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The Global Financial Cycle and International Monetary Policy Cooperation

Shangshang Li[1]

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Keywords: policy cooperation, global financial cycle, currency mismatch.
JEL classification: E44, E52, E58, E61, F34, F42

The author

[1] University of Liverpool. Email: shangshang.li@liverpool.ac.uk.

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January 2024

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†University of Liverpool. Email: shangshang.li@liverpool.ac.uk.

1 Introduction

Whether central banks should coordinate their monetary policy with each other has been extensively debated in the literature for decades.[1] The conventional wisdom since Friedman (1953) is that flexible exchange rates should insulate the economy from the effects of foreign shocks. Thus, central banks should use monetary policy for domestic stabilisation. There is little scope for international monetary cooperation, which is supported by other studies such as Obstfeld and Rogoff (2002) and Benigno and Benigno (2006).

Meanwhile, papers such as Miranda-Agrippino and Rey (2015) document that monetary policy shocks from a global financial centre, such as the U.S., generate sizable spill-overs to emerging economies as the financial periphery. This 'global financial cycle' (GFC) motivates Rey (2015) to postulate that the financial periphery must choose between monetary policy independence and free capital mobility regardless of the exchange rate regime adopted. This 'Dilemma' hypothesis implies that flexible exchange rates do not insulate the economy from external shocks. Therefore, global financial cycles potentially create scope for international monetary policy cooperation to manage cross-border macroeconomic spillovers.

In this paper, I assess how cross-border spillovers from the financial centre to the periphery affect the gains from international monetary policy cooperation between them. For this purpose, I build a two-country New Keynesian DSGE model where the key spillovers arise from two sources. The first source is the financial linkages between the two countries, and the second source is the dominant role of the financial centre country's currency in the cross-border financial flows. The frictions on the financial intermediaries amplify these spillovers to generate co-movements of macroeconomic and financial variables consistent with the GFC.

I evaluate the gains from international monetary policy cooperation by comparing the global and national welfare achieved by a cooperative Ramsey equilibrium with those achieved by a non-cooperative Nash equilibrium. A benevolent social planner chooses the cooperative Ramsey equilibrium to maximise global joint welfare. Two self-oriented national central banks choose the non-cooperative Nash equilibrium to maximise their national welfare, taking the other country's policy path as given. In my model, although the cooperative policy achieves higher global joint welfare, the cross-border spillovers from the financial centre to the periphery make cooperation gains unevenly distributed at the national level. Moreover, the gains are so unevenly distributed that cooperation cannot benefit both countries simultaneously compared to non-cooperation. Thus, even with global financial cycles, it is not necessarily beneficial or practical for the financial periphery to cooperate with the financial centre.

[1] Bordo and Schenk (2016) distinguish between policy cooperation and policy coordination. However, the boundary between the two concepts is often ambiguous. Thus, I follow the convention of most literature and use the two terms interchangeably.

The key friction for the model to replicate the spillovers documented in the GFC literature is that banks in the financial periphery finance their lending partly by borrowing abroad in the currency of the financial centre. This setup captures the dominant role of the financial centre's currency in the global financial markets and creates a currency mismatch on the balance sheets of financial periphery banks.[2] Suppose that the monetary policy tightens in the financial centre country. This shock leads to an appreciation of the financial centre's currency. The appreciation pushes up the real values of foreign currency debt for banks in the financial periphery. Consequently, the net worth of these banks decreases. The lower net worth forces these banks, subject to financial constraints, to reduce their lending to production firms. This effect dominates over the standard expenditure-switching channel that improves the trade balance. Therefore, output falls, and macroeconomic volatility rises in the financial periphery.

Other shocks also initiate exchange rate fluctuations that affect banks in the financial periphery through foreign currency debt. Without cooperation, this mismatch friction motivates the financial periphery central bank to appreciate its currency relative to the dominant currency. This policy minimises the inefficiency associated with financial intermediation. Depending on shocks, the financial periphery central bank may need to trade off this motive with the motive of devaluing the currency to improve its trade balance. By contrast, similar shocks do not directly impact banks in the financial centre. This asymmetry in policy trade-offs of the national central banks implies that cooperation may not improve welfare for both countries simultaneously. If either country incurs domestic productivity, markup, and preference shocks, it gains from cooperation at the cost of the other country. However, either of the two countries benefits from cooperation in response to foreign rather than domestic net worth shocks.

As the financial periphery country borrows less in foreign currency in the steady state, the asymmetry in policy trade-offs across the two countries is much less prominent. Consequently, the cooperative gains in my model become more evenly distributed. When the degree of mismatch is very low or absent in the model, the cooperative policy creates small positive gains for both countries compared to the non-cooperative policy. Meanwhile, if the financial periphery is comparably smaller, the country is more susceptible to the impact of spillovers. Thus, the financial periphery is more likely to gain from cooperation. Nevertheless, the asymmetric distribution of cooperation gains is robust to these scenarios and the policy instruments used under non-cooperation.

In addition, in most cases, both countries cannot simultaneously gain if they transition from the non-cooperative Nash equilibrium to cooperation. The financial periphery gains if it is relatively small or borrows less in foreign currency in the steady state.

Lastly, I consider gains from cooperation if both countries adopt implementable mon-

[2] The source of this friction is taken as exogenous in this study. Eichengreen and Hausmann (1999), Eichengreen et al. (2007), and Shin (2014) discuss the reasons for the mismatch in detail.

etary policy rules. Cooperation still fails to benefit both countries simultaneously compared to non-cooperation. However, both countries gain by cooperating if they transition from the non-cooperative Nash equilibrium. Meanwhile, among the monetary policy rules that I consider, rules responding to the exchange rate always dominate over purely inward-looking rules for the financial periphery, regardless of the policy rule of the financial centre. The same is true for the financial centre unless the financial periphery already responds strongly to the exchange rate.

My paper is primarily related to two strands of literature. First, my paper is linked to the literature on the international dimension of monetary policy, which is comprehensively summarised by Corsetti et al. (2010). Seminal contributions such as Obstfeld and Rogoff (2002) and Benigno and Benigno (2006) generally find that the cooperation gains are quantitatively small. Nevertheless, the size of the cooperative gain is sensitive to the parameterisation of the model (Obstfeld and Rogoff, 2002), to the types of shocks (Benigno and Benigno, 2006), to frictions and policy trade-offs in the model (Tchakarov, 2004; Canzoneri et al., 2005; Coenen et al., 2007; Bergin and Corsetti, 2013), to whether central banks can commit (Cooley and Quadrini, 2003), and to what instruments central banks are using in the non-cooperative Nash game (Sims, 2007). My paper contributes to this literature by including relevant financial frictions to assess how GFCs affect the desirability of international monetary policy cooperation.

Second, similar to Mimir and Sunel (2015), Aoki et al. (2018), and Akinci and Queralto (2018), my model features moral hazard and currency mismatch frictions in the banking sector to replicate co-movements of macroeconomic variables in GFCs. Unlike them, I evaluate how GFCs impact the gains from monetary policy cooperation. Banerjee et al. (2016) shows that the impulse responses under the optimal cooperative and non-cooperative policy to a financial shock from the financial centre are identical in a two-country model with similar frictions. My results differ from theirs due to several crucial factors. First, I allow the financial periphery banks in my model to choose the amount of foreign currency debt endogenously. This strengthens the financial transmission by creating an endogenous UIP deviation. Second, I evaluate monetary policy cooperation gains by calculating and comparing welfare measures. Lastly, I consider cooperation gains under different shocks, calibration, and policy instruments.

The rest of the paper is organised as follows: Section 2 describes the model. Section 3 reports the calibration of the model and demonstrates that the model can replicate the policy spillovers as documented by the GFC literature. Section 4 defines the cooperative and the non-cooperative policy and presents the main results. Section 5 considers the transitional gains if the two countries move between the non-cooperative and the cooperative equilibrium. Section 6 extends the analyses by considering implementable monetary policy rules. Section 7 concludes.

