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International business cycles and financial frictions☆

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ABSTRACT

In this study, I build a two-country DSGE model to investigate the impact of financial integration on business cycle co-movements with financial frictions. In this model, the investor can borrow but faces a collateral constraint that is tied to the value of her capital and real estate holdings. I show quantitatively that the degree of financial integration and real exchange rate adjustment are important for understanding business cycle synchronization under different types of shocks. With the technology shock, greater financial integration leads to lower cross-country correlations, while with the financial shock, greater financial integration leads to stronger cross-country correlations. These findings are consistent with the empirical evidence from the literature.

1. Introduction

This study examines the effect of financial integration on the transmission of shocks across countries when agents face financial frictions. The onset and spread of the 2007 financial crisis highlight the importance of financial integration for international business cycle co-movements. Kalemli-Ozcan et al. (2013) show that greater financial integration leads to greater business cycle synchronization during a financial crisis but leads to lower business cycle synchronization during other times. This paper embeds collateral constraint within a two-country, two-good international real business cycle model with portfolio choice to analyze the transmission mechanism of technology and financial shocks. The model illustrates that the impact of financial integration on the exchange rate movement is important in understanding business cycle synchronization. The simulation results show that the model can match the business cycle correlations in the data reasonably well.

I build a two-country model in which credit contracts are imperfectly enforceable. Each country has two types of agent, an investor and a saver. The investor can borrow but faces a collateral constraint that is tied to the value of her capital and real estate holdings. The capital that she holds can be either domestic or foreign, but the housing that she holds is only domestic. The saver is more patient than the investor and always wants to lend. The bond market is international, so the saver is allowed to lend to investors in both countries. In the model, I introduce a technology shock and a financial shock, where the latter is modeled as a shock to the collateral constraint. As I am interested in evaluating business cycle implications quantitatively, I model explicitly the endogenous labor supply and capital accumulation.

The main findings of this study are summarized as follows. First, the model shows that the degree of foreign capital exposure affects business cycle synchronization. When the technology shock is present, higher exposure to foreign capital leads to less appreciation in the real exchange rate and lower business cycle co-movements. However, when the financial shock is present, higher exposure to foreign capital leads to less depreciation in the real exchange rate and greater business cycle co-movements. This finding is consistent with the empirical evidence documented by Kalemli-Ozcan et al. (2013).

Second, the model shows that except for the channels of foreign capital exposure and exchange rate adjustment, the investor's holding of housing also plays an important role in the transmission of shocks through the collateral constraint. With international financial market, although the investor only holds domestic housing and uses it as collateral, when the economy experiences a negative shock, there will be a rise in the borrowing premium in both countries, which means tightened collateral constraints and a simultaneous decline in real estate holdings in both countries. The synchronization of the borrowing premium predicted by the model is consistent with the highly correlated loan rate spreads across countries in the data.

Third, the model predicts that higher exchange rate volatility is related to lower foreign capital exposure. This result is consistent with

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the empirical evidence documented by Fidora et al. (2007), who found a positive and significant relationship between real exchange rate volatility and equity home bias.

This study is related to the large body of literature on financial frictions in an open economy context. Early work includes Iacoviello and Minetti (2006), Gertler et al. (2007), and Faia (2007). However, none of these studies address the impact of financial frictions when constrained agents hold foreign capital. Following the 2007 financial crisis, the literature has focused on the role of financial integration in the transmission of shocks with financial frictions. Examples include Devereux and Yetman (2010), Kollmann et al. (2011), Kalemli-Ozcan et al. (2013), Kamber and Thoenissen (2013), and Perri and Quadrini (2018), of which Devereux and Yetman (2010) is closest to my work, as they study financial frictions and capital portfolio choice in a two-country, one-good model. My study differs from theirs in three ways. First, I incorporate capital accumulation and endogenous labor choice into the model to evaluate the business cycle implications quantitatively. The benchmark model can match the cross-country correlations in the data reasonably well. In this respect, my paper is also related to the literature on international business cycle co-movements, starting with Backus et al. (1992). Second, my model allows the investor to use housing as part of the collateral, so variations in the housing price and housing holdings have direct effects on the investor's collateral constraint. Third, I explicitly examine the role of fluctuations in terms of trade on the transmission of shocks across countries. The third aspect differentiates my paper from Kollmann et al. (2011) and Kalemli-Ozcan et al. (2013), who study the importance of the degree of banking exposure under a two-country, one-good framework. Kamber and Thoenissen (2013) take a similar approach to that of Kollmann et al. (2011) but allow for changes in the terms of trade; however, they assume a small open economy setting, rather than two countries of the same size.

2. Model

In this section, I outline a two-country, two-good international real business cycle model. The world economy consists of a home country (country 1) and a foreign country (country 2), both of which are of the same size. Each country is populated by two infinitely lived agents, an investor and a saver. The investor and saver are distinct from each other to motivate lending and borrowing. The investor can borrow, with her borrowing capacity determined by the value of her holding of capital and housing. The saver consumes, works, and lends to the domestic investor, foreign investor, and foreign saver. In each country, there is a fixed amount of housing that can be used either by the investor as an input for production and collateral for loans or by the saver as a consumption good.

The intermediate good producer in each country uses capital, housing, and labor to produce. I denote the good produced in country 1 as good *a* and that produced in country 2 as good *b*. Each country has a final good producer to combine the intermediate goods into a country-specific final good, and a capital producer to facilitate the introduction of capital price variations.

2.1. Household

2.1.1. Investor

The investor in each country i chooses consumption c_{it}^I, provides labor services l_{it}^I, and makes a portfolio choice among capital, housing, and debt. The investor has a Greenwood-Hercowitz-Huffman (GHH) preference:

$$E_t \sum_{t=0}^{\infty} \left(\beta_{it}^I\right)^t \frac{1}{1-\gamma} \left(c_{it}^I - \psi^I \frac{\left(l_{it}^I\right)^{1+\theta}}{1+\theta} \right)^{1-\gamma} \qquad i = 1, 2 \tag{1}$$

which is widely used in the open economy literature. This preference eliminates the wealth effect on labor supply, suggesting that the path of hours closely follows that of output. To ensure a stationary equilibrium, I follow Mendoza (1991) and assume an endogenous discount factor $\beta_{it}^I = \left(1 + C_{it}^I - \psi^I \frac{(L_{it}^I)^{1+\theta}}{1+\theta}\right)^{-\omega^I}$, where C_{it}^I and L_{it}^I denote the aggregate consumption and hours, respectively.

