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Financial Integration and International Dynamics: The Role of Volatility Shocks

Aidi Tang

School of International Trade and Economics, Central University of Finance and Economics, 39 South College Road, Haidian District, Beijing 100081, China; aiditang@cufe.edu.cn

Abstract: This study investigates the impact of financial integration on international dynamics from the perspective of volatility shocks. By incorporating time-varying volatilities, recursive preferences, and a global bank into the IRBC model, it illustrates that volatility shocks trigger precautionary saving incentives, but the specific effects vary based on the type of shock. Financial integration facilitates international capital flows and leads to an unequal distribution of international bank loans between two countries, resulting in greater divergence in their business cycles in the presence of productivity volatilities. In contrast, countries with higher financial integration experience more synchronized business cycles, due to simultaneous fluctuations in the international financial market, ultimately yielding greater synchronization in the face of financial volatilities. Disregarding volatility shocks leads to underestimating the impact of financial integration on the comovement of business cycles across countries. Furthermore, welfare analysis also indicates that financial markets play a crucial role in enhancing social welfare, regardless of the type of volatility.

Keywords: financial integration; volatility shocks; business cycle comovement

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1. Introduction

In the face of the worldwide spread of the coronavirus and the economic turmoil triggered by the global financial crisis, increased cross-border risk contagion has raised significant concerns regarding the macroeconomic effects of time-varying volatility shocks. Volatility shocks have the potential to spread across borders, impacting other countries through diverse channels, including global value chains, cross-border capital flows, and population movements [1–6]. This results in interconnected shifts in business cycles among nations. Mounting evidence suggests that financial integration plays a crucial role as a channel for transmitting international business cycles [7–18]. Although most studies have focused on the level of shocks (e.g., productivity and financial shocks), little attention has been paid to the volatility of shocks. This paper argues that neglecting volatility shocks underestimates the impact of financial integration on the comovement of business cycles across countries. Furthermore, a failure to address volatility shocks reduces the precision of welfare analysis when evaluating financial integration.

This paper investigates how financial integration affects the comovement of business cycles in the presence of volatility shocks. To conduct the analysis, this study constructs an international real business cycle (IRBC) model with a global bank, incorporating time-varying volatilities and recursive preferences. Drawing inspiration from Fernández-Villaverde and Rubio-Ramírez [19] and Fernández-Villaverde et al. [1], the analysis considers the volatility of risky asset returns in the model to depict financial volatilities. It is thus possible to investigate the cross-country transmission of economic cycles under both productivity and financial market volatility shocks. The findings highlight the significance of precautionary saving motives as a crucial mechanism in the cross-country transmission of uncertainty shocks. The impact of financial integration on business cycle synchronization crucially depends on the type of shock. In the presence of productivity volatility shocks, financial integration weakens the synchronization of economic cycles, whereas in the presence of financial volatility shocks, financial integration enhances the cross-country transmission of economic cycles. Moreover, in response to the ongoing debate about the pros and cons of financial integration, the paper conducts a welfare analysis. The quantitative results show that financial integration improves social welfare, regardless of the type of volatility shock.

The contagion mechanisms of the two kinds of volatility shocks work as follows: The first scenario characterizes how financial integration affects international dynamics in the presence of a productivity volatility shock. As the risk of domestic productivity fluctuations increases, precautionary saving by domestic residents increases, reducing bank deposit rates and, correspondingly, corporate lending rates. The decrease in lending rates is transmitted abroad through the interest rate channel, which enables firms in the foreign financially integrated sector to hire more labor at a lower cost and expand production. This, in turn, squeezes out loans from the domestic financially integrated sector. Thus, productivity volatility shocks lead to an unequal distribution of international bank loans between firms in the two countries, causing a reverse movement in firm investment and output. Consequently, when a productivity volatility shock occurs, countries with higher levels of financial integration demonstrate greater inequality in loan distribution, leading to more divergent business cycles. In contrast to productivity volatility shocks, financial volatility shocks impact sectors that hold risky assets in banks, especially for financially integrated sectors where both countries are equally exposed to volatility in international financial markets. Therefore, the larger the relative size of the financially integrated sector (i.e., the higher the degree of financial integration), the more synchronized the comovements in the business cycles of the two countries will be.

The existing theoretical literature has not yet conducted a detailed examination of the impact of financial integration on business cycle synchronization under uncertainty shocks. Most studies have overwhelmingly focused on the level of exogenous shocks (i.e., magnitude, persistence, or correlation), rather than second-order moments such as volatility, let alone a comparison between different types of volatility. In studies that addressed this issue from the perspective of uncertainty shocks, the majority primarily concentrated on the volatility of productivity shocks [3–5,20–22]. Colacito et al. [5] demonstrated that recursive preferences significantly improve the explanatory power of the theoretical model regarding the pass-through of output volatility and risk sharing across countries. However, they fell short in considering financial market conditions as a significant factor in shock transmission. Silva-Yanez [22] recognized this limitation and investigated the effects of TFP volatility shocks on foreign asset accumulation, risk sharing, and social welfare in emerging economies. Their model showed that the presence of volatility shocks strengthens the precautionary saving motive and encourages a more significant accumulation of foreign assets in a small open economy. With increased financial integration, representative households can diversify income risk, thereby weakening the incentive for precautionary saving and reducing the willingness to accumulate foreign assets. Kollmann [4] emphasized that recursive preference magnifies the terms of trade response to a productivity shock, thus strengthening the transnational transmission of the shock, assuming the labor wealth effect is muted. Other studies explored volatilities stemming from government spending shocks, consumption preference shocks, labor supply shocks, and monetary policy shocks [23,24].

Only a few studies focused on the uncertainty of financial shocks. Most of the research on this issue is empirical studies [25–30]. These studies analyzed the volatility of financial shocks by examining stock market returns or the VIX index. They emphasized the crucial role of credit markets in the propagation of uncertainty shocks and highlighted the significance of the level of financial development. Their findings suggested that, compared to developed economies, emerging economies with relatively lower levels of financial development and less robust capital markets typically experience stronger negative impacts from uncertainty shocks. This is primarily due to their limitations in mitigating risks through international financial markets. In contrast, there is a scarcity of theoretical articles specifically addressing the volatility associated with financial shocks. Fernández-Villaverde et al. [1] and Fernández-Villaverde and Rubio-Ramírez [19] pointed out the existence of an external financing premium between loan rates and risk-free interest rates. An increase in the volatility of interest rates in the financial market results in increased corporate financing risk, reflecting an elevated level of financial risk. The study most relevant to this paper is Gete and Melkadze [31], which documented the cross-country patterns of uncertainty and credit variables with an international focus. By simultaneously examining the effects of uncertainty shocks on key economic variables, such as the current account, investment, output, and credit flows, Gete and Melkadze [31] argued that the traditional IRBC model can explain the impact of uncertainty shocks on current account surplus, but it fails to account for credit contraction and increased risk premiums. To address this issue, they extended a two-country incomplete market IRBC model by incorporating a credit supply channel that considers the default and lenders' exposure to aggregate risk. According to Gete and Melkadze [31], uncertainty shocks increase the household sector's incentive for precautionary saving, leading to a higher current account surplus. These shocks also increase a firms' default risk, which tightens bank credit and raises lending rates. Consequently, firms face difficulties in corporate financing, resulting in a simultaneous decline in their investment activities. The uncertainty in the analysis above still primarily pertains to TFP volatility shocks. Nonetheless, Gete and Melkadze [31] provided an improvement over other researches by comparing volatility shocks to the international rate and TFP. They referred to the model of Fernández-Villaverde et al. [1] in a small open economy with complete interest rate pass-through for simplicity. According to their conclusions, shocks to interest rate volatility and TFP volatility are isomorphic. In contrast, this paper presents a two-country two-sector IRBC model with incomplete interest rate pass-through that accounts for a financially closed sector, which is closer to reality. This study highlights the necessity of distinguishing between different volatility shocks and serves as a valuable complement to the work of Gete and Melkadze [31].

This paper is also related to the literature on the ongoing debate about the benefits of financial integration. The scholarly perception of the relationship between financial integration and social welfare has gradually evolved over time. Early studies expressed a positive outlook on financial globalization, emphasizing its potential to enhance consumption smoothing [32–39]. These studies highlighted the crucial role of capital markets in facilitating risk sharing. International credit markets provided increased liquidity. Additionally, cross-border asset holdings and diversified portfolios effectively diversified country-specific and nonsystematic risks. Consequently, financial integration was believed to effectively mitigate country-specific risk shocks, thereby promoting overall social welfare. In other studies, however, scholars have found that the impact of financial liberalization on international risk sharing is not significant [40], especially for developing countries with low levels of financial integration [41–47]. Bai and Zhang [40] argued that, in the presence of financial frictions and the risk of sovereign debt default, the removal of capital controls and deregulation of financial markets cannot deliver significant improvement in international risk sharing. Kim et al. [41] discovered that the degree of risk sharing among East Asian countries is significantly lower than in developed economies, with nearly 80% of shocks not being effectively shared. Capital markets play an insignificant role, while credit markets are effective but limited. Their research also explored the impact of regional and global risk sharing, leading to the conclusion that East Asian countries exhibit considerably less financial market integration than European financial markets. As a result, consumer risk sharing is more likely to be achieved through global financial markets. Other similar studies, such as Calvi et al. [45], Yu et al. [46], and Park and Lee [47], mostly supported the notion that the financial integration process in East Asian countries is relatively sluggish and lags behind the integration process in the real economy.

With the outbreak of the global financial crisis, many scholars began to reflect on the disadvantages of financial integration. The costs of financial integration can be summarized as follows: First, capital flows have aggregation effects and procyclicality. Historical experience shows that cross-border capital inflows are concentrated in a few middle-income countries in Latin America and Asia, and small countries with low levels of economic development still face financing difficulties, even if they open their capital accounts [48–50]. Furthermore, capital flows are strongly procyclical. The influx of capital during economic booms causes capital overheating; the withdrawal of capital during economic downturns, not only exacerbates the risk of runs [51], but also causes liquidity crises for those firms that are overly dependent on capital. Second, capital mismatch can bring distortion. Overheated capital will lead to stock and housing bubbles, which will crowd out investment in the real economy and lead to numerous high-leverage and rent-seeking behaviors, hampering long-term economic growth [52]. Moreover, financial integration serves as a significant channel that triggers economic volatility, as highlighted by Stiglitz [53], Agénor [52], Pancaro [54], and Cavoli et al. [55]. Pancaro [54] argued that rather than aiding in smoothing consumption, capital liberalization has actually led to a rise in consumption volatility in emerging economies. This is particularly problematic for low-income countries, as excessive credit expansion can escalate credit risk and amplify output volatility.

This paper contributes to the growing literature on the study of financial integration in international dynamics. In comparison to other theoretical works, this paper possesses two advantages. On the one hand, by examining the issue through the lens of volatility shocks, the paper provides valuable insights. This work investigates both productivity and financial market volatility shocks, uncovering distinct transmission mechanisms that differ from the findings of Gete and Melkadze [31]. Disregarding volatility shocks underestimates the impact of financial integration on the comovement of business cycles and results in less accurate alignment of business cycle statistics with real data. On the other hand, quantitative findings also contribute to the discussion of the benefits of financial integration. This research found that financial integration plays a critical role in effectively mitigating the adverse impact of volatility shocks on social welfare. This is primarily because financial integration enables individuals and firms to save and borrow from international financial markets. As a result, precautionary saving motives are reduced, and consumption fluctuations caused by volatility shocks are dampened, leading to an enhancement in social welfare.

The paper is organized as follows: Section 2 lays out the theoretical model. Section 3 analyzes the quantitative results and compares the transmission mechanism under a TFP volatility shock and a financial volatility shock. Section 4 performs a sensitivity analysis. Finally, Section 5 concludes the paper.

2. Model

This paper considers a two-country, two-sector dynamic stochastic general equilibrium model with time-varying volatilities in an open economy. Each sector comprises households, firms, and commercial banks. Sector I is a financially closed sector, where commercial banks can only engage in borrowing and lending activities among firms and households within the same sector. On the other hand, sector II is a financially integrated sector, where financial transactions occur through global banks. The size of sector I is denoted as $(1 - n)$, while that of sector II is represented by n. The exogenous parameter n reflects the degree of financial integration, with higher values indicating greater integration. The two countries in the model are perfectly symmetric, and their economic behaviors mirror each other. Below is a detailed description of the model setup, taking the home country as an illustrative example, and variables related to foreign counterparts are denoted with an asterisk.

