Financial Frictions and the International Transmission of Shocks

Woong Yong Park

This study presents a two-good, two-country model with financial frictions, where banks facing a borrowing constraint intermediate funds between households and firms. The endogenous fluctuations of international relative prices increase the business cycle co-movement across countries when combined with habit formation in consumption and investment adjustment costs. Financial frictions due to the borrowing constraint of the banks further amplify the effects of productivity and capital quality shocks within a country and across the two countries.

Keywords: Financial friction, International transmission of shock, Business cycle co-movement

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I. Introduction

The financial crisis in 2007–2008 has renewed interests in the role that financial factors play in the business cycle. Particularly, the rapid propagation of disruptions in financial markets from the U.S. to outside the U.S. at the onset of the financial crisis brings our attention to the international transmission of shocks through financial linkages.

This study builds a two-good, two-country model in which financial intermediation facing a borrowing constraint has nontrivial implications on the business cycle domestically and internationally. In the model, financial intermediaries or banks intermediate funds between households and firms. However, banks face a borrowing constraint due to limited contract enforceability. I assume a simple agency problem following Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) to introduce an endogenous borrowing constraint for banks. Financial frictions due to borrowing constraint are shown to amplify the effect of a country-specific shock across countries and within the country where the shock originates. Endogenous fluctuations of the asset prices affect the balance sheet condition of banks and consequently their lending to firms. The cross-border effect of a shock is amplified because banks are directly exposed to foreign shocks through foreign asset holdings.

The model incorporates devices, such as habit formation in consumption and investment adjustment costs. The quantitative macroeconomic literature has found that such devices are useful in explaining the business cycle quantitatively. Particularly, the present study shows that when combined with habit formation in consumption and investment adjustment costs, the fluctuations of international relative prices propagate a country-specific shock internationally. Furthermore, these fluctuations make the business cycle co-move across countries. Frictions in financial intermediation amplify this propagation of a country-specific shock.

Kiyotaki and Moore (1997) and Bernanke, Gertler, and Gilchrist (1999) incorporated financial factors into the quantitative macroeconomic framework. Afterward, many attempts have been made that extend financial factors to an open economy and investigate their effects on the international transmission of shocks. Earlier papers that used a two-country framework include those of Gilchrist, Hairault, and Kempf (2003); Iacoviello and Minetti (2006); and Faia (2007). The recent financial crisis renewed interests in the effects of financial frictions on

the international business cycle. Devereux and Yetman (2010) and Yao (2019) studied the international transmission of shocks when investors face a leverage constraint in borrowing. Kollmann, Enders, and Muller (2011) assumed that global banks face a capital requirement and investigate how such a requirement affects the international business cycle. Kim (2011) studied international macroeconomic fluctuations in Korea by focusing on the fluctuation sources in key international macroeconomic variables.

My model contributes to this literature in several aspects. First, I allow for endogenous fluctuations of international relative prices, unlike Devereux and Yetman (2010) and Yao (2019). Each country produces differentiated intermediate goods, and the final good production in each country is biased toward local intermediate goods. Therefore, international relative prices fluctuate in response to shocks, which is an important channel for the international transmission of the shocks (Heathcote and Perri, 2002). The co-movement of business cycles across countries is not entirely attributed to financial frictions in my model. Second, I introduce endogenous capital accumulation and labor supply, which are important factors in propagating the business cycle, in contrast to Devereux and Yetman (2010) who fix capital and labor supply. Lastly, the explicit consideration of financial intermediation in the model following Gertler and Karadi (2011) and Gertler and Kiyotaki (2010) provides a framework. The objective is to extend the model in the future and study the effects of unconventional policy measures against the disruptions in financial intermediation during a financial crisis.

This paper is organized as follows. The benchmark model is described in Section II, and its solution method is explained in Section III. Section IV presents the impulse response functions to shocks and the cross-country correlations of macroeconomic variables and discuss the results. Section V concludes this study.

II. Benchmark Model

The world economy consists of two countries of the same size, Home and Foreign. The structure of each country is similar to Gertler and Kiyotaki (2010), and I extend their model to a two-country model by allowing international trade of goods and assets.

Each country has households, intermediate-good-producing firms (*i*-firms), final-good-producing firms (*f*-firms), a capital-good-

producing firm (*c*-firm), and banks. *i*-Firms produce a country-specific, differentiated intermediate good, whereas *f*-firms use the local and foreign intermediate goods to produce final goods for consumption and investment. Intermediate goods are freely traded across countries, whereas final goods are not tradable. The *c*-firm builds new capital, which is in turn sold to local *i*-firms. Banks intermediate funds between households and *i*-firms, which need to borrow for the purchase of new capital. I use the final goods as a numeraire in each country.

I describe the agents and their economic choices in turn. I omit the description of a sector of the Foreign economy when it is clear that the Foreign sector is defined symmetrically to the corresponding sector of the Home economy. A superscript "$*$" is used to distinguish a variable for Foreign from its corresponding variable for Home. Subscripts 1 and 2 denote a variable initiated by agents in Home and Foreign, respectively. For example, $Y^{*}_{1,t}$ denotes intermediate goods produced in Home and exported to Foreign, whereas $S_{2,t}$ denotes lending by Foreign banks to *i*-firms in Home.

A. Households

A representative household in both countries has a continuum of members of measure one. A fraction $1 - m$ of the members denotes workers who supply labor and earn labor income, and the rest of the household members are bankers who manage banks in the same country. This heterogeneous composition of households is a device to have nonzero borrowing and lending in equilibrium. I assume that perfect consumption insurance works between workers and bankers in a household.

A representative household of Home chooses consumption of final goods C_t, supplies labor L_t, and deposits to banks in Home to maximize the expected discounted sum of utilities, as shown as follows:

$$E_t \sum_{j=0}^{\infty} \beta^j \frac{1}{1-\gamma} \left[\left(C_{t+j} - hC_{t+j-1} \right) - \frac{\chi}{1+\varepsilon} L_{t+j}^{1+\varepsilon} \right]^{1-\gamma}, \tag{1}$$

subject to the flow budget constraint

$$C_t = w_t L_t + \Pi_t - T_t + R_{t-1} D_{t-1} - D_t \tag{2}$$

where D_t denotes a deposit to local (Home) banks; W_t real wage; Π_t dividends from the ownership of banks and the *c*-firm in Home; and T_t a lump-sum tax net of transfers. The expression for Π_t is given later after describing the problem of banks and the *c*-firm. The deposit is noncontingent and earns interests at the gross interest rate of R_t between period t and period $t + 1$. I assume that the households cannot lend to foreign banks. The households also own *i*-firms and *f*-firms of Home, but their profits are zero in equilibrium because they are perfectly competitive.

The period utility function in (1) features habit formation in consumption and nests a Greenwood–Hercowitz–Huffman (GHH 1988)-type preference. When no habit formation ($h = 0$) exists, the GHH preference exhibits no wealth effects on labor supply.[1] Although certain wealth effects operate on labor supply in the presence of habit formation, the effects are weaker than a standard preference.

The optimality conditions for the representative household are

$$w_t U_{C,t} + U_{L,t} = 0, \tag{3}$$

where

$$U_{C,t} = \left(C_t - hC_{t-1} - \frac{\chi}{1+\varepsilon} L_t^{1+\varepsilon} \right)^{-\gamma} - \beta h E_t \left(C_{t+1} - hC_t - \frac{\chi}{1+\varepsilon} L_{t+1}^{1+\varepsilon} \right)^{-\gamma},$$

$$U_{L,t} = \left(C_t - hC_{t-1} - \frac{\chi}{1+\varepsilon} L_t^{1+\varepsilon} \right)^{-\gamma} \left(-\chi L_t^{\varepsilon} \right),$$

and

$$E_t \Xi_{t,t+1} R_t = 1 \tag{4}$$

where $\Xi_{t,t+1} = \beta U_{C,t+1} / U_{C,t}$ is the stochastic discount factor.

[1] The open economy literature, such as Mendoza (1991), Neumeyer and Perri (2005), Chang and Fernández (2013), and Yao (2019), has found that the GHH preference helps replicate certain open-economy business cycle facts. GHH preference is also used in the credit market imperfection literature, such as Miao and Wang (2010) and Gertler, Kiyotaki, and Queralto (2011).

B. Nonfinancial Firms

a) *i*-Firms

Each country has a continuum of perfectly competitive *i*-firms of measure one that produce country-specific intermediate goods. *i*-Firms have common constant returns to scale technology, with capital and labor as inputs. I assume that capital and labor cannot move across countries. The aggregate production function for the Home intermediate good is given by

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{5}$$

where A_t is a country-specific productivity shock, K_t denotes capital, and L_t is labor input.