The budget constraint of the investor in country 1 is:

$$\begin{aligned} c_{1t}^I + q_{1t}^k k_{11,t+1} + e_t q_{2t}^k k_{12,t+1} + q_{1t}^h h_{1t+1}^I \\ = B_{11,t+1} + e_t B_{12,t+1} - R_{11,t}^d B_{11,t} - e_t R_{12,t}^d B_{12,t} + q_{1t}^a w_{1t} l_{1t}^I \\ + \left((1-\delta) q_{1t}^k + q_{1t}^a R_{1t}^k\right) k_{11,t} + e_t \left((1-\delta) q_{2t}^k + q_{2t}^b R_{2t}^k\right) e^{-\tau} k_{12,t} \\ + \left(q_{1t}^h + q_{1t}^a R_{1t}^h\right) h_{1t}^I. \end{aligned} \tag{2}$$

Let $k_{ij,t}^I$ denote the capital in country j held by the investor from country i. In each period, the home investor purchases domestic capital $k_{11,t+1}$, foreign capital $k_{12,t+1}$, and domestic housing h_{1t+1}^I. q_{it}^k and q_{it}^h denote the prices of capital and housing, respectively, in country i. e_t denotes the real exchange rate, which is defined as the price of country 2's consumption relative to that of country 1's. The investor borrows from the international bond market, where $B_{ij,t}$ is a one-period claim to country j's final good held by investor i and $R_{ij,t}^d$ is the corresponding interest rate.

In each period, the investor receives returns on capital R_{it}^k and housing R_{it}^h by renting them to the intermediate firm. She also receives wage income w_{it} by working at the firm. Here, w_{it}, R_{it}^k, and R_{it}^h are expressed in units of the local intermediate good, where q_{it}^a and q_{it}^b are the prices of goods *a* and *b*, respectively, relative to country i's final good. At the end of each period, the investor sells the housing and the undepreciated capital. The investor faces a cost when she invests in foreign capital: following Tille and van Wincoop (2010), the income that the investor receives from holding foreign capital is subject to an iceberg cost $e^{-\tau} < 1$, reflecting the cost of gathering information on an unfamiliar market.[1]

The investor is assumed to be less patient than the saver; therefore, in equilibrium, the investor always borrows from the saver to finance her asset purchase. However, the investor may default on her debt; thus, she always has to put down collateral against her debt. Here, the investor faces a collateral constraint that restricts her debt to be smaller than a fraction κ_{it} of the value of the assets offered as collateral. Following Iacoviello and Minetti (2006), I assume that a fraction λ of the collateral is used for borrowing in the domestic market, while a fraction (1 − λ) is used for the foreign market. The collateral constraint for country 1's investor is[2]

$$B_{11,t+1} \le \kappa_{1t} \lambda \left(q_{1t}^k k_{11,t+1} + e_t q_{2t}^k k_{12,t+1} + q_{1t}^h h_{1t+1}^I \right) \tag{3}$$

$$e_t B_{12,t+1} \le \kappa_{1t} (1-\lambda) \left(q_{1t}^k k_{11,t+1} + e_t q_{2t}^k k_{12,t+1} + q_{1t}^h h_{1t+1}^I \right) \tag{4}$$

Given that the debt level is linked directly to the investor's total asset value, any fluctuation in asset prices will have an immediate impact on the borrowing capacity of the investors. Following Dedola and Lombardo (2012) and Jermann and Quadrini (2012), I assume that the collateral constraint is subjected to a financial shock: $\ln(\kappa_{it}) = (1-\rho_k) \ln(\overline{\kappa}) + \rho_k \ln(\kappa_{it-1}) + \nu_{it}$ where $\overline{\kappa}$ is the steady-state leverage ratio. Let $\mu_{11,t}$ and $\mu_{12,t}$ be the Lagrange multipliers on the home investor's collateral constraints (3) and (4). Solving the home investor's problem leads

[1] Note that τ is assumed to be a second-order term, which means that while it affects the solution for the equilibrium portfolio, it does not affect the first-order dynamics of the model, except insofar as it affects the choice of the portfolio itself. Devereux and Sutherland (2011) offer detailed explanations.

[2] I follow Mendoza (2010) in imposing a collateral constraint in which the current asset prices are used to value the collateral, rather than the next-period asset prices. However, the model will produce similar results when the collateral is valued at next-period prices.

to the following FOCs:

$$U^I_{c_{1,t}} = \beta^I_{1t} E_t U^I_{c_{1},t+1} r^k_{1t+1} + \kappa_{1t}(\lambda\mu_{11t} + (1-\lambda)\mu_{12t}) \tag{5}$$

$$U^I_{c_{1,t}} = \beta^I_{1t} E_t U^I_{c_{1},t+1} r^k_{2t+1} e^{-\tau} + \kappa_{1t}(\lambda\mu_{11t} + (1-\lambda)\mu_{12t}) \tag{6}$$

$$\begin{aligned} & q^h_{1t}\left(U^I_{c_{1,t}} - \kappa_{1t}(\lambda\mu_{11t} + (1-\lambda)\mu_{12t})\right) \\ & \quad = \beta^I_{1t} E_t U^I_{c_1,t+1}\left(q^h_{1t+1} + q^a_{1t+1} R^h_{1t+1}\right) \end{aligned} \tag{7}$$

$$U^I_{c_1,t} = \beta^I_{1t} E_t U^I_{c_1,t+1} R^d_{11,t+1} + \mu_{11,t} \tag{8}$$

$$U^I_{c_1,t} = \beta^I_{1t} E_t U^I_{c_1,t+1} \frac{e_{t+1}}{e_t} R^d_{12,t+1} + \mu_{12,t} \tag{9}$$