2.1. Households

This analysis considers an Epstein–Zin recursive utility function, which offers a more accurate representation of the characteristics observed in the real economy. In contrast to the CRRA utility function, the Epstein–Zin recursive utility function enables the separation of the coefficient of relative risk aversion (RRA) and the intertemporal elasticity of substitution (IES) in the preference structure; that is, these two parameters are no longer inversely related. Recursive utility allows consumers to exhibit different attitudes toward current and intertemporal consumption risks, providing a more flexible characterization of consumers' subjective attributes. Assuming homogeneity among households and a continuous distribution in the interval [0, 1], the objective of the representative household is to maximize the expected lifetime utility function, which is expressed as follows:

$$V_{it} = max\left\{(1-\beta)[u(c_{it}, l_{it})]^{\frac{1-\gamma}{\rho}} + \beta\left[E_t V_{it+1}^{1-\gamma}\right]^{\frac{1}{\rho}}\right\}^{\frac{\rho}{1-\gamma}}, \tag{1}$$

where $u(c_{it}, l_{it}) = c_{it} - \mu\frac{l_{it}^{1+\theta}}{1+\theta}$, $\rho = \frac{1-\gamma}{1-\frac{1}{\psi}}$, β is the intertemporal discount factor, θ is the inverse of the labor supply elasticity, μ is the labor level adjustment parameter, γ is the risk aversion coefficient of households, ψ represents the IES, and the recursive utility function simplifies to the CRRA utility function when $\gamma = \frac{1}{\psi}$.

The household's budget constraint is given by

$$c_{it} + \frac{b_{it+1}}{R_{it}} = w_{it}l_{it} + d_{it} + b_{it}. \tag{2}$$

where c_{it} represents household consumption in sector i in period t, l_{it} is labor input, b_{it} is household savings in commercial banks from period $t-1$ to t, R_{it} is the deposit rate, w_{it} is the unit labor wage, and d_{it} is the corporate dividend. The household maximizes the lifetime utility Equation (2) under the budget constraint Equation (1) to obtain the corresponding first-order conditions:

$$w_{it} = \mu l_{it}^{\theta}, \tag{3}$$

$$\beta R_{it}\left[\frac{E_t V_{it+1}^{1-\gamma}}{V_{it+1}^{1-\gamma}}\right]^{\frac{1}{\theta}-1} \cdot \left[\frac{u(c_{it+1}, l_{it+1})}{u(c_{it}, l_{it})}\right]^{\frac{1-\gamma}{\theta}-1} = 1. \tag{4}$$

Since sector II is fully financially integrated, households in both countries can allocate their savings to international commercial banks. Therefore, for sector II, the interest rates on savings in the home and foreign household sectors are equal, i.e., $R_{2t} = R_{2t}^*$.

2.2. Firms

The representative firm is risk neutral, continuously distributed in the interval [0,1], and invests labor and capital in production activities in each period with a production function in Cobb–Douglas form:

$$Y_{it} = e^{z_t}K_{it}^{\alpha}L_{it}^{1-\alpha}. \tag{5}$$

Here, K_{it} and L_{it} represent capital inputs and labor inputs, respectively, and the coefficient α denotes the share of capital in output. Assume that productivity z_t follows a time-varying AR(1) process, and introduce v_t and v_t to capture the volatility of productivity, which also follows an AR(1) process. Furthermore, η_t^v and η_t^v represent the productivity volatility shocks from the two countries, respectively, and these are assumed to follow an i.i.d. distribution. Finally, A_z and B_v represent the correlation coefficient matrix.

$$\begin{bmatrix} z_t \\ z_t^* \end{bmatrix} = A_z \begin{bmatrix} z_{t-1} \\ z_{t-1}^* \end{bmatrix} + \begin{bmatrix} e^{v_t} \varepsilon_t^z \\ e^{v_t^*} \varepsilon_t^{z^*} \end{bmatrix}, \tag{6}$$

$$\begin{bmatrix} v_t \\ v_t^* \end{bmatrix} = B_v \begin{bmatrix} v_{t-1} \\ v_{t-1}^* \end{bmatrix} + \begin{bmatrix} \eta_t^v \\ \eta_t^{v^*} \end{bmatrix}. \tag{7}$$

The manufacturer needs to borrow working capital from the bank to pay a portion of the workers' wages prior to receiving sales revenue [56,57]. The firm's optimization problem involves choosing various types of factor inputs and making investment decisions to maximize its expected profits, taking into account investment adjustment costs:

$$\max E_t \sum_{t=0}^{\infty} M_{it} D_{it}, \tag{8}$$

where M_{it} is the stochastic discount factor, given by $M_{it+1} = \beta \left[\frac{E_t V_{it+1}{}^{1-\gamma}}{V_{it+1}{}^{1-\gamma}} \right]^{\frac{1}{\theta}-1} \left[\frac{u(c_{it+1}, l_{it+1})}{u(c_{it}, l_{it})} \right]^{\frac{1-\gamma}{\theta}-1}$. D_{it} represents the net profit of the firm after subtracting all operating expenses, including workers' wages, firm investments, and interest on borrowed working capital. The profit of the representative firm can be expressed as:

$$D_{it} = Y_{it} - w_{it} L_{it} - X_{it} - (R_{it}^e - 1)\chi w_{it} L_{it}, \tag{9}$$

Here, the product price is normalized to 1, X_{it} represents the firm's investment, χ denotes the proportion of total wages that the firm needs to borrow as working capital, and R_{it}^e denotes the interest rate on the firm's financing loan. Similarly, in the case of sector II, where both domestic and foreign producers can borrow from global banks and achieve full financial integration, the borrowing interest rate faced by domestic and foreign manufacturers will be exactly the same. That is, $R_{2t}^e = R_{2t}^{e^*}$.

The dynamic capital accumulation equation is given by

$$K_{it+1} = \left(1 - \delta\right) K_{it} + \Phi\left(\frac{X_{it}}{K_{it}}\right) K_{it}, \tag{10}$$

$$\Phi\left(\frac{X_{it}}{K_{it}}\right) = \frac{\eta_1}{1-\xi}\left(\frac{X_{it}}{K_{it}}\right)^{1-\xi} + \eta_2, \tag{11}$$

where δ is the capital depreciation rate and $\Phi(X/K)$ is the investment adjustment cost function and satisfies $\Phi > 0$, $\Phi' > 0$, and $\Phi'' < 0$ [8,58]. The settings of η_1 and η_2 make the steady state in the presence of investment adjustment costs consistent with the steady state in the absence of adjustment costs, satisfying $\Phi(\delta) = \delta$ and $\Phi'(\delta) = 1$. Here, δ is the capital depreciation rate, and $\Phi(X/K)$ is the investment adjustment cost function, which satisfies $\Phi > 0$, $\Phi' > 0$, and $\Phi'' < 0$ [8,58]. The values of η_1 and η_2 are chosen such that the steady state with investment adjustment costs aligns with the steady state without adjustment costs, satisfying $\Phi(\delta) = \delta$ and $\Phi'(\delta) = 1$.

The first-order condition obtained by solving the above optimal solution satisfies

$$E_t\left\{\beta M_{it+1}\left[\alpha e^{z_{t+1}}\left(\frac{K_{it+1}}{L_{it+1}}\right)^{\alpha-1}+\frac{1-\delta\ +\Phi\left(\frac{X_{it+1}}{K_{it+1}}\right)}{\Phi'\left(\frac{X_{it+1}}{K_{it+1}}\right)}-\frac{X_{it+1}}{K_{it+1}}\right]\right\}=\frac{1}{\Phi'\left(\frac{X_{it}}{K_{it}}\right)}, \tag{12}$$

$$(1-\alpha)e^{z_t}\left(\frac{K_{it}}{L_{it}}\right)^{\alpha}=\left[1+\chi(R_{it}^e-1)\right]w_{it}. \tag{13}$$

2.3. Commercial Banks

Commercial banks serve as a crucial intermediary between households and firms, performing the basic function of credit intermediation. Household savings in the non-financially integrated sectors in both countries are $\frac{b_{1t+1}}{R_{1t}}$ and $\frac{b_{1t+1}^*}{R_{1t}^*}$, while the financially integrated sectors can save in international banks, and the total household savings in sector two in both countries are $\frac{b_{2t+1}+b_{2t+1}^*}{R_{2t}}$. There are two main uses of savings deposits in commercial banks; one is to provide risk-free corporate loans that are used as working capital for manufacturers, and the other is used to invest in risky assets. R_t^m and $R_t^{m^*}$ denote the return on risky assets in each country, and the mean asset return is the same in both countries in equilibrium. Assume that the expected return on risky assets is high enough that each commercial bank invests the maximum share allowed by its banking regulation. $\overline{m}$ is used to denote this share and satisfies $0<\overline{m}<1$. In sector I, commercial banks' lending and investment activities are limited to that sector in that country, while in sector II, international banks can lend to manufacturers in both countries and allocate diversified international investments. Finally, referring to the model setting of Kalemli-Ozcan et al. [14], commercial banks need to incur certain operating costs τ to organize and manage various business activities. Under the assumption of competitive banks, the profit of commercial banks is zero in equilibrium:

$$\overline{m}R_t^m+(1-\overline{m})R_{1t}^e=R_{1t}+\tau, \tag{14}$$

$$\overline{m}R_t^{m^*}+(1-\overline{m})R_{1t}^{e^*}=R_{1t}^*+\tau, \tag{15}$$

$$\overline{m}\left(\frac{R_t^m}{2}+\frac{R_t^{m^*}}{2}\right)+(1-\overline{m})R_{2t}^e=R_{2t}+\tau. \tag{16}$$

Assuming that the returns on risky assets in both countries follow a bivariate AR(1) process, this paper incorporates a depiction of financial shock volatility into the model based on the approach proposed by Fernández-Villaverde and Rubio-Ramírez [19] and Fernández-Villaverde et al. [1].

$$\begin{bmatrix}R_t^m\\R_t^{m*}\end{bmatrix}=\begin{bmatrix}I-A_R\end{bmatrix}\begin{bmatrix}\overline{R}^m\\\overline{R}^m\end{bmatrix}+A_R\begin{bmatrix}R_{t-1}^m\\R_{t-1}^{m}{}^*\end{bmatrix}+\begin{bmatrix}e^{s_t}\varepsilon_t^R\\e^{s_t^*}\varepsilon_t^{R^*}\end{bmatrix}, \tag{17}$$

$$\begin{bmatrix}s_t\\s_t^*\end{bmatrix}=B_s\begin{bmatrix}s_{t-1}\\s_{t-1}^*\end{bmatrix}+\begin{bmatrix}\eta_t^s\\\eta_t^{s^*}\end{bmatrix}. \tag{18}$$

where $\overline{R}^m$ represents the average return on risky assets, ${\varepsilon_t}^R$ and ${\varepsilon_t}^{R^*}$ denote the exogenous financial shocks in both countries, and s_t represents the fluctuations in the return on risky assets following an AR(1) process. The variables η_t^s and η_t^s represent the financial market volatility shocks in the two countries. All the variables, ${\varepsilon_t}^R$, ${\varepsilon_t}^{R^*}$, η_t^s, and η_t^s, are assumed to follow i.i.d distributions. The correlation coefficient matrices A_R and B_s are of size 2×2.

2.4. Equilibrium

The equilibrium stateof the entire economic system is defined as follows: given exogenous shocks $\{z_t, z_t^*, R_t^m, R_t^{m^*}, v_t, v_t^*, s_t, s_t^*\}$ and initial conditions, the price series $\{R_{it}, R_{it}^*, R_{it}^e, R_{it}^{e^*}, w_{it}, w_{it}^*\}$ and the allocation sequence $\{c_{it}, c_{it}^*, l_{it}, l_{it}^*, d_{it}, d_{it}^*, b_{it+1}, b_{it+1}^*, K_{it+1}, K_{it+1}^*, X_{it}, X_{it}^*, L_{it}, L_{it}^*, D_{it}, D_{it}^*\}$ are determined in a way that satisfies the following conditions: The household sector maximizes expected lifetime utility, the producer maximizes expected profit, the budget constraint of each economic agent is satisfied, competitive commercial bank profits are zero, and each market clears.