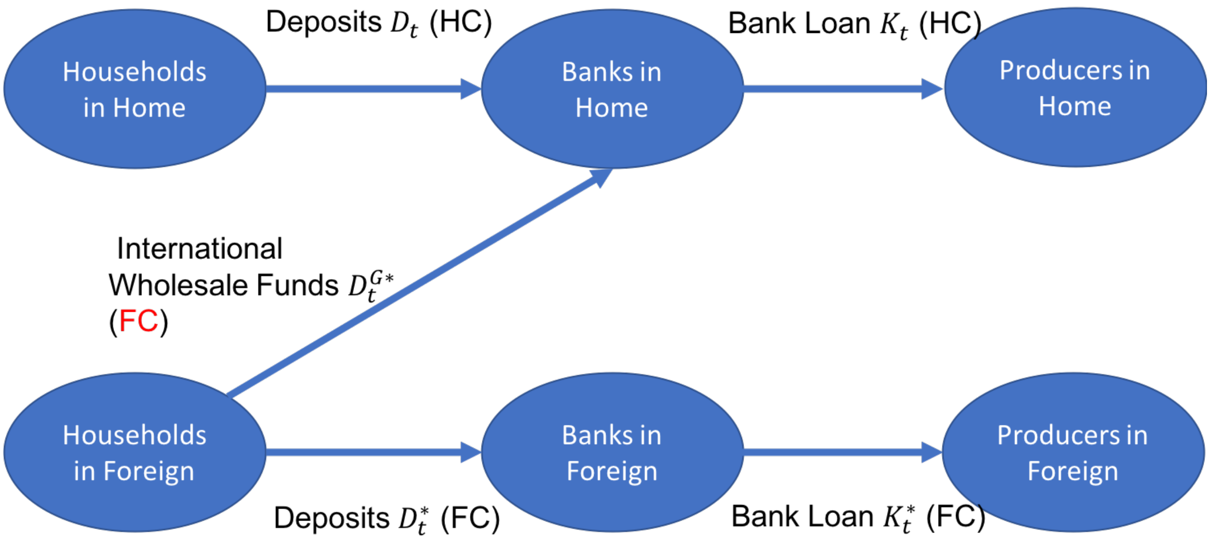

Figure 1: The Financing Structure of the Model

Note: HC denotes the Home currency, FC denotes the Foreign currency.

2 The Model

The model assumes that there are two countries in the world economy, Home and Foreign, with population sizes m and $1 - m$, respectively. The firms in each country specialise in one type of goods, and each type of goods consists of a number of brands with measure equal to the population size. There is no trade barrier, so firms' output can be used to satisfy either domestic or foreign demand.

Figure 1 shows the financing structure of the model. Assume Home to be the financial periphery country, such as the emerging market economies (EMEs), whereas Foreign to be the financial centre country, such as the US. The output production in both countries combines labour and capital borrowed from banks in their own country. Home banks finance themselves by domestic household deposits and borrowing from the international wholesale funds market in foreign currency. Foreign banks finance their lending by deposits from foreign households only. The international wholesale funds and the foreign banks can be regarded as two subsidiaries of a global bank that resides in the Foreign country. As documented by Cetorelli and Goldberg (2012) and Bruno and Shin (2013), global banks transmit financial conditions across borders by channelling liquidity globally. Moreover, the US dollar plays a much more important role in cross-border banking than other currencies of assets and liability. The model setup here captures these empirical aspects.

The behaviour of each sector of the economy is characterised below. An asterisk denotes all variables for the Foreign country.

2.1 Households

The representative household in each country consists of a continuum of bankers and workers. The bankers manage domestic banks. Each period, a banker will retire to become a worker with probability $1-\omega$ and transfer the remaining net worth of her bank to the household. Meanwhile, an equal number of workers will become new bankers with entering endowments as a fraction ξ of the bank's total assets in the current period. Workers supply labour to domestic firms each period.

The representative household in the Home country maximises the expected lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t [log(C_t)\epsilon_{c,t} - \frac{\zeta L_t^{1+\chi}}{1+\chi}], \tag{1}$$

where β is the discounting factor, χ is the inverse of the Frisch elasticity of labour supply, L_t is the total labour supply that the household supplies to firms, $\epsilon_{c,t}$ captures demand shocks. C_t is a CES aggregator of the household consumption over all brands of domestic and foreign goods:

$$C_t = [a^{\frac{1}{\phi}} C_{H,t}^{\frac{\phi-1}{\phi}} + (1-a)^{\frac{1}{\phi}} C_{F,t}^{\frac{\phi-1}{\phi}}]^{\frac{\phi}{\phi-1}},$$

where

$$C_{H,t} = ((\frac{1}{m})^{\frac{1}{\varphi}} \int_0^m C_t(h)^{\frac{\varphi-1}{\varphi}} dh)^{\frac{\varphi}{\varphi-1}}$$
$$C_{F,t} = ((\frac{1}{1-m})^{\frac{1}{\varphi}} \int_m^1 C_t(f)^{\frac{\varphi-1}{\varphi}} df)^{\frac{\varphi}{\varphi-1}}$$

are the aggregate consumption of domestic and foreign goods, respectively. $C_t(h)$ and $C_t(f)$ are the consumption of particular brand of goods. $a = 1 - \nu(1-m)$ captures the home bias of Home residents over domestic goods, where ν is the degree of openness. ϕ is the elasticity of substitution between the H-type goods produced in Home and the F-type goods produced in Foreign, and φ is the elasticity of substitution among the brands within each type of goods.

The consumption aggregators above imply that the prices for aggregated bundles are:

$$P_{H,t} = (\frac{1}{m} \int_0^m P_t(h)^{1-\varphi} dh)^{\frac{1}{1-\varphi}}$$
$$P_{F,t} = (\frac{1}{1-m} \int_m^1 P_t(f)^{1-\varphi} df)^{\frac{1}{1-\varphi}}$$
$$P_t = [a{P_{H,t}}^{1-\phi} + (1-a){P_{F,t}}^{1-\phi}]^{\frac{1}{1-\phi}}.$$

In addition to purchasing consumption goods, the household may lend to banks. The budget constraint that the household faces in period t is:

$$P_t C_t + D_t = W_t L_t + (1 + i_{t-1}) D_{t-1} + P_t \Pi_t, \tag{2}$$

where W_t is the nominal wage per labour hour, D_t is the deposit to domestic banks, and i_t is the net nominal interest rate accrued to deposits.

In addition, households earn profits from owning various firms and financial intermediaries and exogenous government transfers, which is characterised by Π_t:

$$\Pi_t = \frac{1}{m}\{[q_t - 1 - \frac{\kappa_I}{2}(\frac{I_t}{I_{t-1}} - 1)^2] I_t + \int_0^m [(\frac{\mathcal{P}_t(h)}{P_t} - mc_t) y_t(h) + (\frac{\mathcal{E}_t \mathcal{P}_t^*(h)}{P_t^*} - mc_t) y_t^*(h)] dh +$$
$$(1-\omega)[(R_t^K + (1-\delta) q_t) K_{t-1} - \widetilde{R}_t d_{t-1} - \varepsilon_t R_t^{G*} d_{t-1}^{G*}] - \xi (R_t^K + (1-\delta) q_t) K_{t-1} + TR_t\}.$$

The first component is the profit from owning investment goods production firms. The second component is the profit from owning output production firms. The third component is the profit brought by retiring bankers. The fourth component is the transfer made to new bankers. The last component is the government transfer. The parameters and variables in these components will be defined in sequence below in this section.

The first-order conditions that maximise the household utility (1) subject to the budget constraint (2) and a Transversality Condition are characterised below:

$$\zeta L_t^{\chi} C_t = \frac{W_t}{P_t} \epsilon_{c,t} = w_t \epsilon_{c,t} \tag{3}$$

$$\mathbb{E}_t[\beta(\frac{C_t \epsilon_{c,t+1}}{C_{t+1}\epsilon_{c,t}}) \frac{1 + i_t}{\pi_{t+1}}] = \mathbb{E}_t[\Lambda_{t,t+1} R_{t+1}] = 1, \tag{4}$$

where $\Lambda_{t,t+1} = E_t[\beta(\frac{C_t \epsilon_{c,t+1}}{C_{t+1}\epsilon_{c,t}})]$ is the stochastic discounting factor for the representative household, $\pi_t = \frac{P_t}{P_{t-1}}$ is the gross CPI inflation rate, R_t is the gross real returns for deposits.

The representative household in Foreign maximises an expected discounted utility function that is symmetrically defined subject to the budget constraint

$$P_t^* C_t^* + D_t^* + D_t^{G*} = W_t^* L_t^* + (1 + i_{t-1}^*)(D_{t-1}^* + D_{t-1}^{G*}) + P_t^* \Pi_t^*,$$

where D_t^{G*} is the deposit to international wholesale funds, and the rest variables are defined similarly as those for Home. The utility maximisation problem yields the following set of first-order conditions:

$$\zeta^* L_t^{*\chi} C_t^* = \frac{W_t^*}{P_t^*} \epsilon_{c,t}^* = w_t^* \epsilon_{c,t}^*$$

$$\mathbb{E}_t[\beta(\frac{C_t^* \epsilon_{c,t+1}^*}{C_{t+1}^* \epsilon_{c,t}^*}) \frac{1 + i_t^*}{\pi_{t+1}^*}] = \mathbb{E}_t[\Lambda_{t,t+1}^* R_{t+1}^*] = 1. \tag{5}$$

2.2 Financial Intermediaries

2.2.1 Banks in the Home Country

Loans to Firms $q_t K_t^i$	Deposits from Home Households d_t^i Borrowing from International Wholesale Funds $\varepsilon_t d_t^{Gi*}$ Net Worth n_t^i

Table 1: The Balance Sheet of Banks in the Home Country

Table 1 describes a typical Home bank's balance sheet. The typical bank lends K_t^i to domestic production firms to obtain the rental and resale income. This is partly financed by deposits d_t^i from households and own net worth n_t^i. In addition, the bank borrows from international wholesale funds in the Foreign currency. These banks are, however, not large enough to hedge against this exchange rate risk.[3] The bankers manage the banks until their retirement. The retirement assumption assumes away the possibility that the bankers will eventually be unconstrained by the incentive compatibility constraint (described below) after having accumulated enough wealth.