$$q^a_{1t} w_{1t} = \psi^I \left(l^I_{1t}\right)^\theta \tag{10}$$

where $r^k_{1t} = \frac{(1-\delta)q^k_{1t} + q^a_{1t} R^k_{1t}}{q^k_{1t-1}}$ and $r^k_{2t} = \frac{e_t}{e_{t-1}} \frac{(1-\delta)q^k_{2t} + q^b_{2t} R_{2t}}{q^k_{2t-1}}$ are the gross returns on home and foreign capital, denoted in units of home final good. Condition (5) yields the following expression for domestic capital price, which is the sum of the expected present value of future returns to domestic capital:

$$q^k_{1t} = E_t\left[\sum_{j=0}^{\infty}\left(\prod_{s=0}^{j} m_{1,t+1+s}\right)(1-\delta)^{s-1} q^a_{1,t+1+s} R^k_{1,t+1+s}\right] \tag{11}$$

where $m_{1,t+1+s} = \beta^I_{1t} \frac{U^I_{c_{1,t+1+s}}}{U^I_{c_{1,t+s}} - \kappa_{1t+s}(\lambda\mu_{11,t+s} + (1-\lambda)\mu_{12,t+s})}$ is the stochastic discount factor. Note that the stochastic discount factor differs from the standard model because it adjusts for the shadow value of the collateral constraint.

2.1.2. Saver

The saver's problem is standard, with the exception of housing (services) in the utility function.[3] The saver solves the following problem:

$$E_0 \sum_{t=0}^{\infty} \left(\beta^S_{it}\right)^t \frac{1}{1-\gamma}\left(c^S_{it}\left(h^S_{it}\right)^\nu - \psi^S \frac{\left(l^S_{it}\right)^{1+\theta}}{1+\theta}\right)^{1-\gamma} \qquad i = 1,2 \tag{12}$$

where the discount factor for the saver is defined similarly to that of the investor as $\beta^S_{it} = \left(1 + C^S_{it}\left(H^S_{it}\right)^\nu - \psi^S \frac{(L^S_{it})^{1+\theta}}{1+\theta}\right)^{-\omega^S}$. At each date in country 1, the saver supplies labor l^S_{1t} to the firm, lends $B_{11,\ t+1}$ to the domestic investor, lends $B_{21,\ t+1}$ to the foreign investor, and lends B_{t+1} (or borrows $-B_{t+1}$) to (from) the foreign saver. She also receives interests from previous bonds, which are denoted as $R^d_{11,\ t}$, $R^d_{21,\ t}$, and R^d_t. Her budget constraint is:

$$\begin{aligned} c^S_{1t} + q^h_{1t} h^S_{1t+1} \quad = \quad & q^a_{1t} w_{1t} l^S_{1t} - B_{11,t+1} - B_{21,t+1} - B_{t+1} \\ & + R^d_{11,t} B_{11,t} + R^d_{21,t} B_{21,t} + R^d_t B_t + q^h_{1t} h^S_{1t}. \end{aligned} \tag{13}$$

Solving the saver's problem in country 1 leads to the following FOCs:

$$\begin{aligned} U^S_{c_1,t} &= \beta^S_{1t} E_t U^S_{c_1,t+1} R^d_{11,t+1} \\ U^S_{c_1,t} &= \beta^S_{1t} E_t U^S_{c_1,t+1} R^d_{21,t+1} \\ U^S_{c_1,t} &= \beta^S_{1t} E_t U^S_{c_1,t+1} R^d_{t+1} \\ q^h_{1t} U^S_{c_1,t} &= \beta^S_{1t} E_t \left(q^h_{1t+1} U^S_{c_1,t+1} + U^S_{h_1,t+1}\right) \\ q^a_{1t} w_{1t} &= \frac{\psi^S \left(l^S_{1t}\right)^\theta}{\left(h^S_t\right)^\nu} \end{aligned}$$

2.2. Capital producer

In each country, the capital producer uses final goods i_{it} and undepreciated physical capital $(1-\delta)k_{it}$ to produce new installed capital k_{it+1}, which is sold at the end of period t at q^k_{it}. Therefore, the capital producer solves the following problem:

$$\max\left\{q^k_{it} k_{it+1} - q^k_{it}(1-\delta)k_{it} - i_{it}\right\} \tag{14}$$

where the following production technology is used to produce new capital:

$$k_{it+1} = (1-\delta)k_{it} + \phi\left(\frac{i_{it}}{k_{it}}\right) k_{it} \tag{15}$$

I assume that the production of new capital is subject to an investment adjustment cost $\phi(\frac{i_{it}}{k_{it}}) = \frac{g_1}{1-\pi}(\frac{i_{it}}{k_{it}})^{1-\pi} + g_2$.[4] The optimality condition for the capital producer is $q^k_{it} = \frac{1}{\phi'(\frac{i_{it}}{k_{it}})}$, where the parameter π controls the elasticity of the capital price with respect to the investment-to-capital ratio. The investment adjustment cost allows the capital price to diverge from 1, therefore, capital price variation could affect the investor's balance sheet.

2.3. Production

2.3.1. Intermediate good production

The intermediate firm in country 1 produces one good called good a, while that in country 2 produces a different good called good b. The intermediate firm's production function is Cobb-Douglas in domestic capital, housing, and labor,

$$y_{it} = e^{z_{it}}(k_{it})^\alpha \left(h^I_{it}\right)^\zeta (l_{it})^{1-\alpha-\zeta} \qquad i = 1,2 \tag{16}$$

where z_{it} is an exogenous technology shock. The law of motion for the technology shock $z_t = [z_{1t}, z_{2t}]$ is given by $z_t = \Phi z_{t-1} + \varepsilon_t$, where Φ is a 2×2 matrix and ε_t is a 2×1 vector of independently distributed random variables. The intermediate firm solves

$$\max_{l_{it}, k_{it}, h^I_{it}} \left\{y_{it} - w_{it} l_{it} - R^k_{it} k_{it} - R^h_{it} h^I_{it}\right\} \qquad i = 1,2 \tag{17}$$

[3] I follow Iacoviello and Minetti (2006) by including housing in the saver's utility to allow for a residual demand of fixed housing. A similar approach was taken by Kiyotaki and Moore (1997) and Devereux and Sutherland (2011). The investor can be viewed as an entrepreneur who holds capital and commercial housing, while the saver can be viewed as a household that holds residential housing.