The labor market clearing conditions are

$$L_{1t} = (1-n)l_{1t}, \tag{19}$$

$$L_{2t} = nl_{2t}. \tag{20}$$

The total profits of firms are distributed among households in proportion to their individual dividends. In other words, the profit distribution is cleared according to the following mechanism:

$$D_{1t} = (1-n)d_{1t}, \tag{21}$$

$$D_{2t} = nd_{2t}. \tag{22}$$

The capital market is cleared under the condition that the working capital of each sector is equal to the loans provided in that sector. Specifically, in sector I, the bank loans are limited to advances for workers' wages in each country's sector I firms. In sector II, the working capital corresponds to the total global bank loans provided to sector II in both countries. This ensures that the capital market is in equilibrium and all capital requirements are met.

$$\chi w_{1t} L_{1t} = (1-\overline{m})\frac{(1-n)b_{1t+1}}{R_{1t}}, \tag{23}$$

$$\chi w_{1t}^* L_{1t}^* = (1-\overline{m})\frac{(1-n)b_{1t+1}^*}{R_{1t}^*}, \tag{24}$$

$$\chi(w_{2t}L_{2t} + w_{2t}^* L_{2t}^*) = (1-\overline{m})\frac{n(b_{2t+1} + b_{2t+1}^*)}{R_{2t}}. \tag{25}$$

2.5. Calibration and Solution Method

The parameter values were chosen based on relevant studies by Kollmann [4] and Colacito et al. [5] and set the risk aversion coefficient of consumers, denoted as γ, to 10, and the IES, denoted as ψ, to 1.5. The parameters of the level shocks refer to the method of Kalemli-Ozcan et al. [14]. To ensure comparability, σ_e^z is used to match the quarterly GDP growth rate in the US of 1.32% in the two cases. σ_e^z is calibrated to 0.625% for productivity shock only, with 0.58% when both productivity and financial shocks hit.

Regarding the parameters related to volatility shocks, the productivity volatility shock parameters were taken from Mumtaz and Theodoridis [24]. The autocorrelation coefficient of productivity volatility, denoted ρ_v, is set to 0.99, and the variance of productivity volatility, denoted σ_e^v, is calibrated to 0.065. The correlation of productivity volatility between the two countries is assumed to be 0, implying that productivity shocks are uncorrelated across countries [3,24,59]. For the parameters related to financial volatility shocks, references are made to Mencia and Sentana [60] and Skintzi and Refenes [61]. The autocorrelation coefficient of financial volatility, denoted ρ^s, is set to 0.98, and the standard deviation of the variance, represented as σ_e^s, is calibrated to 0.064. The autocorrelation coefficient ρ^s is set to 0.98. The VIX index reflects investors' expectations of market volatility. The higher the index, the more volatile the market. According to the VIX index calculated by Ederington and Guan [62], the standard deviation of the variance σ_e^s is calibrated as 0.064. The correlation of financial volatility between countries is also assumed to be 0. Following Mendoza [63] and Perri and Quadrini [15], χ, the fraction of the wage bill that is paid in advance, is set to 0.26, matching the ratio of working capital to GDP in the data. The size of sector II, n, is calibrated to match an average value of 0.15 for the level of financial integration in the U.S. during the sample period. $US\ Integration_t$ is calculated with BIS data, using the fraction $\frac{\sum_i (Asset_{iUS,t}+Liabilities_{iUS,t}+Asset_{USi,t}+Liabilities_{USi,t})}{GDP_{USt}+\sum_i GDP_{it}}$. The share and average return of risky assets is set to 0.4 and 0.06, according to statistics in the U.S. [14,64]. Other parameter values are selected using the same settings as those in the international macro literature. For example, the discount factor β, the capital share α, the capital depreciation rate δ, and the labor supply adjustment μ are set such that the average yearly return to capital equals 4%, labor's share of GDP equals 64%, the annual depreciation rate is 10 %, and the labor supply is approximately 1/3 in steady state. The parameter calibration values are summarized in Table 1.

Table 1. Summary of parameter values.

Parameter	Definition	Value	Source/Target
Preference and technology			
β	Discount factor	0.99	The average yearly return to capital of 4%
α	Capital share	0.36	Labor's share of GDP equals 64%
δ	Depreciation rate	0.025	The annual depreciation rate of 10%
θ	Elasticity of labor supply	0.6	Greenwood et al. [65]
μ	Labor supply level	4.561	Labor supply in steady state equals 1/3
γ	Risk aversion	10	Kollmann [4], Colacito et al. [5]
ψ	Intertemporal elasticity of substitution	1.5	Kollmann [4], Colacito et al. [5]
ξ	Investment adjustment cost	0.067	Baxter and Crucini [8]
χ	Working capital ratio	0.26	Ratio of working capital to GDP [63]
n	Size of sector II	0.487	Financial integration level in the U.S. is 0.15.
$\overline{m}$	Share of risky assets	0.4	Bekhtiar et al. [64]
τ	Intermediation cost	0.04	The spread between lending rate and deposit rate is 3%.
$\overline{R}^m$	Average return to risky asset	0.06	Kalemli-Ozcan et al. [14]
Shock Process			
ρ_z	Persistence of productivity shock	0.95	Kalemli-Ozcan et al. [14]
ρ_e^z	Correl. of prod. innovations	0.3	Kalemli-Ozcan et al. [14]
ρ_R	Persistence of financial shock	0.95	Kalemli-Ozcan et al. [14]
ρ_e^R	Correl. of financial innovations	0.3	Kalemli-Ozcan et al. [14]
σ_e^z	Std. dev. of prod. shock	0.625%, 0.58%	The quarterly GDP growth rate in the US is 1.32%
σ_e^R	Std. dev. of financial shock	4.0%	The increase in financial shock volatility during the 2008 financial crisis
ρ^v	Persistence of prod. volatility shock	0.99	Mumtaz and Theodoridis [24]
σ_e^v	Std. dev. of prod. volatility shock	0.065	Mumtaz and Theodoridis [24]
ρ^s	Persistence of financial volatility shock	0.98	Mencia and Sentana [60], Skintzi and Refenes [61]
σ_e^s	Std. dev. of financial volatility shock	0.064	Std. dev. of VIX index [62]

Since an exact solution for the DSGE model is not available, the Taylor approximation method, also known as the perturbation method, is commonly employed to obtain an approximate solution. This method linearizes the model by performing a Taylor expansion around the steady-state value. The first-order approximation solution, based on the principle of certainty equivalence in first-order moment expansion, assumes a risk premium of 0. The second-order approximation, although influencing the level of the risk premium, fails to capture the volatility of uncertainty shocks, which are shocks characterized by exogenous shock variance. Given that the model does not feature an occasionally binding constraint, the higher-order approximation is expected to provide a more accurate solution closer to the global solution. Moreover, the higher-order approximation facilitates handling models with a greater number of state variables, as is the case in this paper. Therefore, a high-order approximation is employed to solve the model. This approach not only compensates for the zero risk premium in the first-order approximation and the constant risk premium in the second-order approximation, which cannot account for time-varying uncertainty shocks, but it also allows for the quantification of the welfare changes resulting from financial integration under various types of external shocks [3,59,66].

3. Quantitative Results

This section analyzes the quantitative implications of the model with different shocks. First, impulse response functions (IRFs) are employed to examine how financial integration affects the business cycle comovement of various economic activities and to compare the transmission mechanisms under TFP volatility shocks and financial volatility shocks. Second, model-simulated data are used to conduct regression analysis. Comparing the results before and after the introduction of uncertainty shocks confirms that the role of financial integration is underestimated when volatility shocks are not considered. Next, the simulated moments are reported, which demonstrate that the model aligns well with the data. Finally, welfare analysis is conducted to quantitatively evaluate the effect of financial integration.

3.1. Impulse Response Analysis

3.1.1. Responses to Productivity Volatility Shocks

The analysis begins by investigating the cross-country transmission path of business cycles under productivity volatility shocks. Figure 1 presents the impulse response results of key economic variables in both countries when the home country experiences a positive productivity volatility shock of one unit standard deviation. The horizontal axis represents the time period in quarters, while the vertical axis represents the percentage deviation of each variable from its equilibrium value. Additionally, Figure 2 illustrates the impulse response results for each sector in the two countries under the same shock.

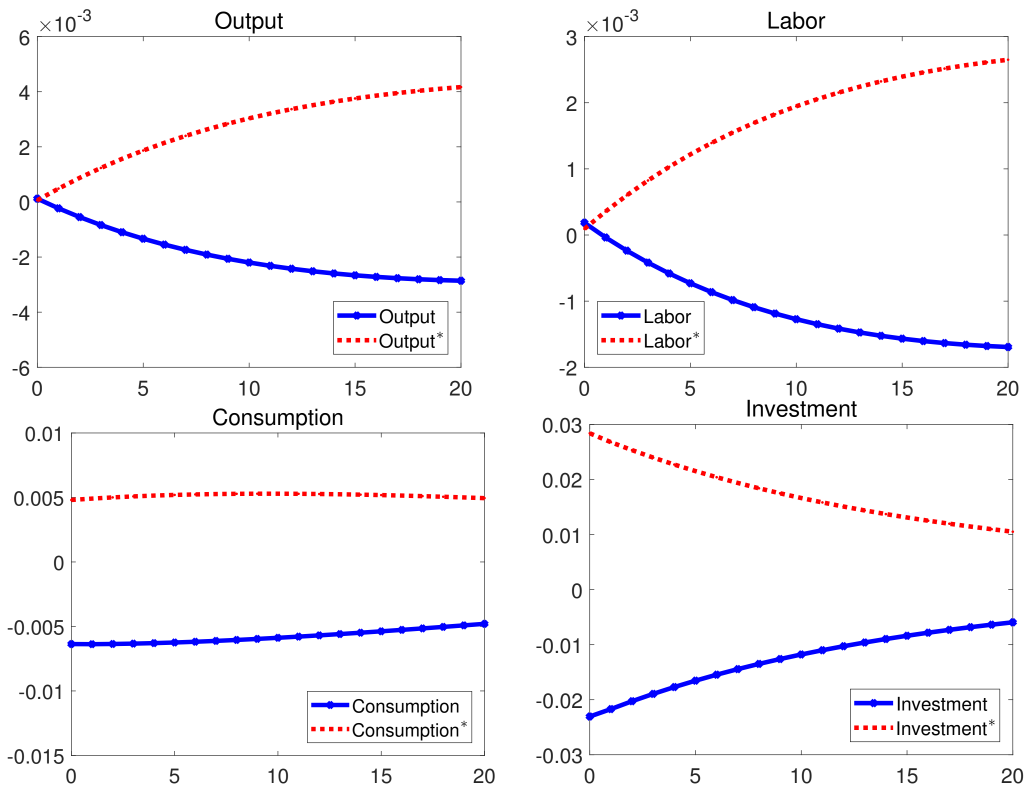

Figure 1. Impulse responses for each country under productivity volatility shock. (label * denotes variables related to the foreign country)