The typical bank maximises the expected net worth

$$V_t^i = \mathbb{E}_t \sum_{j=1}^{\infty} \Lambda_{t,t+j} \omega^{j-1} (1-\omega) n_{t+j}^i,$$

where the net worth

$$n_t^i = (R_t^K + (1-\delta) q_t) K_{t-1}^i - \varepsilon_t R_t^{G*} d_{t-1}^{Gi*} - \widetilde{R}_t d_{t-1}^i.$$

R_t^K is the real return for capital, δ is the depreciation rate, q_t is the resale value of capital, ε_t is the real exchange rate, R_t^{G*} is the cost of borrowing from international wholesale funds, $\widetilde{R}_t$ is the cost incurred by borrowing from households. Note that $\widetilde{R}_t - R_t = \tau_t^r > 0$, where τ_t^r is an exogenous premium banks incur when borrowing from domestic households.[4] The maximisation is subject to the balance sheet constraint

$$q_t K_t^i = n_t^i + d_t^i + \varepsilon_t d_t^{Gi*}, \tag{6}$$

[3]This assumption is consistent with the empirical observation by Shin (2014) and Bruno and Shin (2015) if we consider the balance sheet of banks and firms in the emerging markets jointly.

[4]This implies that borrowing from domestic households will be more expensive than from international wholesale funds in the steady state where households in both countries are equally patient. This assumption motivates Home banks to borrow internationally as in Akinci and Queralto (2018) and Aoki et al. (2018).

and the incentive compatibility constraint (IC)

$$V_t^i \geq \vartheta(x_t^i) q_t K_t^i.$$

The latter constraint is motivated by the moral hazard argument in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011). The banker can divert a fraction $\vartheta(x_t^i)$ of its total asset and transfer this amount back to the household. However, this activity cannot go through without being noticed. If this happens, the creditors of the bank can force the bank into bankruptcy and recover the remaining $1 - \vartheta(x_t^i)$ fraction of the total asset, whilst the banker will lose the franchise to manage the bank and thus the expected net worth altogether. Therefore, in equilibrium, the contract between the creditors and the bank will involve the IC constraint above to eliminate the incentive to divert funds.

Specifically, the fraction of divertible funds is defined in the similar way as in Aoki et al. (2018):

$$\vartheta(x_t^i) = \bar{\vartheta}(\frac{\kappa_b}{2}(x_t^i)^2 + 1),$$

where

$$x_t^i = \frac{\varepsilon_t d_t^{Gi*}}{q_t K_t^i}$$

is the ratio of the foreign currency liability to total assets. Intuitively, the fraction that the creditors recover in the event of the bank's bankruptcy, $1 - \vartheta(x_t^i)$, is lower if the bank finances its operation by a higher proportion of foreign currency borrowing. This assumption captures the idea that it is harder for foreign lenders to monitor and enforce contracts with the borrowing banks. The assumption can also be motivated by the observation of Shin (2009) that creditor banks, such as wholesale funding providers, are subject to external constraints. When these banks suddenly decrease lending by prudential risk management, the effect on debtor banks can be devastating, given the very short-term nature of interbank funding. Hence, creditors would impose stricter leverage constraints in response to a higher level of the bank's borrowing from wholesale funds banks.

Define $\psi_t^i = \frac{V_t^i}{n_t^i}$ and substitute in the balance sheet constraint (6), we have:

$$\psi_t^i = \frac{V_t^i}{n_t^i} = \mu_{0,t}\Gamma_t^i + \mu_{1,t}\Gamma_t^i x_t^i + \mu_{2,t},$$

where $\Gamma_t^i = \frac{q_t K_t^i}{n_t^i}$ is the leverage ratio of the bank, and

$$\mu_{0,t} = \mathbb{E}_t\{\Omega_{t,t+1}(\frac{R_{t+1}^K + (1-\delta)q_{t+1}}{q_t} - \widetilde{R}_{t+1})\} \tag{7}$$

$$\mu_{1,t} = \mathbb{E}_t\{\Omega_{t,t+1}(\widetilde{R}_{t+1} - \frac{R_{t+1}^{G*}\varepsilon_{t+1}}{\varepsilon_t})\} \tag{8}$$

$$\mu_{2,t} = \mathbb{E}_t\{\Omega_{t,t+1}\widetilde{R}_{t+1}\} \tag{9}$$

$$\Omega_{t,t+1} = \mathbb{E}_t\{\Lambda_{t,t+1}(1-\omega+\omega\psi_{t+1})\}. \tag{10}$$

$\mu_{0,t}$ is the expected credit premium between the loan rate for firms and the deposit rate for households. $\mu_{1,t}$ is the expected relative cost advantage of financing through interbank lending over domestic deposits, which can be regarded as a currency premium.

The maximisation problem of the bank can be rewritten as maximising ψ_t^i subject to the incentive compatibility constraint, which can be rewritten as

$$\psi_t^i \geq \vartheta(x_t^i)\Gamma_t^i. \tag{11}$$

For the equilibrium where the IC always binds, we have

$$\Gamma_t^i = \frac{\mu_{2,t}}{\vartheta(x_t^i) - \mu_{0,t} - \mu_{1,t}x_t}. \tag{12}$$

Therefore, the bank's leverage depends on the credit premium $\mu_{0,t}$, the currency premium $\mu_{1,t}$, and the strength of financial constraint $\vartheta(x_t^i)$.

Combine the first-order conditions of this constrained maximisation problem with respect to Γ_t^i and x_t^i, we get

$$x_t^i = \frac{\sqrt{1+\frac{2}{\kappa_b}(\mu_t)^2} - 1}{\mu_t}, \tag{13}$$

where

$$\mu_t = \frac{\mu_{1,t}}{\mu_{0,t}}. \tag{14}$$

It can be shown that x_t^i is increasing in μ_t. The intuition is that the cheaper borrowing from international wholesale funds relative to domestic households, the higher the proportion of interbank borrowing will be in the bank's balance sheet.

Lastly, the aggregate net worth of Home banks evolves according to

$$n_t = (\omega+\xi)(R_t^K + (1-\delta)q_t)K_{t-1} - \omega\varepsilon_t R_t^{G*}d_{t-1}^{G*} - \omega\widetilde{R}_t d_{t-1} \tag{15}$$

and the aggregate balance sheet constraint, the leverage ratio, and the proportion of the interbank lending are respectively:

$$q_t K_t = n_t + d_t + \varepsilon_t d_t^{G*}$$
$$\Gamma_t = \Gamma_t^i$$
$$x_t = x_t^i.$$

2.2.2 Banks in the Foreign Country

Loans to Firms $q_t^* K_t^{i*}$	Deposits from Foreign Households d_t^{i*}
	Net Worth n_t^{i*}

Table 2: The Balance Sheet of Banks in the Foreign Country

Foreign banks are standard Gertler and Karadi (2011) type banks. Table 2 describes the balance sheet of a typical foreign bank. The bank finances the lending of capital K_t^{i*} to domestic firms by deposits d_t^{i*} from households and own net worth n_t^{i*}.

The bank maximises the expected net worth:

$$V_t^{i*} = \mathbb{E}_t \sum_{j=1}^{\infty} \Lambda_{t,t+j}^* \omega^{j-1}(1-\omega) n_{t+j}^{i*},$$

where the net worth is

$$n_t^{i*} = (R_t^{K*} + (1-\delta)q_t^*)K_{t-1}^{i*} - R_t^* d_{t-1}^{i*}.$$

The maximisation is subject to the balance sheet constraint

$$q_t^* K_t^{i*} = n_t^{i*} + d_t^{i*}$$

and the incentive compatibility constraint (IC)

$$V_t^{i*} \geq \bar{\vartheta}^* q_t^* K_t^{i*}.$$

Similar to Home banks, Foreign banks maximise:

$$\psi_t^{i*} = \mu_{0,t}^* \Gamma_t^{i*} + \mu_{1,t}^*,$$

where

$$\mu^*_{0,t} = \mathbb{E}_t\{\Omega^*_{t,t+1}(\frac{R^{K*}_{t+1} + (1-\delta)q^*_{t+1}}{q^*_t} - R^*_{t+1})\}$$
$$\mu^*_{1,t} = \mathbb{E}_t\{\Omega^*_{t,t+1}R^*_{t+1}\}$$
$$\Omega^*_{t,t+1} = \mathbb{E}_t\{\Lambda^*_{t,t+1}(1-\omega+\omega\psi^*_{t+1})\}, \tag{16}$$

subject to the IC constraint

$$\psi^{i*}_t \geq \bar{\vartheta}^*\Gamma^{i*}_t. \tag{17}$$

In the equilibrium where the IC constraint always binds, we have

$$\Gamma^{i*}_t = \frac{\mu^*_{1,t}}{\bar{\vartheta}^* - \mu^*_{0,t}}.$$

Lastly, the aggregate net worth for all Foreign banks evolves according to

$$n^*_t = (\omega+\xi^*)(R^{K*}_t + (1-\delta)q^*_t)K^*_{t-1} - \omega R^*_t d^*_{t-1}.$$

