{1}{1-\gamma}\right) \int_\gamma^1 P_t(f)^{1-\epsilon_p} df\right]^{\frac{1}{1-\epsilon_p}},$$

where $P(h)$ and $P(f)$ are prices of differentiated home and foreign goods.

3.1.2 Exchange Rates and Terms of Trade

We assume the law of one price holds for individual differentiated goods; that is, $P_t(h) = \mathcal{E}_t P_t^*(h)$ and $P_t(f) = \mathcal{E}_t P_t^*(f)$, where $\mathcal{E}_t$ is the nominal exchange rate measured by the price of one unit of foreign currency in the domestic currency. The law of one price further implies

$$P_{H,t} = \mathcal{E}_t P_{H,t}^*, \quad P_{F,t} = \mathcal{E}_t P_{F,t}^*. \tag{3.7}$$

When home bias exists, $\upsilon < 1$, the purchasing power parity does not hold; that is, $P_t \neq \mathcal{E}_t P_t^*$. In this case, we define the real exchange rate as

$$\mathcal{Q}_t \equiv \mathcal{E}_t P_t^* / P_t \tag{3.8}$$

and the terms of trade as

$$\mathcal{T}_t \equiv P_{F,t} / P_{H,t}. \tag{3.9}$$

3.1.3 Optimization Problem

The household receives utility from consumption C_t and disutility from labor supply L_t. It maximizes its lifetime utility given by

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left[\frac{(C_{t+j} - bC_{t+j-1})^{1-\zeta} - 1}{1-\zeta} - \chi \frac{L_{t+j}^{1+\eta}}{1+\eta} \right], \tag{3.10}$$

where $\beta < 1$ is the subjective discount factor, $b < 1$ is a measure of internal habit formation, $\zeta > 0$ is the inverse of elasticity of intertemporal substitution, $\eta \geq 0$ is the inverse of Frisch elasticity of labor supply, and $\chi > 0$ is a scaling parameter.

The household's budget constraint is

$$P_t C_t + D_t \leq MRS_t L_t + R_{t-1}^d D_{t-1} + DIV_t - P_t X - P_t T_t, \tag{3.11}$$

where D_t is one-period deposits, and R_t^d is the associated nominal interest rate from t to $t+1$. The household earns MRS_t from supplying labor, receives nominal dividends DIV_t from the domestic intermediary and firms, makes a real transfer X to the financial intermediary, and pays a lump-sum tax T_t in real terms to the home government.

The first-order conditions are

$$\mu_t = (C_t - bC_{t-1})^{-\zeta} - b\beta\mathbb{E}_t(C_{t+1} - bC_t)^{-\zeta}, \tag{3.12}$$

$$\Lambda_{t,t+1} = \beta\frac{\mu_{t+1}}{\mu_t}, \tag{3.13}$$

$$1 = R_t^d\mathbb{E}_t(\Lambda_{t,t+1}\Pi_{t+1}^{-1}), \tag{3.14}$$

$$\chi L_t^\eta = \mu_t MRS_t, \tag{3.15}$$

where $\Lambda_{t,t+1}$ is the real stochastic discount factor of the household, μ_t is the Lagrange multiplier on the household's budget constraint, and $\Pi_t \equiv P_t/P_{t-1}$ is the CPI inflation.

3.2 Financial Market

3.2.1 Long-Term Bonds

The intermediate firm and government issue long-term bonds. We structure long-term bonds as perpetuities, following Woodford (2001). One unit of bonds delivers a coupon payment of one unit of the domestic currency next period, and the coupon payments decay at the rate of $\kappa \in (0,1)$ afterwards. The total coupon liability due at time t is B_{t-1}, which is known at $t-1$. We can express the new issue at time t as $B_t - \kappa B_{t-1}$.

Let Q_t denote the price of a new issue in domestic currency, and then, $\kappa^j Q_t$ is the time t price of the bonds that are issued in period $t-j$. Purchasing bonds at time $t-1$ and selling them at t yields the return of

$$R_t = \frac{1+\kappa Q_t}{Q_{t-1}}. \tag{3.16}$$

3.2.2 The Case of Financial Integration

One key innovation of our model is an internationally integrated financial market in which the financial intermediary can hold both home- and foreign-issued bonds. The representative financial intermediary finances itself with its net worth N_t and the domestic household's deposits D_t. It can hold domestic and foreign long-term bonds, as well as reserves issued by the domestic central bank RE_t. The balance-sheet condition is

$$Q_t^P B_{H,t}^{P,FI} + Q_t^G B_{H,t}^{G,FI} + Q_t^{P*} B_{F,t}^{P,FI} \mathcal{E}_t + Q_t^{G*} B_{F,t}^{G,FI} \mathcal{E}_t + RE_t = D_t + N_t, \tag{3.17}$$

where $B_{H,t}^{P,FI}$ and $B_{H,t}^{G,FI}$ are their holdings of home-issued private and government bonds. $B_{F,t}^{P,FI}$ and $B_{F,t}^{G,FI}$ are their holdings of foreign bonds. Q_t^P, Q_t^G, Q_t^{P*}, and Q_t^{G*} are their corresponding prices. Bonds are denominated in the currency of their issuing country.

Entering period t, the financial intermediary's beginning balance is

$$\begin{aligned}
\mathcal{B}_t = & \left(R_t^P - R_{t-1}^d\right) Q_{t-1}^P B_{H,t-1}^{P,FI} + \left(R_t^G - R_{t-1}^d\right) Q_{t-1}^G B_{H,t-1}^{G,FI} \\
& + \left(R_t^{P*} \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} \left[1 - \omega/2 (b_{F,t-1}^{P,FI}/b_F^{P,FI} - 1)^2\right] - R_{t-1}^d\right) Q_{t-1}^{P*} B_{F,t-1}^{P,FI} \mathcal{E}_{t-1} \\
& + \left(R_t^{G*} \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} \left[1 - \omega/2 (b_{F,t-1}^{G,FI}/b_F^{G,FI} - 1)^2\right] - R_{t-1}^d\right) Q_{t-1}^{G*} B_{F,t-1}^{G,FI} \mathcal{E}_{t-1} \\
& + \left(R_{t-1}^{re} - R_{t-1}^d\right) RE_{t-1} + R_{t-1}^d N_{t-1},
\end{aligned} \tag{3.18}$$

where R_t^P, R_t^G, R_t^{P*}, and R_t^{G*} are the holding-period returns of long-term bonds and related to Q_t^P, Q_t^G, Q_t^{P*}, and Q_t^{G*} according to (3.16). R_{t-1}^{re} is the nominal interest rate on central bank reserves, or the monetary policy rate.

The two terms in the first row are excess returns of holding domestic private bonds and government bonds relative to the cost of funding via deposits. Similarly, the second and third rows capture the excess returns of holding foreign assets. The quadratic terms in the square brackets are foreign transaction costs charged by the government, where ω controls the degree of financial openness with a smaller value corresponding to a more open international financial market. $b_{F,t}^{P,FI} \equiv B_{F,t}^{P,FI}/P_t^*$ and $b_{F,t}^{G,FI} \equiv B_{F,t}^{G,FI}/P_t^*$ are the real holdings, and $b_F^{P,FI}$ and $b_F^{G,FI}$ are the corresponding steady-state values. In the last row, the first term captures the excess return of holding reserves. The last term measures the saving from financing with the financial intermediary's own net worth as opposed to deposits.

Each period, the financial intermediary pays out a $1-\sigma$ fraction of its beginning balance as dividends to the household and receives a new liquidity injection of X in real terms from the household. Therefore, the net worth is

$$N_t = \sigma \mathscr{B}_t + P_t X. \tag{3.19}$$

An intermediary maximizes the present discounted value of its future dividends on behalf of their household owner:

$$V_t = \max\ (1-\sigma)\mathbb{E}_t \sum_{j=1}^{\infty} \Lambda_{t,t+j} \mathscr{b}_{t+j}, \tag{3.20}$$

where $\mathscr{b}_t \equiv \mathscr{B}_t/P_t$ is the real beginning balance and $(1-\sigma)\mathscr{b}_t$ is the real dividend payment.

The financial intermediary faces a costly enforcement constraint such that it finds continuing rather than filing for bankruptcy optimal:

$$V_t \geq \theta \left\{ \left[Q_t^P b_{H,t}^{P,FI} + \Delta Q_t^G b_{H,t}^{G,FI} \right] + \left[Q_t^{P*} b_{F,t}^{P,FI} + \Delta Q_{B,t}^{G*} b_{F,t}^{G,FI} \right] \mathcal{Q}_t \right\}, \tag{3.21}$$

where θ is the fraction of private bonds, domestic or foreign, the intermediary can keep if it chooses to file for bankruptcy. The fraction for the government bonds is $\theta\Delta$, where $0 \leq \Delta \leq 1$. Reserves, on the other hand, are fully recoverable by the depositors. With this constraint, no bankruptcy occurs in the equilibrium.

The financial intermediary maximizes its objective function in (3.20) subject to the constraint in (3.21), and the first-order conditions are

$$\frac{\lambda_t}{1+\lambda_t}\theta = \mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\left(R_{t+1}^P - R_t^d\right) \tag{3.22}$$

$$\frac{\lambda_t}{1+\lambda_t}\theta\Delta = \mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\left(R_{t+1}^G - R_t^d\right) \tag{3.23}$$

$$\begin{aligned}\frac{\lambda_t}{1+\lambda_t}\theta &= \mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\Big\{R_{t+1}^{P*}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}\times \\ &\quad \left[1-\frac{1}{2}\omega(b_{F,t}^{P,FI}/b_F^{P,FI}-1)(3b_{F,t}^{P,FI}/b_F^{P,FI}-1)\right]-R_t^d\Big\}\end{aligned} \tag{3.24}$$

$$\begin{aligned}\frac{\lambda_t}{1+\lambda_t}\theta\Delta &= \mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\Big\{R_{t+1}^{G*}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \\ &\quad \left[1-\frac{1}{2}\omega(b_{F,t}^{G,FI}/b_F^{G,FI}-1)(3b_{F,t}^{G,FI}/b_F^{G,FI}-1)\right]-R_t^d\Big\}\end{aligned} \tag{3.25}$$

$$0 = \mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\left(R_t^{re} - R_t^d\right), \tag{3.26}$$

where λ_t is the Lagrangian multiplier on the constraint. Derivations and the expression of the auxiliary variable Ω_{t+1} can be found in Appendix A.2.

Equations (3.22) - (3.23) state that when the constraint binds, $\lambda_t > 0$, longing the long-term bonds and shorting the deposits yields an excess return, and the excess return is larger for holding private bonds than government bonds. Equations (3.24) - (3.25) are similar conditions for holding foreign long-term bonds that incorporate the exchange rate and foreign transaction costs.

Empirically, the slope of the yield curve has almost always been positive. To account for a positive slope in the steady state, we assume the enforcement constraint always binds.[3] Although structured with a representative intermediary, the intermediary's problem is similar to Gertler and Karadi (2011) and Sims and Wu (2021) for a closed economy.

[3]In a model with the enforcement constraint only binding occasionally, the slope of the yield curve is zero in the steady state.

3.2.3 The Case of Financial Autarky

In the case of financial autarky, the financial intermediary can only hold long-term bonds issued by firms or the government in its own countries. Therefore, the first-order conditions in (3.24) - (3.25) are replaced with

$$B_{F,t}^{P,FI} = 0, \tag{3.27}$$

$$B_{F,t}^{G,FI} = 0. \tag{3.28}$$

3.3 Production

Production features four stages: (i) A representative capital producer transforms domestically produced composite final good I_t into new physical capital $\widehat{I_t}$ subject to a convex adjustment cost; (ii) a representative wholesale firm produces an intermediate good $Y_{w,t}$ using capital and labor and faces a loan-in-advance constraint; (iii) a continuum of retail firms repackage the intermediate good into differentiated goods $Y_t(h)$ and set prices using PCP while facing monopolistic competition and price stickiness; and (iv) a representative final-good producer aggregates differentiated goods into final output Y_t in a process outlined in Section 3.1.1.

A continuum of labor unions repackage labor from the household and sell it to a representative labor packer that aggregates differentiated labor into final labor supply $L_{d,t}$. Labor unions face wage stickiness. We only discuss the wholesale firm in the main text and leave other parts to Appendix A.3 - Appendix A.4.

3.3.1 Wholesale Firm

The representative wholesale firm produces an intermediate output according to a Cobb-Douglas function:

$$Y_{w,t} = A_t(u_t K_t)^{\alpha} L_{d,t}^{1-\alpha}, \tag{3.29}$$

where $Y_{w,t}$ is the intermediate output, A_t represents productivity, K_t and $L_{d,t}$ are capital and labor inputs, and u_t captures capital utilization. $0 < \alpha < 1$ measures the capital share in intermediate-good production.

Capital accumulation follows

$$K_{t+1} = \widehat{I}_t + (1 - \delta(u_t))K_t, \tag{3.30}$$

where $\widehat{I}_t$ is the new physical capital purchased from the capital producer, and $\delta(u_t)$ maps utilization into depreciation.

The wholesale firm faces a loan-in-advance constraint: it must issue long-term bonds to finance a fraction $\psi \in (0, 1]$ of its investment; that is,

$$\psi P_t^k \widehat{I}_t \leq Q_t^P \left(B_t^P - \kappa B_{t-1}^P\right), \tag{3.31}$$

where P_t^k is the price of new physical capital and $B_t^P - \kappa B_{t-1}^P$ is the nominal bonds issued by the firm. This condition is crucial in terms of transmitting financial frictions to the real economy.

The wholesale firm maximizes the present discounted value of real dividends over K_t, $L_{d,t}$, and u_t, subject to the loan-in-advance constraint. For details, see Appendix A.3.2.