Capital is owned by *i*-firms. The *i*-firms purchase new capital I_t from the *c*-firm of the same country, financing the purchase by issuing one-period securities against payoffs on capital to local and foreign banks. Let S_t denote the total number of securities or outstanding securities. Then, the asset supply in period t is determined as

$$S_t = I_t + (1-\delta) K_t,$$

where δ is a capital depreciation rate. However, capital is subject to a shock to its quality at the beginning of the next period; thus, capital is accumulated as

$$K_{t+1} = \psi_{t+1} S_t. \tag{6}$$

The capital quality shock ψ_t is introduced as a reduced-form shock to trigger a sudden collapse of the asset price.[2] I assume that ψ_t is a one-time shock with no persistence.

The profit maximization conditions of *i*-firms are given by

$$w_t = (1-\alpha) \frac{Y_t}{L_t} P_{1,t} \tag{7}$$

[2] Gertler and Kiyotaki (2010) and Gertler, Kiyotaki and Queralto (2011) introduced a shock to the capital quality and interpreted it as capturing a certain form of economic obsolescence.

and

$$Z_t = \frac{P_{1,t}Y_t - w_t L_t}{K_t} = \alpha A_t \left(\frac{L_t}{K_t}\right)^{1-\alpha} P_{1,t}, \tag{8}$$

where $P_{1,t}$ is the price of the Home intermediate good in units of the final goods of Home; and Z_t is the payoff per unit of capital, which will be entirely paid out to those banks holding claims to the capital return.

b) *f*-Firms

For notational simplicity, I introduce perfectly competitive *f*-firms rather than assuming that consumption and investment are a function of country-specific goods. A representative *f*-firm in Home produces a final good using Home and Foreign intermediate goods as inputs. This *f*-firm has the following constant elasticity of substitution production function

$$F_t = \left[\varphi^{\frac{1}{\eta}} Y_{1,t}^{\frac{\eta-1}{\eta}} + (1-\varphi)^{\frac{1}{\eta}} Y_{2,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}, \tag{9}$$

where $Y_{1,t}$ and $Y_{2,t}$ are the Home and the Foreign intermediate goods, respectively. The steady-state fraction of the Home intermediate goods in the Home final good production is given by φ. When $\varphi > 1/2$, a home bias is observed in the final good production. Let $P_{2,t}$ denote the price of the Foreign intermediate goods in units of the Home final goods. Then, *f*-firms maximize a profit, as shown as follows:

$$\left[\varphi^{\frac{1}{\eta}} Y_{1,t}^{\frac{\eta-1}{\eta}} + (1-\varphi)^{\frac{1}{\eta}} Y_{2,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} - P_{1,t}Y_{1,t} - P_{2,t}Y_{2,t},$$

taking the prices $P_{1,t}$ and $P_{2,t}$ as given. The profit maximization condition is given by

$$\frac{Y_{1,t}}{Y_{2,t}} = \frac{\varphi}{1-\varphi}\left(\frac{P_{1,t}}{P_{2,t}}\right)^{-\eta},$$

and the factor demand for $Y_{1,t}$ and $Y_{2,t}$ is determined as

$$Y_{1,t} = \varphi P_{1,t}^{-\eta} F_t \tag{10}$$

$$Y_{2,t} = (1-\varphi) P_{2,t}^{-\eta} F_t, \tag{11}$$

respectively.

c) *c*-Firm

The *c*-firm transforms final goods to capital subject to convex adjustment costs and sell new capital to *i*-firms. The new capital is sold only to local firms because capital is immobile across borders.[3] The *c*-firm solves

$$\max_{\{I_{t+j}\}_{j=0}^{\infty}} E_t \sum_{j=0}^{\infty} \Xi_{t,t+j} \left[Q_{t+j} I_{t+j} - \left(1 + \Psi \left(\frac{I_{t+j}}{I_{t+j-1}} \right) \right) I_{t+j} \right],$$

taking Q_t, the market price of new capital, as given. The *c*-firm discounts the future profits using the stochastic discount factor of the households $\Xi_{t,t+j}$ because the households in Home own the *c*-firm.

The *i*-firms purchase new capital by issuing securities; thus, Q_t is equal to the asset price. The production of new capital incurs adjustment cost $\Psi(I_t / I_{t-1}) \cdot I_t$, where the function Ψ satisfies $\Psi(1) = \Psi'(1) = 0$ and $\Psi''(I_t / I_{t-1}) > 0$. The adjustment cost is introduced to generate a time-varying price of capital. I assume that the adjustment cost is a function of changes in investment following Christiano, Eichenbaum, and Evans (2005) and Gertler and Kiyotaki (2010), who found that

[3] I assume that capital is not mobile across borders to focus on the role of financial intermediation subject to frictions in international transmissions of the shocks. Only local *c*-firms supply new capital to meet an investment surge after a positive productivity shock in an economy where capital is immobile across borders. Thus, the price of new capital will rise; thus, an investment surge will be contained. Moreover, an investment surge can be supported by imported and domestically produced capital in an economy where capital is freely mobile across borders. Next, investment increases more compared with an economy where capital imports are impossible. However, all else equal, investment will be depressed in the foreign country because of the rise of the price of new capital. Therefore, international co-movement in investment will deteriorate in an economy where capital is freely mobile across borders compared with an economy where capital cannot move across borders.

this type of investment adjustment costs is useful in explaining the quantitative response of the economy to a shock. The optimality condition is given by

$$Q_t = 1 + \Psi\left(\frac{I_t}{I_{t-1}}\right) + \left(\frac{I_t}{I_{t-1}}\right)\cdot\Psi'\left(\frac{I_t}{I_{t-1}}\right) - E_t\Xi_{t,t+1}\left(\frac{I_{t+1}}{I_t}\right)^2\cdot\Psi'\left(\frac{I_{t+1}}{I_t}\right). \quad (12)$$

Future investment and thus the future asset prices may affect current investment through the forward-looking term on the right-hand side.

C. Banks

A continuum of banks of measure m intermediates funds between households and i-firms. Banks take deposits from local households and lend to local and foreign firms that use the funds to finance their investment. I assume an agency problem arising due to the limited enforceability of a contract, as in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). That is, the banker managing a bank may embezzle certain asset holdings. This agency problem will impose an endogenous constraint on the borrowing of the bank. On the contrary, no friction exists between banks and firms.[4] I also assume that banks pay small second-order stochastic costs when they lend to foreign firms to match the degree of diversification in portfolio observed in the data.

The balance sheet of a bank in Home is given by

$$Q_t s_{1,t} + e_t Q_t^* s_{1,t}^* = n_t + d_t, \quad (13)$$

where Q_t^* denotes the price of the Foreign asset in units of the Foreign final good; $s_{1,t}$ and $S_{1,t}^*$ denote lending to Home and Foreign i-firms, respectively; n_t is the net worth; and d_t denotes the deposit by Home households.[5] The real exchange rate e_t is quoted as the price of the

[4] I assume no frictions between banks and firms to focus on the role of financial intermediation, as in Gertler and Kiyotaki (2010). Devereux and Yetman (2010) and Yao (2019) also assumed no frictions when a production firm rents capital from investors.

[5] I do not allow the banks in one country to invest in other financial assets, such as bonds of another country, to focus on the role of financial intermediation subject to frictions in international transmissions of the shocks. Generally, investment in foreign bonds will operate as a channel through which

Foreign final goods in terms of the Home final goods. Net worth at the beginning of period t after shocks are revealed is the gross payoff to lending made in the previous period net borrowing costs, as shown as follows:

$$\begin{aligned} n_t &= \psi_t \left[Z_t + (1-\delta) Q_t \right] s_{1,t-1} + e_t \psi_t^* \left[Z_t^* + (1-\delta) Q_t^* \right] s_{1,t-1}^* - R_{t-1} d_{t-1} \\ &= R_{k,t} Q_{t-1} s_{1,t-1} + \left(R_{k,t}^* \frac{e_t}{e_{t-1}} \right) e_{t-1} Q_{t-1}^* s_{1,t-1}^* - R_{t-1} d_{t-1}, \end{aligned} \tag{14}$$

where Z_t^* is the payoff on capital in Foreign

$$Z_t^* = \frac{P_{2,t}^* Y_t^* - w_t^* L_t^*}{K_t^*},$$

and $R_{k,t}$ and $R_{k,t}^*$ are returns on Home and Foreign assets

$$R_{k,t} = \frac{\psi_t \left[Z_t + (1-\delta) Q_t \right]}{Q_{t-1}} \text{ and } R_{k,t}^* = \frac{\psi_t^* \left[Z_t^* + (1-\delta) Q_t^* \right]}{Q_{t-1}^*},$$

respectively.