The aggregate balance sheet constraint of Foreign banks is

$$q^*_t K^*_t = n^*_t + d^*_t.$$

The leverage ratio is accordingly

$$\Gamma^*_t = \Gamma^{i*}_t.$$

2.2.3 International Wholesale Funds

International wholesale funds are owned by Foreign households and channel funds across borders. They take deposits from Foreign households and promise the same payoff as Foreign banks. Then they lend to Home banks at the rate:

$$R^{G*}_t = R^*_t. \tag{18}$$ [5]

2.3 Monopolist Producers

The monopolistic producer of a particular brand of the H-type good produces output $Y_t(h)$ according to the production function

$$Y_t(h) = A_t(\frac{K_{t-1}(h)}{\alpha})^{\alpha}(\frac{L_t(h)}{1-\alpha})^{1-\alpha},$$

[5] In practice, large banks that operate across borders are able to hedge away exchange rate risks incurred (Cesa-Bianchi et al., 2018). Therefore, I assume that Home banks are small local banks which cannot directly borrow from Foreign households. The cross-border lending activities are conducted by wholesale funds providers that operate internationally.

where $\alpha \in [0, 1]$. $K_{t-1}(h)$ and $L_t(h)$ are the capital and labour inputs. A_t is the aggregate productivity which follows an exogenous process

$$A_t = A_{t-1}^{\rho_A} \exp(\epsilon_{a,t}).$$

The cost minimisation implies the following first-order conditions:

$$\begin{aligned} Y_t(h) &= A_t(\frac{K_{t-1}(h)}{\alpha})(\frac{R_t^K}{w_t})^{1-\alpha} \\ Y_t(h) &= A_t(\frac{L_t(h)}{1-\alpha})(\frac{w_t}{R_t^K})^{\alpha}. \end{aligned} \tag{19}$$

The corresponding real marginal cost is

$$mc_t(h) = \frac{1}{A_t}(R_t^K)^{\alpha} w_t^{1-\alpha} = mc_t, \tag{20}$$

which implies that the real marginal costs for producing different brands are equalised.

Every period, the producer can reset its prices in both countries in its domestic currency with probability $(1-\theta)$ as in Calvo (1983). They maximise the expected profit

$$\mathbb{E}_t\{\sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k}[(\frac{\mathcal{P}_t(h)}{P_{t+k}} - mc_{t+k})y_{t+k}(h) + (\frac{\mathcal{E}_t\mathcal{P}_t^*(h)}{P_{t+k}} - mc_{t+k})y_{t+k}^*(h)]\}$$

where $\mathcal{P}_t(h)$ and $\mathcal{P}_t^*(h)$ are the prices chosen by the firm, and $\mathcal{E}_t$ is the nominal exchange rate. The profit maximisation is subject to the demand for the particular brand from both countries

$$y_{t+k}(h) = (\frac{\mathcal{P}_t(h)}{P_{H,t+k}})^{-\varphi} y_{H,t+k} \qquad \text{and} \qquad y_{t+k}^*(h) = \frac{1-m}{m}(\frac{\mathcal{P}_t^*(h)}{P_{H,t+k}^*})^{-\varphi} y_{H,t+k}^*.$$

$y_{H,t}$ and $y_{H,t}^*$ are the total demand for the H-type goods in Home and Foreign, respectively:

$$\begin{aligned} y_{H,t} &= a(\frac{P_{H,t}}{P_t})^{-\phi}(C_t + I_t + G_t + \frac{\kappa_I}{2}(\frac{I_t}{I_{t-1}} - 1)^2 I_t) \\ y_{H,t}^* &= a^*(\frac{P_{H,t}^*}{P_t^*})^{-\phi}[C_t^* + I_t^* + G_t^* + \frac{\kappa_I}{2}(\frac{I_t^*}{I_{t-1}^*} - 1)^2 I_t^*]. \end{aligned}$$

The optimisation implies the optimal domestic price as:

$$\mathcal{P}_t(h) = \mathbb{E}_t \frac{\sum_{k=0}^{\infty} \mu^P \theta^k \Lambda_{t,t+k} y_{H,t+k} P_{H,t+k}^{\varphi} mc_{t+k}}{\sum_{k=0}^{\infty} \theta^k \Lambda_{t,t+k} y_{H,t+k} P_{H,t+k}^{\varphi} P_{t+k}^{-1}},$$

where $\mu^P = \frac{\varphi}{\varphi-1}$.

Meanwhile, firms will optimally choose identical prices across borders because the demand elasticities are constant and symmetric across borders. Thus

$$\mathcal{P}_t(h) = \mathcal{E}_t \mathcal{P}_t^*(h)$$

holds for all brands of goods, where $\mathcal{P}_t(h)$ and $\mathcal{P}_t^*(h)$ are prices of good h in the two countries set by the producer. In other words, the Law of One Price holds for all brands of goods.

With this pricing behaviour, the aggregate price index of the H-type goods evolves according to:

$$P_{H,t} = (\theta P_{H,t-1}^{1-\varphi} + (1-\theta)\mathcal{P}_t(h)^{1-\varphi})^{\frac{1}{1-\varphi}},$$

which can be rewritten as

$$\theta \pi_{H,t}^{\varphi-1} + (1-\theta)(\frac{\mathcal{P}_t(h)}{P_{H,t}})^{1-\varphi} = 1.$$

Aggregate the demand for capital from (19) to get:

$$K_{t-1} = \int_0^m K_{t-1}(h)dh = \frac{\alpha}{A_t}(\frac{R_t^K}{w_t})^{\alpha-1} Y_{H,t} s_t,$$

where $Y_{H,t} = y_{H,t} + y_{H,t}^*$ is the total output produced in Home, and $s_t = \int_0^m (\frac{\mathcal{P}_t(h)}{P_{H,t}})^{-\varphi} dh$ is the price dispersion. The law of motion for s_t is

$$s_t = (1-\theta)(\frac{\mathcal{P}_t(h)}{P_{H,t}})^{-\varphi} + \theta \pi_{H,t}^{\varphi} s_{t-1}.$$

Similarly, the aggregate demand for labour is:

$$L_t = \frac{1-\alpha}{A_t}(\frac{R_t^K}{w_t})^{\alpha} Y_{H,t} s_t. \tag{22}$$

A symmetric set of equations hold for production firms in the Foreign country as well.

2.4 Capital Producers

Capital producers create a unit of capital good using a unit of final good and pay a quadratic adjustment cost. They maximise

$$V_{Kt} = \left[q_t - 1 - \frac{\kappa_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \right] I_t + \mathbb{E}_t[\Lambda_{t,t+1} V_{Kt+1}(I_t)].$$

The first-order condition is

$$q_t = 1 + \frac{\kappa_I}{2}(\frac{I_t}{I_{t-1}} - 1)^2 + \frac{I_t}{I_{t-1}}\kappa_I(\frac{I_t}{I_{t-1}} - 1) - \kappa_I \mathbb{E}_t[\Lambda_{t,t+1}(\frac{I_{t+1}}{I_t} - 1)\frac{I_{t+1}^2}{I_t^2}].$$

The aggregate capital accumulates according to:

$$K_t = (1 - \delta)K_{t-1} + I_t.$$

A symmetric set of equations hold for the Foreign country as well.

2.5 Market Equilibrium

In both countries, the output produced by their domestic firms is either consumed, invested, exported, purchased by governments, or used to pay adjustment costs. The labour and capital markets also clear within each country.

The government budget constraints in both countries are

$$G_t + TR_t = 0$$
$$G_t^* + TR_t^* = 0.$$

Lastly, by aggregating the Home household budget constraints, the net foreign liabilities evolve according to:

$$d_t^{G*} = R_t^{G*} d_{t-1}^{G*} + \frac{P_{F,t}^*}{P_t^*} y_{F,t} - \frac{P_{H,t}^*}{P_t^*} y_{H,t}^*. \tag{23}$$

3 Parameterisation and Empirical Relevance of the Model

For parameterisation of the model, Foreign is considered a bloc of financial centre countries, such as the OECD group, most notably the US and the EU. Home is considered a bloc of emerging market countries, such as Latin American and East European countries. The two country blocs are assumed to be equal in size so that $m = 0.5$. The model is calibrated around a steady state with no inflation in both blocs.

Table 3 reports the parameter values. β is chosen so that the annualised real interest rates for both regions are 2%. The values of χ, ϕ, δ, κ_I, and α standard as in, for example, Christiano et al. (2009), Coenen et al. (2007). φ is set to 6 so that the steady-state price markup is 20% as estimated in Justiniano et al. (2008). The choice of θ implies that the prices are not expected to change in a year. The values of ζ and ζ^* imply that the steady state labour hour is $\frac{1}{3}$ in Home. All parameters above are set symmetrically across the two regions. ν is set to 0.4, which implies a home bias of 0.8 for both countries. In steady state, the export-to-GDP ratio is 21% for Home, which compromises divergent values of various emerging markets.[6]

[6]See, for example, The World Bank (2018).