3.4 Monetary and Fiscal Authorities

The central bank implements a standard Taylor (1993) rule whereby the short-term nominal policy rate targets domestic PPI inflation $\Pi_{H,t}$ and output fluctuation:

$$\begin{aligned} \ln R_t^{re} - \ln R^{re} = {} & \rho_r \left[\ln R_{t-1}^{re} - \ln R^{re}\right] + (1 - \rho_r) \left[\phi_\pi \left(\ln \Pi_{H,t} - \ln \Pi_H\right) + \phi_y \left(\ln Y_t - \ln Y_{t-1}\right)\right] \\ & + s_r \varepsilon_t^r, \end{aligned} \tag{3.32}$$

where variables without the t subscript are steady-state values. R_t^{re} is the policy rate. $0 < \rho_r < 1$ measures the inertia of nominal interest rate adjustment. $\phi_\pi > 1$ and $\phi_y > 0$ characterize the response of the nominal interest rate to domestic inflation and output. ε_t^r is the monetary policy shock, with s_r denoting its standard deviation.

The central bank implements QE by changing its real holdings of long-term domestic bonds, which we model as exogenous processes:

$$
\begin{aligned}
b_t^{P,CB} - b^{P,CB} &= \rho_P \left(b_{t-1}^{P,CB} - b^{P,CB} \right) + s_P \varepsilon_t^{P,CB}, & (3.33) \\
b_t^{G,CB} - b^{G,CB} &= \rho_G \left(b_{t-1}^{G,CB} - b^{G,CB} \right) + s_G \varepsilon_t^{G,CB}, & (3.34)
\end{aligned}
$$

where $b_t^{P,CB} \equiv B_t^{P,CB}/P_t$ and $b_t^{G,CB} \equiv B_t^{G,CB}/P_t$. $0 < \rho_P, \rho_G < 1$ are autoregressive coefficients, $\varepsilon_t^{P,CB}$ and $\varepsilon_t^{G,CB}$ are QE shocks, and s_P and s_G are their corresponding standard deviations.

The central bank issues reserves to finance its QE operations, and its balance-sheet condition is

$$Q_t^P B_t^{P,CB} + Q_t^G B_t^{G,CB} = RE_t. \tag{3.35}$$

The central bank makes a profit T_t^{CB} via its QE operation and returns it to the fiscal authority through a lump-sum transfer.

The government's budget constraint is as follows:

$$
\begin{aligned}
P_t G_t + P_{t-1} b^G \;=\;& P_t T_t + P_t T_t^{CB} + Q_t^G P_t b_G \left(1 - \kappa \Pi_t^{-1}\right) \\
&+ R_t^{P*} \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} \omega/2 (b_{F,t-1}^{P,FI}/b_F^{P,FI} - 1)^2 Q_{t-1}^{P*} B_{F,t-1}^{P,FI} \mathcal{E}_{t-1} \\
&+ R_t^{G*} \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} \omega/2 (b_{F,t-1}^{G,FI}/b_F^{G,FI} - 1)^2 Q_{t-1}^{G*} B_{F,t-1}^{G,FI} \mathcal{E}_{t-1}, \qquad (3.36)
\end{aligned}
$$

where G_t is the government's real expenditures, and $P_{t-1} b^G$ is the coupon payments to past issues. For the sake of parsimony, we assume the long-term public bond supply from the government is fixed; that is, b^G is exogenous and time-invariant.

The government finances its spending by levying a tax T_t on the household, receiving the central bank's profit remittance T_t^{CB}, issuing long-term bonds (the last term in the first row), and imposing foreign transaction fees on the intermediary (the last two rows). The government adjusts lump-sum taxes on the household to keep its budget constraint (3.36) always balanced. For more details, see Appendix A.5.

3.5 Market-Clearing Conditions

The goods-market clearing yields

$$Y_t = C_{H,t} + C^*_{H,t} + I_t + G_t \tag{3.37}$$

for the home production, and

$$Y^*_t = C^*_{F,t} + C_{F,t} + I^*_t + G^*_t \tag{3.38}$$

for foreign goods. Here we assume the capital producer and government in the home (foreign) country only take the home (foreign) final good for investment and government spending. The derivation for goods-market-clearing conditions can be found in Appendix A.

The market-clearing conditions for private and public long-term bonds issued in the home country are

$$b_t^P = b_{H,t}^{P,FI} + \frac{1-\gamma}{\gamma} b_{H,t}^{P,FI*} + b_t^{P,CB}, \tag{3.39}$$

$$b_t^G = b_{H,t}^{G,FI} + \frac{1-\gamma}{\gamma} b_{H,t}^{G,FI*} + b_t^{G,CB}. \tag{3.40}$$

For the foreign-issued bonds, we have

$$b_t^{P*} = b_{F,t}^{P,FI*} + \frac{\gamma}{1-\gamma} b_{F,t}^{P,FI} + b_t^{P,CB*}, \tag{3.41}$$

$$b_t^{G*} = b_{F,t}^{G,FI*} + \frac{\gamma}{1-\gamma} b_{F,t}^{G,FI} + b_t^{G,CB*}. \tag{3.42}$$

Table 1: **Calibrated Parameters**

Parameters	Value / Target	Description
ϑ	3	Elasticity of substitution between home and foreign goods
υ	0.5	Degree of openness
ζ	1	Inverse of intertemporal elasticity of substitution
γ	0.5	Population size of home country
ω	0.1	Foreign transaction costs
$b_H^{P,FI}/b_H^{P,FI*}$	4	Home private bonds held by home vs. foreign intermediary
$b_H^{G,FI}/b_H^{G,FI*}$	4	Home Treasuries held by home vs. foreign intermediary

4 Financial Integration and Monetary Policy

In this section, we quantitatively investigate the role financial integration plays in how monetary policy shocks transmit in an open economy. We compare the case of financial integration with financial autarky and study shocks to both conventional interest rate policy and QE.

4.1 Model Parameters

We calibrate the model at the quarterly frequency. Table 1 reports the calibrated parameters along the open economy dimension. For the parameters that govern household preferences, we follow De Paoli (2009) and De Paoli and Lipinska (2013): the elasticity of substitution between home- and foreign-produced goods ϑ is 3; υ measures the degree of trade openness and is set to 0.5. We also set the inverse of intertemporal elasticity of substitution ζ to one, following Galí and Monacelli (2005). We assume the two countries share the same size, or $\gamma = 0.5$. With υ less than one, this calibration features a home bias of household consumption, with a share of domestic sourcing for final consumption being 0.75.

For the case of financial integration, the international financial market is (almost) completely open with $\omega = 0.1$.[4] The quantity of home-issued bonds held by the home financial intermediary is assumed to be four times that held by the foreign intermediary, and the ratio is the same for both private and government bonds. This number matches the fact that

[4] A non-zero ω ensures invertibility. We set $\omega = 0.1$ to stay close to the "symmetric" benchmark.

20% of U.S. total federal debt is held by foreign and international investors from 1970 until now, on average. The remaining parameters are calibrated following the literature on closed economy macroeconomics, and we discuss them in Appendix C. Foreign parameters take the same values as their home counterparts.

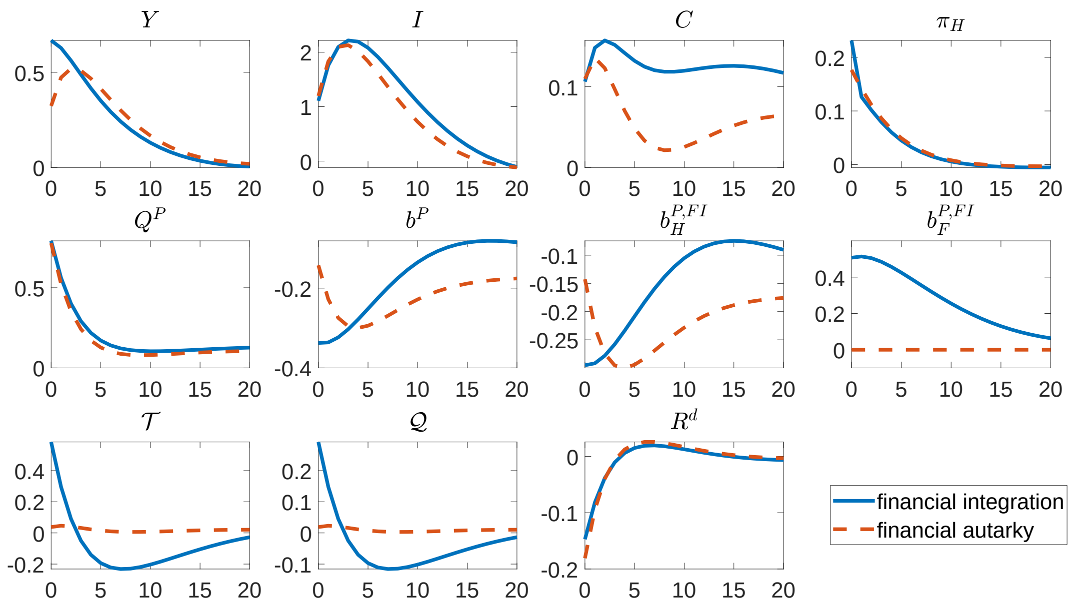
4.2 Conventional Monetary Policy

This section investigates the transmission of conventional monetary policy that adjusts the short-term nominal interest rate. Figure 4 plots impulse responses of home variables to a 25-basis-point expansionary monetary policy shock at home. The first rows are aggregate variables: output, investment, consumption, and PPI inflation. The second rows are financial variables: the price of domestically issued private bonds, the quantities of total domestic private bonds, those domestic private bonds held by the domestic financial intermediary, and its holdings of foreign private bonds. The last rows are the terms of trade, the real exchange rate, and the deposit rate, which is the same as the policy rate in equilibrium.

Output, investment, consumption, and PPI inflation all increase in the home country in response to an expansionary monetary shock. The real exchange rate $\mathcal{Q}$ depreciates initially, and the terms of trade $\mathcal{T}$ depreciates twice as much. These responses are standard in the literature; see, for instance, Casas et al. (2017). For the financial market, a lower interest rate implies a higher stochastic discount factor per (3.14), which increases the continuing value of a financial intermediary (see equation (3.20)) and relaxes its enforcement constraint (3.21). Consequently, the financial intermediary increases its demand for long-term bonds, which drives up bond prices. To finance the same amount of investment with higher bond prices, the wholesale firm needs to issue fewer bonds. On the other hand, higher investment puts pressure on issuing more bonds. On net, with our calibration, bond issuance drops slightly. This mechanism is similar to Gertler and Karadi (2011) and Sims and Wu (2021), who focus on a closed economy.

Next, we tackle the key question by comparing financial integration (blue solid lines) with

Figure 4: **Impulse Responses to a Home Monetary Policy Shock**

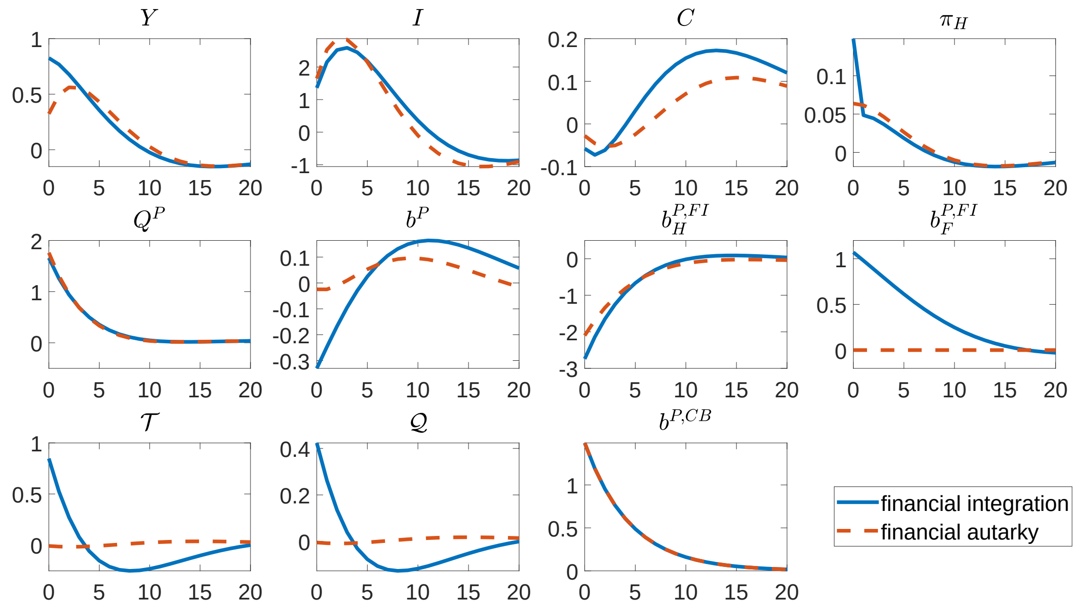


Notes: The figure plots the home-country responses to a 25 bp expansionary monetary policy shock at home. The blue solid and red dashed lines correspond to financial integration and financial autarky, respectively. The x-axis is time, and the y-axis is the percentage change from the steady state. The variables are output, investment, consumption, PPI inflation, the price of private bonds, the quantity of total private bonds, the quantity of domestic private bonds that are held by the domestic financial intermediary, the quantity of foreign private bonds that are held by the domestic financial intermediary, terms of trade, the real exchange rate, and the deposit rate.

financial autarky (red dashed lines). Figure 4 shows financial integration amplifies the effects of an expansionary domestic monetary policy shock. When the financial intermediary can hold foreign bonds, output, investment, consumption, and domestic PPI inflation all increase more. Financial integration affects the economy through the terms of trade and through the financial market. The differences in output and consumption are primarily driven by larger fluctuations in the terms of trade in the case of financial integration, and we denote this channel as the *consumption switching channel*. The initial increase in the terms of trade makes foreign goods less competitive and increases demand for home production. However, the subsequent appreciation of the terms of trade leads households to consume more foreign goods, and thus, consumption remains persistently high when domestic output drops.