In every period, a fraction $1 - \pi$ of the bankers in each household is randomly selected, quits the banking business, and becomes workers. That is, the survival probability of bankers' period by period is π, and the average survival time is $1 / (1 - \pi)$. This assumption of entry and exit of bankers prevents banks from accumulating wealth and becoming financially unconstrained. I assume that $m(1 - \pi)$ workers become bankers every period, such that the proportion of the occupations stay constant over time.

The exiting bankers hand over their net worth to the households as dividends. Newly entering bankers receive a start-up fund from their households and take part in the deposit market. The new bankers have the same decision problem as the old bankers, except that they do not have deposits from the previous period on their balance sheet. The objective of a banker at the end of period t is to maximize the expected

the banks can hedge against adverse effects of the foreign productivity shocks on their balance sheets. Hence, the amplification of the shock transmission by financial intermediation will be dampened.

present value of dividends, as shown as follows:

$$E_t \sum_{j=1}^{\infty} \Xi_{t,t+j} \left(1-\pi\right) \pi^{j-1} n_{t+j}. \tag{15}$$

The banker uses $\Xi_{t,t+j}$ to discount future dividends in period $t + j$ because the bank is owned by a household in Home.

After a bank obtains funds from depositors and lends to firms, its banker may divert a fraction θ of the asset holdings to his household, where $0 < \theta < 1$. If the banker cheats, then the bank is forced to default, and the creditors of the bank recover whatever remains. Let $V_t(\boldsymbol{s}_t)$ denote the maximized value function of (15), given $\boldsymbol{s}_t = \left\{s_{1,t}, s^*_{1,t}, d_t\right\}$. The following incentive constraint is imposed on the banker's problem to prevent the embezzlement:

$$V_t\left(\boldsymbol{s}_t\right) \geq \theta\left(Q_t s_{1,t} + e_t Q^*_t s^*_{1,t}\right), \tag{16}$$

which implies that the continuation value of banking is greater than or equal to private gains from the diversion. I assume that no difference in private gains from the diversion and subsequent recovery of local and foreign assets exists. In summary, the problem of a banker is to maximize (15) subject to (13) and (16).

The value function of a banker can be written recursively as

$$V_t\left(\boldsymbol{s}_t\right) = E_t \Xi_{t,t+1}\left[\left(1-\pi\right) n_{t+1} + \pi \max_{\boldsymbol{s}_{t+1}} V_{t+1}\left(\boldsymbol{s}_{t+1}\right)\right]. \tag{17}$$

To solve the problem, I conjecture that the value function is linear in its arguments and verify it later. That is,

$$V_t\left(\boldsymbol{s}_t\right) = \nu_{s,t} s_{1,t} + \nu_{s^*,t} s^*_{1,t} - \nu_{d,t} d_t,$$

where $\nu_{s,t}$ is the marginal value of the Home asset holdings, $\nu_{s^*,t}$ the marginal value of the Foreign asset holdings, and $\nu_{d,t}$ the marginal cost of deposits. The first-order conditions are given by

$$\frac{\nu_{s,t+1}}{Q_{t+1}} - \nu_{d,t+1} = \frac{\theta \lambda_{t+1}}{1+\lambda_{t+1}}, \tag{18}$$

with respect to $s_{1,t+1}$ and

$$\frac{\nu_{s^*,t+1}}{e_{t+1}Q^*_{t+1}} - \nu_{d,t+1} = \frac{\theta\lambda_{t+1}}{1+\lambda_{t+1}}, \tag{19}$$

with respect to $s^*_{1,t+1}$, where λ_{t+1} is the Lagrange multiplier for the incentive constraint (16). Using the complementary slackness condition,

$$\lambda_t \left[V_t\left(\boldsymbol{s}_t\right) - \theta\left(Q_t s_{1,t} + e_t Q^*_t s^*_{1,t}\right)\right] = 0,$$

the value function can be written as

$$V_t\left(\boldsymbol{s}_t\right) = \nu_{d,t}\left(1+\lambda_t\right) n_t. \tag{20}$$

Plugging (20) back into (17), then

$$V_t = E_t \Xi_{t,t+1} \Omega_{t+1} n_{t+1},$$

where $\Omega_{t+1} = \left(1-\pi\right) + \pi\nu_{d,t+1}\left(1+\lambda_{t+1}\right)$ is the marginal value of net worth. Net worth evolves according to (14) by the method of undetermined coefficients. Thus, I obtain

$$\nu_{s,t} = E_t \Xi_{t,t+1} \Omega_{t+1} \psi_{t+1}\left[Z_{t+1} + \left(1-\delta\right) Q_{t+1}\right], \tag{21}$$

$$\nu_{s^*,t} = E_t \Xi_{t,t+1} \Omega_{t+1} \psi^*_{t+1}\left[Z^*_{t+1} + \left(1-\delta\right) Q^*_{t+1}\right] e_{t+1}, \tag{22}$$

and

$$\nu_{d,t} = E_t \Xi_{t,t+1} \Omega_{t+1} R_t. \tag{23}$$

The first-order conditions (18) and (19) imply that

$$E_t \Xi_{t,t+1} \Omega_{t+1}\left(R_{k,t+1} - R_t\right) = E_t \Xi_{t,t+1} \Omega_{t+1}\left(R^*_{k,t+1}\frac{e_{t+1}}{e_t} - R_t\right) = \mu_t,$$

where $\mu_{t+1} = \theta\lambda_{t+1} / \left(1+\lambda_{t+1}\right)$ is the marginal excess value of assets over the marginal cost of deposits, and

$$E_t \Xi_{t,t+1} \Omega_{t+1}\left(R_{k,t+1} - R^*_{k,t+1}\frac{e_{t+1}}{e_t}\right) = 0. \tag{24}$$

Equation (24) implies an uncovered parity for the rates of return on capital between the Home and Foreign assets. The effective discount factor $\Xi_{t,t+1}\Omega_{t+1}$ is that of the households augmented by the marginal value of net worth representing the interest of the banker in the continuation of the banking business.

Following Gertler and Kiyotaki (2010), I select the parameter values of the model, such that the incentive constraint (16) binds in the steady state. I also analyze the dynamics of the model in the neighborhood of the steady state. That is, I assume that the incentive constraint (16) always binds. Then, (16) may be written as

$$Q_t s_{1,t} + e_t Q_t^* s_{1,t}^* = \phi_t n_t, \tag{25}$$

where $\phi_t = \nu_{d,t}\left(1+\lambda_t\right)/\theta$ can be interpreted as the leverage ratio of the bank. The marginal value of net worth Ω_{t+1} can be rewritten as

$$\Omega_{t+1} = \left(1-\pi\right) + \pi\left(\nu_{d,t+1} + \mu_{t+1}\phi_{t+1}\right),$$

which implies that an additional unit of net worth has the same unit value when the banker quits with probability of $1-\pi$. However, such an additional unit saves the marginal cost of a unit of deposits $\nu_{d,t+1}$ and earns an excess value μ_{t+1}, multiplied by the leverage ratio ϕ_{t+1} when the banker survives with probability π.