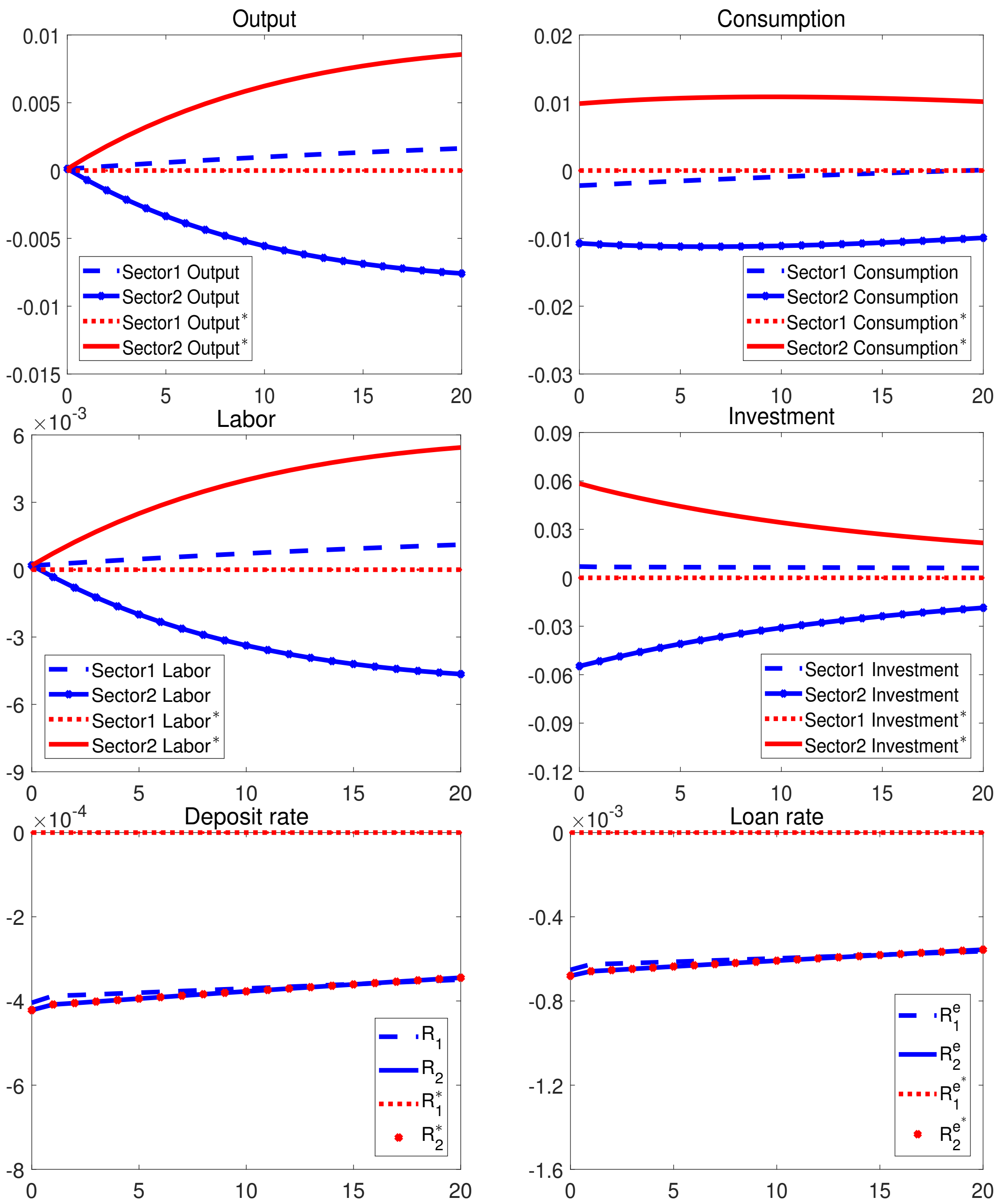

Figure 2. Impulse responses for each sector under productivity volatility shocks. (label * denotes variables related to the foreign country)

In the presence of consumer risk aversion, the marginal utility of expected future consumption is higher in the presence of volatility shocks than in the certainty case. Consequently, as the risk of domestic productivity volatility rises, residents of the home country tend to save more and allocate a greater portion of their income toward future consumption, driven by the "precautionary saving" motive. This increase in precautionary saving is clearly observed in Figure 2, where a significant reduction in consumption is evident in both home sector I and sector II. The transmission of volatility shocks to the foreign sector occurs through the interest rate channel. As residents of the home country increase their savings, deposit rates in domestic banks decline, and as a result, corporate lending rates also decrease. Since sector II in both countries is financially integrated and faces the same interest rates for savings and loans, the decline in savings rates affects foreign residents' savings and leads to an increase in consumption within foreign sector II.

Note that, while both sector I and sector II in the home country face the same productivity volatility shock, their output, labor, and investment exhibit opposite trends. This disparity arises due to differences in the level of financial integration. Specifically, firms in sector I can only access loans from domestic commercial banks. As domestic savings increase, more capital is available for borrowing, leading to an increase in firms' working capital. Consequently, they can hire more labor for productive activities, resulting in higher investment and output. Sector II, on the other hand, is fully financially integrated, and loans from international banks are allocated to sector II firms in both countries. Domestic sector II is directly affected by productivity volatility shocks, which result in increased output uncertainty. In contrast, the foreign sector does not face direct productivity volatility shocks. However, the decrease in lending rates caused by productivity fluctuation shocks in the home country can be transmitted abroad through the interest rate channel. This allows foreign firms in sector II to expand their production and hire more labor at a lower cost. In contrast, global banks have a preference for lending more to the foreign sector that is not subject to productivity volatility shocks. As a result, lending to the domestic sector II is crowded out, leading to a decrease in firms' working capital. Figure 2 demonstrates that the demand for labor in domestic sector II decreases, investment declines, and output falls. Labor in domestic sector II experiences a slight increase in response to productivity volatility shocks, which can be attributed to the Oi–Hartman–Abel effect. The Oi–Hartman–Abel effect, as proposed by Oi [67], Hartman [68], and Abel [69], and others, suggests that labor demand is a convex function with respect to total factor productivity based on the first-order condition of firm profit maximization. According to Jensen's inequality, an increase in productivity volatility leads to an increase in labor demand. This effect is observed when firms have the ability to endogenously determine their production scale and flexibly adjust factor inputs. However, as lending to domestic sector II continues to be crowded out by the foreign sector, investment by firms in domestic sector II declines, resulting in decreased labor demand.

In the presence of productivity volatility shocks, there is an observed divergence in the behavior of output, consumption, and investment between the two countries. This leads to a reduction in business cycle comovements. Furthermore, firms in the financially integrated and financially closed sectors exhibit distinct responses to productivity volatility shocks, highlighting the significant role of financial integration in transmitting international dynamics.

3.1.2. Responses to Financial Volatility Shocks

The global financial crisis not only resulted in a shrinkage of financial assets but also triggered intense volatility in financial markets. To analyze the theoretical mechanism through which financial integration affects the cross-country transmission of business cycles under financial volatility shocks, this paper incorporates the volatility of risky asset returns into the international economic cycle model. The dynamic adjustment process of the key economic variables in both countries following a positive financial volatility shock of one unit standard deviation is illustrated in Figure 3. Additionally, Figure 4 presents the impulse responses of each sector under the same financial shock for both countries.

In the face of financial market volatility shocks, the uncertainty of risky asset returns increases, leading to a higher possibility of bank asset losses and increased risk of being unable to fulfill repayment of residents' savings. This, in turn, amplifies the financing risk faced by enterprises. To mitigate potential adverse financial shocks in the future, residents have a stronger incentive to save as a precautionary measure and reduce their current consumption. Simultaneously, firms respond to the risk by increasing investment and capital accumulation, to safeguard against possible financing difficulties arising from a future credit crunch. As residents' savings increase, the interest rate on their deposits decreases. Under the equilibrium condition of zero profit for competitive commercial bank, the interest rate on loans provided to firms also decreases. This enables firms to expand their labor force, leading to an increase in labor demand. Despite facing domestic financial uncertainty shocks, financial integration plays a crucial role in transmitting business cycles across countries. In particular, sector II, which holds risky assets in international banks, exhibits precautionary savings behavior among its residents in response to international financial market volatility. This behavior is evident in Figure 4 as a simultaneous decrease in residential consumption and an increase in business investment in sector II in both countries. The impact of volatility shocks is more pronounced in sector I, as firms in this sector are unable to borrow through international financial markets, and resident's savings are limited to their own bank.

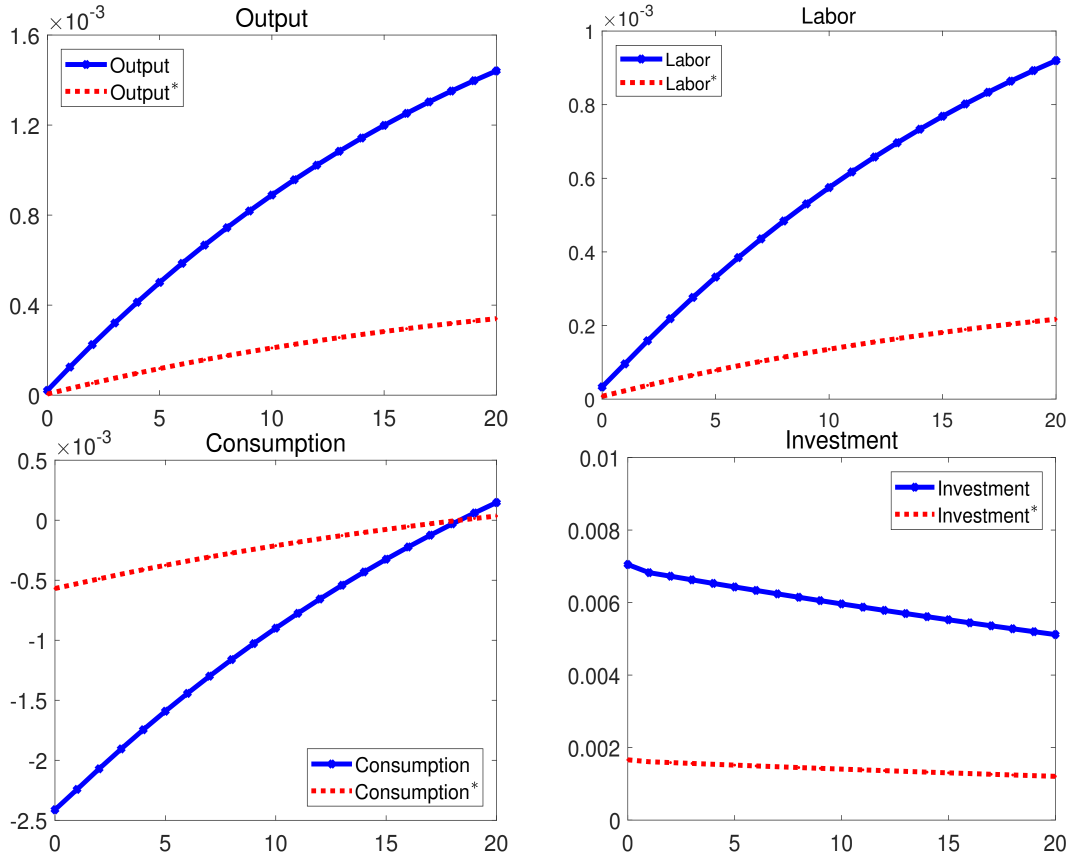

Figure 3. Impulse responses for each country under financial volatility shocks. (label * denotes variables related to the foreign country)

Under the influence of productivity volatility shocks, the transmission of business cycles between the two countries occurs indirectly through the interest rate channel. In contrast, financial volatility shocks directly impact sectors that hold risky assets in banks, particularly the financially integrated sector II. As a result, both countries are exposed to similar fluctuations in the international financial market, leading to a more synchronized output, consumption, and investment. Financial integration further amplifies the cross-country transmission of economic cycles. To some extent, this observation helps to explain the phenomenon observed during the 2008 financial crisis, where the subprime mortgage crisis in the US propagated to Europe through financial interconnections. This contagion effect then spread across global financial markets, resulting in a synchronized downturn in the global economy. This outcome has not solely been attributed to conventional financial shocks [14,18] but also to volatility shocks in financial markets that amplified the contagion of the crisis.