Financial integration promotes more investment through the *financial channel*, which works as follows: although the total amount of home-issued private bonds decreases under

Figure 5: **Impulse Responses to a Home QE shock**



Notes: The figure plots the home-country responses to a home QE shock, respectively. The shock is scaled such that the initial response of home output to the home shock under financial autarky is similar to a 25 bp cut in the policy rate. The blue solid and red dashed lines correspond to financial integration and financial autarky, respectively. The x-axis is time, and the y-axis is the percentage change from the steady state. The variables are the same as in Figure 4 except for the exogenous shock to the home central bank's private bond holdings $b^{P,CB}$.

both financial integration and financial autarky due to higher bond prices, the adjustment is instant in the first case because the financial intermediary can substitute home bonds with relatively cheaper foreign bonds. In subsequent periods, when the domestic bond price drops, an open financial market also allows the amount of private bonds to rise at a faster pace, which then translates into more investment. Compared with the financial channel, the consumption switching channel through the terms of trade is more prominent.

4.3 QE

We now turn to the transmission of QE shocks, which is implemented by varying the central bank's holdings of domestic long-term private bonds.[5] Figure 5 is structured similarly to Figure 4. The QE shock is scaled such that the initial response of home output to a home

[5]The results are similar when the QE shocks are on the central bank's holdings of domestic long-term public bonds.

shock under financial autarky is the same as the response to a 25-basis-point cut in the policy rate; or the initial point of the red dashed lines in the (1,1) panel are the same in the two figures.

Figure 5 shares many similar patterns with Figure 4, with two key differences. First, financial integration amplifies a domestic QE shock more than a conventional monetary policy shock. Whereas the amplification factor on the initial response of output is 1.5 for monetary policy, it is 2 for QE. This result is intuitive because both QE and financial integration work through the long-term bonds. Second, for investment and consumption, the initial differences are more visible than those in Figure 4. This finding is again driven by the long-term bond market. Given that the differences between QE and conventional monetary policy are mostly quantitative rather than qualitative, we focus primarily on conventional monetary policy hereafter.

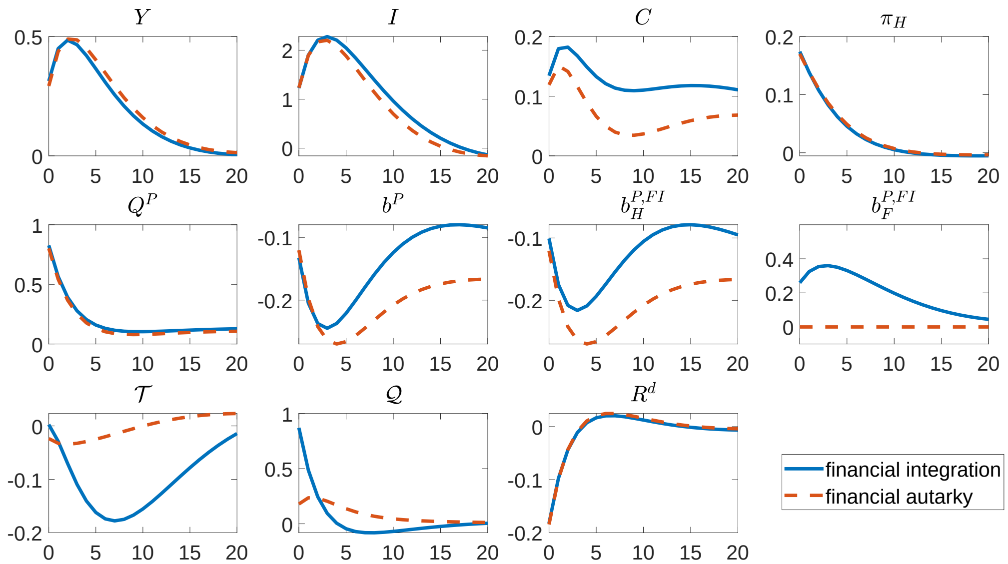
4.4 Local Currency Pricing

Our baseline model assumes PCP. A popular alternative is local currency pricing (LCP). For model details, see Appendix D. Figure 6 plots the impulse responses to a domestic conventional monetary policy shock under LCP. Comparing Figure 6 with Figure 4, the main difference appears in the initial sign of the terms of trade: if we compare the blue lines in the two cases, we find the terms of trade depreciates initially with PCP, but it barely moves with LCP. This result is consistent with findings in the literature; see, for example, Gopinath et al. (2020). Consequently, LCP weakens how much financial integration amplifies domestic monetary policy shock initially, although this result, together with other comparisons between the red lines and blue lines, is still qualitatively robust.

4.5 International Spillover

We inspect the spillover effects from a foreign shock in Figure 7. Panel (a) shows how home variables respond to an expansionary foreign monetary policy shock, and is structured sim-

Figure 6: **Impulse Responses to a Home Monetary Policy Shock - LCP**



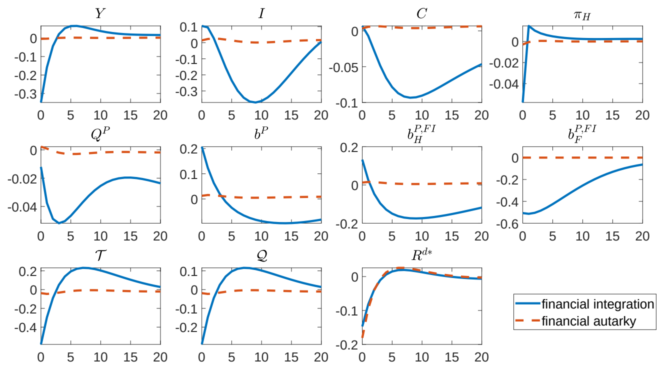
Notes: This figure shows the impulse responses to a 25 bp expansionary monetary policy shock in the home country under LCP. The blue solid and red dashed lines correspond to financial integration and financial autarky, respectively. The x-axis is time, and the y-axis is the percentage change from the steady state. The variables are output, investment, consumption, PPI inflation, the price of private bonds, the quantity of total private bonds, the quantity of domestic private bonds that are held by the domestic financial intermediary, the quantity of foreign private bonds that are held by the domestic financial intermediary, terms of trade, the real exchange rate, and the deposit rate.

ilarly to Figure 4. In the case of financial autarky (red dashed lines), we observe a weak appreciation in the real exchange rate and a slight worsening in the terms of trade. Similar to the literature (e.g., Rey, 2016), two competing channels affect the dynamics of production. First, the consumption switching channel implies households switch their consumption from the domestic good to the imported foreign good when the terms of trade drops. Second, the demand augmenting channel implies an expansionary foreign monetary policy shock stimulates foreign demand for domestic produced goods. In equilibrium, the latter channel slightly dominates the former one, and thus, output, investment, and consumption all increase, but the changes are negligible compared with the case of financial integration (blue solid lines).

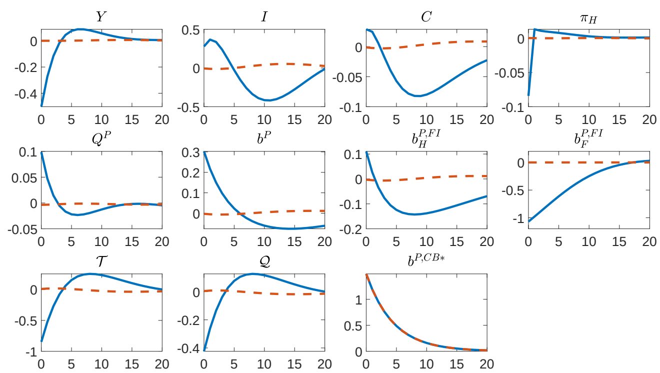
When the financial market is integrated internationally, the foreign shock, however, has a large negative impact on the home economy: output, investment, and consumption all decrease. The movements of the real exchange rate and the terms of trade in Figure 7(a) are mirror images of those in Figure 4. The large initial appreciations in the terms of

Figure 7: **Impulse Responses to a Foreign Shock**

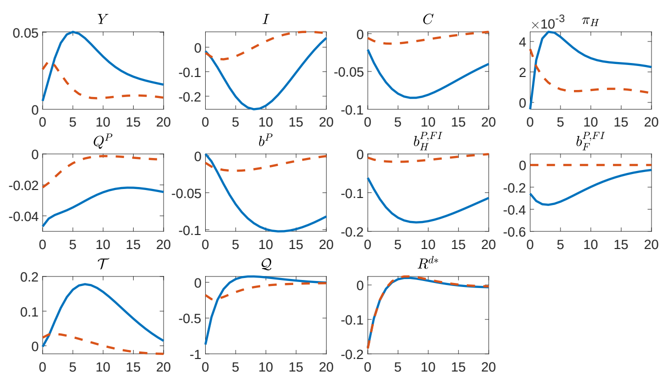
(a) Conventional monetary policy



(b) QE



(c) Conventional monetary policy - LCP



Notes: Panel (a) plots the home-country responses to a 25 bp expansionary monetary policy shock in the foreign country. Panel (b) plots the home-country responses to a foreign QE shock, which is scaled such that the initial response of home output to the home shock under financial autarky is similar to a 25 bp cut in the policy rate. Panel (c) repeats Panel (a) with LCP. The blue solid and red dashed lines correspond to financial integration and financial autarky, respectively. The x-axis is time, and the y-axis is the percentage change from the steady state. The variables are output, investment, consumption, PPI inflation, the price of private bonds, the quantity of total private bonds, the quantity of domestic private bonds that are held by the domestic financial intermediary, the quantity of foreign private bonds that are held by the domestic financial intermediary, terms of trade, the real exchange rate, and the deposit rate in Panels (a) and (c) or the foreign central bank's private bond holdings in Panel (b).

trade decrease demand for home production via the consumption switching channel, which dominates the effects of the demand augmenting channel. Therefore, the net effect amounts to a strong downward pressure on home production. In the following periods, the subsequent depreciation in the terms of trade decreases consumption of foreign goods; together with the shortage of domestic supply, consumption remains persistently below the steady state. Similar to Figure 4, the decrease in investment is driven by the financial channel.

Panel (b) shows the responses of home variables to an expansionary foreign QE shock, and the patterns are similar to what we observe in Panel (a). The only exception is the response of the price of domestically issued private bonds, which is boosted up by the foreign central bank's bond purchases.

In summary, under an expansionary foreign monetary policy shock, the consumption switching channel dominates the demand augmenting channel, which yields a negative spillover to the home economy.

The negative spillover result is not a result of how we model financial integration. In a robustness check, we replace financial integration with the standard prefect international risk sharing between households and find a qualitatively similar result; see Section 5.3. Moreover, many models in the literature without the same structure of financial integration reach a similar result. For example, Gopinath et al. (2020) find a prolonged negative spillover after the initial periods in a model with only riskless bonds. Kolasa and Wesołowski (2020) find a sizable negative spillover of an expansionary QE shock in a model where two types of households access short- and long-term bonds differently.

Rather, the negative sign is a function of how prices are set. When we replace PCP with LCP in Panel (c), the negative spillover disappears. This result comes from the difference in the initial sign of the terms of trade between Panel (c) and Panel (a).

Next, we relate our results to the empirical literature. First, consistent with our baseline result in Panel (a), a large empirical literature documents a short-term currency appreciation in a foreign country subject to a US monetary expansion, regardless of conventional or unconventional policy. For example, see Curcuru et al. (2018) and Rogers et al. (2018) among others. Second, the empirical literature finds mixed signs of the spillover effect. For conventional monetary policy, some studies find a positive spillover (e.g., Banerjee et al., 2016; Dedola et al., 2017; Iacoviello and Navarro, 2019), whereas others find the effect insignificant or negative (e.g., Blanchard et al., 2016; Rey, 2016; Liao et al., 2023). In particular, Rey (2016) highlights a negative spillover similar to our baseline case: subject to a monetary easing in the US, foreign countries such as Canada experience an immediate output contraction, which lasts for a few quarters, and then followed by an expansion thereafter. The QE literature often finds mixed signs within the same study, varying across sample countries; for example, see Bluwstein and Canova (2016), Chen et al. (2016), and Bhattarai et al. (2021).

5 Key Aspects of Financial Integration

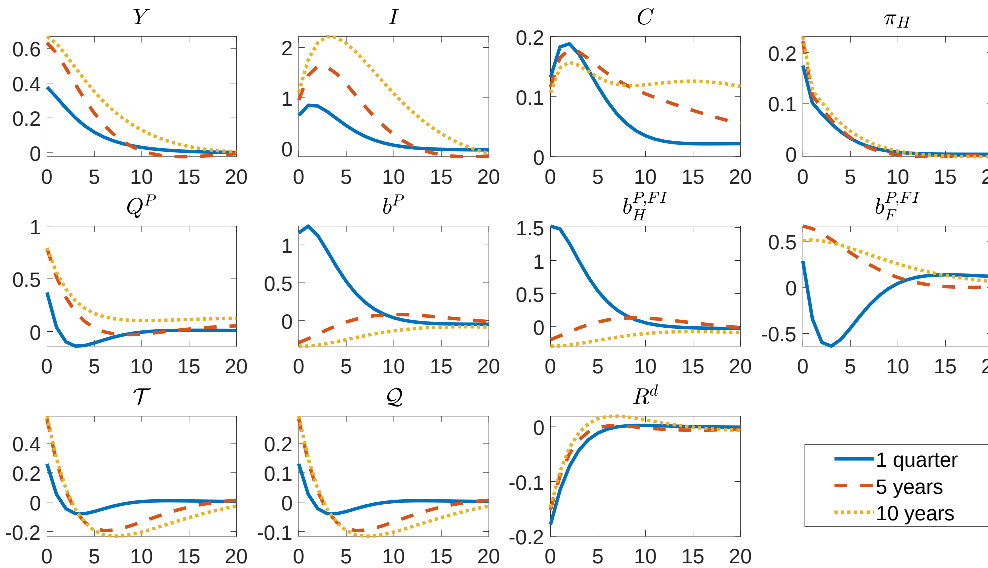
This section inspects key aspects of how we set up financial integration: the duration of long bonds and the enforcement constraint that generates the spread between holding long-term and short-term assets. Finally, we compare our model with a standard model with prefect risk sharing between households and show such a model cannot generate similar dynamics as in our model.