Aggregation across banks is straightforward. The balance sheet of an individual bank (13) is aggregated as

$$Q_t S_{1,t} + e_t Q_t^* S_{1,t}^* = N_t + D_t, \tag{26}$$

where $S_{1,t}$ and $S_{1,t}^*$ denote the aggregate holdings of the Home and Foreign assets, respectively, by Home banks; N_t is the aggregate net worth of Home banks; and D_t is the aggregate deposits in Home. The aggregation of (25) results in the aggregate asset demand equation

$$Q_t S_{1,t} + e_t Q_t^* S_{1,t}^* = \phi_t N_t, \tag{27}$$

where ϕ_t is common across individual banks, and thus aggregation is possible. The aggregate net worth N_t at the beginning of each period, after shocks are revealed and the entry and exit are determined, is the sum of the net worth of surviving banks and the start-up funds

of newly entering bankers. I assume that the new bankers receive a fraction τ of the value of the asset holdings managed by exiting bankers. Therefore,

$$N_t = \pi \left\{ R_{k,t} Q_{t-1} S_{1,t-1} + e_t R^*_{k,t} Q^*_{t-1} S^*_{1,t-1} - R_{t-1} D_{t-1} \right\} + \tau \left\{ R_{k,t} Q_{t-1} S_{1,t-1} + e_t R^*_{k,t} Q^*_{t-1} S^*_{1,t-1} \right\}. \tag{28}$$

D. International Relative Prices and Balance of Payments

By the law of one price,

$$P^*_{1,t} e_t = P_{1,t} \text{ and } P_{2,t} \frac{1}{e_t} = P^*_{2,t},$$

where $P^*_{2,t}$ and $P^*_{1,t}$ are the Foreign final good price of the Foreign and Home intermediate goods, respectively. Then, the real exchange rate is determined as the ratio of the prices

$$e_t = \frac{P_{1,t}}{P^*_{1,t}} = \frac{P_{2,t}}{P^*_{2,t}}. \tag{29}$$

The real exchange rate is not generally constant in the presence of bias in the final good production; thus, the purchasing power parity does not hold in this model. The terms of trade are defined as the relative price of imported to exported goods, that is,

$$P_{ToT,t} = \frac{P_{2,t}}{P_{1,t}} \text{ and } P^*_{ToT,t} = \frac{P^*_{1,t}}{P^*_{2,t}}.$$

Notably, $P_{ToT,t} = 1 / P^*_{ToT,t}$ because of the law of one price. Net exports are exports minus imports of intermediate goods in units of the local final goods, that is,

$$NX_t = P_{1,t} Y^*_{1,t} - P_{2,t} Y_{2,t} \text{ and } NX^*_t = P^*_{2,t} Y_{2,t} - P^*_{1,t} Y^*_{1,t},$$

for Home and Foreign, respectively. Notably, $NX_t + e_t NX^*_t = 0$. Net foreign assets in units of the local final good are given by

$$NFA_t = e_t Q^*_t S^*_{1,t} - Q_t S_{2,t} \text{ and } NFA^*_t = \frac{1}{e_t} Q_t S_{2,t} - Q^*_t S^*_{1,t}$$

for Home and Foreign, respectively, where $S_{2,t}$ is the aggregate holdings of the Foreign asset by Home banks. Notably, $NFA_t + e_t NFA_t^* = 0$.

E. Equilibrium and Market Clearing Conditions

An equilibrium of the model is defined as a set of prices and allocations, such that all the agents solve their problems, taking the prices given and the markets are cleared.

The intermediate good is used locally or exported. Therefore, its global resource constraint is given by

$$Y_t = Y_{1,t} + Y_{1,t}^*$$

for the Home intermediate good, where $Y_{1,t}^*$ is exported to Foreign; and

$$Y_t^* = Y_{2,t}^* + Y_{2,t}$$

for the Foreign intermediate good, where $Y_{2,t}^*$ is sold in Foreign. The gross domestic product in units of the final good is given by

$$GDP_t = P_{1,t} Y_t \text{ and } GDP_t^* = P_{2,t}^* Y_t^*.$$

The market-clearing condition for the final good is

$$F_t = C_t + \left(1 + \Psi\left(\frac{I_t}{I_{t-1}}\right)\right) I_t + G_t \tag{30}$$

for Home and

$$F_t^* = C_t^* + \left(1 + \Psi\left(\frac{I_t^*}{I_{t-1}^*}\right)\right) I_t^* + G_t^* \tag{31}$$

for Foreign. The sum of the Home asset held by Home banks and Foreign banks should be equal to the Home asset supplied by the *i*-firms of Home

$$S_{1,t} + S_{2,t} = S_t, \tag{32}$$

and an analogous condition holds for the Foreign asset market, that is,

$$S^*_{2,t} + S^*_{1,t} = S^*_t. \tag{33}$$

The government is assumed to balance its budget and keep its expenditure constant as

$$G_t = \bar{G} = T_t \text{ and } G^*_t = \bar{G} = T^*_t.$$

Households in the model have two flow budget constraints, and at least one of them should be included in the system of equilibrium equations. The profit paid as dividends by banks and the *c*-firm in the flow budget constraint for households are given by

$$\begin{aligned}\Pi_t = Q_t I_t - \left(1 + \Psi\left(\frac{I_t}{I_{t-1}}\right)\right) I_t + (1-\pi)\left[R_{k,t} Q_{t-1} S_{1,t-1} + e_t R^*_{k,t} Q^*_{t-1} S^*_{1,t-1} - R_{t-1} D_{t-1}\right] \\ -\tau\left[R_{k,t} Q_{t-1} S_{1,t-1} + e_t R^*_{k,t} Q^*_{t-1} S^*_{1,t-1}\right]\end{aligned} \tag{34}$$

in Home and

$$\begin{aligned}\Pi^*_t = Q^*_t I^*_t - \left(1 + \Psi\left(\frac{I^*_t}{I^*_{t-1}}\right)\right) I^*_t + (1-\pi)\left[R^*_{k,t} Q^*_{t-1} S^*_{2,t-1} + \frac{1}{e_t} R_{k,t} Q_{t-1} S_{2,t-1} - R^*_{t-1} D^*_{t-1}\right] \\ -\tau\left[R^*_{k,t} Q^*_{t-1} S^*_{2,t-1} + \frac{1}{e_t} R_{k,t} Q_{t-1} S_{2,t-1}\right]\end{aligned} \tag{35}$$

in Foreign.

III. Solution and Simulation

A. Portfolio Choice

I analyze the dynamics of the model in the neighborhood of the deterministic steady state using the first-order accurate approximation. Thus, a portfolio choice problem arises when banks choose to lend to local and foreign firms. The expected returns on the Home and Foreign assets in (24) are identical up to first order; hence, the banks are indifferent between the two assets. The total asset supplied, the total asset demanded, and net foreign assets are identified, but not their decompositions.

I use a method developed by Devereux and Sutherland (2011) to compute the zeroth-order component of portfolio allocations, which

is needed to calculate the first-order accurate approximation of the dynamics of the other variables. The idea is to use the second-order accurate approximation of equilibrium conditions, such as (24), involving the rates of return of the assets to identify the zeroth-order component of the asset holdings.

I write equilibrium conditions in terms of the total asset supplied S_t and S_t^*, the value of the total asset holdings $M_t = Q_t S_{1,t} + e_t Q_t^* S_{1,t}^*$ and $M_t^* = Q_t^* S_{2,t}^* + (1/e_t)(Q_t S_{2,t})$, and the excess return on foreign assets $S_{1,t}^*$ and $S_{2,t}$ to apply their method. Specifically, the asset market clearing conditions (30) and (31) are written as

$$Q_t S_t = Q_t \left(S_{1,t} + S_{2,t} \right) = M_t - NFA_t$$

in Home and

$$Q_t^* S_t^* = Q_t^* \left(S_{2,t}^* + S_{1,t}^* \right) = M_t^* - NFA_t^*$$

in Foreign. The payoffs on the asset holdings in equations, such as (28), (34), and (35), are written as

$$R_{k,t} Q_{t-1} S_{1,t-1} + e_t R_{k,t}^* Q_{t-1}^* S_{1,t-1}^* = R_{k,t} M_{t-1} + \left(R_{k,t}^* \frac{e_t}{e_{t-1}} - R_{k,t} \right) e_{t-1} Q_{t-1}^* S_{1,t-1}^*$$

in Home and

$$R_{k,t}^* Q_{t-1}^* S_{2,t-1}^* + \frac{1}{e_t} R_{k,t} Q_{t-1} S_{2,t-1} = R_{k,t}^* M_{t-1}^* + \left(R_{k,t} \frac{e_{t-1}}{e_t} - R_{k,t}^* \right) \frac{1}{e_{t-1}} Q_{t-1} S_{2,t-1}$$

in Foreign. Those terms involving the excess return on foreign assets will disappear in the deterministic steady state and in the first-order accurate approximation because of the equality of all the asset returns. Thus, the foreign asset holdings will drop out except for their zeroth-order term.

When solving the model, I modify (24) as

$$E_t \Xi_{t,t+1} \Omega_{t+1} \left(R_{k,t+1} - R_{k,t+1}^* \frac{e_{t+1}}{e_t} \exp\left(-x_{t+1} \right) \right) = 0$$

to introduce a small stochastic transaction cost x_{t+1} in foreign asset

holdings. The transaction cost is of second order and thus does not affect the first-order dynamics of the other variables. The transaction cost only affects the portfolio choice problem. Such a transaction cost is often used in the open-economy literature to adjust portfolio diversification of investors (See Tille and van Wincoop (2010), Devereux and Yetman (2010), and Yao (2019)). The literature introduces such a transaction cost to reduce excess diversification toward foreign assets and match a home bias in portfolio observed in the data. However, I introduce the transaction cost to increase diversification toward foreign assets. The difference here is that banks want to short foreign assets when the transaction is at no cost in the presence of the risk of international relative price fluctuations. The result is consistent with Heathcote and Perri (2013), who showed that domestic assets are a good hedge against nondiversifiable domestic risks when international relative prices fluctuate. In their model, portfolio diversification is biased toward domestic assets.