[4] $\pi \geq 0$ and the parameters g_1 and g_2 are set by imposing $\phi(\delta) = \delta$ and $\phi'(\delta) = 1$ in the steady state.

2.3.2. Final good production

The final good firm buys intermediate goods and combines them to produce a local final good using the following technology:

$$J(a_{1t}, b_{1t}) = \left[\omega a_1^{\frac{\sigma-1}{\sigma}} + (1-\omega) b_1^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$
$$J(a_{2t}, b_{2t}) = \left[(1-\omega) a_2^{\frac{\sigma-1}{\sigma}} + \omega b_2^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{18}$$

where $\omega > 0.5$ determines the size of local intermediate input bias in the final good production, and σ is the elasticity of substitution between goods a and b. The final good producer solves

$$\max_{a_{it}, b_{it}} \left\{ J(a_{it}, b_{it}) - q_{it}^a a_{it} - q_{it}^b b_{it} \right\} \qquad i = 1, 2 \tag{19}$$

Before I close the model, let me define relative prices here. Let $p_t = q_{1t}^b / q_{1t}^a$ denote the terms of trade, which is the price of imports relative to exports. As the prices of traded intermediate goods are defined in units of the local final good, applying the law of one price to intermediate goods implies that $q_{2t}^a e_t = q_{1t}^a$ and $q_{2t}^b e_t = q_{1t}^b$. Hence, the exchange rate is expressed as $e_t = q_{1t}^a / q_{2t}^a = q_{1t}^b / q_{2t}^b$.

2.4. Market clearing

Labor markets clear, which implies that within each country, the investor's and saver's labor supply sum up to the total labor supply: $l_{it} = l_{it}^I + l_{it}^S$. The housing market also clears, which implies that the total housing held by the investor and saver in a country is fixed, $h_{it}^I + h_{it}^S = 1$. The capital markets clear, which implies that capital in each country is owned by both domestic and foreign investors: $k_{1t} = k_{11,t}^I + k_{21,t}^I$ and $k_{2t} = k_{12,t}^I + k_{22,t}^I$. The markets for the intermediate good clear: $a_{1t} + a_{2t} = y_{1t}$ and $b_{1t} + b_{2t} = y_{2t}$. The final good markets also clear: $c_{it}^I + c_{it}^S + i_{it} = J(a_{it}, b_{it})$.

2.5. Discussion

Up to a first-order approximation, Euler Eqs. (5) and (6) imply $E_t r_{1t+1}^k = E_t r_{2t+1}^k$, which means that the expected gross returns on home and foreign capital are the same. Therefore, the expected excess returns on capital relative to bond (i.e., the equity premium) are also the same: $E_t r_{1t+1}^k - R_{11,\, t+1}^d = E_t r_{2t+1}^k - R_{11,\, t+1}^d$. Substituting the equilibrium conditions of the home and foreign households into the equity premium expression gives us[5]

$$(1-\kappa_{1t}) \frac{\mu_{1t}}{\beta_t^I E_t U_{c_1,t+1}^I} = (1-\kappa_{2t}) \frac{\mu_{2t}}{\beta_t^I E_t U_{c_2,t+1}^I \dfrac{e_t}{e_{t+1}}} \tag{20}$$

Eq. (20) shows that, up to a first-order approximation, the collateral constraint creates a wedge between expected return to capital and bond. When the equity premium of home capital rises because of a tightening of the collateral constraint in the home country, the equity premium of foreign capital will also rise, which implies a tightening of the foreign collateral constraint. Another way to see this is to consider the borrowing premium, which is the premium at which the investor will choose debt amounts that satisfy the collateral constraint when the constraint is not imposed directly. The borrowing premium faced by the domestic investor over the domestic interest rate is $\frac{\mu_{1t}}{\beta_t^I E_t U_{c_1,t+1}^I}$, while the borrowing premium faced by the foreign investor over the foreign interest rate is $\frac{\mu_{2t}}{\beta_t^I E_t U_{c_2,t+1}^I}$. Eq. (20) implies that, with international capital and bond market, the borrowing premia between the two countries are highly synchronized.

3. Calibration

I now choose the parameter values.[6] A period in the model corresponds to one quarter. The sample period in the data ranges from 1972:1 to 2008:4.

The risk aversion γ is set to 2. The parameter ω^S, which controls the saver's discount factor, is set to 0.077 to match an annual interest rate of 4%. Following Bernanke et al. (1999), I use the investor's discount factor to match a borrowing premium on loans of 2%, which is approximately the historical average spread between the commercial and industrial loan rates over the intended federal funds rate. This gives ω^I a value of 0.172. The implied steady-state discount factor for the saver is 0.99 and that for the investor is 0.97. Consistent with Bernanke et al. (1999), the difference in agents' discount factors leads to the fact that the collateral constraints are always binding.[7] In line with Greenwood et al. (1988), the elasticity of the labor supply is calibrated to 1.7, which corresponds to $\theta = 0.6$.

I set δ to 0.025, which corresponds to an annual depreciation rate of 10%. I use $\psi^I = 1.58$ (investor's labor supply level) and $\psi^S = 1.42$ (saver's labor supply level) to match the hours of 0.3 for each type of agent. Capital share α is set to 0.3. Following Iacoviello and Minetti (2006), I set the real estate share in output ζ to 0.1. The weight on housing in the saver's utility ν is set to 0.15, which implies that real estate is split nearly equally between commercial and residential uses.

Following Bernanke et al. (1999), I set π, the elasticity of the capital price with respect to the investment-to-capital ratio, to 0.25.[8] In the sensitivity analysis, I experiment with other values of the investment adjustment cost. Following Dedola and Lombardo (2012), I calibrate the leverage ratio to be 2, which corresponds to 2/3 for $\overline{\kappa}$. The weight on the domestic intermediate good ω is set to 0.87 to match the import-to-output share of 0.15. Following Heathcote and Perri (2002), I set the elasticity between the local and foreign goods σ to 0.9, which is in line with values typically used in the international macro literature, which are close to 1.[9] I also experiment with a higher value of σ in the sensitivity analysis.