In terms of the parameters for the banking sector, I follow Aoki et al. (2018)'s choice for ω and ω^* of 0.94, so that the annual dividend payout is $4(1-\omega) = 24\%$ of the net worth, which is reasonable if one includes the bonus payments to executives. For Foreign banks, ϑ^* and ξ^* are pinned down by two targets: a credit spread of 150 basis points annually and a leverage multiple of 4. The latter is a compromised value between high leverage ratios in commercial and investment banks and low ratios in non-financial business, as in Gertler and Karadi (2011). For Home banks, I target a domestic credit spread of 150 basis points, a leverage multiple of 4, and a 25% foreign-debt-to-total-asset ratio in the steady state. The exogenous premium for borrowing from domestic households, τ^r, is set to be 0.0025, so the average currency premium is 100 basis points annually. These targets are broadly consistent with targets used in Akinci and Queralto (2018) and Mimir and Sunel (2015), and they pin down the values of ϑ, ξ, and κ_b.

I assume 8 shocks in the model, 4 for each country. The productivity shocks in both countries are assumed to have a persistence of 0.95, a standard deviation of 0.01, and a correlation of 0.2, consistent with the range of values in Baxter (1995) and Eichenbaum et al. (2017). The process for preference shocks is assumed to be the same as the productivity shocks, as in Stockman and Tesar (1995) and Benigno (2009). Lastly, both countries' price markup and net worth shocks are assumed to be mutually independent one-off shocks with a standard deviation of 0.01. The different types of shocks are assumed to be mutually independent as well.

To check the model's property, I assume two symmetric benchmark Taylor rules as:[7]

$$\frac{1+i_t}{1+\bar{i}} = (\frac{1+i_{t-1}}{1+\bar{i}})^{\rho_m}(\frac{\pi_{H,t}}{\bar{\pi}_H})^{\varphi_\pi(1-\rho_m)} \tag{24}$$

$$\frac{1+i_t^*}{1+\bar{i}^*} = (\frac{1+i_{t-1}}{1+\bar{i}^*})^{\rho_m}(\frac{\pi_{F,t}^*}{\bar{\pi}_F^*})^{\varphi_\pi(1-\rho_m)}, \tag{25}$$

where $\bar{i}$, $\bar{i}^*$, $\bar{\pi}_H$, and $\bar{\pi}_F^*$ are steady-state levels of the corresponding variables. ρ_m is the smoothing coefficient, set to be 0.8. φ_π is the response coefficient to the PPI inflation, set to be 1.5.

The blue lines in Figure 2 plot impulse responses of key macroeconomic variables in the model to a shock of 25 basis points increase in the Foreign (financial centre) interest rate. The shock induces an appreciation of the Foreign currency relative to the Home currency. Through the expenditure-switching channel, Home exports (Foreign imports) increase, and imports from Foreign decrease. This contributes to the initial increase in output and CPI inflation in Home. Meanwhile, foreign currency appreciation reduces the

[7] The benchmark rules assume that central banks respond to domestic inflation only. Additional checks show that the results presented below are not significantly different if central banks respond to CPI inflation instead.

Parameter	Value	Interpretation
Household, Firms, and Trade		
β, β^*	$1.02^{-0.25}$	discount factor for households
χ, χ^*	3	inverse of the Frisch elasticity of labour supply
ν	0.4	degree of openness
ζ, ζ^*	90	relative weight of labour in utility
ϕ, ϕ^*	1	elasticity of substitution between Home and Foreign goods
φ, φ^*	6	elasticity of substitution between brands of commodities within a single type of goods
δ, δ^*	0.025	depreciation rate
α, α^*	0.33	share of capital cost in production
κ_I, κ_I^*	1.2	adjustment cost for investment
θ, θ^*	0.75	price rigidity
Financial Intermediaries		
ω, ω^*	0.94	survival rate of bankers
ξ	0.0091	initial endowment for entry bankers
ξ^*	0.0103	initial endowment for entry bankers
ϑ	0.340	proportion of divertible funds
ϑ^*	0.329	proportion of divertible funds
κ_b	2.482	increase in the proportion of divertible funds with the increase in Foreign currency lending
Shocks		
ρ_A, ρ_A^*	0.95	persistence of the productivity shock
σ_A, σ_A^*	0.01	standard deviation of the productivity shock
σ_{AA^*}	0.2	correlation coefficient of the productivity shocks
ρ_c, ρ_c^*	0.95	persistence of preference shock
σ_c, σ_c^*	0.01	standard deviation of preference shock
σ_{cc^*}	0.2	correlation coefficient of preference shocks
σ_p, σ_p^*	0.01	standard deviation of mark-up shock
σ_n, σ_n^*	0.01	standard deviation of net worth shock

Table 3: Calibration of Parameters

home bank's net worth due to a rise in the value of foreign currency-denominated debt on their balance sheets. Through the effects of the financial constraint, credit spread in Home is higher, and investment declines. The declining capital price also shrinks the bank's net worth and reduces investment. Ultimately, these effects dominate the expenditure-switching effects and put downward pressure on output and inflation.

The red dashed lines in the same figure depict the responses to the same shock if Home banks could raise debt abroad in the Home currency. In this counterfactual scenario, the wholesale funds providers still finance their lending to Home banks by deposits in Foreign currency from Foreign households. Moreover, as subsidiaries of internationally-operated large banks, the wholesale funds providers can hedge away any exchange rate mismatch on their balance sheets. This setting keeps the calibration and the steady state of the model unchanged from the baseline model. The technical details of this model are presented in Appendix A.[8] It is clear from the figure that the shock inflicts much milder responses across all variables in Home when the currency mismatch is absent in the model. The banking sector is not significantly affected by the shock. Thus, the decrease in investment is much lower.

Overall, this exercise shows that the effects of a monetary policy tightening shock in the financial centre (Foreign) are contractionary for the financial periphery (Home). Consequently, both countries' credit spreads and output comove, replicating the empirical observations of the global financial cycle literature. The cross-border transmission of the shock via the currency mismatch friction in financial intermediaries is essential for my model to reproduce this result.

4 Gains from Monetary Policy Cooperation

This section uses the model above to evaluate gains from international monetary policy cooperation. I first define cooperative and non-cooperative equilibrium and describe the methods for deriving policy equilibriums and evaluating cooperation gains. Then, I report and discuss the results. Lastly, I check the robustness of my results.

4.1 Derive and Evaluate Policy Cooperation Gains

The gains from policy cooperation are evaluated by comparing welfare measures under a cooperative Ramsey optimal policy equilibrium against those under a non-cooperative open-loop Nash equilibrium.

In the optimal cooperative policy equilibrium, a benevolent social planner maximises

[8] Another counterfactual is to set $x_t = 0$. However, this assumption essentially means that Home banks cannot borrow internationally, not just that they cannot borrow in their own currency. Moreover, the steady state of such a model is different from the baseline model.