Given the benchmark parameter values (which will be explained in Section III. *C.*), I find the returns of domestic and foreign assets in units of the domestic final good are negatively correlated with the effective stochastic discount factor in (24). However, the return of foreign assets has a lower negative correlation than the return of domestic assets.[6] Therefore, banks attempt to borrow from *i*-firms in a foreign country when the transaction is at no cost. I induce the banks to lend to a foreign country by introducing the transaction cost because a key assumption of the model is that the banks can borrow only from local households. Following Heathcote and Perri (2013), I set the size of the transaction cost, such that the banks hold 25% of their portfolio in foreign assets.

B. Solution Method

I solve for the steady state of the model and linearize the equilibrium equations around the steady state. Then, I solve the resulting system of

[6] The model has two types of shock, namely, productivity and capital quality shocks. I do not use the capital quality shock in simulating the model and computing the correlations because the capital quality shock starts a sudden collapse of asset prices. The correlations of the returns of the assets may vary when different shocks are assumed in the model.

equations using the linear rational expectations model solution method by Sims (2002).

When the asset markets are incomplete, certain variables of an open-economy model, such as wealth distribution, become nonstationary. Applying a device to make the model stationary is common in the literature. For example, Devereux and Yetman (2010) and Yao (2019) introduced an endogenous discount factor, and Heathcote and Perri (2002) assumed small convex adjustment costs for portfolio holdings. Schmitt-Grohe and Uribe (2003) presented several methods to induce stationarity of a small open-economy model and compared their resulting dynamics. However, the first-order accurate approximation to the equilibrium conditions around the steady state is arbitrarily accurate with a sufficiently small perturbation around the steady state despite its nonstationarity, as pointed out by Kim, Kim, Schaumburg, and Sims (2008). Thus, I do not try to "close" the model or make the model stationary. A first-order accurate approximation does not converge to the steady state around which the original system is approximated, or it does not have the saddle path stability. However, the approximate system stays in the neighborhood of the steady state when shocks are sufficiently small.

Stationarity is a long-run property, and making a model stationary in the long run does not require significant changes in the short- and medium-run dynamics of the model. Moreover, closing a model affects the dynamics of the model significantly which is undesirable. This finding suggests that closing a model is of no practical benefit. Of course, in the long run, an unclosed model will diverge with probability one. Thus, simulations of finite samples should be used instead of simulations of extremely long samples to calculate the moments of variables. Simulating samples of the same size as the data is also a common practice.

C. Parameter Values

In this section, I explain the parameter values that I use in the following simulation exercise. I identify Home with the U.S. and Foreign with the rest of the world.[7] The frequency of the model is set to a

[7] The rest of the world is a fictional country that includes 15 major European countries, Canada, and Japan.

quarter.

Table 1 summarizes the benchmark parameter values. I assign values that are conventional in the literature for preference and technology parameters. These parameters and their respective values include the following: discount factor $\beta = 0.99$, coefficient of risk aversion $\gamma = 2$, habit formation parameter $h = 0.5$, relative utility weight of labor $x = 0.25$, inverse of the Frisch elasticity of labor supply $\epsilon = 0.5$, capital share in the intermediate good production $\alpha = 0.33$, and quarterly depreciation rate $\delta = 0.025$. The inverse of the elasticity of investment with respect to the price of capital $\kappa \equiv \Psi''(\cdot)$ is set to 1.5, which is the same as the value used by Gertler and Kiyotaki (2010). By contrast, such a value is slightly less than the estimate of 2.5 by Christiano, Eichenbaum, and Evans (2005) and the estimate of 2.85 by Justiniano, Primiceri, and Tambalotti (2010). If the κ is small, then the persistence of investment induced by the investment adjustment cost is also small. The model includes financial frictions as an additional mechanism to generate the investment persistence, unlike the models estimated by Christiano, Eichenbaum, and Evans (2005) and Justiniano, Primiceri, and Tambalotti (2010). Thus, I choose a smaller value for κ.

The share of imported goods in final good production $1 - \omega$ is assumed to be 0.15 based on the fact that the volume of imports of the U.S. is approximately 15% of its output. The value implies that a Home bias is observed in consumption and investment. Following Heathcote and Perri (2002), I set the elasticity of substitution between the intermediate goods η to 0.9.

I follow Gertler and Kiyotaki (2010) for the parameters related to financial intermediation. The quarterly survival rate of bankers π is set to 0.975, which implies that the average survival period is 10 years. The transfer parameter for newly entering bankers τ is set to 0.001, and the fraction of assets that a banker can divert θ is set to 0.4. Gertler and Kiyotaki (2010) selected τ and π to match an average annual credit spread of 100 basis points. One hundred is the approximate average of the spreads between mortgage rates and government bonds rates, BAA corporate bonds rates and government bonds, and commercial paper rates and Treasury Bill rates before 2007. With these values of the parameters, the model implies a leverage ratio of 4.39.

For the productivity shock process, I assume that productivity shocks exhibit high persistence but have no spillovers across countries. Specifically, the productivity shock process is as follows

$$\begin{pmatrix} \log A_t \\ \log A_t^* \end{pmatrix} = \begin{pmatrix} 0.91 & 0 \\ 0 & 0.91 \end{pmatrix} \begin{pmatrix} \log A_{t-1} \\ \log A_{t-1}^* \end{pmatrix} + \begin{pmatrix} u_t \\ u_t^* \end{pmatrix}, \tag{36}$$

where $(u_t, u_t^*)' \sim \text{i.i.d } N(0, I_2)$. I attempt to describe the properties of the model regarding the transmission and amplification of productivity shocks rather than to use the model to match the business cycle moments. Thus, I simply choose a unit standard deviation for the shocks and assume that the innovations to the productivity shocks are not correlated across countries. For the capital quality shock process, I assume that ψ_t and ψ_t^* are *i.i.d.*

IV. Results

In this section, I report and compare the impulse response functions of the model with financial frictions due to the borrowing constraint and the model without such financial frictions.[8] I investigate the effects of a negative shock to the productivity and the capital quality using the benchmark parameter values.

A. Shocks to Productivity

Figures 1-3 show the impulse response functions to a 1% negative shock to the productivity in Foreign. First, I analyze the impulse response functions of the model without financial frictions and discuss the co-movement of impulse responses across countries particularly. Then, I explain the impulse response functions of the model with financial frictions and show that financial intermediation amplifies the effects of shocks to the productivity domestically and internationally in the presence of financial frictions.

a) Model without Financial Frictions

When a negative shock to the productivity hits, the economy of Foreign falls into a recession. Output and investment drop on impact and fall further for one to two years. Habit formation in consumption and the investment adjustment cost induce a hump-shaped response for output, consumption, and investment. Consumption decreases

[8] The model without financial frictions does not have the incentive constraint (16); therefore, $\lambda_t = \mu_t = 0$. The aggregate demand equation (27) also declines.

modestly on impact due to habit formation and keeps falling for a period of time. Employment picks up slightly on impact due to wealth effect, but it declines subsequently as substitution effects dominate.

The shock is transmitted to Home and causes a recession in Home. Thus, investment in Home declines. Consumption and employment increase on impact but decrease in subsequent periods. An important channel for the negative effect on the Home economy is adjustment through the fluctuations of international relative prices. The Home intermediate goods are now more abundant than the Foreign intermediate goods; thus, the relative price of the Home intermediate goods declines. Therefore, the terms of trade in Figure 3 go up. This phenomenon leads to substitution between the Home and Foreign intermediate goods in the final good production in Home, but the substitution is not perfect. In addition, the production of Foreign intermediate goods is reduced due to the shock. Therefore, the production of final goods in Home falls. Given the decline in the final good production, investment falls considerably because consumption is not adjusted remarkably due to habit. A fall in investment causes the asset price in Home in the current period and in the future to drop because of the investment adjustment cost; consequently, investment further decreases.[9] Consumption ends up increasing slightly on impact because of the amplified fall in investment. The investment will increase on impact without habit formation and investment adjustment costs (Heathcote and Perri 2002).

Employment increases on impact despite a fall in actual wage because wealth effects dominate substitution effects. However, substitution effects dominate wealth effects in subsequent periods, and employment declines. Output declines in Home in response to the shock to the productivity in Foreign.