In the data, countries exhibit home bias toward domestic equity and debt, and there is substantial heterogeneity in home bias among different countries. Fidora et al. (2007) document that the equity home bias for developed countries is 0.69 on average, with the Euro area having an equity home bias as low as 0.65 and Japan showing a bias as high as 0.9. In the benchmark calibration, I set $\tau = 0.0003\%$ to match the equity home bias of 0.69 and set $\lambda = 0.74$ to match the bond home bias of 0.74, which are the average levels for the developed economies.

The AR (1) process for technology is estimated from the data,[10] with the autocorrelation matrix set to $\begin{bmatrix} 0.97 & 0. \\ 0. & 0.97 \end{bmatrix}$ and $\sigma(\varepsilon_i) = 0.006$, *corr* $(\varepsilon_1, \varepsilon_2) = 0.32$. For the financial shock, I calibrate the persistence to be 0.97 and the standard deviation of the shock to be 0.008 in line with Jermann and Quadrini (2012). For simplicity, the financial shocks between countries are assumed to be independent.

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5 It is easy to show that the Lagrange multipliers on the investor's collateral constraints are the same for each country up to a first-order approximation, that is, $\mu_{11,\,t} = \mu_{12,\,t}$ and $\mu_{21,\,t} = \mu_{22,\,t}$. To save notation, I use μ_{1t} to denote $\mu_{11,\,t}$ and $\mu_{12,\,t}$, and μ_{2t} to denote $\mu_{21,\,t}$ and $\mu_{22,\,t}$.

6 The model is solved following Devereux and Sutherland (2010), where information from a second-order approximation is used to pin down the steady-state portfolio shares. See the online appendix for technical details.

7 The saver is more patient than the investor and is therefore always willing to lend to the investor. In the simulation, the Lagrange multipliers μ_{ijt} are positive and the constraints are always binding.

8 A reasonable assumption about the adjustment cost suggests that the value should lie within a range of 0 to 0.5. Jermann (1998) used a value of 0.23. Christensen and Dib (2008) obtained an estimate of 0.59.

9 Corsetti et al. (2008) estimated the elasticity to be 0.85. Stockman and Tesar (1995) used a value of 1. Backus et al. (1992) set the elasticity to 1.5.

10 I identify country 1 as the U.S. and country 2 as the rest of the industrial world (an aggregate of Europe, Japan, and Canada). Data are from the OECD Quarterly National Accounts. See the online appendix for details.

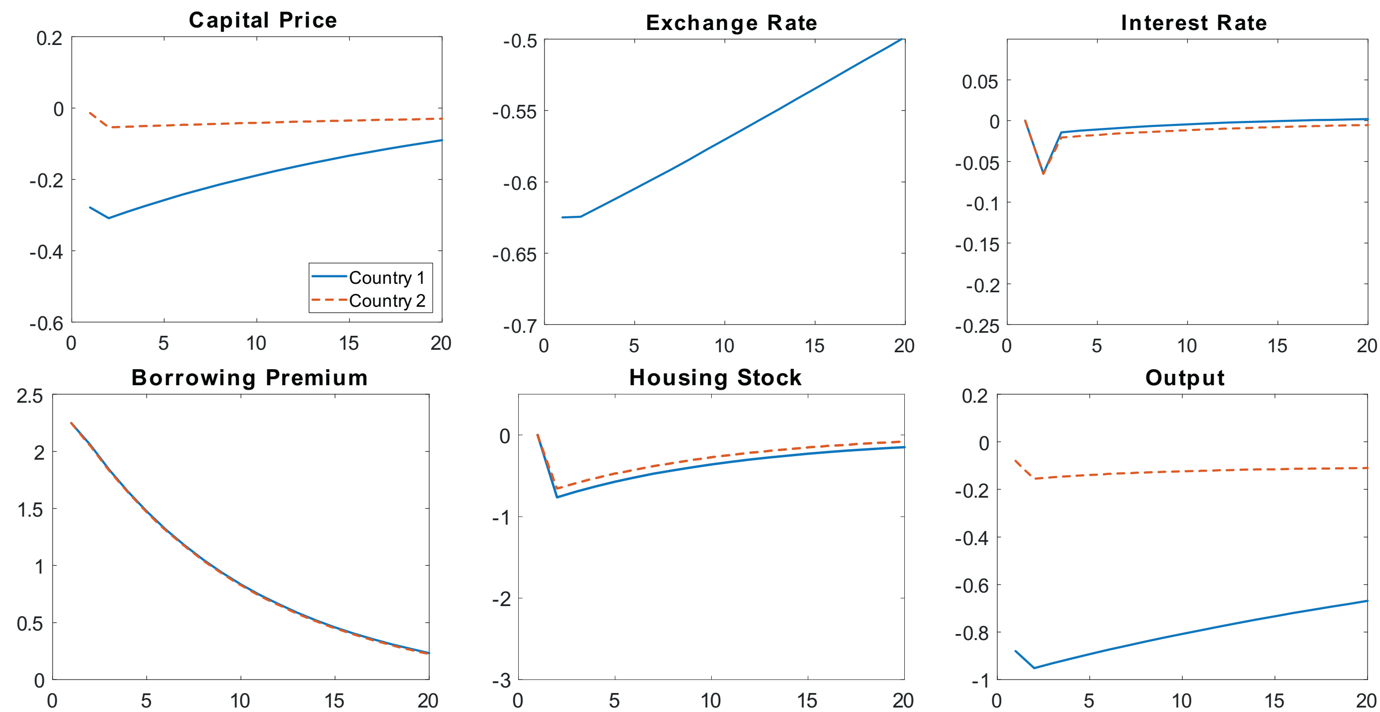

Fig. 1. IRFs of the technology shock. *Note*: The model's response to a negative technology shock in country 1. Variables are expressed in percentage deviation from the steady state. “Housing Stock” is the housing used in production.

4. Benchmark results

In this section, I analyze the quantitative implications of the benchmark model with different shocks. First, I use impulse response functions (IRFs) to analyze the model mechanism. Second, I report the model moments and compare them with the data.