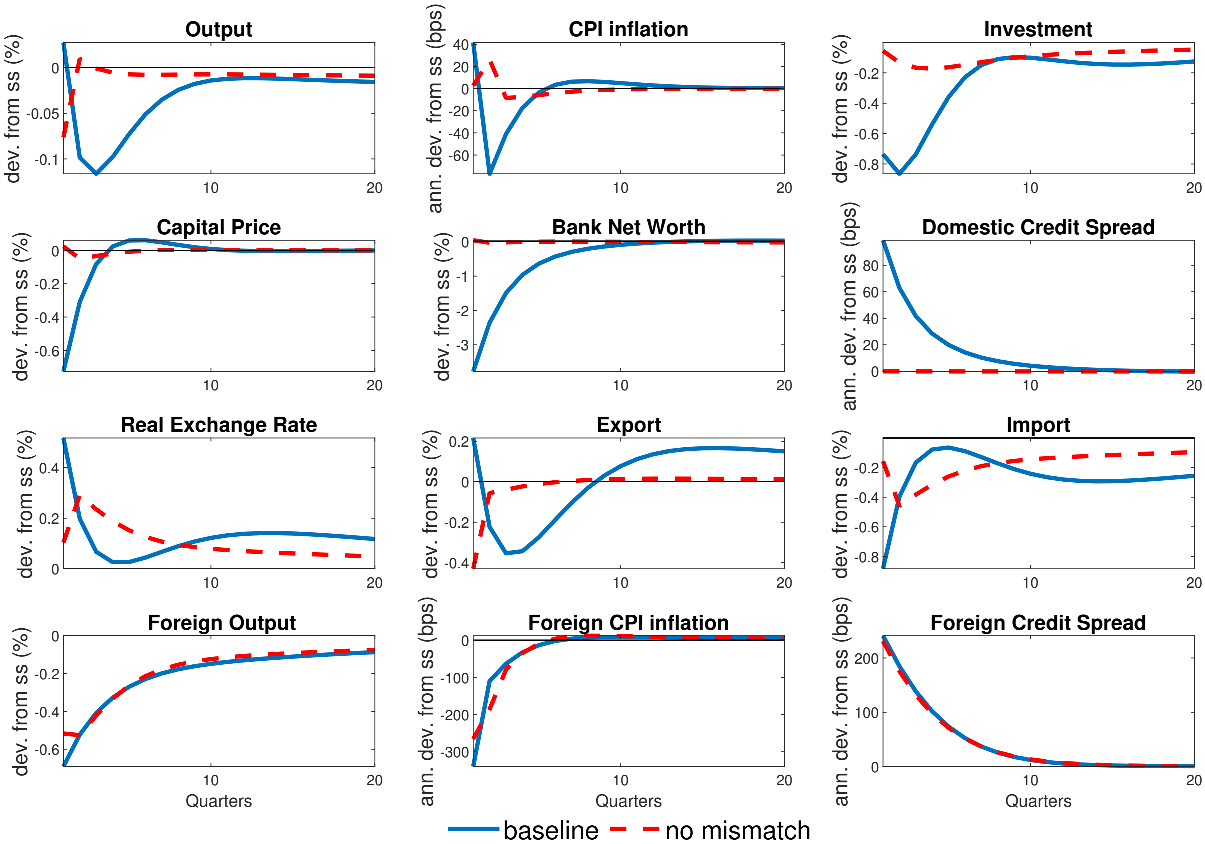

Figure 2: Impulse Response Functions to a Foreign MP Shock

Note: The variables presented in the figure are Home variables unless otherwise stated in the panel title.

the world's joint welfare

$$\mathbb{W}_t = \upsilon U_t + (1-\upsilon)U_t^* + \beta^W \mathbb{E}_t \mathbb{W}_{t+1}$$

with respect to all endogenous variables, subject to the structural constraints of the economy. U_t is the Home utility, defined as

$$U_t = log(C_t)\epsilon_{c,t} - \frac{\zeta L_t^{1+\chi}}{1+\chi}.$$

U_t^* is the corresponding utility measure for the Foreign country. υ is the weight attached to the Home utility. I set $\upsilon = m = 0.5$. β^W is the aggregate welfare discount parameter, set to $1.02^{-0.25}$.

In the non-cooperative open-loop Nash equilibrium, there are two national central banks, one for each country. They maximise the aggregate welfare of households in their own country with respect to all endogenous variables of the model except the policy instrument variable of the other country, subject to the structural constraints of the economy, taking the entire sequence of policy moves of the other central bank as given. In equilibrium, each central bank's policy is the best response to the other central bank's policy.

The optimal policy paths in the cooperative and non-cooperative equilibrium are solved under the assumption of timeless perspective. In addition, both national central banks have commitment devices. The optimal policy paths are derived by maximising the non-linear welfare functions subject to the non-linear structural constraints (i.e. the Lagrangian approach). The derivation is implemented in Dynare using the toolbox developed by Bodenstein et al. (2019). For now, assume also that benevolent social planners use the producer-price-index (PPI) inflation as their operating instruments under cooperative and non-cooperative regimes as in Benigno and Benigno (2006). The robustness of the results to the choice of instruments will be examined in section 4.3.

The welfare measures are evaluated by approximating the model under the corresponding optimal policy regimes to the second order, as in Schmitt-Grohe and Uribe (2007). Let $\mathbb{W}^{ck}$ be the welfare of country k achieved by the optimal cooperative policy equilibrium, $\mathbb{W}^{nk}$ be the welfare of country k achieved by the optimal non-cooperative policy equilibrium, and λ^k be the unit of consumption that one would give up under the non-cooperative equilibrium to live under the cooperative equilibrium. The welfare gain from monetary policy cooperation evaluated by the consumption-equivalent measure is

$$\lambda^k = [\exp((1-\beta^k)(\mathbb{W}^{ck} - \mathbb{W}^{nk})) - 1] \times 100\%,$$

which is the measure reported in tables in the rest of this paper.

Shocks	Welfare Gains (Baseline)			Welfare Gains (No-Mismatch)		
	λ^H	λ^F	λ^W	λ^H	λ^F	λ^W
All Shocks	-0.1288	0.1762	0.0236	0.0193	0.0206	0.0199
Productivity, Home	0.0874	-0.0758	0.0057	-0.0006	0.0050	0.0022
Productivity, Foreign	-0.1134	0.1140	0.0002	0.0020	0.0004	0.0012
Net Worth, Home	-0.1180	0.1188	0.0003	-0.0004	0.0013	0.0004
Net Worth, Foreign	0.0479	-0.0175	0.0152	0.0162	0.0056	0.0109
Mark-up, Home	0.0097	-0.0067	0.0015	-0.0008	0.0077	0.0035
Mark-up, Foreign	-0.0164	0.0189	0.0013	0.0025	0.0002	0.0013
Preference, Home	0.0064	-0.0053	0.0005	0.0001	0.0002	0.0001
Preference, Foreign	-0.0126	0.0129	0.0002	0.0001	0.0003	0.0002

Table 4: Gains from Optimal Cooperative Ramsey Equilibrium Relative to the Optimal Non-cooperative Nash Equilibrium (%)

4.2 Gains from Cooperation

Table 4 reports the unconditional welfare gains from policy cooperation relative to the non-cooperative Nash equilibrium. The welfare gains are also decomposed into the contribution of each shock. The table also compares the baseline results (columns 2-4) with those for the model without currency mismatch (columns 5-7). The welfare gains are denoted by λ^H (for Home), λ^F (for Foreign), and λ^W (for world's joint).

The table shows that the world's joint welfare improves by 0.024% of the steady state consumption when central banks are cooperative compared to non-cooperative in the baseline model, conditional on all shocks. This magnitude is consistent with those found in other contributions in the literature. However, the distribution of this cooperative gain is highly uneven despite the equal country size and largely symmetric parameter values chosen for both countries in my calibration. Home loses by 0.129% whilst Foreign gains by 0.176% of the steady state consumption from cooperating. The magnitudes of these welfare gains and losses for individual countries are much higher than the joint welfare. In other words, cooperation is highly desirable for the Foreign country but undesirable for the Home country.

Conditional on individual shocks, the distribution of cooperative gains remains highly uneven. Either of the two countries that incurs domestic productivity, markup, and preference shocks gains from cooperation at the cost of the other country. However, either of them gains from cooperation in response to foreign rather than domestic net worth shocks. Moreover, the productivity and net worth shocks are the principal contributors to the welfare gains and losses. For the productivity shocks, this might be partly due to the large persistence and cross-country correlation of the shock.[9]

By contrast, in the model without the currency mismatch friction, the cooperative

[9]However, note that the preference shock is calibrated in the same way as the productivity shocks and does not contribute much to the welfare changes.

gains for both countries become positive and much smaller in magnitude. This is the case when all shocks are considered jointly and conditional on individual shocks. Even in cases where one country loses by cooperation, the welfare losses are negligible compared to those conditional on the same shock in the baseline model.

These results suggest that the cross-border transmission of shocks through the financial intermediaries with the currency mismatch friction is crucial for the policy trade-off. In my model, the intertemporal allocation of capital is characterised by combining equations (4), (7), (8), (10), (11), and (18):

$$\mathbb{E}_t\{\Lambda_{t,t+1}\frac{R^K_{t+1}+(1-\delta)q_{t+1}}{q_t}\} = 1+\Delta_t^{spread}+\Delta_t^{UIP}, \tag{26}$$

where

$$\Delta_t^{spread} = \frac{\mu_{0,t}+\mu_{1,t}-Cov(\Lambda_{t,t+1}(\frac{R^K_{t+1}+(1-\delta)q_{t+1}}{q_t}-\frac{R^{G*}_{t+1}\varepsilon_{t+1}}{\varepsilon_t}),1-\omega+\omega\vartheta(x_{t+1})\Gamma_{t+1})}{\mathbb{E}_t(1-\omega+\omega\vartheta(x_{t+1})\Gamma_{t+1})},$$

and

$$\Delta_t^{UIP} = \mathbb{E}_t[\Lambda_{t,t+1}(\frac{R^*_{t+1}\varepsilon_{t+1}}{\varepsilon_t}-R_{t+1})]+\frac{Cov(\Lambda_{t,t+1}(\frac{R^{G*}_{t+1}\varepsilon_{t+1}}{\varepsilon_t}),1-\omega+\omega\vartheta(x_{t+1})\Gamma_{t+1})}{\mathbb{E}_t(1-\omega+\omega\vartheta(x_{t+1})\Gamma_{t+1})}.$$

Meanwhile, the first-best inter-temporal allocation implies:

$$\mathbb{E}_t\{\Lambda_{t,t+1}(R^K_{t+1}+1-\delta)\} = 1.$$

Compared to the first best, the Home central bank in the decentralised model must minimise the deviations in credit spread and the UIP condition, Δ_t^{spread} and Δ_t^{UIP}, to improve efficiency. Moreover, the exchange rate directly influences these deviations. As shown by Figure 2, a Home currency depreciation (Foreign currency appreciation) erodes Home banks' net worth and contributes to higher credit spread and UIP deviations. Therefore, the Home central bank is biased towards appreciating its currency to improve national welfare, which reduces the real debt for its banking sector and suppresses these deviations. This motive will likely dominate the motive to depreciate the currency to improve the trade balance in the non-cooperative Nash equilibrium.