I allow the productivity shocks in both countries to fluctuate following (36), simulate the model, and estimate the cross-country correlations of

[9] This feedback effect is observed in the following log-linearized optimality condition for the *c*-firm:

$$\hat{i}_t = i_{t-1} + \frac{1}{\kappa}\sum_{j=0}^{\infty} E_t \beta^j \hat{q}_{t+j},$$

where $\hat{i}_t$ and $\hat{q}_t$ are the log deviation from the steady state of investment and the asset price in Home, respectively.

variables. The objective is to quantitatively measure the business cycle co-movement in response to shocks to productivity and compare it with the findings of the literature. Table 2 shows the result.[10] Indeed, shocks to productivity generate positive co-movement for output, consumption, investment, and employment in the model. The cross-country correlation of output is 0.45, which is still smaller than that of consumption (0.52) as opposed to what is observed in the data. However, the level is considerably higher than what is found in the literature. For example, Heathcote and Perri (2002) found that the cross-country correlation of output in their model was 0.17–0.24. Moreover, the difference between the cross-country correlations of consumption and output is 0.47–0.61, depending on the international asset market structure.

The literature has documented that generating positive co-movement of investment and employment across countries is difficult for a two-country model (See Backus, Kehoe, and Kydland (1992)). The economy with relatively high productivity tends to invest more and produce more because of the efficient allocation of resources. Baxter and Crucini (1995) and Kollmann (1996) restricted the menu of assets that could be traded across countries. However, they were successful in generating international co-movements only if productivity shocks were persistent and therefore insurance for country-specific risks matters. Heathcote and Perri (2002) constructed a two-country model with country-specific goods that allows for time-varying terms of trade. However, they concluded that the model could not account for positive co-movement of investment and employment unless the international asset trade is completely shut down. In this model, the fluctuations of the terms of trade in combination with habit formation in consumption and investment adjustment costs can generate positive co-movement of investment and employment.

b) Model with Financial Frictions

Financial frictions imposed on the benchmark model through financial intermediation amplify the effects of productivity shocks domestically and internationally. A recession is deeper in Foreign and

[10] I simulate the model only using productivity shocks. Therefore, the empirical cross-country correlations reported in Table 2 are not intended for direct comparison. I report them only to provide an insight about the empirical cross-country correlations observed in the data.

Home compared with the model with no financial frictions. In both countries, output, consumption, investment, and employment decline more in the model with financial frictions than that without financial frictions.

The mechanism of amplification is the balance sheet channel through which the endogenous fluctuations of the asset prices propagate and amplify the effects of shocks (Kiyotaki and Moore 1997; Bernanke, Gertler, and Gilchrist 1999; Gertler and Kiyotaki 2010). When a negative shock to the productivity in Foreign exists, the asset prices of Foreign drop. This event also tightens the borrowing constraint of banks in Home because the banks in Home are lending to *i*-firms in Foreign. Figure 2 shows the Lagrange multiplier for the borrowing constraint jumps. An increase in the credit spread between the risk-free rate and the return on the assets in Figure 2 is the result of the more tightly binding borrowing constraint. The worsened balance sheet condition of the banks in Home forces the banks to reduce their lending to the *i*-firms in Home. Additional effects are observed on the demand for the Home asset by the deteriorated balance sheet condition of banks in Foreign. Consequently, the demand for Home asset contracts and its price drops. This event further tightens the borrowing constraint of the banks in Home and Foreign and adds to the effects of the falling prices in Foreign. The asset prices further fall in both countries.

In summary, financial intermediation, which faces a borrowing constraint, deepens the response of the world economy to country-specific productivity shocks. Moreover, such financial intermediation increases the business cycle co-movement between the two countries. Table 2 shows that the cross-country correlations of output, consumption, investment, and employment in the model with financial frictions increase compared with those without financial frictions.

B. Shocks to Capital Quality

I present the impulse response functions to a 1% negative shock to the capital quality in Foreign in Figures 4–6. The basic mechanism of propagation of the shock is similar to that of a negative shock to productivity. Thus, I present and discuss the results of the model with and without financial frictions together.

The world economy responds to a negative shock to the capital quality in Foreign similarly to a negative shock to the productivity in

Foreign. The shock induces a recession in Foreign and has negative effects on the Home economy. Financial frictions amplify the effects of the shock domestically and internationally, and the recession caused by the shock is deeper in Foreign and Home. The terms of trade and the real exchange rate rise because Foreign intermediate goods are less abundant than Home intermediate goods.

The most notable difference in the impulse response functions to a negative shock to productivity and capital quality is that the latter generates larger and more persistent responses of the Home economy. Particularly, investment in Home falls below investment in Foreign, and it recovers slowly. The reason for the difference is that the marginal product of capital jumps in Foreign because part of the capital stock is lost. Therefore, the banks in Home and Foreign attempt to lend more to the *i*-firms in Foreign to exploit the higher payoff to their capital. The adjustment goes on until the return on capital becomes equal across countries. Then, the demand for the Foreign asset is higher than that for the Home asset, and investment in Foreign is also higher than that in Home.

Net foreign assets of Home are negative on impact despite the outflow of capital because certain Foreign asset holdings of the Home banks are lost due to the shock. Net exports of Home are positive because an investment in Foreign is higher than investment in Home.

Financial frictions amplify the effects of shocks to capital quality due to the borrowing constraint in response to a negative shock to productivity. Moreover, financial frictions deepen the recession through the balance sheet channel of the banks in Home and Foreign.

C. Sensitivity Analysis

This section reports sensitivity analysis results in terms of the degree of habit formation in consumption and the elasticity of investment adjustment cost with respect to the capital price. Table 2 shows the results. When I drop habit formation in consumption by setting $h = 0$, the model fit for the cross-country correlation of investment deteriorates. By contrast, the model fit improves marginally in terms of the cross-country correlations of output, consumption, and employment. This result is the case in the model with and without financial frictions. When I assume a strong habit formation in consumption by setting $h = 0.95$, the model generates cross-country correlations that are stronger than those in the data, as expected. A more elastic investment

adjustment cost with $\kappa = 2.5$ helps the model fit the cross-country correlation of investment at the expense of generating excessively strong cross-country correlations, specifically in consumption. The sensitivity result shows that an adjustment cost helps explain the international business cycle to introduce financial frictions in the model with habit formation in consumption and investment adjustment costs.

V. Conclusion

This study presented a two-good, two-country model in which banks facing a borrowing constraint intermediate funds between households and firms. First, I showed that the endogenous fluctuations of international relative prices increase the business cycle co-movement across countries when combined with habit formation in consumption and investment adjustment costs. Then, I showed that financial frictions due to the borrowing constraint of the banks further amplify the effects of productivity and capital quality shocks within a country and across countries. The model serves as a framework for the study of international monetary policy coordination in a global financial crisis, which is left for future research.