4.1. Impulse responses

4.1.1. Technology shock

I present the IRFs to a one-standard-deviation negative productivity shock to the home country. All of the variables are measured in units of the final good in its own country. As shown in Fig. 1, a fall in the home productivity lowers the expected future return of domestic capital, which leads to a fall in the domestic capital price. The fall in domestic productivity also leads to a lower supply of the domestic intermediate good, and therefore the terms of trade and exchange rate appreciate.[11] Because the investor's bond claim is pledged to the value of her total asset holdings, the reduction of the domestic capital price and the appreciation of the exchange rate tighten the domestic collateral constraint and reduce the domestic investor's borrowing. Given that the bond market is international, real interest rates fall with similar magnitudes in both countries. Since the domestic collateral constraint is tightened, the borrowing premium increases in the home country. As discussed in the previous section, with integrated financial market, a rise in the borrowing premium in one country is accompanied by a similar rise in the borrowing premium in the other country, which implies a tightened collateral constraint in the foreign country. The foreign investor hence reduces her housing purchases, which lowers next period output. As the terms of trade appreciates, the foreign wage falls which leads to the decline of foreign employment and output on impact.

4.1.2. Financial shock

Fig. 2 shows the IRFs to a one-standard-deviation negative financial shock to the home country. The negative financial shock tightens the domestic collateral constraints, which reduces the investor's borrowing ability and pushes up the domestic borrowing premium. With less borrowing, the domestic investor consumes less and demands less final good from the home country. Given that the production of the final good uses more local intermediate good, demand for intermediate good *a* falls, and the terms of trade and exchange rate depreciate. Since the home investor's collateral constraint is tightened, she reduces her housing purchases, which leads to a decline in domestic output next period. Moreover, the interest rates fall because of a lower demand for funds from the home investor.

In the foreign country, the increased foreign borrowing premium implies that the foreign investor's constraint is also tightened; hence, her house holding is reduced, which lowers next period output. As the depreciation of terms of trade raises the foreign wage, foreign employment increases, which results in a small increase in foreign output on impact. That is, although foreign output falls in the second period because of the decline in housing, it actually increases in the first period. This pattern is consistent with the output dynamics in the data during the 2007 crisis. Fig. 3 shows the hp-filtered real GDP and employment for the U.S. and the rest of the industrial world. The vertical line denotes 2007:4, which is the peak of the business cycle dated by the NBER. This figure highlights that the U.S. GDP falls while the rest of the industrial world's GDP increases in the first quarter of the crisis. Moreover, the rest of the industrial world's GDP starts to decline from the second quarter, which is also in line with the model's prediction that foreign output declines immediately after the initial rise.[12] Similarly, the dynamics for employment in Fig. 3 is also consistent with the model's prediction.

[11] The production structure results in a linear relationship between movements in the terms of trade and the exchange rate.

[12] Note that the initial rise of foreign output is unique to the 2007 financial crisis. In the online appendix, I show that the outputs of the U.S. and the rest of the industrial world both fall immediately in the previous five recessions.

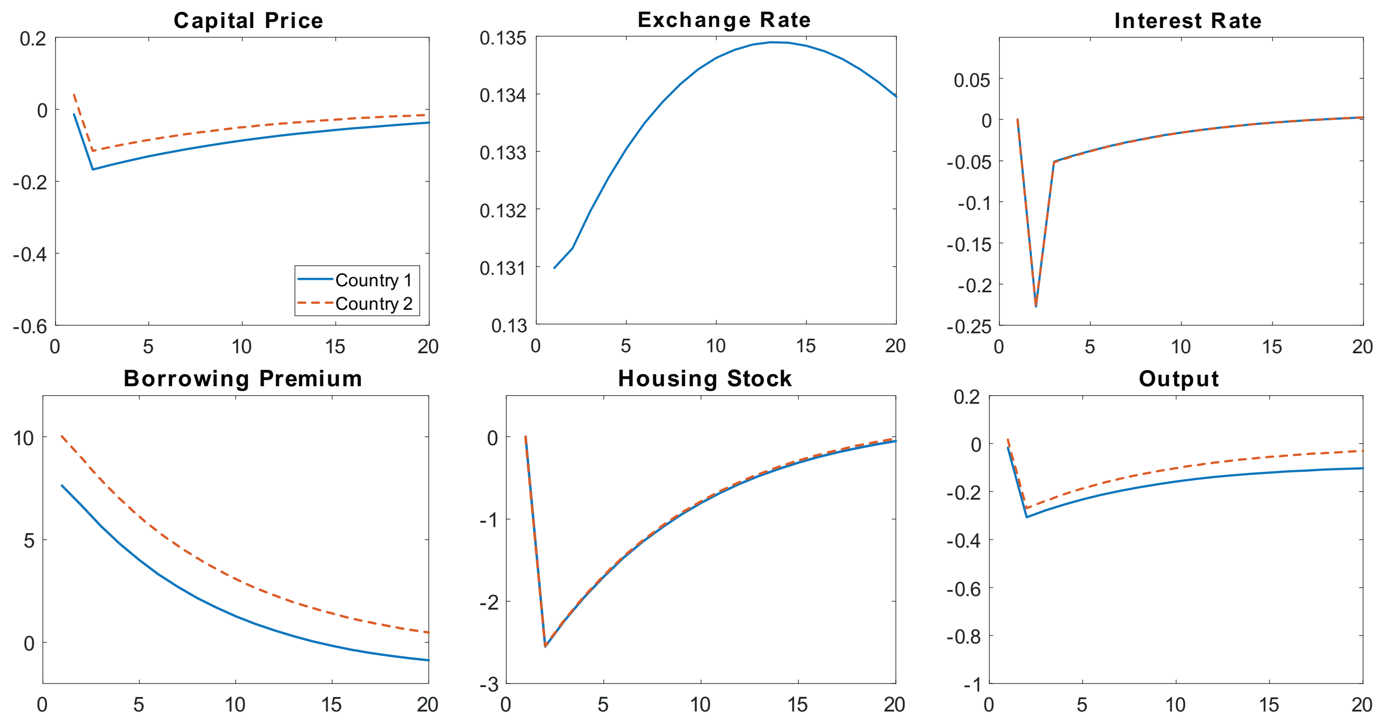

Fig. 2. IRFs of the financial shock. *Note*: The model's response to a negative financial shock in country 1. Variables are expressed in percentage deviation from the steady state. "Housing Stock" is the housing used in production.