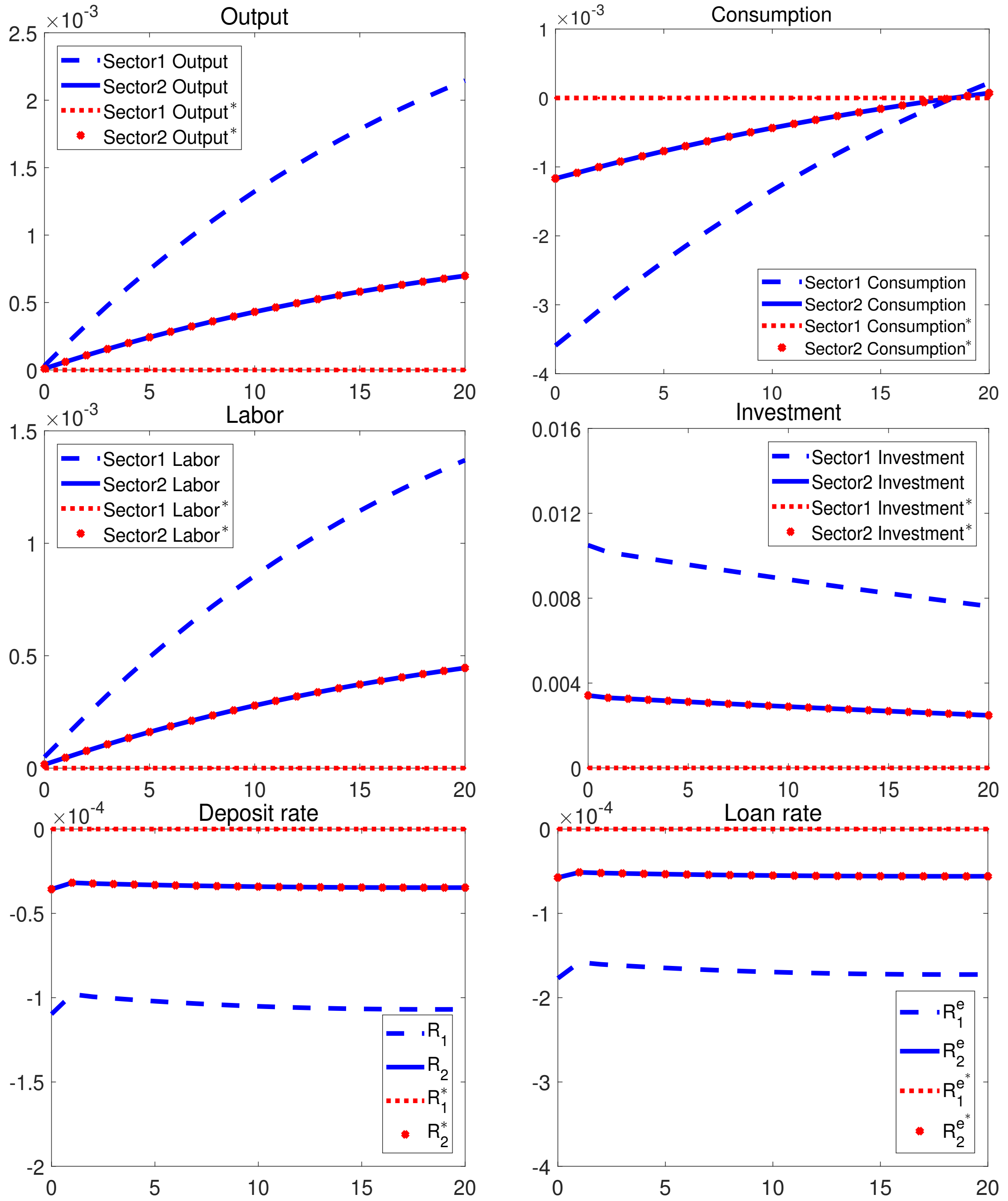

Figure 4. Impulse responses for each sector under financial volatility shocks. (label * denotes variables related to the foreign country)

3.1.3. Discussion on the Effect of Financial Integration

Under the impact of productivity volatility shocks, output, consumption, and investment in both countries exhibit changes in opposite directions, driven by the different responses of the financially integrated sectors in each country. The domestic productivity volatility shock results in an uneven distribution of international bank loans between sector II in the two countries, leading to a countermovement in firm investment. This suggests that the divergence will be more pronounced as the size of sector II increases; that is, a higher degree of financial integration. This conjecture is supported by Figure 5, which compares the changes in the main macroeconomic variables for different levels of financial integration. Increasing the size of sector II (n) to 0.8 and comparing it with the benchmark model ($n = 0.487$) confirms this observation.

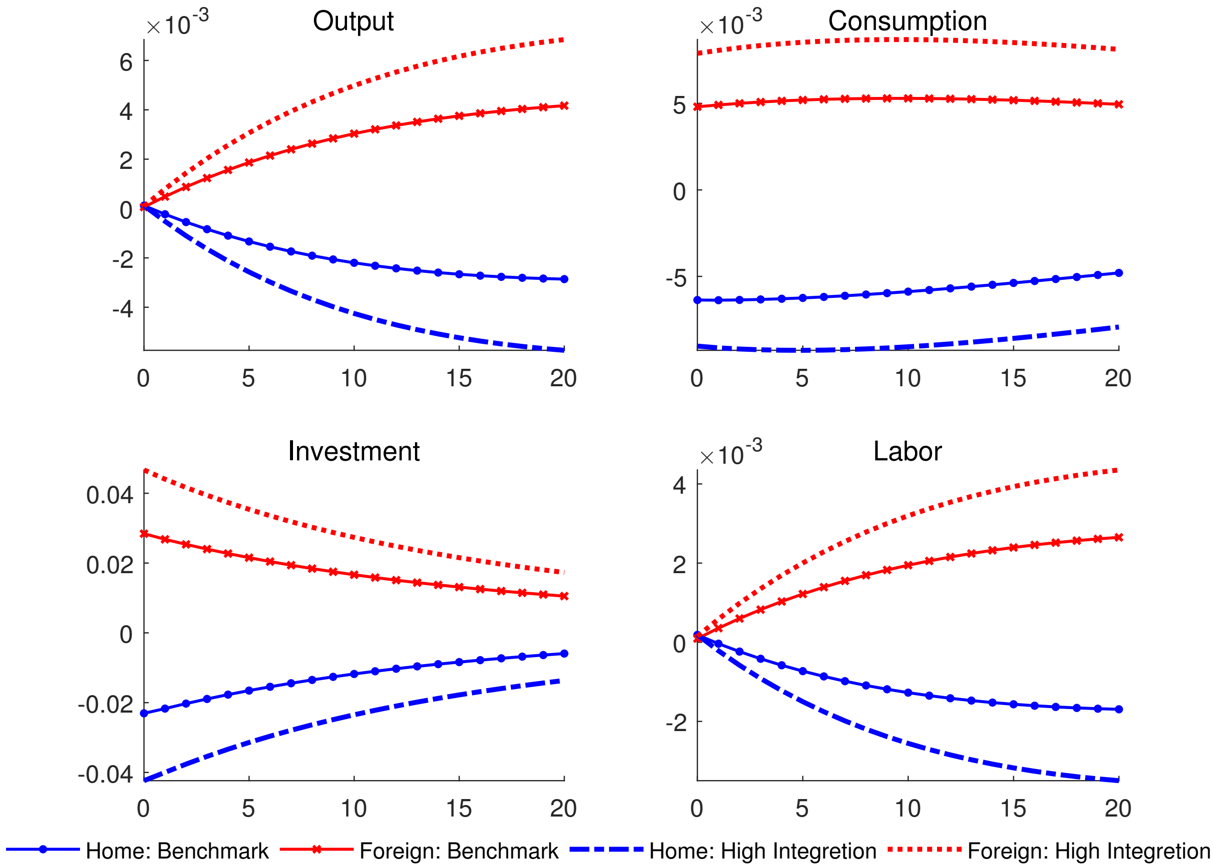

Figure 5. Degree of financial integration and productivity volatility shocks.

In the presence of financial volatility shocks, residents and firms in sector II of both countries are exposed to the same international financial market volatility. Therefore, the larger the size of sector II, the more closely the business cycles of the two countries become, resulting in higher synchronization (see Figure 6). Appendix A illustrates the trend of the cross-country correlation coefficient at different levels of financial integration. Figure A1 compares the impact of productivity shocks alone versus the combination of productivity shocks and productivity volatility shocks, revealing that the inclusion of productivity volatility shocks decreases the correlation of output, consumption, investment, and labor in both countries. Figure A2 further incorporates an additional financial volatility shock into the analysis of productivity and financial shocks. The results demonstrate that the effect of the financial volatility shock is not significant at low levels of financial integration. However, as financial integration deepens, the financial volatility shock amplifies the correlation of economic volatility between countries, with a more pronounced effect being observed at higher levels of integration.

3.2. Regressions Analysis of Simulated Data

In this section, regression analysis is conducted using the data obtained from the numerical simulation of the model. The simulation process involves the following steps: first, 20 levels of financial integration at equal intervals are selected, representing different degrees of financial integration. For each level of financial integration, 100 periods are simulated while considering the simultaneous effects of productivity shocks and productivity volatility shocks. Additionally, another 100 periods are simulated under the joint impact of all shocks. This simulation is performed for 10 country pairs. The model employed incorporates productivity shocks and productivity volatility shocks, enabling simulation of the dynamics of the economy during nonfinancial crises. Additionally, productivity shocks, financial shocks, and volatility shocks are introduced into both sides of the model to simulate the changes in each economic variable during the global financial crisis.

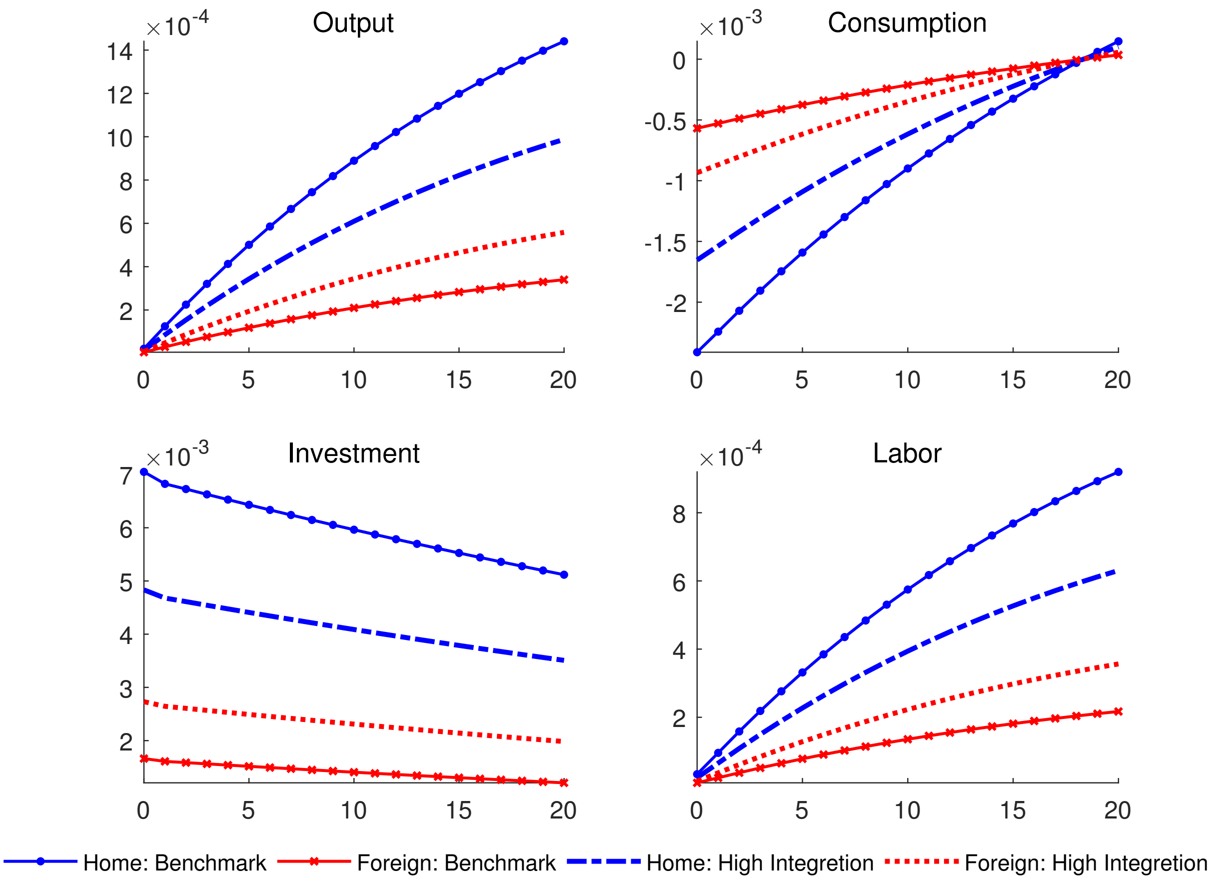

Figure 6. Degree of financial integration and financial volatility shocks.

A comparison of the regression results before and after the introduction of volatility shocks is presented in Table 2. The findings indicate that the introduction of uncertainty shocks does not alter the original results, but it leads to larger absolute values of the coefficients of financial integration and the interaction term. This suggests that the impact of financial integration on business cycle comovement becomes stronger during both nonfinancial and financial crises. In the presence of productivity volatility shocks, financial integration further diminishes business cycle synchronization. On the other hand, in the presence of financial volatility shocks, financial integration facilitates the cross-country transmission of business cycles, highlighting its underestimated role in the contagion of crises. In contrast to the findings of Gete and Melkadze [31], this study reaches a different conclusion by introducing various types of volatility shock in a two-country open economy model. It highlights that the role of financial integration in the cross-country transmission of productivity volatility shocks and financial market volatility shocks differs significantly. This disparity in transmission channels is considered one of the theoretical contributions of this research.