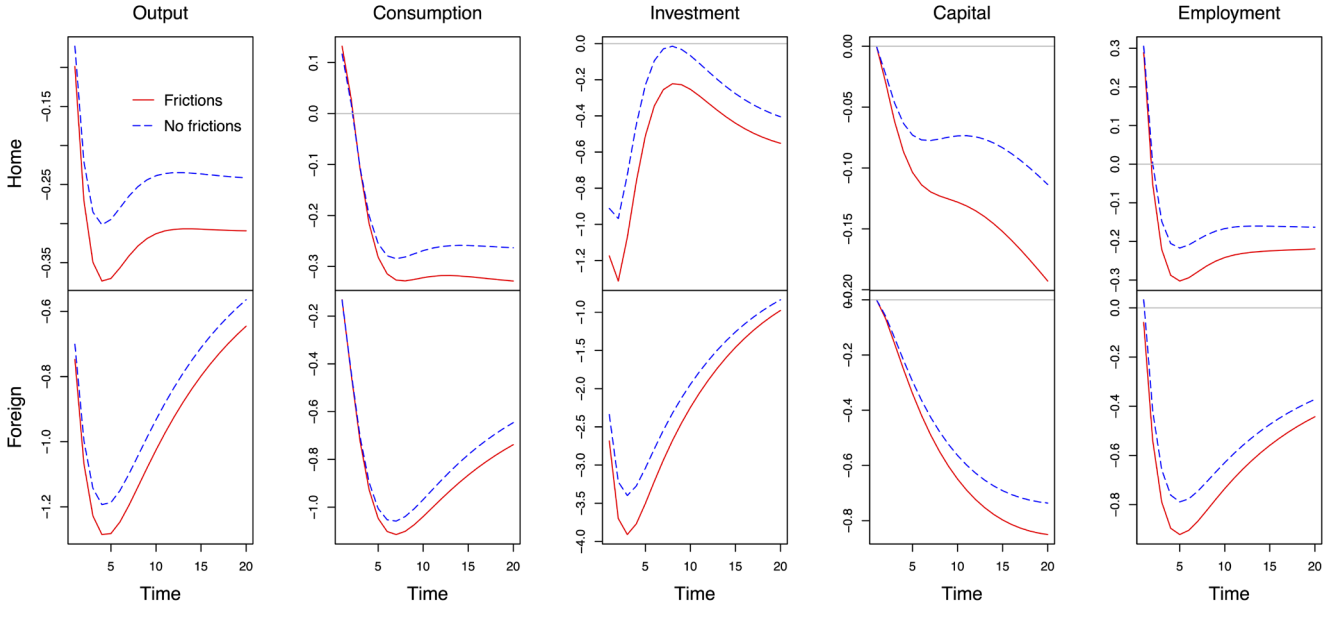
Table 1
Benchmark Parameter Values

Parameter	Value	Description
β	0.99	Discount factor
γ	2	Coefficient of risk aversion
h	0.5	Habit formation parameter
χ	0.25	Relative utility weight of labor
ϵ	0.5	Inverse Frisch elasticity of labor supply
α	0.33	Capital share
δ	0.025	Depreciation rate
κ	1.5	Inverse elasticity of investment with respect to the price of capital
$1-\varphi$	0.85	Share of imported goods in final good production
η	0.9	Elasticity of substitution between traded goods
$\bar{G} / \bar{Y}$	0.2	Share of government expenditures
θ	0.4	Fraction of total assets which can be diverted
τ	0.001	Parameter of transfer to newly entering bankers
π	0.975	Period-to-period survival rate of bankers

TABLE 2
CROSS-COUNTRY CORRELATIONS

	Output	Consumption	Investment	Employment
Data	0.50	0.36	0.40	0.51
Model without financial frictions				
Benchmark	0.45	0.52	0.22	0.49
No habit ($h = 0$)	0.46	0.51	0.12	0.46
Strong habit ($h = 0.95$)	0.56	0.62	0.46	0.70
Less elastic investment adjustment cost ($\kappa = 0.5$)	0.41	0.48	0.09	0.43
More elastic investment adjustment cost ($\kappa = 2.5$)	0.47	0.54	0.30	0.54
Model with financial frictions				
Benchmark	0.53	0.58	0.35	0.58
No habit ($h = 0$)	0.52	0.53	0.29	0.52
Strong habit ($h = 0.95$)	0.70	0.73	0.61	0.77
Less elastic investment adjustment cost ($\kappa = 0.5$)	0.46	0.52	0.16	0.47
More elastic investment adjustment cost ($\kappa = 2.5$)	0.57	0.61	0.44	0.63

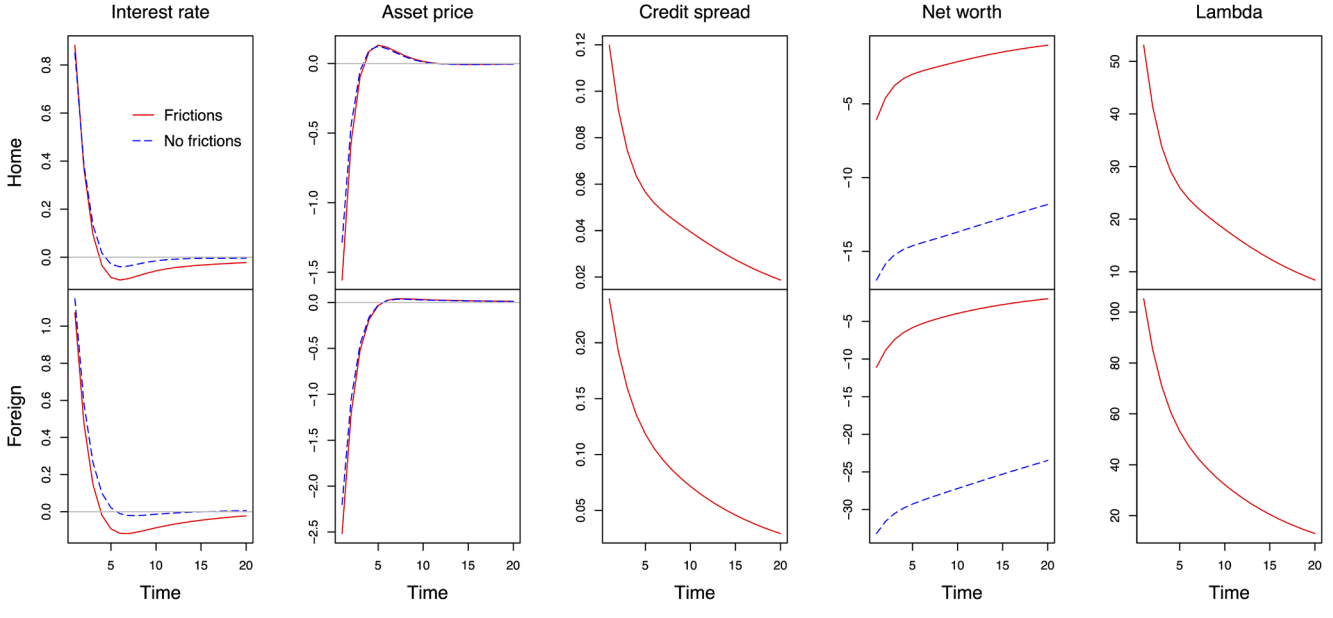
Notes: The cross-country correlations of the models are sample means of 10,000 simulations using only productivity shocks. The empirical cross-country correlations are not intended for direct comparison with the model cross-country correlations. The data for output, consumption, and investment are taken from OECD Quarterly National Accounts (OECD-QNA), and they are gross domestic product, private consumption expenditure, and gross fixed capital formation, respectively. The data span the period from 1972:1 to 2006:4. For the rest of the world, I use an aggregate of Canada, Japan, and 15 European countries, including Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. I construct the data of Japan prior to 1980 using the growth rates of each variable in the dataset compiled by Heathcote and Perri (2002) because the OECD-QNA provides the data only after 1980 for Japan. The data for output, consumption, and investment are a volume whose base year is 2000, and I convert them to the constant 2000 U.S. dollar prices. I use PPP exchange rates in 2000, calculated using a consumer price index, to aggregate the data of the non-US countries. The series for employment is the civilian employment index taken from OECD Main Economic Indicators. For the rest of the world, the employment series is an aggregate of employment in Canada, Japan, Austria, Finland, Germany, Italy, Sweden, and the United Kingdom, whose employment series is available for all the sample periods.



Notes: The size of the shock is 1%. The scale of the impulse response is the percentage deviation from the steady state for all the variables. Output = GDP_t and GDP_t^*, consumption = C_t and C_t^*, investment = I_t and I_t^*, capital = K_t and K_t^*, and employment = L_t and L_t^*.

FIGURE 1

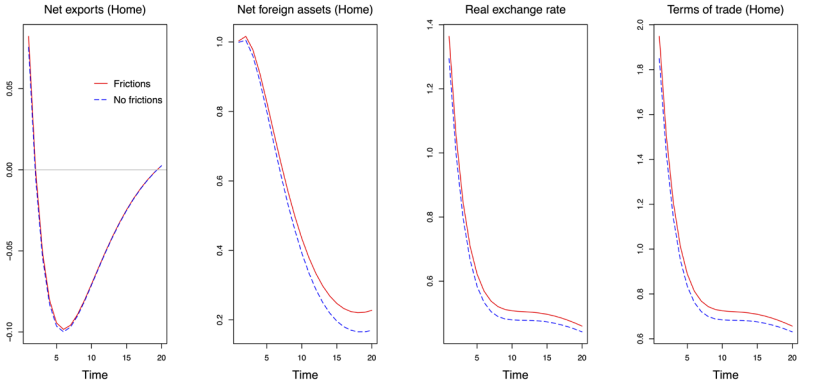
IMPULSE RESPONSE FUNCTIONS TO A SHOCK TO THE PRODUCTIVITY IN FOREIGN (1)



Notes: The size of the shock is 1%. The scale of the impulse response is the percentage deviation from the steady state for all the variables. Interest rate = R_t and R_t^*, asset price = Q_t and Q_t^*, credit spread = $E_t\,(R_{k,t+1} - R_t)$ and $E_t\,(R_{k,t+1}^* - R_t^*)$, net worth = N_t and N_t^*, and lambda = λ_t and λ_t^*.