5.1 Duration

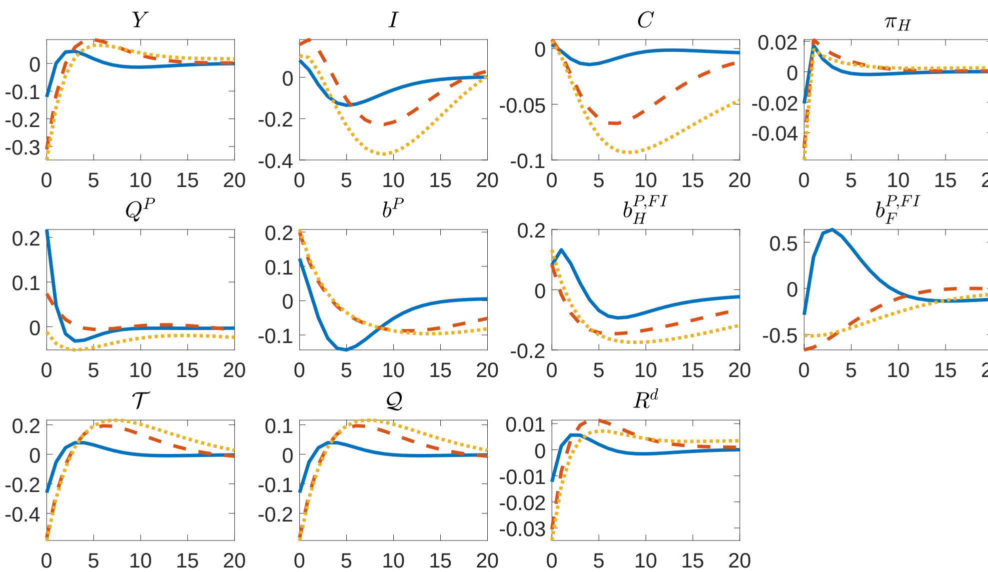
First, we assess whether the duration of long-term bonds, or the average maturity of coupon payments, plays a role. In the baseline calibration, κ is calibrated such that the duration of long-term bonds is 10 years. In Figure 8, we allow the duration to take on different values. The blue solid lines correspond to one quarter. In this case, long-term bonds collapse into short-term bonds, which completely eliminates the duration effect of our model. The red dashed lines map into a duration of five years, which captures a medium maturity, and the

Figure 8: **Different Bond Durations: Financial Integration**

(a) Home shock



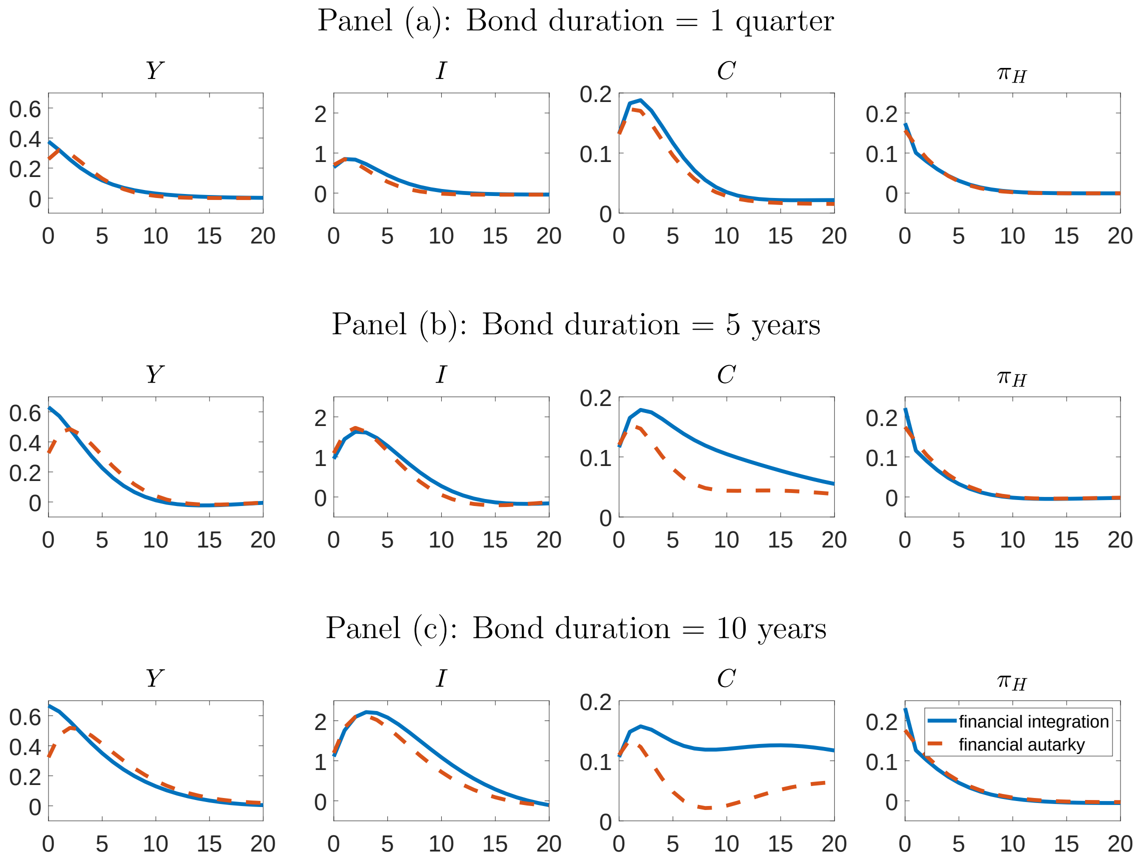
(b) Foreign shock



Notes: Panels (a) and (b) plot the home-country responses to a 25 bp expansionary monetary policy shock at home and in the foreign country under financial integration. The blue solid, red dashed, and yellow dotted lines correspond to durations of 1 quarter, 5 years, and 10 years, respectively. The x-axis is time, and the y-axis is percentage change from steady state.

yellow dotted lines correspond to our baseline with a duration of 10 years, which captures the long-end of the yield curve. Panels (a) and (b) are the responses to an expansionary home and foreign monetary policy shocks, respectively.

Figure 9: **Different Bond Durations: Financial Integration vs. Financial Autarky**

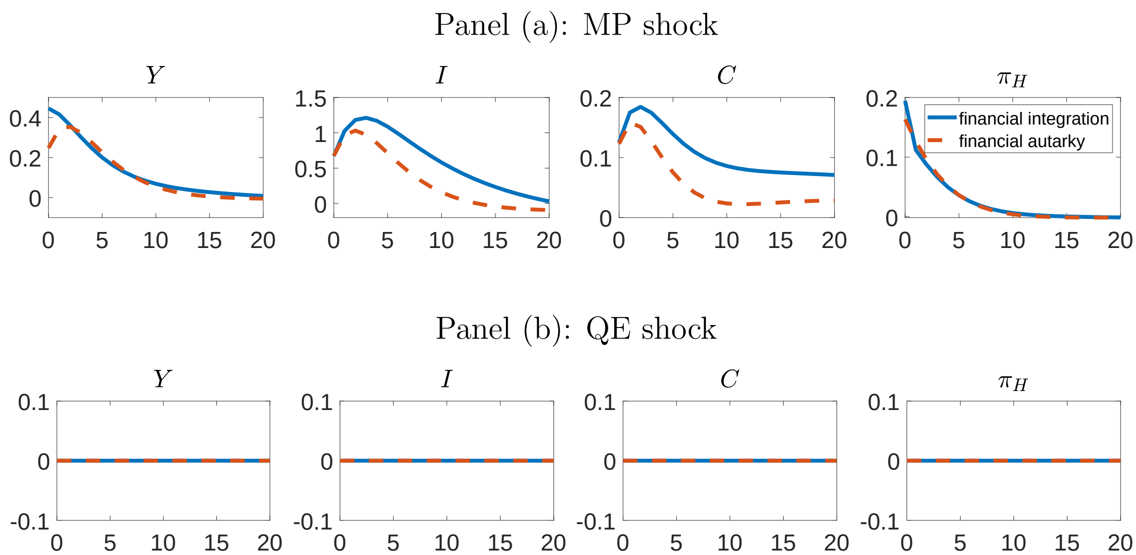


Notes: Panels (a), (b), and (c) plot the home-country responses to a 25bp expansionary monetary policy shock at home when the bond duration is 1 quarter, 5 years, and 10 years, respectively. The blue solid lines and red dashed lines correspond to financial integration and financial autarky, respectively. The x-axis is time, and the y-axis is the percentage change from steady state.

We find that the longer the duration of bonds, the stronger the effect of a monetary policy shock, regardless of the origin of the shock. Use the home shock in Panel (a) for illustration. The transmission mechanism works similar to Section 4. First, the duration works through the terms of trade via the consumption switching channel. A long duration causes a larger initial depreciation in the terms of trade, which increases demand for home production. The subsequent larger appreciation of the terms of trade keeps consumption persistently high. Second, a longer duration allows more investment, which works through the financial channel.

Next, Figure 9 further illustrates that the differences caused by different durations in

Figure 10: **Non-Binding Enforcement Constraint**



Notes: Panels (a) and (b) plot impulse responses of expansionary monetary policy and QE shocks at home when the enforcement constraint does not bind. The shock sizes are taken from Figures 4 and 5. The blue solid and red dashed lines correspond to financial integration and financial autarky, respectively. The x-axis is time, and the y-axis is the percentage change from the steady state.

Figure 8 have consequences when we compare financial integration with financial autarky. The differences between financial integration (blue solid lines) and financial autarky (red dashed lines) become larger for output, investment, consumption, and inflation when the duration increases. This result is most pronounced for consumption, which again works through the consumption switching channel.

5.2 Enforcement Constraint

One key friction in our model is the costly enforcement constraint in (3.21). In the baseline specification, this constraint always binds. This section discusses an alternative where this constraint does not bind, which is implemented by imposing the following condition on the Lagrangian multiplier: $\lambda_t = 0$.[6]

Panel (a) of Figure 10 plots such a case for an expansionary monetary policy shock. Compared with Figure 4, the responses of both output and investment are smaller in size.

[6]Specifically, for the equilibrium conditions laid out in Appendix B, we replace (A.11) with $\lambda_t = 0$.

The difference between financial integration (blue solid lines) and financial autarky (red dashed lines) is larger for investment and smaller for consumption. The former goes through the financial channel, whereas the latter works via the consumption switching channel. Panel (b) plots responses to a QE shock. Without the enforcement constraint, QE does not have any effects.

5.3 Financial Integration vs. Household Risk Sharing

In this section, we ask whether our model of financial integration can be approximated by the standard setting of a complete market with household perfect risk sharing. We begin by setting up such a model. The model differs from the baseline case described in Section 3 in several aspects. First, the household sector features a complete international market for trading the one-period state-contingent securities. Thus, the perfect risk sharing between households in the two countries yields

$$\mu_t^* = \mu_t \mathcal{Q}_t, \tag{5.1}$$

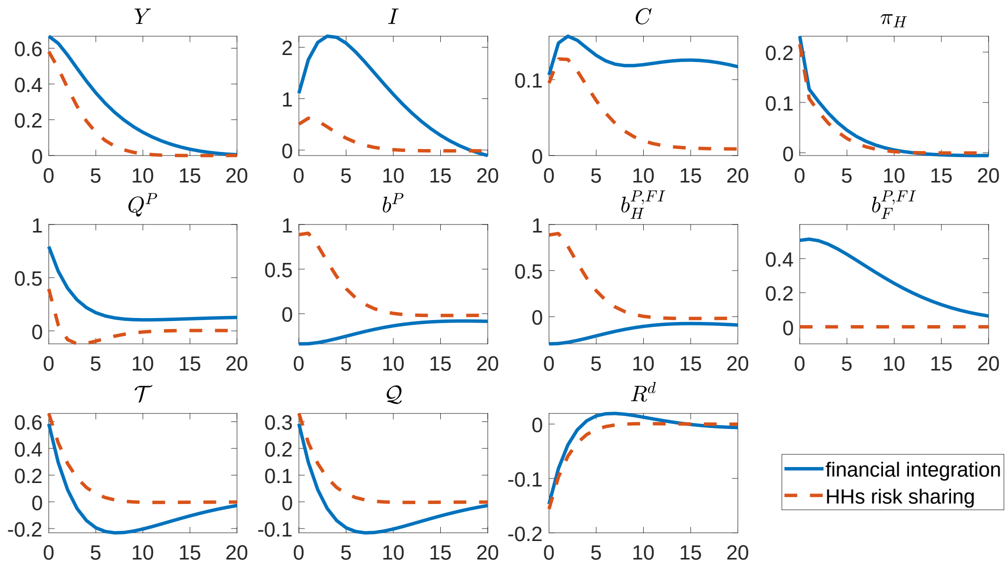
and (5.1) replaces (3.11) in the equilibrium conditions discussed in Appendix B.

The other differences from the baseline case lie in the financial sector. First, we shut down long-term bonds and the enforcement constraint; for details, see Sections 5.1 and 5.2. Second, we do not allow cross-boarder bond holdings in the financial market; see Section 3.2.3. Other parts of the model are the same as in the baseline case described in Appendix B.