3.3. Simulated Moments

Next, the main predictions of the model are presented and shown to conform well to the data. Table 3 provides a comparison of statistics related to the business cycle before and after the inclusion of volatility shocks. Consistent with the findings of Kollmann [4] and Silva-Yanez [22], the introduction of uncertainty shocks leads to higher volatility in output, consumption, and investment. Comparing the results in Columns (2) and (4) reveals that productivity volatility shocks decrease the correlation coefficients of consumption, output, investment, and labor between countries, while increasing the volatility of investment and net exports. Furthermore, comparing Column (3) with Column (5) indicates that the introduction of financial volatility shocks significantly increases the cross-country correlation coefficients for each macro variable. A comparison between Columns (3) and (6) reveals that the inclusion of uncertainty shocks brings the correlation coefficient statistics closer to the actual data level, thereby improving the model's ability to capture business-cycle-related statistics.

Table 2. Comparison before and after volatility shocks.

	With Volatility Shocks			**Without Volatility Shocks**		
	Synch ^{Y} **(1)**	***Synch*** ^{C} **(2)**	***Synch*** ^{I} **(3)**	***Synch*** ^{Y} **(4)**	***Synch*** ^{C} **(5)**	***Synch*** ^{I} **(6)**
Integration	−0.0075 ***	−0.0363 ***	−0.6860 ***	−0.0071 ***	−0.0115 ***	−0.6215 ***
	(0.0008)	(0.0022)	(0.0423)	(0.0004)	(0.0004)	(0.0173)
Integration × *Crisis*	0.0269 ***	0.0980 ***	0.1596 ***	0.0250 ***	0.0804 ***	0.1246 ***
	(0.0046)	(0.0128)	(0.0149)	(0.0040)	(0.0047)	(0.0130)
Country-Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Country Time Trends	Yes	Yes	Yes	Yes	Yes	Yes
Observation	39,600	39,600	39,600	39,600	39,600	39,600
Adj. R^2	0.168	0.156	0.212	0.080	0.094	0.138

Note: This table presents the estimation results obtained from a regression analysis using numerical simulation data. The first three columns include the introduction of volatility shocks, while the last three columns do not. The coefficient on the constant term is excluded. All continuous variables are expressed in logarithmic form. Controls also include country-pair fixed effects, time fixed effects, and country-specific time trends. Standard errors clustered at the country-pair level are reported in parentheses. Significance levels are denoted by *** at the 1% level.

Table 3. Business cycle statistics.

	Data (1)	**Prod. Shock** (2)	**Prod. + Financial** (3)	**Prod.+ Prod. Vol.** (4)	**Prod.+ Financial Financial Vol.** (5)	**All** (6)
Percentage Standard Deviation						
Output	1.32	1.32	1.32	1.47	1.34	1.47
Standard Deviation Relative to Output						
Consumption	0.62	0.64	0.86	0.64	0.89	0.88
Investment	2.85	2.19	2.27	2.22	2.29	2.31
Labor	0.66	0.62	0.82	0.62	0.84	0.84
Net Export	0.40	0.29	0.41	0.32	0.41	0.44
Cross-Correlation with Output						
Consumption	0.78	0.99	0.90	0.99	0.90	0.91
Investment	0.94	0.94	0.91	0.93	0.91	0.90
Labor	0.84	1.00	0.91	1.00	0.91	0.92
Net Export	−0.44	−0.25	−0.12	−0.26	−0.12	−0.14
Cross-Country Correlations						
Consumption	0.49	0.25	0.51	0.22	0.52	0.48
Output	0.20	0.29	0.35	0.27	0.36	0.33
Investment	0.35	−0.08	0.09	−0.13	0.11	0.05
Labor	0.38	0.28	0.52	0.26	0.53	0.50

Notes: The statistics in Column (1) were calculated based on the research by Heathcote and Perri [70]. Columns (2) to (6) present the statistics of the economy under different types of shocks. The model was simulated for 200 periods, with the initial 20 periods discarded. The statistics were computed by repeating the simulations 200 times and taking the average. All variables were Hodrick–Prescott (HP) filtered with a smoothing parameter of 1600. All statistics, except for net exports, are presented in logarithmic form. The net export statistics represent the ratio (Exports − Imports)/GDP.

4. Sensitivity Analysis

The precautionary saving motive plays a vital role as a channel through which uncertainty shocks influence the economy. This section examines the role of precautionary saving in the transmission of business cycles across countries by exploring different parameters, such as the autocorrelation coefficient of volatility shocks, risk aversion coefficient, and IES. Moreover, these results are compared with the impulse responses in the benchmark model to validate the mechanism of the cross-country transmission channel of uncertainty shocks.

4.1. Autocorrelation Coefficient of Volatility Shocks

First, the autocorrelation coefficient of the productivity volatility shock is reduced to 0.9 [59]. Figure 7 illustrates the responses of the main macro variables to domestic productivity volatility shocks under this parameter setting (dashed line) and includes the impulse response results obtained from the benchmark model (solid line) for comparison. The findings reveal that the impact of less persistent productivity volatility shocks is smaller. The lower autocorrelated shock allows the economy to return to its equilibrium more quickly, thereby weakening the incentive for precautionary savings in response to uncertainty shocks. Consequently, compared to the benchmark model, the increase in precautionary savings leads to a smaller decrease in the savings rate and a lower increase in foreign residential consumption. With a reduced decline in corporate lending rates, the foreign sector experiences a smaller gain, resulting in less pronounced increases in labor demand and investment. In turn, the domestic financial integration sector is crowded out with less corporate lending and smaller declines in domestic investment, labor, and output. Furthermore, as the persistence of shocks decreases, all economic variables converge more rapidly to their steady state values.

Similarly, the persistence parameter of financial volatility shocks is set to 0.95, compared to 0.98 in the benchmark model. The results shown in Figure 8 indicate that financial volatility shocks with lower persistence moderate the precautionary saving incentives compared to the benchmark results. Consequently, when an economy experiences a negative financial volatility shock, the decline in residential consumption is reduced. Furthermore, the precautionary incentive for firms to increase investment against risk is also diminished as the shock persistence decreases. These tests confirm the significant role played by precautionary saving motives in the cross-country transmission of volatility shocks, as evidenced by the reduced magnitude of changes in all major macroeconomic variables, both domestically and internationally.

4.2. Risk Aversion Coefficient

The risk aversion coefficient represents the level of risk compensation required to hedge against uncertainty and reflects consumers' attitudes toward risk in the current period. Consumers with high risk aversion demand a higher risk premium, and conversely those with low risk aversion require less compensation for risk. Therefore, lower risk aversion mitigates the dampening effect of volatility shocks on household consumption, thereby weakening the incentive for precautionary saving.

In this section, the risk aversion coefficient is set to 4, following the parameter settings of Neumeyer and Perri [57] and Devereux and Yu [17], to examine the cross-country transmission mechanism of the precautionary saving motive to business cycles under volatility shocks. The impulse response results presented in Figures 9 and 10 demonstrate that, for both productivity and financial volatility shocks, reducing the risk aversion coefficient significantly dampens the impact of the shocks compared to the benchmark model. In particular, for financial shocks, a decrease in risk aversion considerably weakens the effect of financial shocks on the transmission of business cycles. Figure 10 illustrates that when the risk aversion coefficient is set to 4, there is only a modest change in each macro variable. This test further confirms the crucial role played by precautionary saving motives in the cross-country transmission of volatility shocks.

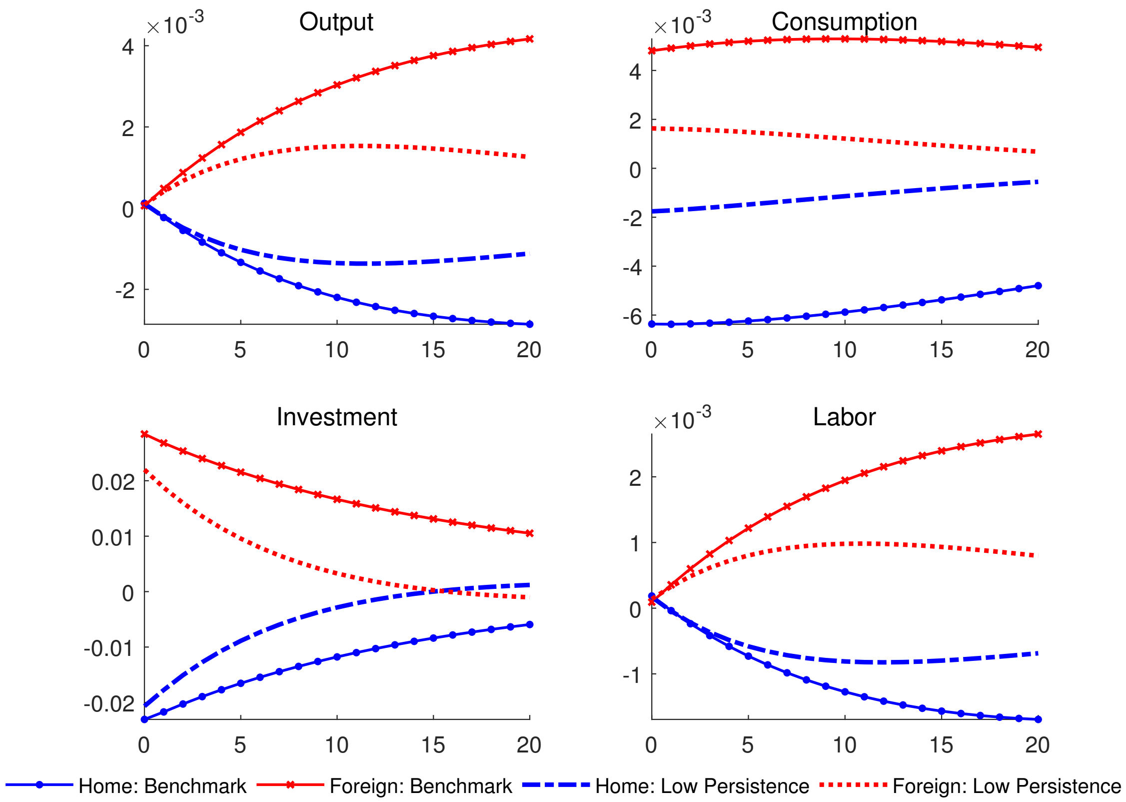

Figure 7. Lower persistence of productivity volatility shocks.

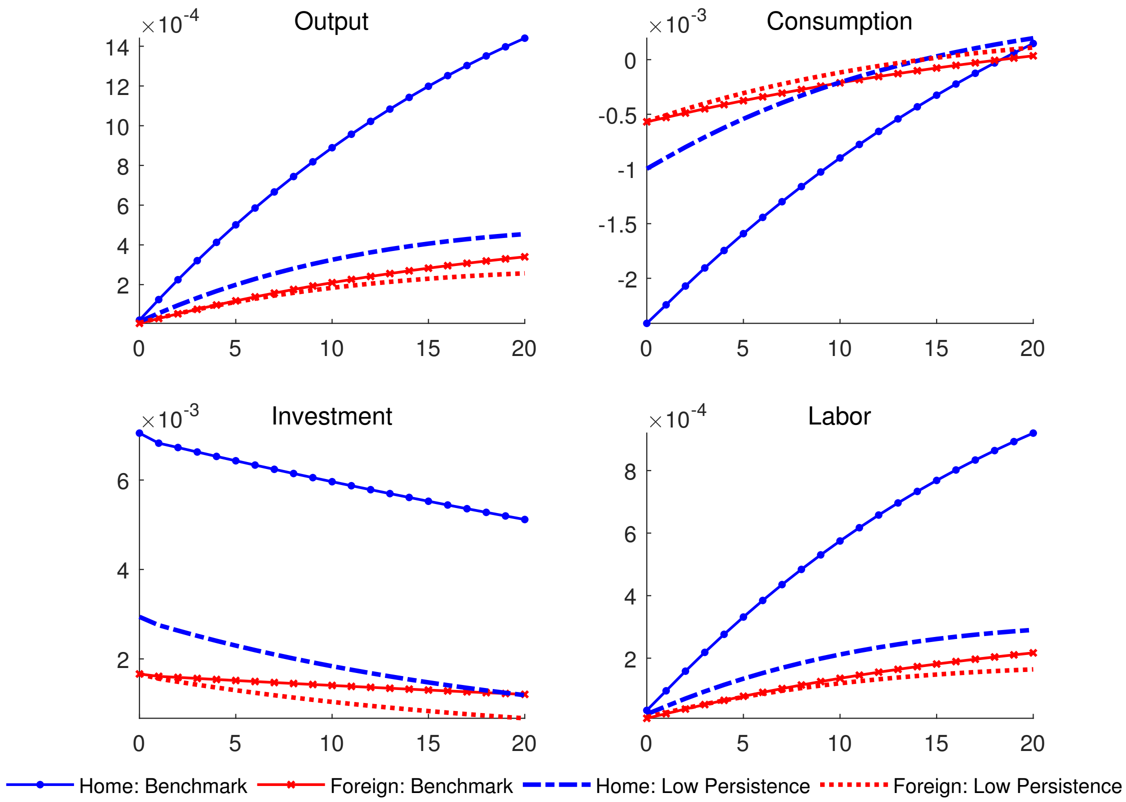

Figure 8. Lower persistence of financial volatility shocks.