By contrast, by combining equations (5), (7), (16), and (17), the inter-temporal allocation for Foreign is simply:

$$\mathbb{E}_t\{\Lambda^*_{t,t+1}\frac{R^{K*}_{t+1}+(1-\delta^*)q^*_{t+1}}{q^*_t}\} = 1+\Delta_t^{spread*}, \tag{27}$$

where

$$\Delta_t^{spread*} = \frac{\mu_{0,t}^* - Cov(\Lambda_{t,t+1}^*(\frac{R_{t+1}^{K*}+(1-\delta^*)q_{t+1}^*}{q_t^*} - R_{t+1}^*), 1-\omega^* + \omega^*\vartheta^*\Gamma_{t+1}^*)}{\mathbb{E}_t(1-\omega^* + \omega^*\vartheta^*\Gamma_{t+1}^*)}.$$

Therefore, the Foreign central bank is not incentivised to appreciate its currency like the Home central bank is.

This intuition is confirmed by Table 5, which reports the differences of unconditional means and standard deviations of a selection of variables between the cooperative and non-cooperative equilibrium for the baseline model under all shocks. Compared with non-cooperation, the Home currency is depreciated on average under cooperation. Although the depreciation reduces the currency premium, which is the first component of Δ_t^{UIP}, the credit spread and its volatility increase. Overall, Home deviates more from the efficient intertemporal allocation. Despite achieving lower output and CPI inflation volatilities, Home consumption decreases by 0.105% and labour hours rise by 0.024% under cooperation. Therefore, Home loses from cooperation.

By contrast, cooperation benefits the Foreign country by achieving lower credit spread and lower inflation and output volatilities. Overall, Foreign consumption increases by 0.163% and labour hours decrease by 0.013% compared to the non-cooperative equilibrium. Table C.1 - C.2 in Appendix C report the moments conditional on individual shocks. The salient feature is that Home only benefits from cooperation if the Home currency is more appreciated under cooperation than under non-cooperation.

When there is no currency mismatch on Home banks' balance sheets, the inefficiency from the deviation from the UIP condition, Δ_t^{UIP}, becomes 0, and the change in the exchange rate will not directly affect Δ_t^{spread}. Thus, equation (26) reduces to a symmetric Home version of equation (27). This implies that the two national central banks are more symmetric in their policy trade-offs. Hence, the welfare gains from cooperation become more evenly distributed and smaller than those in the baseline model.

4.3 Sensitivity Analysis

As pointed out by Coenen et al. (2007), the magnitude of the cooperative gains is sensitive to the calibration of the model and the particular policy instruments used by national central banks in the non-cooperative policy game. This section examines the robustness of the above results to different parameterisation and policy instruments.

Strength of financial frictions The results in the previous section show that the currency mismatch friction is crucial in driving the large and uneven distribution of cooperation gains. Therefore, it is natural to investigate how cooperative gains and losses vary with the degree of currency mismatch friction. Table 6 lists cooperative gains

Variable	Mean	STD
Home Variables		
Consumption	-0.1050	-0.0008
Labour	0.0238	0.0001
CPI Inflation	-0.0000	-0.0029
Output	0.0017	-0.0011
Credit Spread	0.6287	0.0009
Currency Premium	-4.2019	0.0005
Foreign Variables		
Consumption	0.1630	0.0003
Labour	-0.0133	-0.0001
CPI Inflation	-0.0000	-0.0024
Output	0.0792	-0.0027
Credit Spread	-5.9816	-0.0017
International Variables		
Real Exchange Rate	0.0333	-0.0009

Table 5: Differences in Unconditional Moments under All Shocks

Note: This table reports the differences in unconditional means of variables under the cooperative relative to the non-cooperative equilibrium. Differences in means for all variables except inflation are the percentage change relative to the mean under the non-cooperative equilibrium. The inflation measures are simple differences.

under various degrees of currency mismatch.

In the baseline calibration, the foreign-currency-debt-to-total-asset ratio for Home banks, x, is relatively high, corresponding to situations in countries such as Turkey. The alternative values of steady-state x are in line with those suggested by Akinci and Queralto (2018), Chui et al. (2016), and Hahm et al. (2013) for various emerging economies.

The results in the table suggest that the cooperative gains are more evenly distributed with a lower degree of currency mismatch. The intuition is that spillovers of policy actions become more symmetric as the Home banks' balance sheets are less sensitive to exchange rate fluctuations. With a high currency mismatch, such as when $x = 0.3$ or 0.25, Home loses and Foreign gains heavily. By contrast, with a low mismatch, such as when $x = 0.05$, cooperation becomes preferable for both countries.[10]

Investment adjustment costs and country size Table 7 reports how the baseline results change with alternative investment adjustment costs and relative country sizes. In the baseline calibration, the investment adjustment cost parameters κ_I are 1.2 for both countries. If these parameters are higher, the propagation through the financial intermediation will be stronger. The policy spillovers become larger and strengthen the

[10] I also experimented with alternative steady state spreads and currency premium, the uneven distribution of cooperative gains and losses in the baseline is robust to all those cases.

Steady-state foreign-currency debt ratio x	Welfare Gains (Baseline)		
	λ^H	λ^F	λ^W
$x = 0.30$	-0.4221	0.4650	0.0205
$x = 0.25$ (Baseline)	-0.1288	0.1762	0.0236
$x = 0.18$	-0.0010	0.0493	0.0241
$x = 0.05$	0.0160	0.0260	0.0210
$x = 0$ (No Mismatch)	0.0193	0.0206	0.0199

Table 6: Cooperative Gains (%) with Different Strengths of Financial Frictions

baseline results. The first two rows of the table confirm this intuition. If, instead, the size of Home m is smaller, the cross-border spillovers through the trade channel become more important for Home but less so for Foreign. Consequently, the Foreign economy is more insulated from spillovers from Home. By contrast, Home is more exposed to the externality of the Foreign central bank's policy. The Home is thus more likely to lose less and gain more by cooperating, and vice versa for the Foreign country.

Calibrated Parameters	Welfare Gains (Baseline)			Welfare Gains (No-Mismatch)		
	λ^H	λ^F	λ^W	λ^H	λ^F	λ^W
$\kappa_I = \kappa_I^* = 2.5$	-0.4164	0.4594	0.0206	0.0230	0.0267	0.0248
$\kappa_I = \kappa_I^* = 5$	-0.8231	0.8616	0.0157	0.0262	0.0318	0.0290
$m = 0.4$	-0.0120	0.0563	0.0290	NSE	NSE	NSE
$m = 0.25$	1.1181	-0.3162	0.0405	NSE	NSE	NSE

Table 7: Cooperative Gains (%) with Alternative Calibrations

Note: NSE stands for "No Stable Equilibrium".

Policy instruments As pointed out by Sims (2007) and Corsetti et al. (2010), another important dimension that influences the magnitudes of cooperative gains is the instruments used by central banks. Table 8 reports the welfare gains from policy cooperation when the two national central banks use different combinations of instruments. Four alternative instruments are considered for each country: PPI inflation ($\pi_{H,t}$, $\pi^*_{F,t}$), CPI inflation (π_t, π^*_t), growth of nominal GDP ($DY_t = \frac{P_{H,t}y_{H,t}}{P_{H,t-1}y_{H,t-1}}$, $DY^*_t = \frac{P^*_{F,t}y^*_{F,t}}{P^*_{F,t-1}y^*_{F,t-1}}$), and change in nominal exchange rate ($DNER_t$, $DNER^*_t$). This makes a total of 16 combinations.[11]

Home incurs significant welfare loss among all these combinations, whereas Foreign wins significant welfare gains. By contrast, both countries gain from cooperation if a stable equilibrium exists for the corresponding cases in the no-mismatch model. Therefore, the key finding of the baseline results is robust to a wide range of non-cooperative

[11]The nominal interest rates (i_t, i^*_t) are used by central banks in practice but are not considered here. This is because all those cases lead to equilibrium indeterminacy, consistent with findings in, for example, Coenen et al. (2007) and Bodenstein et al. (2019).

instrument combinations. Interestingly, Home loses the most from cooperation when its central bank uses $DNER_t$ as the instrument regardless of the instrument used by Foreign. This result implies that manipulating the nominal exchange rate under non-cooperation confers better gains for Home than other instruments.