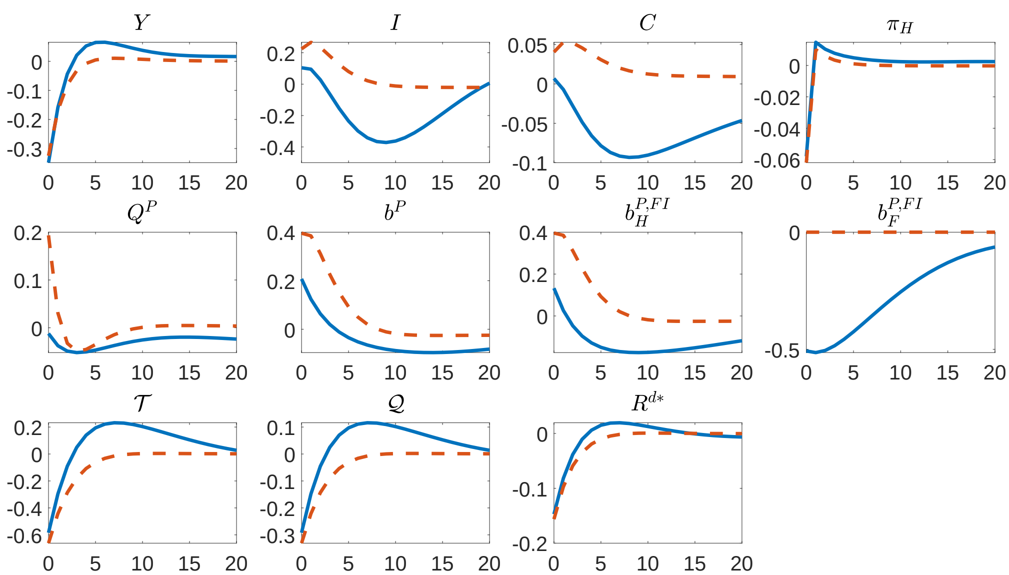
Figure 11 compares our baseline case of financial integration with the case of household risk sharing, and Panels (a) and (b) are the responses to a home and foreign policy shock, respectively. We find sizable differences in all the aggregate real variables: output, investment, and consumption. We focus on the domestic shock in panel (a) to illustrate the transmission mechanism. The difference in consumption is due to the consumption switching channel,

Figure 11: **Financial Integration vs. Household Risk Sharing**

(a) Home shock



(b) Foreign shock



Notes: Panels (a) and (b) plot the home-country responses to a 25 bp expansionary monetary policy shock at home and in the foreign country, respectively. The blue solid lines and red dashed lines correspond to financial integration and household perfect risk sharing, respectively. The x-axis is time, and the y-axis is percentage change from steady state.

which works through the terms of trade. Financial integration generates larger fluctuation in the terms of trade, which also features an undershooting. The difference in investment comes from the financial channel. For the standard model, which only has short-term bonds (red dashed lines), the bond price moves mechanically as a function of the policy rate, and the excess return is zero. In this case, the quantity of bonds increases instead of decreasing. The primary driver of this result is the bond duration; see a similar contrast in Figure 5.1. Without financial integration, the cross-country bond holding is zero by construction. Output captures the combination of the two channels. Note, in panel (b), the negative spillover exists in both cases, which is further discussed in Section 4.5.

6 Financial Integration and Trade Openness

This section studies financial integration together with trade openness in terms of monetary policy transmission. We first discuss the degrees of financial integration and trade openness separately. Then, we study their interaction and compare them.

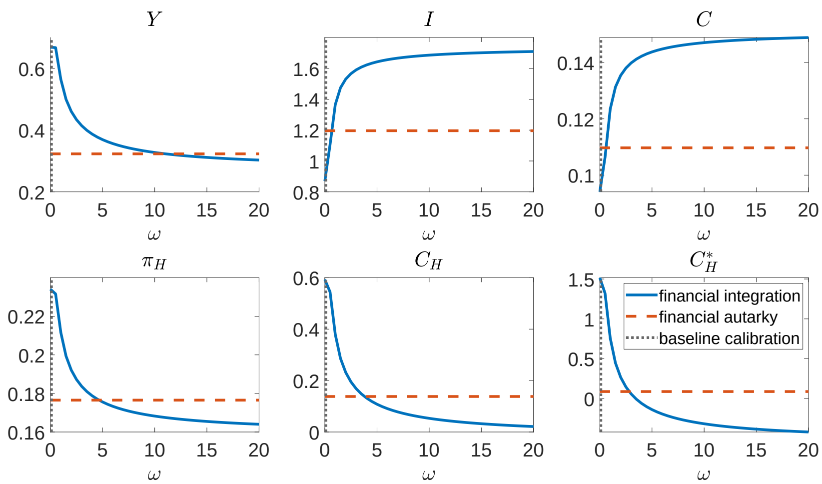
6.1 Degree of Financial Integration

So far, we have explored the role of financial integration in monetary policy shock transmission by comparing two extreme cases. In this section, we further investigate financial market openness at various degrees to mimic different countries, as illustrated in Figure 3.

Figure 12 plots the home country's initial responses to an expansionary domestic monetary policy shock against different values of $\omega \in [0.01, 20]$. A smaller ω corresponds to a smaller foreign transaction cost and a more open international financial market. Our baseline calibration, $\omega = 0.1$, corresponds to an (almost) completely open case. In the case of $\omega = 20$, when the financial intermediary holds 1% more foreign bonds than in their steady state, its return on these bonds reduces by 10 bps, which is a large number that prevents the financial intermediary from deviating from steady-state holdings. Financial autarky corresponds to the flat, red dashed lines because in this case, the financial intermediary is not allowed to hold foreign-issued bonds, and hence, foreign transaction costs are irrelevant.

By contrast, financial openness has important implications for monetary policy transmis-

Figure 12: **Degree of Financial Integration**



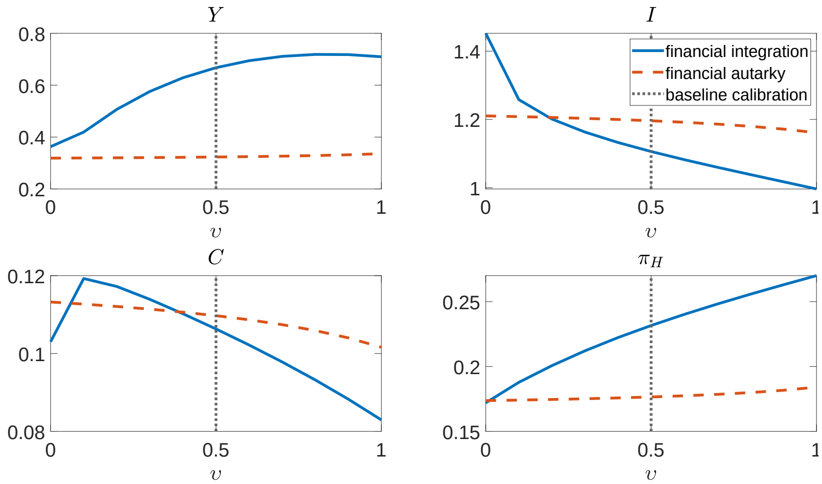
Notes: X-axis: $\omega \in [0.01, 20]$. Y-axis: percentage change from the steady state. For each value of ω, we plot initial responses to a 25 bp cut in the policy rate at home. The blue solid lines and red dashed lines correspond to financial integration and financial autarky, respectively. The black dotted lines mark our baseline calibration ($\omega = 0.1$).

sion when financial markets are integrated. Comparing the two extremes in the blue lines, the output response at $\omega = 0.01$ is more than double the number at $\omega = 20$. Note that whereas output is decreasing in ω, both investment and consumption are increasing in ω. To reconcile this observation, we plot the parts of output that are consumed by domestic household C_H and foreign household C_H^*, both of which are decreasing in ω. Therefore, the main driving force of how output changes with ω is the consumption demand through the consumption switching channel. Also notice the blue lines do not converge to the red dashed lines, due to the difference in steady-state foreign bond holdings. In the case of financial autarky, the financial intermediary is not allowed to hold any foreign bonds. By contrary, under financial integration, even when $\omega \to \infty$, the financial intermediary still holds foreign bonds at the non-zero steady-state level.

6.2 Trade Openness

In this section, we investigate trade openness conditioning on financial integration or financial autarky. In Figure 13, we plot initial responses to an expansionary domestic monetary policy

Figure 13: **Trade Openness: Initial Responses**



Notes: X-axis: $\upsilon \in [0,1]$. Y-axis: percentage change from the steady state. For each value of υ, we plot the home country's initial responses to a 25 bp cut in the domestic policy rate. The blue solid lines and red dashed lines correspond to financial integration and financial autarky, respectively. The black dotted lines mark our baseline calibration ($\upsilon = 0.5$).

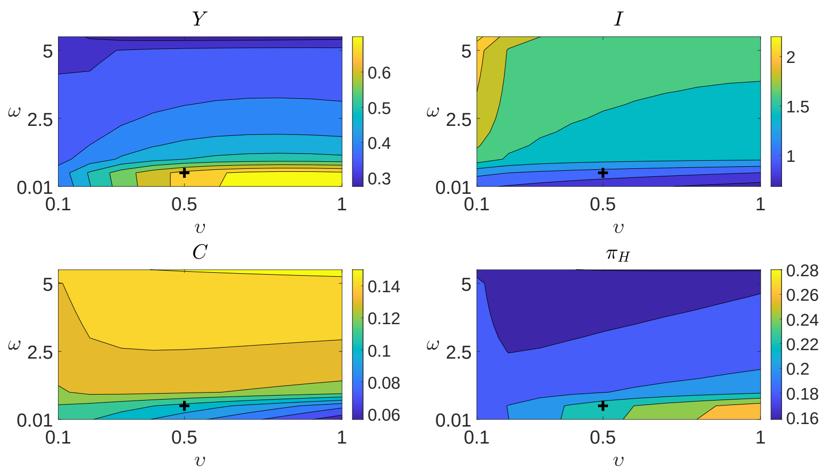
shock against different values of trade openness $\upsilon \in [0,1]$. $\upsilon = 0$ represents a closed economy, whereas $\upsilon = 1$ corresponds to an economy that is fully open on the real side (i.e., no home bias). In the baseline calibration, $\upsilon = 0.5$.

In the case of financial autarky in red dashed lines, the initial response of home output is not sensitive to trade openness. The initial responses of investment and consumption (inflation) monotonically decrease (increase) with respect to υ as the countries become more open, but only to a mild degree.

By contrast, the effects of monetary policy under financial integration (blue solid lines) depend on trade openness. For instance, when the economy is fully open (i.e., $\upsilon = 1$), the output response to a monetary policy shock is 2.2 times the response in a fully closed ($\upsilon = 0$) economy.

This result illustrates an important interaction between the real channel and financial channel for shock transmission. In general, trade openness and financial integration together contribute to large fluctuations in the terms of trade and the real exchange rate, which affects the demand for home production via the consumption switching channel.

Figure 14: **Interaction between Financial Integration and Trade Openness**



Notes: X-axis: $\upsilon \in [0.1, 1]$, Y-axis $\omega \in [0.01, 5]$. For each value of υ, we plot the home country's initial responses to a 25 bp cut in domestic policy rate. Unit in the contour plot: percentage change from the steady state. We only analyze the case of financial integration. The black crosses mark our baseline calibration.

Interestingly, different from financial autarky, the responses under financial integration are not all monotonic in υ. For example, both output and consumption responses exhibit a hump shape. Conditioning on an internationally integrated financial system, the response of output (consumption) achieves the maximum when the economy is open (closed) but not completely open (closed).

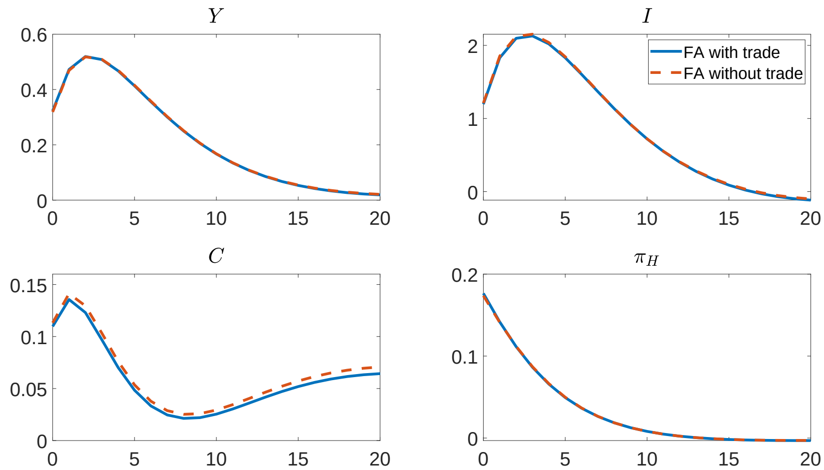
6.3 Interaction and Comparison

We have studied the degrees of financial and trade openness separately. This section combines them, studies their interactions, and makes a comparison. Figure 14 demonstrates the interaction between financial integration and trade openness. We observe an important interaction between the degrees of financial integration and trade openness. The responses in both output and domestic PPI inflation are highest when both the real economy and financial markets are open (with $\omega \approx 0$ and $\nu = 1$). More importantly, the initial responses are driven primarily by the degree of financial integration, which is captured by ω.