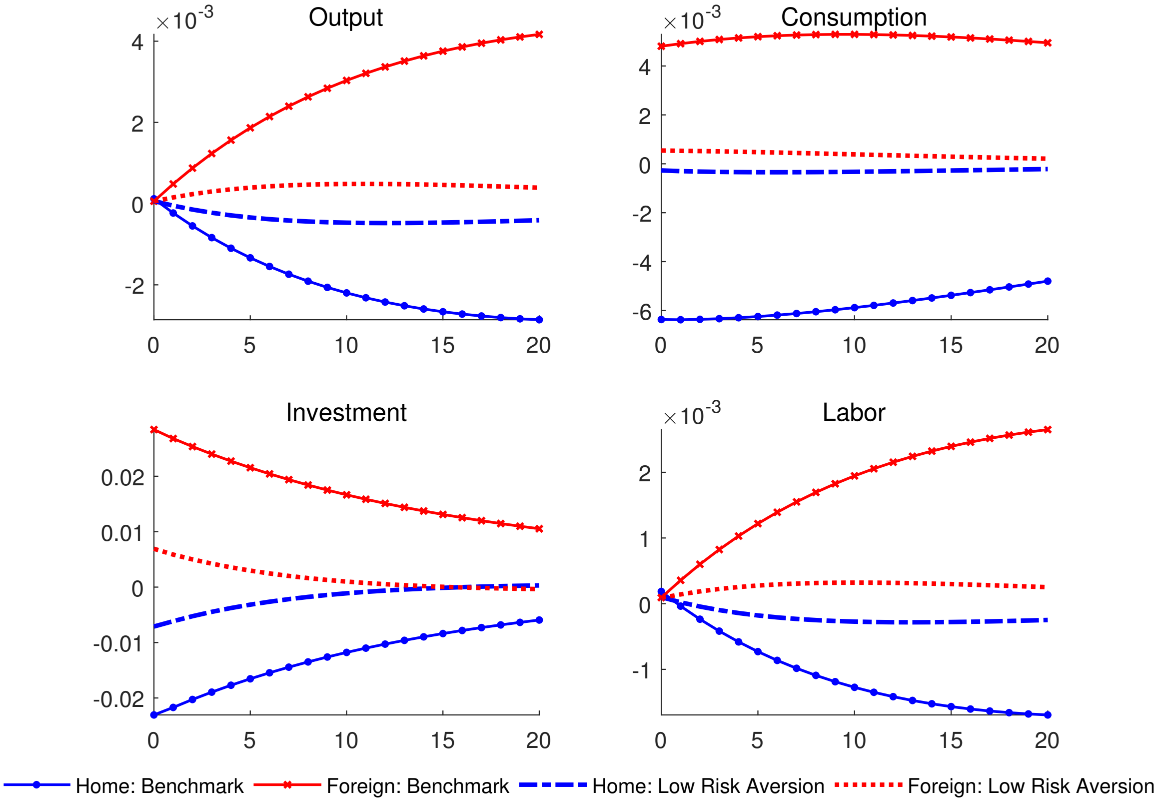

Figure 9. Risk aversion coefficient and productivity volatility shocks.

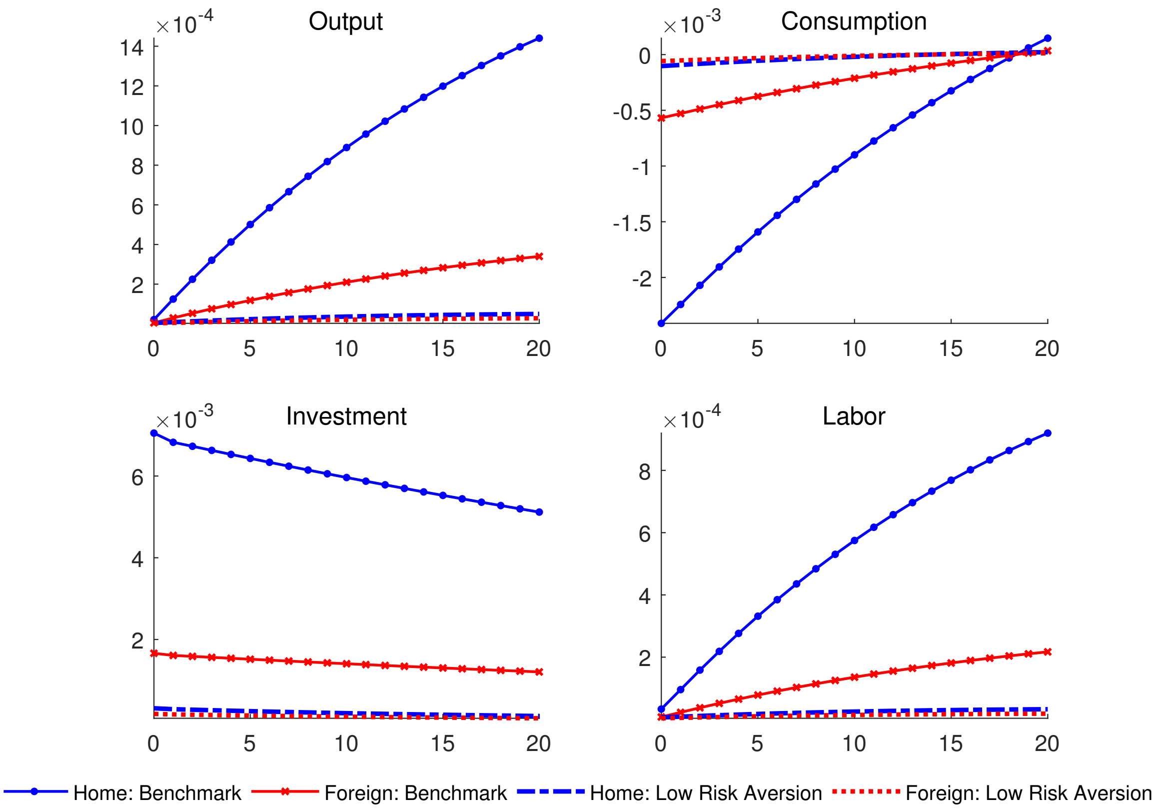

Figure 10. Risk aversion coefficient and financial volatility shocks.

4.3. Intertemporal Elasticity of Substitution

The IES reflects consumers' intertemporal risk aversion and their willingness to adjust consumption over time. A higher IES indicates that consumers are more willing to inter-temporarily adjust their consumption patterns, implying a preference for smooth consumption. Conversely, a lower IES suggests that individuals are less patient in delaying consumption and exhibit less intertemporal substitution behavior. In this subsection, IES is set to 0.5, following the parameter setting used by Bansal and Yaron [71], Ai [72] and Backus et al. [20]. This adjustment allows us to assess the impact of consumers' intertemporal substitution behavior on the cross-country transmission of volatility shocks and evaluate the robustness of the theoretical framework proposed in this study.

The results presented in Figures 11 and 12 demonstrate the impact of reducing the IES on consumers' intertemporal consumption decisions. As the IES decreases, consumers become less willing to postpone their consumption, leading to a smaller decline in domestic residential consumption in response to a volatility shock. Compared to the benchmark model, the reduction in domestic consumption is less pronounced when the IES is lower. As a result, there is a smaller increase in savings and a correspondingly smaller decrease in deposit and loan rates. This effect holds true for both productivity volatility shocks and financial volatility shocks.

In the case of productivity volatility shocks, the decrease in lending rates has a smaller impact on the foreign production sector, leading to a weakened transmission mechanism. This observation is supported by the diminishing effect of productivity volatility shocks as the IES decreases, as depicted in Figure 11. In the case of financial volatility shocks, the responses of the financially integrated sectors of both countries, which hold risky assets in international banks, are perfectly synchronized. With a lower IES, the decline in consumption is less pronounced in both countries, and correspondingly savings increase less; deposit and loan rates decrease less; and business investment, labor input, and output increase less. Therefore, Figure 12 illustrates the diminishing effect of financial volatility shocks under the setting of lower IESs.

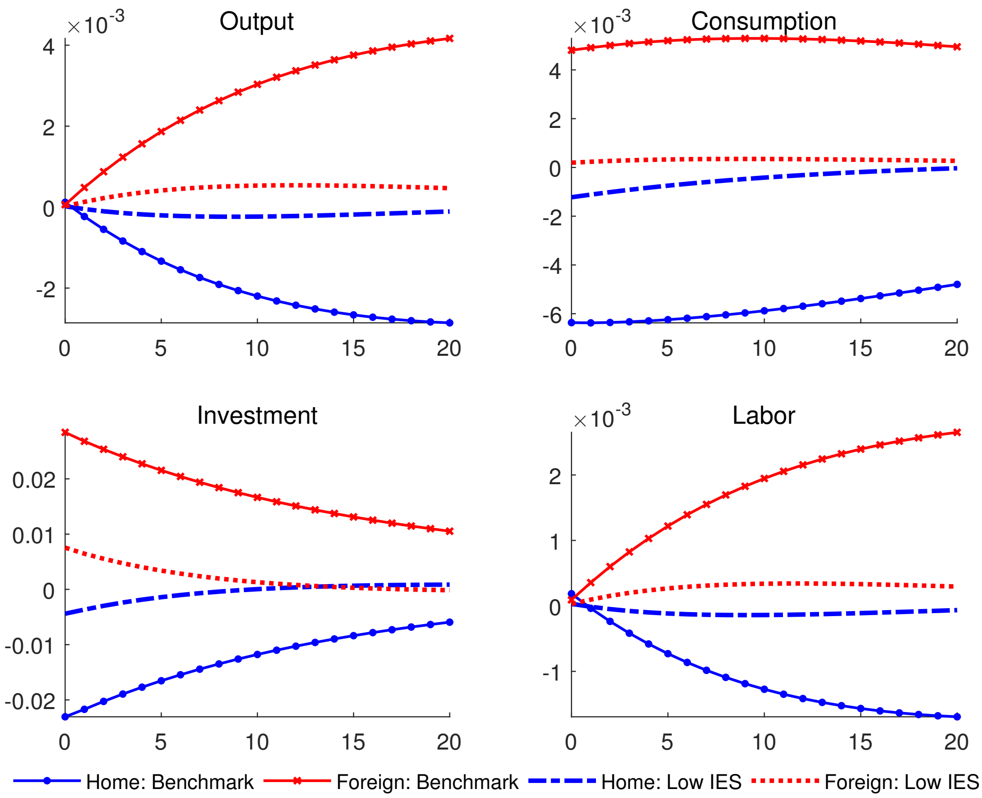

Figure 11. Intertemporal elasticity of substitution and productivity volatility shocks.