Fig. 3. U.S. and the Rest of the Industrial World (RoW). *Note*: The vertical line denotes 2007:4, which is the peak of a business cycle identified. by the NBER Business Cycle Dating Committee.

4.2. Moments

Table 1 presents the simulation results under the benchmark calibration. The first column shows the statistics calculated from the data.[13] As shown in panels (C) and (D) of the first column in the table, the correlation between the loan rate spread and output is −0.29, which means that during a recession, the borrowing premium tends to rise. Moreover, the loan rate spreads tend to move together across countries, leading to a positive correlation of 0.65 in the data.

Column (I) illustrates the moments when only the productivity shock is simulated and the financial shock is kept at zero. For the cross-country correlations in Panel (D), the model matches the fact that consumption, output, investment, employment, and the loan rate spread are positively correlated across countries. This result reflects two channels for the shock transmission. The first is through the balance sheet effect of the collateral constraint, particularly the decline of the housing sector in both countries. The second channel is the adjustment in terms of trade, which leads to a large reduction in foreign employment when the home country experiences a negative productivity shock.

To illustrate the roles played by the collateral constraints, I show in Column (IV) the simulation results from a model without collateral constraints.[14] As shown in Panel (D) of Column (I) and (IV), the presence of the collateral constraint increases the output correlation while lowers the correlations of consumption, investment, and employment, which brings the model closer to the data. First, output correlation is

[13] Panels (A), (B), and (C) are calculated from the U.S. time series for the period 1972:1 to 2008:4. The statistics from panel (D) represent the correlations of the U.S. series with those from the rest of the industrial world. Except for net exports and loan rate spreads, all series are logged and hp-filtered.

[14] Following Devereux and Yetman (2010), when calibrating the model without collateral constraint, the discount factors of savers and investors are used to match an annual interest rate of 4% and to ensure that borrowing by investors is such that the leverage ratio matches that of the economy with collateral constraints.

Table 1
Model moments – benchmark.

	Data	Productivity shock (I)	Financial shock (II)	Both shocks (III)	No collateral (IV)
(A) Standard deviation in %					
Output	1.52	1.28	0.50	1.38	1.18
Net export	0.39	0.05	0.09	0.10	0.01
Exchange rate	3.58	0.89	0.27	0.93	0.99
(B) Standard deviation relative to output					
Consumption	0.63	0.83	0.83	0.83	0.76
Investment	2.82	1.32	2.07	1.44	1.47
Labor	0.67	0.54	0.22	0.51	0.56
(C) Cross-correlation with output					
Consumption	0.82	0.99	0.93	0.98	0.98
Labor	0.86	0.99	0.87	0.96	0.99
Investment	0.95	1.00	0.98	0.98	1.00
Net export	−0.45	0.08	0.01	0.05	0.58
Loan rate spread	−0.29	−0.83	−0.64	−0.44	NA
(D) Cross-country correlations					
Consumption	0.44	0.76	0.67	0.75	0.81
Output	0.61	0.54	0.99	0.60	0.49
Investment	0.46	0.53	0.92	0.64	0.59
Labor	0.43	0.72	0.46	0.71	0.75
Loan rate spread	0.65	1.00	0.96	0.97	NA

Note: The first column shows the statistics calculated from the data. Panels (A), (B), and (C)are calculated from the U.S. time series. The statistics from panel (D)represent the correlation of the U.S. series with series from the rest of the industrial world.

Table 2
Model moments – higher home bias.

	Data	Productivity shock (I)	Financial shock (II)	Both shocks (III)
(A) Standard deviation in %				
Output	1.52	1.27	0.50	1.37
Net export	0.39	0.03	0.11	0.12
Exchange rate	3.58	0.99	0.36	1.05
(B) Standard deviation relative to output				
Consumption	0.63	0.81	0.88	0.82
Investment	2.82	1.32	2.07	1.44
Labor	0.67	0.53	0.24	0.50
(C) Cross-correlation with output				
Consumption	0.82	0.98	0.89	0.97
Labor	0.86	0.99	0.81	0.96
Investment	0.95	1.00	0.98	0.98
Net export	−0.45	0.73	−0.01	0.20
Loan rate spread	−0.29	−0.84	−0.63	−0.44
(D) Cross-country correlations				
Consumption	0.44	0.84	0.47	0.78
Output	0.61	0.56	0.98	0.62
Investment	0.46	0.56	0.90	0.65
Labor	0.43	0.76	0.23	0.74
Loan rate spread	0.65	1.00	0.96	0.97

Note: The first column shows the statistics calculated from the data. Panels (A), (B), and (C)are calculated from the U.S. time series. The statistics from panel (D)represent the correlation of the U.S. series with series from the rest of the industrial world.

higher with the collateral constraint because of a more synchronized housing market. When the investor's borrowing capacity is not limited by the collateral constraint, the reduction in the foreign investor's house holding is much smaller compared to the case with the collateral constraint. Therefore, the decline of output is much less synchronized across countries. Second, collateral constraint lowers the consumption correlation because the constraint makes it more difficult for the agents to smooth their consumption. Third, the employment correlation is lower with the collateral constraint because of less variable terms of trade. The decline in domestic consumption relative to foreign consumption is larger with the collateral constraint, resulting in a weaker response of terms of trade, and hence a weaker response of foreign employment. Fourth, the investment correlation is lower with the collateral constraint. As shown in eq. (11), the stochastic discount factor is higher with collateral constraint because of the positive shadow value. Hence, the relative difference in the domestic and foreign capital prices is larger, resulting in a lower cross-country correlation of investment. Overall, the introduction of the collateral constraint brings the model closer to the data.

Column (II) shows the moments when only the financial shock is simulated and the technology shock is kept at zero. The financial shock generates smaller fluctuations in GDP than the technology shock. For the within-country correlations, the financial shock generates a negative correlation of −0.64 between the loan rate spread and output. For the cross-country correlations, the financial shock generates highly correlated business cycles. Column (III) illustrates the benchmark model simulated with both the technology and financial shocks. The model generates business cycle statistics reasonably well. However, this model shares the failure of many international macro models by under-predicting the real exchange rate volatility.