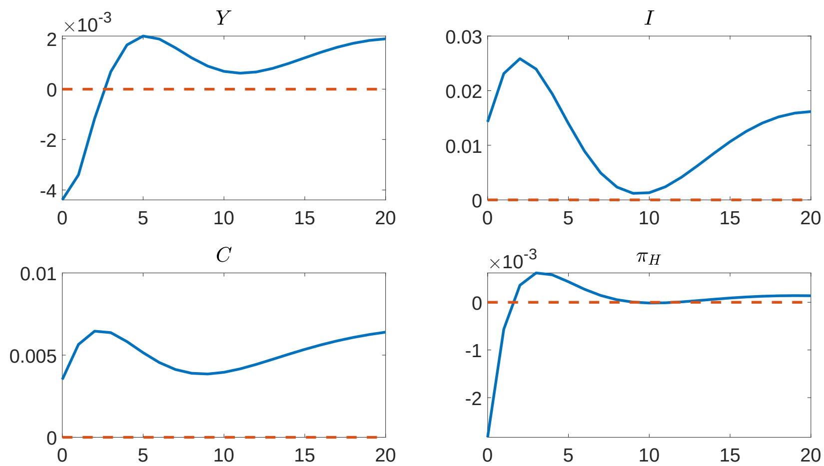
Finally, we compare the importance of financial integration and trade openness in terms

Figure 15: **Impulse Responses: Trade vs. No Trade**

(a) Home shock



(b) Foreign shock



Notes: Panels (a) and (b) plot the home responses to a 25 bp expansionary monetary policy shock at home and in the foreign country, respectively. The blue solid and red dashed lines represent the cases under financial autarky with and without trade, respectively. The x-axis is time, and the y-axis is the percentage change from the steady state.

of monetary policy transmission. Specifically, we investigate if trade alone can contribute as much difference as we see in Section 4. The red dashed lines in Figure 15 correspond to a closed economy in terms of both the real and financial sides of the economy. The blue solid lines correspond to the baseline case. In panel (a), the blue and red lines (almost) overlap for all variables. Although the two colored lines are visually different in panel (b), where the red dashed lines are literally at zero, the differences are orders of magnitudes smaller than those in panel (a) of Figure 7.

Therefore, we conclude trade alone does not make a significant difference in terms of monetary policy transmission, which highlights the importance of financial integration that our paper focuses on.

7 Conclusion

We study the role of financial integration in monetary policy shock transmission with a medium-scale two-country DSGE model. Our innovation is that financial intermediaries can potentially hold foreign long-term bonds. Compared with the case of financial autarky, financial integration amplifies the effects of a domestic shock, and this amplification is larger for QE than conventional interest rate policy. Two channels are at play: a consumption switching channel and a financial channel. On the other hand, financial integration turns an expansionary foreign monetary shock into a contraction. This result speaks to the empirical literature on international spillover, which finds mixed signs.

Inspecting various aspects of how we model financial integration, we find the duration of bonds play a critical role. Specifically, the longer the duration is, the stronger the effects of a monetary policy shock. The enforcement constraint makes a quantitative but not qualitative difference for conventional monetary policy. However, without this constraint, QE is completely muted. Further, we demonstrate our model of financial integration cannot be replicated by a standard model of household perfect risk sharing.

Finally, we find an important interaction between financial integration and trade openness. Specifically, the effects of monetary policy shock are the largest when both dimensions are open. Comparing the two, we find the results are primarily driven by financial integration, and trade alone does not make an economically meaningful difference in terms of monetary policy shock transmission, which highlights our new channel.

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Appendix A The Model

In this section, we show the detailed derivation for the model in Section 3.

Appendix A.1 Household

The household obtains dividends from retail firms, a wholesale firm, capital producers, labor unions, and financial intermediaries:

$$div_t \equiv \frac{DIV_t}{P_t} = \frac{P_{H,t}}{P_t} Y_t - mrs_t L_t - I_t + Q_t^P (b_t^P - \kappa b_{t-1}^P \Pi_t^{-1}) - b_{t-1}^P \Pi_t^{-1} + (1-\sigma)\mathscr{b}_t. \quad \text{(A.1)}$$

Appendix A.2 Financial Intermediary

In this section, we derive the first-order conditions of the financial intermediary's maximization problem given by (3.22) - (3.26) and show the expression of the auxiliary variable Ω_t.

Expressing the balance-sheet condition of the financial intermediry in (3.17) in real terms gives

$$Q_t^P b_{H,t}^{P,FI} + Q_t^{P*} b_{F,t}^{P,FI} \mathcal{E}_t + Q_t^G b_{H,t}^{G,FI} + Q_t^{G*} b_{F,t}^{G,FI} \mathcal{E}_t + re_t = d_t + n_t, \quad \text{(A.2)}$$

where $n_t = N_t/P_t$, $d_t = D_t/P_t$, and $re_t = RE_t/P_t$. By rewriting the net worth of the financial intermediary (3.18) in real terms, we have

$$\begin{aligned} \Pi_t n_t =& \sigma \Big\{ \left(R_t^P - R_{t-1}^d\right) Q_{t-1}^P b_{H,t-1}^{P,FI} + \left(R_t^G - R_{t-1}^d\right) Q_{t-1}^G b_{H,t-1}^{G,FI} \\ &+ \left\{ R_t^{P*} \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} [1 - \omega/2(b_{F,t-1}^{P,FI}/b_F^{P,FI} - 1)^2] - R_{t-1}^d \right\} Q_{t-1}^{P*} b_{F,t-1}^{P,FI} \mathcal{Q}_{t-1} \\ &+ \left\{ R_t^{G*} \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} [1 - \omega/2(b_{F,t-1}^{G,FI}/b_F^{G,FI} - 1)^2] - R_{t-1}^d \right\} Q_{t-1}^{G*} b_{F,t-1}^{G,FI} \mathcal{Q}_{t-1} \\ &+ \left(R_{t-1}^{re} - R_{t-1}^d\right) re_{t-1} + R_{t-1}^d n_{t-1} \Big\} + \Pi_t X. \end{aligned} \quad \text{(A.3)}$$

The real-term expression of (3.19) is

$$n_t = \sigma \mathscr{b}_t + X, \tag{A.4}$$

and

$$\begin{aligned}\Pi_t \mathscr{b}_t = &\left(R_t^P - R_{t-1}^d\right) Q_{t-1}^P b_{H,t-1}^P + \left(R_t^G - R_{t-1}^d\right) Q_{t-1}^G b_{H,t-1}^G \\ &+ \left\{ R_t^{P*} \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} [1 - \omega/2 (b_{F,t-1}^P / b_F^P - 1)^2] - R_{t-1}^d \right\} Q_{t-1}^{P*} b_{F,t-1}^P \mathcal{Q}_{t-1} \\ &+ \left\{ R_t^{G*} \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} [1 - \omega/2 (b_{F,t-1}^G / b_F^G - 1)^2] - R_{t-1}^d \right\} Q_{t-1}^{G*} b_{F,t-1}^G \mathcal{Q}_{t-1} \\ &+ \left(R_{t-1}^{re} - R_{t-1}^d\right) re_{t-1} + R_{t-1}^d n_{t-1}.\end{aligned} \tag{A.5}$$

Rewrite (3.20) as

$$V_t = \max \ \left[(1-\sigma) \mathbb{E}_t \Lambda_{t,t+1} \mathscr{b}_{t+1} + \mathbb{E}_t \Lambda_{t,t+1} V_{t+1} \right]. \tag{A.6}$$

Thus, the Lagrangian with constraint (3.21) is

$$\begin{aligned}\mathbb{L}_t = &\ \max \ (1+\lambda_t) \mathbb{E}_t \left[(1-\sigma) \Lambda_{t,t+1} \mathscr{b}_{t+1} + \Lambda_{t,t+1} V_{t+1} \right] \\ &- \lambda_t \theta \left\{ \left[Q_t^P b_{H,t}^{P,FI} + \Delta Q_t^G b_{H,t}^{G,FI} \right] + \left[Q_t^{P*} b_{F,t}^{P,FI} + \Delta Q_{B,t}^{G*} b_{F,t}^{G,FI} \right] \mathcal{Q}_t \right\},\end{aligned} \tag{A.7}$$

where λ_t is the Lagrangian multiplier. Plugging (A.5) into (A.7) and using the notation

$$\Omega_{t+1} \equiv 1 - \sigma + \frac{\partial V_{t+1}}{\partial \mathscr{b}_{t+1}}, \tag{A.8}$$

we have the first-order conditions given by (3.22) - (3.26).

We now expand the expression of Ω_t by substituting $\partial V_{t+1} / \partial \mathscr{b}_{t+1}$. First, define

$$\phi_t \equiv \frac{V_t}{\sigma \theta \mathscr{b}_t}, \tag{A.9}$$

and then, together with the definition of Ω_{t+1}, (A.9) directly yields

$$\Omega_t = 1 - \sigma + \sigma\theta\phi_t. \tag{A.10}$$

Second, we show the expression of ϕ_t. (A.9) together with the binding constraint (3.21) yields

$$\phi_t = \frac{\left[Q_t^P b_{H,t}^{P,FI} + \Delta Q_t^G b_{H,t}^{G,FI}\right] + \left[Q_t^{P*} b_{F,t}^{P,FI} + \Delta Q_t^{G*} b_{F,t}^{G,FI}\right]\mathcal{Q}_t}{\sigma \mathscr{b}_t}. \tag{A.11}$$

Note we can rewrite (3.18) as

$$\begin{aligned}
\Lambda_{t,t+1}\Omega_{t+1}\mathscr{b}_{t+1} = \Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\Big\{&\left(R_{t+1}^P - R_t^d\right) Q_t^P b_{H,t}^{P,FI} + \left(R_{t+1}^G - R_t^d\right) Q_t^G b_{H,t}^{G,FI} \\
&+ \left\{R_{t+1}^{P*}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}[1 - \omega/2(b_{F,t}^{P,FI}/b_F^{P,FI} - 1)^2] - R_t^d\right\} Q_t^{P*} b_{F,t}^{P,FI}\mathcal{Q}_t \\
&+ \left\{R_{t+1}^{G*}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}[1 - \omega/2(b_{F,t}^{G,FI}/b_F^{G,FI} - 1)^2] - R_t^d\right\} Q_t^{G*} b_{F,t}^{G,FI}\mathcal{Q}_t \\
&+ \left(R_t^{re} - R_t^d\right) re_t + R_t^d n_t\Big\}.
\end{aligned} \tag{A.12}$$

By plugging (A.11) and first-order conditions (3.22) - (3.26) into (A.12), we have

$$\mathbb{E}_t\left[\Lambda_{t,t+1}\Omega_{t+1}\mathscr{b}_{t+1}\right] = \sigma\frac{\lambda_t}{1+\lambda_t}\theta\phi_t\mathscr{b}_t + \mathbb{E}_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\right] R_t^d n_t + \Phi_t, \tag{A.13}$$

where

$$\begin{aligned}
\Phi_t \ &= \omega\mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}R_{t+1}^{P*}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}\left(\frac{b_{F,t}^{P,FI}}{b_F^{P,FI}} - 1\right)\frac{b_{F,t}^{P,FI}}{b_F^{P,FI}} Q_t^{P*} b_{F,t}^{P,FI}\mathcal{Q}_t \\
&\quad + \omega\mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}R_{t+1}^{P*}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}\left(\frac{b_{F,t}^{G,FI}}{b_F^{G,FI}} - 1\right)\frac{b_{F,t}^{G,FI}}{b_F^{G,FI}} Q_t^{G*} b_{F,t}^{G,FI}\mathcal{Q}_t.
\end{aligned} \tag{A.14}$$

Lastly, we rewrite the value function (A.6) using (A.10), (A.9), and (A.13):

$$\begin{aligned}\sigma\theta\phi_t \mathscr{b}_t &= \max\ \mathbb{E}_t\left[\Lambda_{t,t+1}\mathscr{b}_{t+1}\Omega_{t+1}\right] \\ &= \sigma\frac{\lambda_t}{1+\lambda_t}\theta\phi_t\mathscr{b}_t + \mathbb{E}_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\right]R_t^d n_t + \Phi_t.\end{aligned}$$

Dividing $\mathscr{b}_t$ on both sides and rearranging the equation, we obtain

$$\phi_t = \frac{1+\lambda_t}{\sigma\theta}\left\{\mathbb{E}_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\right]R_t^d\frac{n_t}{\mathscr{b}_t} + \frac{\Phi_t}{\mathscr{b}_t}\right\}. \tag{A.15}$$

Dividend The real dividend that the financial intermediary pays the household in period t is

$$div_t^{FI} = (1-\sigma)\mathscr{b}_t.$$

Appendix A.3 Firm Production

Appendix A.3.1 Capital Producer

A representative capital producer generates new physical capital via

$$\widehat{I}_t = \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t, \tag{A.16}$$

where I_t is unconsumed final output and $S(\cdot)$ is a convex function of adjustment cost: $S(I_t/I_{t-1}) = \frac{\kappa_I}{2}(I_t/I_{t-1} - 1)^2$. Profits are discounted by the household's stochastic discount factor. The nominal dividend earned by the capital producer is

$$DIV_{k,t} = P_t^k\left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t - P_t I_t.$$

Its objective is to maximize the present discounted value of real profit using the stochastic discount factor of the household; that is,

$$\max_{I_t} \ \mathbb{E}_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} \left\{ p^k_{t+j} \left[1 - S\left(\frac{I_{t+j}}{I_{t+j-1}} \right) \right] I_{t+j} - I_{t+j} \right\}.$$

The first-order condition is

$$1 = p^k_t \left[1 - S\left(\frac{I_t}{I_{t-1}} \right) - S'\left(\frac{I_t}{I_{t-1}} \right) \frac{I_t}{I_{t-1}} \right] + \mathbb{E}_t \Lambda_{t,t+1} p^k_{t+1} S'\left(\frac{I_{t+1}}{I_t} \right) \left(\frac{I_{t+1}}{I_t} \right)^2. \tag{A.17}$$

Appendix A.3.2 Wholesale Firm

The wholesale firm sells its product to retail firms in a competitive market. Thus, the nominal dividend of the wholesale firm in period t is

$$DIV_{m,t} = P_{w,t} A_t (u_t K_t)^{\alpha} L_{d,t}^{1-\alpha} - W_t L_{d,t} - P^k_t \widehat{I}_t - B^P_{t-1} + Q^P_t \left(B^P_t - \kappa B^P_{t-1} \right), \tag{A.18}$$

where $P_{w,t}$ is the price of intermediate goods and W_t is the nominal cost of labor in a competitive spot market. This firm maximizes the present value of real dividends subject to the constraints (3.30) and (3.31). The associated first-order conditions are given by

$$w_t = (1-\alpha) p_{w,t} A_t (u_t K_t)^{\alpha} L_{d,t}^{-\alpha} \tag{A.19}$$

$$p^k_t M_{1,t} \delta'(u_t) = \alpha p_{w,t} (u_t K_t)^{\alpha-1} L_{d,t}^{1-\alpha} \tag{A.20}$$

$$p^k_t M_{1,t} = \mathbb{E}_t \Lambda_{t,t+1} \left[\alpha p_{m,t+1} A_{t+1} K_{t+1}^{\alpha-1} u_{t+1}^{\alpha} L_{d,t+1}^{1-\alpha} + (1 - \delta(u_{t+1})) p^k_{t+1} M_{1,t+1} \right] \tag{A.21}$$

$$Q^P_t M_{2,t} = \mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \left[1 + \kappa Q^P_{t+1} M_{2,t+1} \right] \tag{A.22}$$

$$\frac{M_{1,t} - 1}{M_{2,t} - 1} = \psi, \tag{A.23}$$

where $w_t = W_t / P_t$ is the real wage, $p_{w,t} = P_{w,t} / P_t$ is the relative price of wholesale output, and $p^k_t = P^k_t / P_t$ is the relative price of new capital. $M_{1,t}$ is one plus the product of ψ with the multiplier on the constraint that firms must issue bonds to finance investment, (3.31), whereas $M_{2,t}$ is simply one plus the multiplier on the constraint.