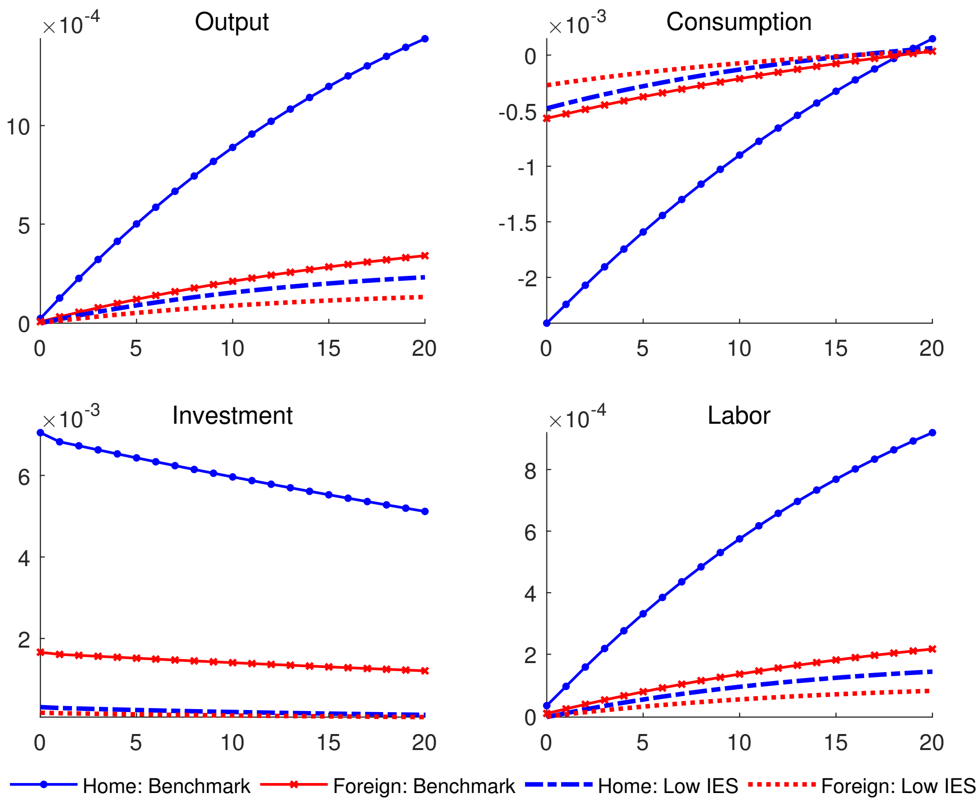

Figure 12. Intertemporal elasticity of substitution and financial volatility shocks.

4.4. Welfare Analysis of Financial Integration

Based on the extensive academic debate on the pros and cons of financial integration, this section attempts to answer the following questions: Is a high degree of financial integration beneficial? Does financial integration amplify the transmission of financial crises, resulting in a decrease in overall social welfare? Alternatively, does it enable countries to diversify their risks, leading to an increase in overall welfare? To address these questions, this paper conducts a quantitative welfare analysis of financial integration. This study examines how the degree of financial integration affects the overall social welfare under various types of volatility shocks. This research serves as a theoretical foundation for exploring the dynamics of financial integration and provides insights into enhancing the macroprudential regulatory system.

The existing literature has extensively examined the welfare implications of financial integration by comparing the social welfare of an economy under complete financial autarky and financial integration [17,33,73–75]. This comparison is typically carried out by calculating the Hicksian equivalent variation (i.e., the percentage change in effective consumption) between the two scenarios. Following this approach, this paper analyzes the welfare of financial integration by examining the deterministic equivalence of effective consumption in the context of autarky and open financial scenarios. Specifically, the welfare of sector i is defined as the conditional expectation of lifetime utility:

$$Welfare_i \equiv E_0 \left\{ \sum_{t=1}^{\infty} \beta^t U(c_{it}, l_{it}) \right\}, i = 1, 2. \tag{26}$$

Summing the welfare of two sectors in the economy yields the total social welfare. Next, the deterministic equivalent of effective consumption, denoted as $\tilde{c}$, is defined using Equation (27) and its magnitude between the two extreme cases of financial autarky and complete financial integration is compared. This makes it possible to capture the change in welfare due to financial openness.

$$Welfare = \frac{\tilde{c}^{1-\gamma} - 1}{1-\gamma}\frac{1}{1-\beta}. \quad (27)$$

The findings in Table 4 show that financial integration leads to a welfare gain of approximately 0.2% in the presence of either a productivity volatility shock or a financial volatility shock. This result is attributed to the precautionary saving motive, which serves as an important channel in the cross-country transmission of uncertainty shocks. Financial integration allows residents and firms to save and borrow through international financial markets, effectively mitigating the precautionary saving motive and helping to diversify consumption risks caused by uncertainty shocks. This, in turn, enhances social welfare. This quantitative finding aligns with the theoretical results presented in Section 3.

Table 4. Welfare analysis of financial integration under volatility shocks.

	Financial Autarky		**Financial Integration**		**Change of $\tilde{c}$ (%)**
	Social Welfare	**Deterministic Equivalence of Cons.**	**Social Welfare**	**Deterministic Equivalence of Cons.**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Prod. Vol. Shock	1.6763	0.01676	1.6796	0.01680	0.1990
Financial Vol. Shock	1.6784	0.01678	1.6817	0.01682	0.1986

5. Conclusions

This paper examined the impact of financial integration on economic cycle comovement under volatility shocks by introducing recursive utility into a dynamic stochastic general equilibrium model. The cross-country transmission mechanism of business cycles was analyzed under both productivity volatility shocks and financial volatility shocks. The sensitivity analysis verified the key role played by precautionary saving motives in the cross-country transmission of business cycles. Finally, the welfare analysis indicated that under volatility shocks, financial integration leads to welfare gains of 0.2%.

Unlike the conclusion reached by Gete and Melkadze [31] of no significant difference between the results regarding the role of productivity volatility shocks and interest rate volatility shocks obtained in a small-country open economy model, this paper obtained different conclusions within the framework of a two-country model in an open economy. The findings suggest that financial integration plays distinct roles in the cross-country transmission mechanisms of different types of volatility shocks: in the presence of productivity volatility shocks, financial integration reduces the synergies of the business cycle, while in the presence of financial volatility shocks, financial integration promotes business cycle synchronization. By comparing the cross-country transmission mechanism of business cycles under these two types of volatility shocks, a theoretical foundation for preventing and coping with various external shocks and reducing uncertainty risks is provided.

The introduction of volatility shocks brings the statistics of the correlation coefficients of macro variables closer to the level observed in real data. Furthermore, the numerical simulation results of the model demonstrated that ignoring volatility shocks will underestimate the impact of financial integration on the synchronization of economic cycles between countries. This paper also contributes to the discussion of the benefits of financial integration. Financial markets play a crucial role in enhancing social welfare, regardless of the type of volatility. The two-country model utilized in this study is a convenient way to showcase the effects of different volatility shocks. It serves as a great starting point and can be adapted to accommodate other factors, such as asymmetry of country size, credit contractions, technology differences, and labor mobilities. Nevertheless, a potential limitation of this model is the exogenously given financial integration level. Therefore, investigating methods to incorporate endogenous financial integration into the theoretical framework of this paper, presents a promising avenue for future research.

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Conflicts of Interest: The author declares no conflict of interest.

Appendix A

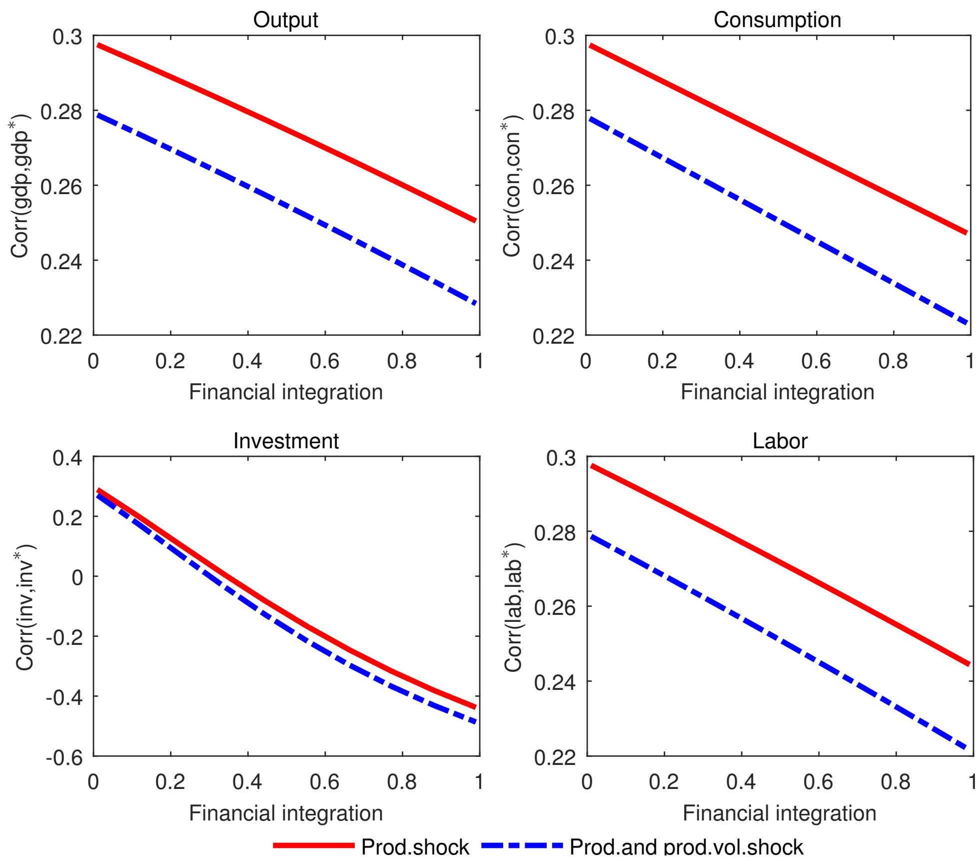

Figure A1. Financial integration and cross-country correlation: role of productivity volatility shocks

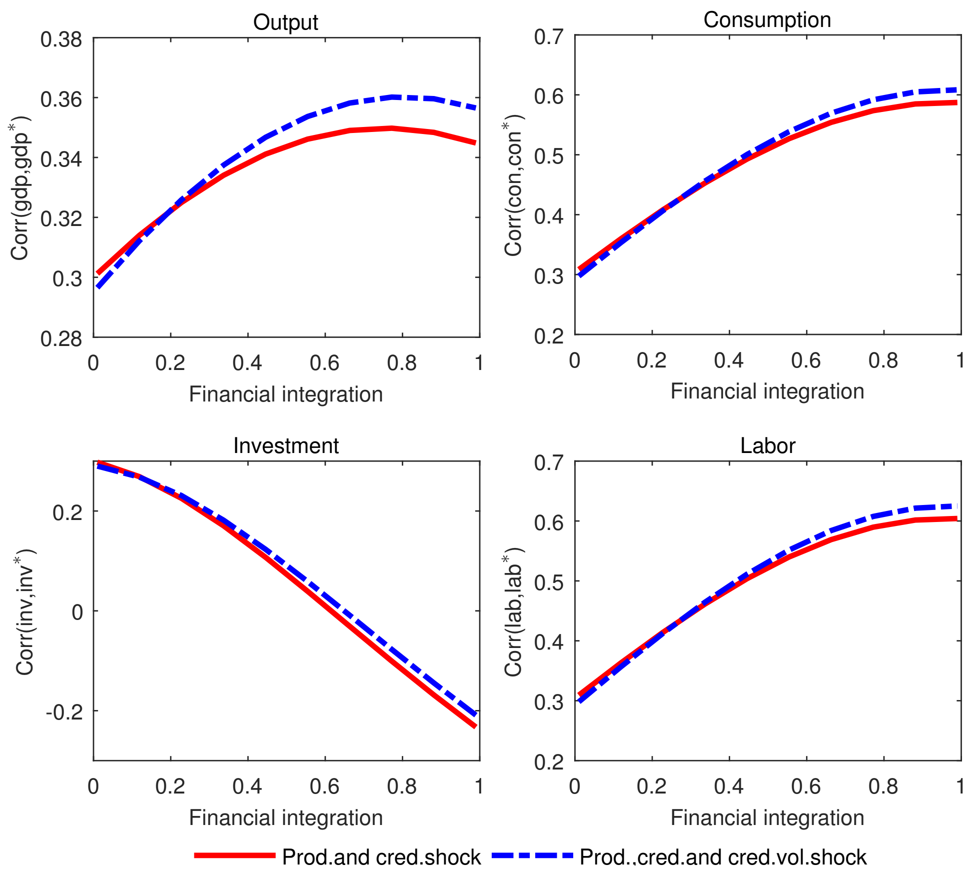

Figure A2. Financial integration and cross-country correlation: role of financial volatility shocks

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