FIGURE 2

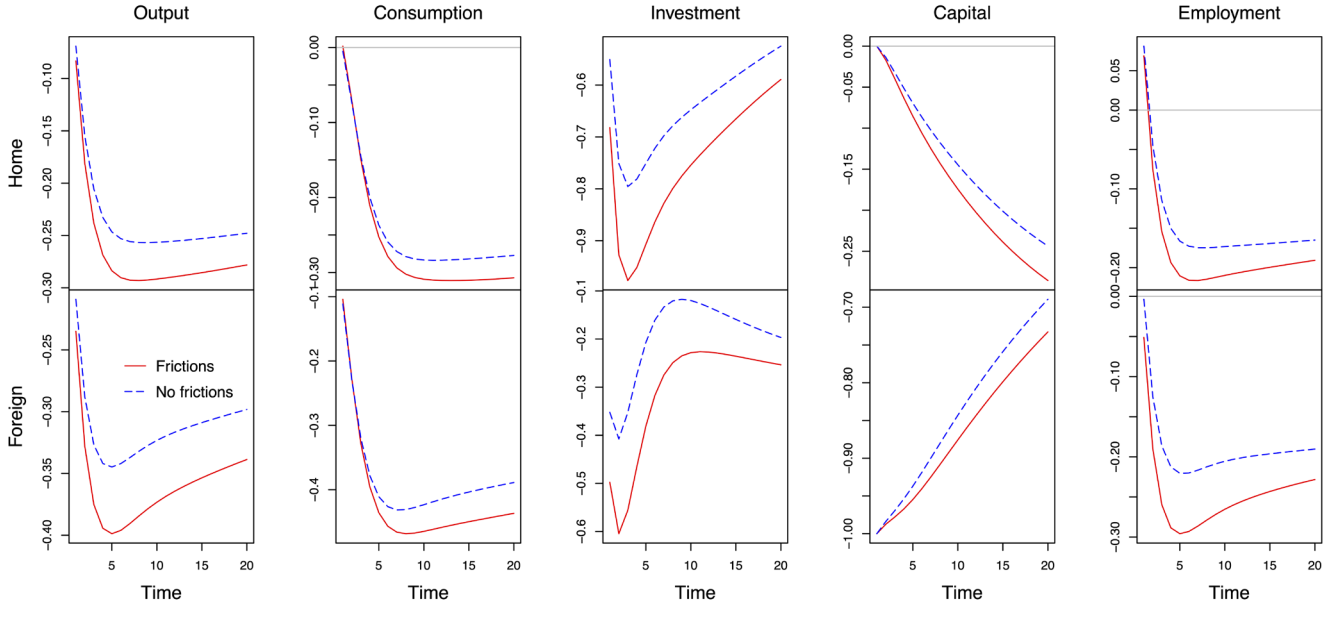
IMPULSE RESPONSE FUNCTIONS TO A SHOCK TO THE PRODUCTIVITY IN FOREIGN (2)



Notes: The size of the shock is 1%. The scale of the impulse response is the percentage deviation from the steady state for the real exchange rate and the terms of trade. The scale of the impulse response of net exports and net foreign assets is 100 times the ratio of net exports and net foreign assets to the steady-state output.

FIGURE 3

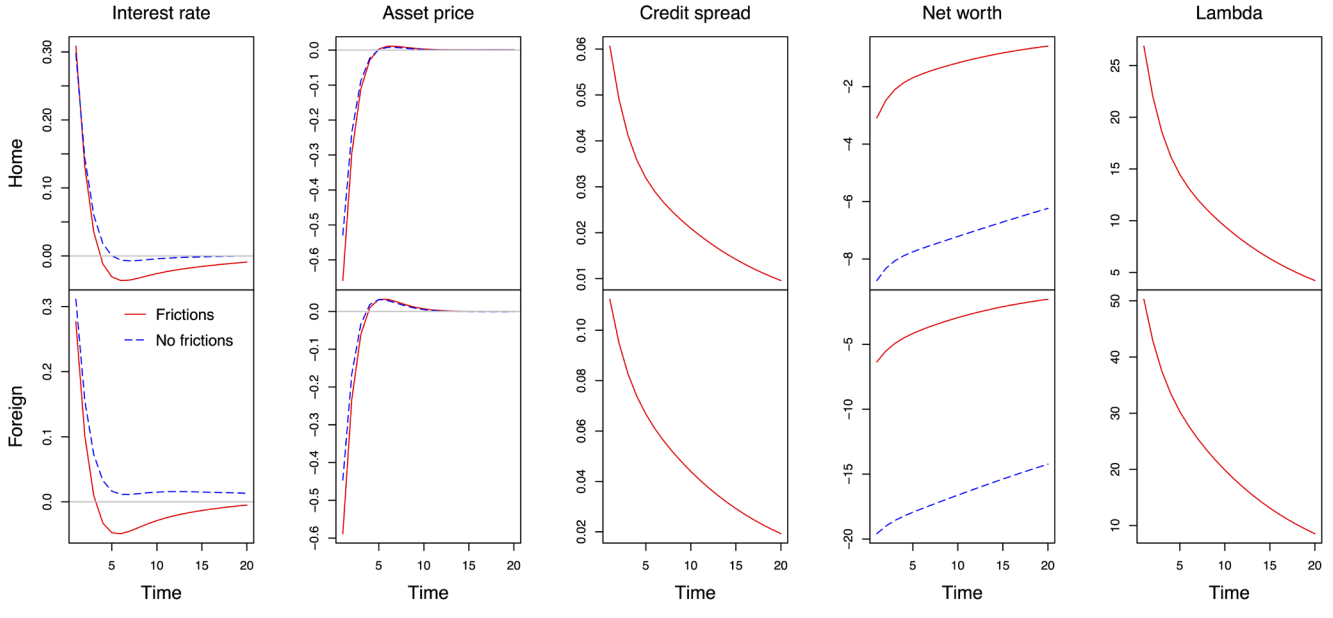
IMPULSE RESPONSE FUNCTIONS TO A SHOCK TO THE PRODUCTIVITY IN FOREIGN (3)



Notes: The size of the shock is 1%. The scale of the impulse response is the percentage deviation from the steady state for all the variables. Output = GDP_t and GDP_t^*, consumption = C_t and C_t^*, investment = I_t and I_t^* capital = K_t and K_t^*, and employment = L_t and L_t^*.

FIGURE 4

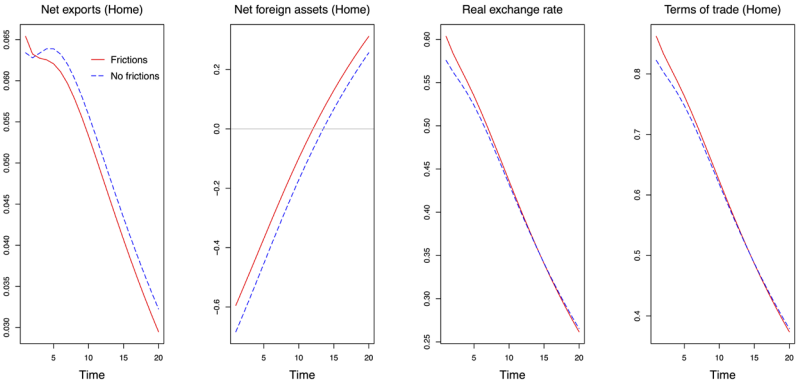
IMPULSE RESPONSE FUNCTIONS TO A SHOCK TO THE CAPITAL QUALITY IN FOREIGN (1)



Notes: The size of the shock is 1%. The scale of the impulse response is the percentage deviation from the steady state for all the variables. Interest rate = R_t and R_t^* , asset price = Q_t and Q_t^*, credit spread = $E_t\,(R_{k,t+1} - R_t)$ and $E_t\,(R_{k,t+1}^* - R_t^*)$, net worth = N_t and N_t^*, and lambda = λt and λ_t^*.

FIGURE 5

IMPULSE RESPONSE FUNCTIONS TO A SHOCK TO THE CAPITAL QUALITY IN FOREIGN (2)



Notes: The size of the shock is 1%. The scale of the impulse response is the percentage deviation from the steady state for the real exchange rate and the terms of trade. The scale of the impulse response of net exports and net foreign assets is 100 times the ratio of net exports and net foreign assets to the steady-state output.

FIGURE 6
IMPULSE RESPONSE FUNCTIONS TO A SHOCK TO THE CAPITAL QUALITY IN FOREIGN (3)

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