Appendix A.3.3 Retail Firms

A continuum of retail firms with the same home-country population size, indexed by $h \in [0, \gamma)$, purchase the intermediate goods and then simply repackage them into differentiated tradable goods; that is, $Y_t(h) = Y_{w,t}(h)$. Given the preference of households in Section 3.1.1, retailers face a downward-sloping demand function:

$$Y_t(h) = \left(\frac{P_{H,t}(h)}{P_{H,t}} \right)^{-\epsilon_p} Y_t, \tag{A.24}$$

where $Y_t = C_{H,t} + C^*_{H,t} + I_t + G_t$. Note each individual firm produces an equal share of total output in each country.

The nominal profit of a retail firm is

$$DIV_{R,t}(h) = P_{H,t}(h)Y_t(h) - P_{w,t}Y_{w,t}(h),$$

and by utilizing $Y_{w,t}(h) = Y_t(h)$ with (A.24), we have

$$DIV_{R,t}(h) = P_{H,t}(h)^{1-\epsilon_p} P^{\epsilon_p}_{H,t} Y_t - P_{w,t} P_{H,t}(h)^{-\epsilon_p} P^{\epsilon_p}_{H,t} Y_t. \tag{A.25}$$

Following the Calvo pricing, we assume a retailer has a fixed probability $1 - \phi_p$ of being able to adjust its price in each period (with $0 \leq \phi_p \leq 1$). A retailer who is able to re-optimize its price in period t maximizes the present discounted value of real profits:

$$\max_{P_{H,t}(h)} \mathbb{E}_t \sum_{j=0}^{\infty} \phi_p^j \Lambda_{t,t+j} P^{-1}_{t+j} \left[P_{H,t}(h)^{1-\epsilon_p} P^{\epsilon_p}_{H,t+j} Y_{t+j} - P_{w,t+j} P_{H,t}(h)^{-\epsilon_p} P^{\epsilon_p}_{H,t+j} Y_{t+j} \right].$$

Note that because all the retail firms that reset prices in any given period will choose the same price, we drop the index h in $P_{H,t}(h)$ and denote it as $P^o_{H,t}$.

The first-order conditions are

$$
\begin{aligned}
p_{H,t}^{o} &= \frac{\epsilon_p}{\epsilon_p - 1}\frac{x_{1,t}}{x_{2,t}} && \text{(A.26)}\\
x_{1,t} &= \tilde{p}_{m,t}Y_t + \phi_p \mathbb{E}_t \Lambda_{t,t+1}\Pi_{H,t+1}^{\epsilon_p} x_{1,t+1} && \text{(A.27)}\\
x_{2,t} &= Y_t + \phi_p \mathbb{E}_t \Lambda_{t,t+1}\Pi_{t+1}^{-1}\Pi_{H,t+1}^{\epsilon_p} x_{2,t+1}, && \text{(A.28)}
\end{aligned}
$$

where $p_{H,t}^{o} = P_{H,t}^{o}/P_t$, $\tilde{p}_{m,t} = P_{w,t}/P_t$, and $x_{1,t}$ and $x_{2,t}$ are two auxiliary variables.

Note that for the intermediate-goods market, $Y_t(h) = Y_{w,t}(h)$ implies

$$
Y_t v_t^p = Y_{w,t}, \tag{A.29}
$$

where v_t^p is a measure of price dispersion given by

$$
v_t^p = \int_0^1 \left(\frac{P_{H,t}(h)}{P_{H,t}}\right)^{-\epsilon_p} dh.
$$

By the property of Calvo pricing, we have

$$
v_t^p = (1-\phi_p)\left(p_{Ht}^{o}P_t/P_{H,t}\right)^{-\epsilon_p} + P_{H,t}^{\epsilon_p}P_{H,t-1}^{-\epsilon_p}\int_{(1-\phi_p)}^{1}\left(\frac{P_{H,t-1}(h)}{P_{H,t-1}}\right)^{-\epsilon_p} dh,
$$

which yields

$$
v_t^p = (1-\phi_p)\left(p_{H,t}^{o}P_t/P_{H,t}\right)^{-\epsilon_p} + \phi_p \Pi_{H,t}^{\epsilon_p} v_{t-1}^p. \tag{A.30}
$$

Similarly, the PPI price $P_{H,t}$ in the home country satisfies

$$
P_{H,t}^{1-\epsilon_p} = (1-\phi_p)\left(P_{H,t}^{o}\right)^{1-\epsilon_p} + \phi_p P_{H,t-1}^{1-\epsilon_p},
$$

which yields

$$
1 = (1-\phi_p)\left(p_{H,t}^{o}P_t/P_{H,t}\right)^{1-\epsilon_p} + \phi_p \Pi_{H,t}^{\epsilon_p - 1}. \tag{A.31}
$$

Appendix A.4 Labor Market

A continuum of labor unions, indexed by $f \in [0, \gamma)$, purchase labor from households at price MRS_t, and repackage it to a representative labor packer. The labor packer combines differentiated labor into final labor used in production, that is, $L_{d,t} = L_t(f)$, and the downward-sloping demand function each union faces is

$$L_{d,t}(f) = \left(\frac{W_t(f)}{W_t}\right)^{-\epsilon_w} L_{d,t}, \tag{A.32}$$

where $W_t(f)$ is the wage paid for union f's labor, and W_t is the aggregate wage level that satisfies

$$W_t^{1-\epsilon_w} = \frac{1}{\gamma}\int_0^\gamma W_t(f)^{1-\epsilon_w} df. \tag{A.33}$$

The nominal profit of a representative labor union is

$$DIV_{L,t}(f) = W_t(f)L_{d,t}(f) - MRS_t L_t(f), \tag{A.34}$$

and by imposing $L_{d,t}(f) = L_t(f)$ and (A.32), we have

$$DIV_{L,t} = W_t(f)^{1-\epsilon_w} W_t^{\epsilon_w} L_{d,t} - MRS_t W_t(f)^{-\epsilon_w} W_t^{\epsilon_w} L_{d,t}. \tag{A.35}$$

We assume the nominal wage is Calvo-type sticky. Each period, the probability that a labor union can adjust its wage is $1 - \phi_w$ (with $0 \leq \phi_w \leq 1$). A labor union that is able to re-optimize its wage in period t maximizes the present discounted value of real profits:

$$\max_{W_t(f)} \mathbb{E}_t \sum_{j=0}^{\infty} \phi_w^j \Lambda_{t,t+j} \left[W_t(f)^{1-\epsilon_w} P_{t+j}^{\epsilon_w - 1} w_{t+j}^{\epsilon_w} L_{d,t+j} - mrs_{t+j} W_t(f)^{-\epsilon_w} P_{t+j}^{\epsilon_w} w_{t+j}^{\epsilon_w} L_{d,t+j}\right], \tag{A.36}$$

where $w_t = W_t/P_t$ and $mrs_t = MRS_t/P_t$. Note that because all the labor unions that reset wages in any given period will choose the same wage, we can drop the index f in $W_t(f)$ and denote it as W_t^*.

The first-order conditions yield

$$
\begin{aligned}
w^* &= \frac{\epsilon_w}{\epsilon_w - 1}\frac{f_{1,t}}{f_{2,t}} && \text{(A.37)}\\
f_{1,t} &= mrs_t w_t^{\epsilon_w} L_{d,t} + \phi_w \Lambda_{t,t+1}\Pi_{t+1}^{\epsilon_w} f_{1,t+1} && \text{(A.38)}\\
f_{2,t} &= w_t^{\epsilon_w} L_{d,t} + \phi_w \Lambda_{t,t+1}\Pi_{t+1}^{\epsilon_w - 1} f_{2,t+1}, && \text{(A.39)}
\end{aligned}
$$

where $w_t^* = W_t^*/P_t$, and $f_{1,t}$ and $f_{2,t}$ are auxiliary variables.

Integrating (A.32) across index f, we have

$$
L_t = L_{d,t} v_t^w, \tag{A.40}
$$

where v_t^w is a measure of wage dispersion given by

$$
v_t^w = \frac{1}{\gamma}\int_0^{\gamma}\left(\frac{W_t(f)}{W_t}\right)^{-\epsilon_w} df.
$$

By the property of Calvo-type wage-setting, we have

$$
v_t^w = (1-\phi_w)\left(\frac{w_t^*}{w_t}\right)^{-\epsilon_w} + \frac{1}{\gamma} W_t^{\epsilon_w} W_{t-1}^{-\epsilon_w}\int_{\gamma(1-\phi_w)}^{\gamma}\left(\frac{W_{t-1}(f)}{W_t}\right)^{-\epsilon_w} df,
$$

which can be re-expressed as

$$
v_t^w = (1-\phi_w)\left(\frac{w_t^*}{w_t}\right)^{-\epsilon_w} + \phi_w \Pi_t^{\epsilon_w}\left(\frac{w_t}{w_{t-1}}\right)^{\epsilon_w} v_{t-1}^w. \tag{A.41}
$$

The wage-aggregation condition (A.33) also yields

$$
w_t^{1-\epsilon_w} = (1-\phi_w)(w_t^*)^{1-\epsilon_w} + \phi_w \Pi_t^{\epsilon_w - 1} w_{t-1}^{1-\epsilon_w}. \tag{A.42}
$$

Appendix A.5 Monetary and Fiscal Authorities

The cental bank transfer to the fiscal authority satisfies

$$T_t^{CB} = (1+\kappa Q_t^P)\Pi_t^{-1} b_{t-1}^{P,CB} + (1+\kappa Q_t^G)\Pi_t^{-1} b_{t-1}^{G,CB} - R_{t-1}^{re}\Pi_t^{-1} re_{t-1}. \tag{A.43}$$

Appendix A.6 Goods-Market-Clearing Conditions

From the household preferences, we can derive the total demand for a generic differentiated good h produced in country H and the demand for a good f produced in country F:

$$Y_t(h) = \frac{1}{\gamma}\left(\frac{P_t(h)}{P_{H,t}}\right)^{-\epsilon_p}\left[C_{H,t} + I_t + G_t\right] + \frac{1}{\gamma}\left(\frac{P_t^*(h)}{P_{H,t}^*}\right)^{-\epsilon_p} C_{H,t}^*, \tag{A.44}$$

$$Y_t^*(f) = \frac{1}{1-\gamma}\left(\frac{P_t(f)}{P_{F,t}}\right)^{-\epsilon_p} C_{F,t} + \frac{1}{1-\gamma}\left(\frac{P_t^*(f)}{P_{F,t}^*}\right)^{-\epsilon_p}\left[C_{F,t}^* + I_t^* + G_t^*\right]. \tag{A.45}$$

Because the law of one price holds for individual goods, we have $P_t(h) = \mathcal{E}_t P_t^*(h)$ and $P_t(f) = \mathcal{E}_t P_t^*(f)$, implying $P_{H,t} = \mathcal{E}_t P_{H,t}^*$ and $P_{F,t} = \mathcal{E}_t P_{F,t}^*$. Then, by plugging the individual-goods demand function into the definition of the aggregate domestic output, $Y_t = \left[\left(\frac{1}{\gamma}\right)^{\frac{1}{\epsilon_p}} \int_0^\gamma Y_t(h)^{\frac{\epsilon_p - 1}{\epsilon_p}} dh\right]^{\frac{\epsilon_p}{\epsilon_p - 1}}$, we obtain

$$Y_t = C_{H,t} + I_t + G_t + C_{H,t}^*. \tag{A.46}$$

Similarly, for the aggregate foreign output, we have

$$Y_t^* = C_{F,t}^* + I_t^* + G_t^* + C_{F,t}. \tag{A.47}$$

Appendix A.7 Exogenous shocks

Besides the monetary policy shock ε_t^r, the model has four other exogenous shocks: productivity shock ε_t^A, government spending shock ε_t^{GS}, private QE shock $\varepsilon_t^{P,CB}$, and public QE shock $\varepsilon_t^{G,CB}$.