5. Financial integration and business cycle synchronization

The degree of equity home bias shows some heterogeneity across countries in the data, as described in the calibration. To study the impact of the degree of capital market integration on business cycle co-movements, I now increase the equity home bias to 0.9 and compare the business cycle moments with the benchmark case, where the home bias is 0.69.

Table 2 shows the simulation results for higher home bias. Comparing Table 2 with the benchmark results in Table 1 reveals two interesting predictions of the model, which are all in line with the empirical evidence. First, the model implies that a lower home bias leads to lower volatility of the real exchange rate. The idea is that with a negative domestic productivity shock, if the domestic investor holds more foreign capital, exchange rate appreciation will lead to a greater decline in her borrowing capacity. Therefore, the domestic investor consumes less and hence demand for the domestic intermediate good falls, which weakens the exchange rate appreciation. In Panel (A) of Tables 1 and 2, the exchange rate volatility is reduced from 0.99 to 0.89 when the home bias changes from 0.90 to 0.69. A similar analysis follows for the financial shock. This prediction is consistent with the empirical evidence documented by Fidora et al. (2007), who find a significant and positive relationship between the real exchange rate volatility and equity home bias using data from major industrialized and emerging economies.

The model also implies that with the technology shock, a lower home bias leads to lower business cycle synchronization, while with the financial shock, a lower home bias leads to higher business cycle synchronization. For a negative productivity shock, a lower home bias leads to less appreciation of the real exchange rate. Therefore, the wage falls less in the foreign country, leading to less correlated employment and output between the two countries. For a negative financial shock, a smaller home bias means the real exchange rate depreciates less; hence, foreign employment increases less, resulting in higher employment correlation between the two countries and higher output correlation. The different impacts of technology and financial shocks on business synchronization are confirmed by Kalemli-Ozcan et al. (2013), who find that during the financial crisis, higher integration leads to higher co-movement between countries, while during other times, higher integration leads to less co-movement. In Panel (D) of Column (III), the model also predicts that when both shocks are present, the effect of the technology shock dominates, that is, higher integration leads to lower cross-country correlations. This finding is also confirmed by Kalemli-Ozcan et al. (2013).

Table 3
Sensitivity analysis.

	Data	Investment adjustment cost π = 0			Elasticity of substitution σ = 1.5		
		Productivity shock (I)	Financial shock (II)	Both shocks (III)	Productivity shock (IV)	Financial shock (V)	Both shocks (VI)
(A) Standard deviation in %							
Output	1.52	1.25	0.52	1.35	1.31	0.51	1.41
Net export	0.39	0.13	0.11	0.17	0.03	0.08	0.09
Exchange rate	3.58	0.63	0.34	0.72	0.48	0.13	0.50
(B) Standard deviation relative to output							
Consumption	0.63	0.75	0.73	0.75	0.85	0.80	0.85
Investment	2.82	2.20	2.81	2.30	1.35	2.05	1.46
Labor	0.67	0.58	0.24	0.54	0.56	0.19	0.53
(C) Cross-correlation with output							
Consumption	0.82	0.99	0.91	0.98	1.00	0.96	0.99
Labor	0.86	1.00	0.84	0.96	1.00	0.95	0.97
Investment	0.95	0.97	0.97	0.97	1.00	0.98	0.98
Net export	−0.45	−0.51	−0.10	−0.39	0.53	0.07	0.21
Loan rate spread	−0.29	−0.73	−0.62	−0.27	−0.81	−0.64	−0.43
(D) Cross-country correlations							
Consumption	0.44	0.63	0.53	0.62	0.63	0.82	0.65
Output	0.61	0.43	0.98	0.51	0.48	1.00	0.55
Investment	0.46	0.07	0.81	0.23	0.42	0.97	0.56
Labor	0.43	0.58	0.29	0.57	0.55	0.84	0.56
Loan rate spread	0.65	1.00	0.96	0.96	1.00	0.96	0.97

Note: The first column shows the statistics calculated from the data. Panels (A), (B), and (C) are calculated from the U.S. time series. The statistics from panel (D) represent the correlation of the U.S. series with series from the rest of the industrial world.

6. Sensitivity analysis

I now assess the sensitivity of the results to alternative values for the investment adjustment cost and elasticity of substitution between goods. The other parameters are recalibrated to match the same steady-state targets as in the benchmark.[htpb].

6.1. Adjustment cost

Table 3 presents the case when the adjustment cost is removed by setting $\pi = 0$. The model then implies a constant capital price, which means that the domestic capital price will not have a large negative effect on the foreign investor's balance sheet and her housing purchases, leading to an output correlation that is lower than the data, as shown in column (III). Moreover, when the adjustment cost is absent, domestic investment declines more upon a negative shock, leading to an investment correlation as low as 0.23. These results indicate that the investment adjustment cost strengthens the propagation of shocks across countries, which is important for the quantitative exercise. In addition, the investment adjustment cost also helps to increase the exchange rate volatility, which brings the model closer to the data.

6.2. Elasticity of substitution

I also experiment with a higher elasticity of substitution between domestic and foreign goods by setting σ to 1.5. A higher elasticity means that the two goods are easier to substitute, which produces small changes in the relative price. Less exchange rate adjustment weakens the transmission of productivity shocks and strenghtens the transmission of financial shocks. Overall, the model with higher elasticity of substitution still matches the business cycle co-movements reasonably well.

7. Conclusions

In this study, I investigate the impact of financial integration on business cycle co-movements when financial friction is present. The calibrated model demonstrates reasonable performance in matching the cross-country correlations of consumption, output, investment, and employment. The model shows that with the technology shock, higher integration leads to lower business cycle synchronization, while with the financial shock, higher integration leads to higher business cycle synchronization.

My study confirms the increasing attention in the open economy literature to integrating financial market frictions into otherwise standard two-country models. I document the importance of financial integration on business cycle co-movements in the analysis. As this model is able to replicate some key facts of international business cycles, I believe that my framework is promising for further application in research, particularly for welfare analysis and the design of monetary and fiscal policies.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jinteco.2019.03.002.

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