Aggregate productivity A_t and government spending G_t follow AR(1) processes after taking log; that is,

$$\ln A_t = \rho_A \ln A_{t-1} + s_A \varepsilon_t^r, \tag{A.48}$$

$$\ln G_t = (1-\rho_{GS}) \ln G + \rho_{GS} \ln G_{t-1} + s_{GS} \varepsilon_t^{GS}. \tag{A.49}$$

The exogenous processes for the central bank holdings of private and public bonds are given by (3.33) and (3.34).

Appendix B Equilibrium conditions

We primarily only list the equations for the home country, and the foreign problems are symmetric. We also only focus on the case of financial integration, because the equilibrium conditions are similar for the case of financial autarky except for replacing (3.24) - (3.25) with (3.27) - (3.28).

For the case of financial integration, the equilibrium conditions include $56 \times 2 + 6 = 118$ equations:

- financial intermediaries (14×2 equations): (3.16)$\times$2 for both government and private bonds, (3.22) - (3.26), (A.2) - (A.4), (A.10), (A.11), (A.14), and (A.15)
- households (4×2 equations): (3.12) - (3.15)
- production (13×2 equations): (3.29) - (3.31), (A.19) - (A.23) for wholesale firms, (A.26) - (A.28) for retailers, (A.16) - (A.17) for capital producers
- labor markets (3×2 equations): (A.37) - (A.39)
- fiscal authorities (1×2 equations): (3.36)
- cenral banks (2×2 equations): (3.35) and (A.43)

- monetary policy (1×2 equations): (3.32)

- aggregation ($14 \times 2 + 6$) equations): (A.29) - (A.31) for prices, (A.40) - (A.42) for wages, (3.37) for goods-market clearing, (3.39) and (3.40) for bond-markets clearing, (3.2) - (3.6) for consumption composites and CPI,

$$\Pi_t = P_t / P_{t-1} \tag{B.1}$$

$$\Pi_{H,t} = P_{H,t} / P_{H,t-1} \tag{B.2}$$

  for definitions of CPI and PPI inflation, and six equations hold for the whole economy: home-country household budget constraint (3.11), home-country dividends (A.1), two law-of-one-price conditions (3.7), and definitions for real exchange rates and terms of trade (3.8) and (3.9)

- exogenous shock processes (4×2 equations): (A.48) - (A.49), (3.33) and (3.34).

We have 118 variables endogenous variables:

- 57×2 variables: $\{R_t^P, Q_t^P, R_t^G, Q_t^G, R_t^{re}, R_t^d, \Pi_t, \Lambda_{t,t+1}, \Omega_t, \lambda_t, \phi_t, \mu_t, C_t, L_t, mrs_t, w_t^r, f_{1t}, f_{2t}, w_t, L_t^d, p_{H,t}^o, x_{1t}, x_{2t}, \tilde{p}_{m,t}, Y_t, Y_{m,t}, u_t, K_t, p_t^k, M_{1t}, M_{2t}, I_t, \hat{I}_t, G_t, b_t^P, T_t, T_t^{CB}, b_t^{P,CB}, b_t^{G,CB}, re_t, v_t^p, v_t^w, d_t, n_t, A_t, C_{H,t}, C_{F,t}, b_{H,t}^{P,FI}, b_{H,t}^{P,FI*}, b_{H,t}^{G,FI}, b_{H,t}^{G,FI*}, p_{H,t}, p_{F,t}, \Pi_{H,t}, P_t, \Phi_t, \mathcal{b}_t\}$

- 4 variables: $\{\mathcal{T}_t, \mathcal{E}_t\, \mathcal{Q}_t, div_t\}$

Appendix C Other Parameters

Table C.1: **Other Parameters**

Parameters	Value / Target	Description
κ	$1-40^{-1}$	Coupon-payment decay rate
θ	$4(\bar{R}^P-\bar{R}^d)=3\%$	Recoverability parameter
ψ	0.81	Fraction of investment from debt
σ	0.95	Survival rate of financial intermediaries
Δ	1/3	Goverment bond recoverability
$b^{P,CB}$	0	Steady-state central bank private bond holdings
$b^{G,CB}$	$\frac{b^{G,cb}Q^G}{4Y}=0.06$	Steady-state central bank Treasury holdings
$\bar{b}^G$	$\frac{b^G Q^G}{4Y}=0.41$	Steady-state goverment debt
β	0.995	Subjective discount factor
Π	1	Steady-state gross inflation
κ_I	2	Investment adjustment cost
G	$\frac{G}{Y}=0.2$	Steady-state government spending
η	1	Inverse of Frisch elasticity of labor supply
χ	L=1	Scaling parameter for labor disutility
b	0.7	Habit formation
α	1/3	Capital share in production
δ_0	0.025	Steady-state depreciation rate
δ_1	$u=1$	Utilization linear term
δ_2	0.01	Utilization squared term
ϵ_p	11	Goods elasticity of substitution
ϵ_w	11	Labor elasticity of substitution
ϕ_p	0.75	Price rigidity
ϕ_w	0.75	Wage rigidity
ρ_r	0.8	Taylor-rule smoothing parameter
ϕ_π	1.5	Taylor-rule inflation
ϕ_y	0.25	Taylor-rule output growth
ρ_A	0.95	AR productivity
ρ_{GS}	0.95	AR government spending
ρ_P	0.8	AR central bank private bonds
ρ_G	0.8	AR central bank Treasuries

We calibrate the remaining parameters in Table C.1, which are standard in the literature. The top panel lists parameters related to the financial sector and central banck assets, which are calibrated following Sims and Wu (2021). The coupon decay rate κ matches the duration of long-term bonds being 10 years, and the recoverability parameter for the financial intermediary θ targets a 3% annual credit spread. The parameter ψ captures the fraction of investment that needs to be financed by long-term debt and is set to 0.81 by targeting the ratio between the outstanding private debt and nominal GDP prior to the Great Recession. The survival rate of financial intermediaries σ is 0.95, the recoverability parameter for Treasury bond Δ is 1/3. The steady-state central bank private and Treasury bond holdingings are set to zero and 6% of annual GDP, respectively. $\bar{b}^G$ is calibrated such that the steady state debt to GDP ratio is 41%. In the middle panel, the discount factor β is set to 0.995 to match the 2% annual risk-free interest rate, and $\Pi = 1$ implies the steady-state aggregate inflation is zero. The parameter of adjustment cost κ_I is set to 2, following Sims and Wu (2021).[7] The remaining parameters in the bottom panel are completely standard.

Appendix D Local Currency Pricing

This section replaces our baseline PCP with LCP by rewriting the problem of retail firms in Appendix A.3.3.

Under LCP, each retailer faces the following downward-sloping demand functions at home and abroad:

$$Y_{H,t}(h) = \left(\frac{P_{H,t}(h)}{P_{H,t}}\right)^{-\epsilon_p}(C_{H,t} + I_t + G_t), \tag{D.1}$$

$$Y^*_{H,t}(h) = \left(\frac{P^*_{H,t}(h)}{P^*_{H,t}}\right)^{-\epsilon_p} C^*_{H,t}, \tag{D.2}$$

where $P^*_{H,t}$ is the foreign price of domestically produced goods, and the total demand for individual home production is $Y_t(h) = Y_{H,t}(h) + Y^*_{H,t}(h)$.

The nominal profit of a retail firm is

$$DIV_{R,t}(h) = P_{H,t}(h)Y_{H,t}(h) + \mathcal{E}_t P^*_{H,t}(h)Y^*_{H,t}(h) - P_{w,t}Y_{w,t}(h),$$

[7] The adjustment cost in an open economy might be larger. With a larger κ_I, the responses of output and investment to a monetary policy become smaller. However, our qualitative comparison between financial integration and financial autarky is robust, and in some cases, the difference becomes even larger.

and then we have

$$
\begin{aligned}
DIV_{R,t}(h) \quad = \quad & P_{H,t}(h)^{1-\epsilon_p} P_{H,t}^{\epsilon_p}(C_{H,t} + I_t + G_t) + \mathcal{E}_t P_{H,t}^*(h)^{1-\epsilon_p} P_{H,t}^{*\epsilon_p} C_{H,t}^* \\
& - P_{w,t} P_{H,t}(h)^{-\epsilon_p} P_{H,t}^{\epsilon_p}(C_{H,t} + I_t + G_t) - P_{w,t} P_{H,t}^*(h)^{-\epsilon_p} P_{H,t}^{*\epsilon_p} C_{H,t}^*. \qquad \text{(D.3)}
\end{aligned}
$$

Assuming Calvo pricing: a retailer has a fixed probability $1 - \phi_p$ of being able to adjust its domestic and foreign prices in each period (with $0 \leq \phi_p \leq 1$). A retailer who is able to re-optimize its prices in period t maximizes the present discounted value of real profits:

$$
\begin{aligned}
\max_{P_{H,t}(h), P_{H,t}^*(h)} \mathbb{E}_t \sum_{j=0}^{\infty} \quad & \phi_p^j \Lambda_{t,t+j} P_{t+j}^{-1} \left[P_{H,t}(h)^{1-\epsilon_p} P_{H,t+j}^{\epsilon_p} (C_{H,t+j} + I_{t+j} + G_{t+j}) + \right. \\
& \mathcal{E}_{t+j} P_{H,t}^*(h)^{1-\epsilon_p} P_{H,t+j}^{*\epsilon_p} C_{H,t+j}^* - P_{w,t+j} P_{H,t}(h)^{-\epsilon_p} P_{H,t+j}^{\epsilon_p} (C_{H,t+j} + I_{t+j} + G_{t+j}) \\
& \left. - P_{w,t+j} P_{H,t}^*(h)^{-\epsilon_p} P_{H,t+j}^{*\epsilon_p} C_{H,t+j}^* \right].
\end{aligned}
$$

All the retail firms that reset prices in any given period will choose the same price. Therefore, we drop the index h and denote the optimal prices as $P_{H,t}^o$ and $P_{H,t}^{o*}$, which are solved via the following first-order conditions:

$$
\begin{aligned}
p_{H,t}^o &= \frac{\epsilon_p}{\epsilon_p - 1} \frac{x_{1,t}}{x_{2,t}} && \text{(D.4)} \\
x_{1,t} &= \tilde{p}_{m,t}(C_{H,t} + I_t + G_t) + \phi_p \mathbb{E}_t \Lambda_{t,t+1} \Pi_{H,t+1}^{\epsilon_p} x_{1,t+1} && \text{(D.5)} \\
x_{2,t} &= C_{H,t} + I_t + G_t + \phi_p \mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \Pi_{H,t+1}^{\epsilon_p} x_{2,t+1}, && \text{(D.6)} \\
p_{H,t}^{o*} &= \frac{\epsilon_p}{\epsilon_p - 1} \frac{x_{3,t}}{x_{4,t}} && \text{(D.7)} \\
x_{3,t} &= \tilde{p}_{m,t} C_{H,t}^* + \phi_p \mathbb{E}_t \Lambda_{t,t+1} \left(\Pi_{H,t+1}^* \right)^{\epsilon_p} x_{3,t+1} && \text{(D.8)} \\
x_{4,t} &= C_{H,t}^* + \phi_p \mathbb{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \left(\Pi_{H,t+1}^* \right)^{\epsilon_p} \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} x_{4,t+1}, && \text{(D.9)}
\end{aligned}
$$

where $p_{H,t}^o = P_{H,t}^o / P_t$, $p_{H,t}^{o*} = \mathcal{E}_t P_{H,t}^{o*} / P_t$, $\tilde{p}_{m,t} = P_{w,t} / P_t$, and $x_{1,t}$, $x_{2,t}$, $x_{3,t}$, and $x_{4,t}$ are auxiliary variables.

For the intermediate goods market,

$$(C_{H,t}+I_t+G_t)v_t^p + C_{H,t}^* v_{H,t}^{p*} = Y_{w,t} \tag{D.10}$$

where the price dispersion v_t^p follow (A.30) and

$$v_{H,t}^{p*} = (1-\phi_p)\left(\frac{p_{H,t}^{o*}P_t}{\mathcal{E}_t P_{H,t}^*}\right)^{-\epsilon_p} + \phi_p \Pi_{H,t}^{*\epsilon_p} v_{H,t-1}^{p*} \tag{D.11}$$

The price of domestic produced goods that are sold domestically $P_{H,t}$ evolves according to (A.31), and the price of domestic goods in the foreign country $P_{H,t}^*$ satisfies

$$\left(P_{H,t}^*\right)^{1-\epsilon_p} = (1-\phi_p)\left(P_{H,t}^{o*}\right)^{1-\epsilon_p} + \phi_p\left(P_{H,t-1}^*\right)^{1-\epsilon_p},$$

which yields

$$1 = (1-\phi_p)\left(\frac{p_{H,t}^{o*}P_t}{\mathcal{E}_t P_{H,t}^*}\right)^{1-\epsilon_p} + \phi_p\left(\Pi_{H,t}^*\right)^{\epsilon_p-1}. \tag{D.12}$$

For equilibrium conditions in Appendix B, we replace (A.26) - (A.29), and (3.7) with (D.4) - (D.6), (D.10) and (D.12), and add four equilibrium conditions in (D.7) - (D.9) and (D.11) to pin down four additional variables $(p_{H,t}^{o*}, x_{3,t}, x_{4,t}, v_{H,t}^{p*})$. Finally, we modify dividend in (A.1) with (D.3) and obtain the following:

$$\begin{aligned} div_t &= P_{H,t}/P_t(C_{H,t}+I_t+G_t+C_{H,t}^*) - mrs_t L_t - I_t + Q_t^P(b_t^P - \kappa b_{t-1}^P \Pi_t^{-1}) \\ &\quad - b_{t-1}^P \Pi_t^{-1} + (1-\sigma)\mathscr{b}_t. \end{aligned} \tag{D.13}$$