Instrument Combinations	Welfare Gains (Baseline)			Welfare Gains (No-Mismatch)		
(Home, Foreign)	λ^H	λ^F	λ^W	λ^H	λ^F	λ^W
$\pi_{H,t}$, $\pi^*_{F,t}$ (baseline)	-0.1288	0.1762	0.0236	0.0193	0.0206	0.0199
$\pi_{H,t}$, π^*_t	-0.1188	0.1689	0.0249		NSE	
$\pi_{H,t}$, DY^*_t	-0.1333	0.1801	0.0233	0.0234	0.0279	0.0257
$\pi_{H,t}$, $DNER^*_t$	-0.1258	0.1744	0.0242		NSE	
π_t, $\pi^*_{F,t}$	-1.0976	1.2271	0.0580		NSE	
π_t, π^*_t	-1.1709	1.3468	0.0800	4.0730	10.2483	7.1161
π_t, DY^*_t	-1.0746	1.1941	0.0534		NSE	
π_t, $DNER^*_t$	-1.2186	1.4111	0.0876	2.4612	3.3110	2.8852
DY_t, $\pi^*_{F,t}$	-0.1423	0.1892	0.0233	0.0194	0.0212	0.0203
DY_t, π^*_t	-0.1333	0.1835	0.0250		NSE	
DY_t, DY^*_t	-0.1468	0.1931	0.0230	0.0235	0.0290	0.0263
DY_t, $DNER^*_t$	-0.1381	0.1867	0.0242		NSE	
$DNER_t$, $\pi^*_{F,t}$	-7.6707	13.6262	2.4257		NSE	
$DNER_t$, π^*_t	-4.4049	8.3182	1.7580		NSE	
$DNER_t$, DY^*_t	-11.7990	21.1817	3.3845		NSE	
$DNER_t$, $DNER^*_t$	-2.2829	4.6895	1.1433		NSE	

Table 8: Cooperative Gains (%) with Alternative Instruments

Note: NSE stands for "No Stable Equilibrium".

5 Transitional Gains from Cooperation

My analyses in the previous section focus on unconditional welfare for evaluating cooperative and non-cooperative regimes. The measures thus do not depend upon the initial condition of the economy. An equally compelling question is whether it is desirable for non-cooperating central banks to cooperate or for cooperating central banks to act strategically. The answer to this question must account for the transitional welfare change from one equilibrium to another by considering conditional welfare measures.

I first assess gains for non-cooperating central banks to cooperate. For this purpose, I set the initial values of endogenous variables in the model to their corresponding unconditional means in the non-cooperative Nash equilibrium. Then, I evaluate the conditional welfare under the cooperative Ramsey equilibrium. The difference between the conditional welfare and the initial welfare can thus be interpreted as the transitional welfare gains if the two countries move from the non-cooperative Nash equilibrium to the cooperative Ramsey equilibrium.

Table 9 reports these transitional gains for the baseline calibration and a selection of alternative scenarios. Moving from non-cooperation to cooperation distributes highly uneven gains for all these cases. In the baseline case, the financial periphery (Home) loses out from cooperation, whilst the financial centre (Foreign) gains. Similar to my findings using unconditional welfare measures, a higher degree of currency mismatch and investment adjustment costs exacerbate the uneven distribution. Meanwhile, if Home has a lower currency mismatch or is smaller relative to Foreign, it becomes desirable for Home to cooperate. Table C.3 in Appendix C reports the results of a more comprehensive selection of cases, as I considered in the previous section. Among all those cases, moving from non-cooperation to cooperation benefits both countries simultaneously only when Home is sufficiently small, or there is a mild degree of currency mismatch in the Home banking sector.

Scenario	Welfare Gains (Baseline)		
	λ^H	λ^F	λ^W
Baseline	-0.0970	0.0878	-0.0046
Higher currency mismatch ($x = 0.3$)	-0.5764	0.4153	-0.0818
Lower currency mismatch ($x = 0.05$)	0.0261	-0.0057	0.0102
Higher investment adjustment ($\kappa_I = 2.5$)	-0.3668	0.2803	-0.0438
Smaller Home country ($m = 0.25$)	0.0913	0.0096	0.0300

Table 9: Transitional Gains: from Non-Cooperation to Cooperation (%)

Next, I calculate the conditional welfare measures under the non-cooperative Nash equilibrium. Here, the initial state of the economy is set to the cooperative Ramsey equilibrium. Thus, the welfare changes reflect the transitional gains for the cooperative central banks to act strategically. Table 10 reports these transitional welfare changes. Home still loses out from acting strategically if it already cooperates with the Foreign central bank unless it is relatively small. If there is a lower currency mismatch in the Home banking sector, both countries lose out from breaking the cooperation. Table C.4 in Appendix C reports the results of a more comprehensive selection of cases. There is no scenario where breaking the cooperation benefits both countries simultaneously.

Scenario	Welfare Gains (Baseline)		
	λ^H	λ^F	λ^W
Baseline	-0.0954	0.0231	-0.0362
Higher currency mismatch ($x = 0.3$)	-0.7997	0.4215	-0.1910
Lower currency mismatch ($x = 0.05$)	-0.0061	-0.0118	-0.0090
Higher investment adjustment ($\kappa_I = 2.5$)	-0.4096	0.1859	-0.1123
Smaller Home country ($m = 0.25$)	0.0423	-0.0419	-0.0209

Table 10: Transitional Gains: from Cooperation to Non-Cooperation (%)

Simple Rule Combinations (Home, Foreign)	Welfare Gains (Baseline) λ^H	λ^F	λ^W	Welfare Gains (No-Mismatch) λ^H	λ^F	λ^W
$\pi_{H,t}=1$, $\pi^*_{F,t}=1$	1.1770	-0.7206	0.2237	0.1796	0.2029	0.1912
$\pi_{H,t}=1$, $\pi^*_t=1$	1.6413	-1.1310	0.2456	1.0116	1.5513	1.2811
$\pi_{H,t}=1$, Taylor	1.4721	-1.0257	0.2154	0.1159	0.2123	0.1641
$\pi_t=1$, $\pi^*_{F,t}=1$	1.5851	-0.7626	0.4044		NSE	
$\pi_t=1$, $\pi^*_t=1$	1.7746	-1.1336	0.3100		NSE	
$\pi_t=1$, Taylor	1.2847	-0.7621	0.2561		NSE	
Taylor, $\pi^*_{F,t}=1$	0.0751	0.1137	0.0944	1.0430	0.7567	0.8998
Taylor, $\pi^*_t=1$	0.5625	-0.3423	0.1090	5.1816	7.2391	6.2054
Taylor, Taylor	0.3707	-0.2030	0.0835	0.8404	0.7264	0.7834

Table 11: Cooperative Gains (%): Ramsey Cooperative Relative to Equilibrium Using Simple Rules

Note: NSE stands for "No Stable Equilibrium".

6 Implementable Monetary Policy Rules

In reality, the central bank practices are often dominated by various simple implementable rules which do not necessarily replicate the optimal allocations. Although studying gains from cooperation when central banks implement simple rules is not the focus of this paper, it helps to get a sense of how my findings change when implementable rules characterise monetary policy in my model.

There are infinite numbers of alternative rules that can be considered. I start by restricting my focus on 3 alternative simple rules for each country: 1) complete stabilisation of the PPI inflation ($\pi_{H,t}=1$ or $\pi^*_{F,t}=1$ for all t), which replicates the optimal policy for a standard two-country New Keynesian model with complete markets (Benigno, 2009); 2) complete stabilisation of the CPI inflation ($\pi_t=1$ or $\pi^*_t=1$ for all t), which stabilises the CPI fluctuations that are directly relevant for welfare; 3) the standard Taylor rules (24) and (25) which typically feature in the literature. I first check how well these rules replicate the optimal cooperative Ramsey equilibrium derived in previous sections. If each country can choose one of the simple rules above, there are 9 possible combinations in total. Table 11 reports the differences in unconditional welfare between the optimal Ramsey cooperation equilibrium and the equilibrium achieved in each combination. None of the scenarios considered replicates the world's joint welfare achieved by the optimal Ramsey cooperation equilibrium. Home achieves significantly higher welfare by adopting the simple rule in all cases. However, Foreign consistently achieves much lower welfare by adopting the simple rule except in one case. Without currency mismatch, the cooperative Ramsey equilibrium confers higher welfare for both countries if a stable equilibrium exists.

According to the same table, the gap in the world's joint welfare is the smallest if

For Home Welfare	$\pi^*_{F,t} = 1$	$\pi^*_t = 1$	Taylor
$\pi_{H,t} = 1$	0.8033	1.2659	1.0973
$\pi_t = 1$	1.2099	1.3987	0.9106
Taylor	-0.2945	0.1910	0.0000
For Foreign Welfare	$\pi^*_{F,t} = 1$	$\pi^*_t = 1$	Taylor
$\pi_{H,t} = 1$	-0.5187	-0.9299	-0.8244
$\pi_t = 1$	-0.5608	-0.9325	-0.5602
Taylor	0.3174	-0.1396	0.0000
For Joint Welfare	$\pi^*_{F,t} = 1$	$\pi^*_t = 1$	Taylor
$\pi_{H,t} = 1$	0.1401	0.1620	0.1319
$\pi_t = 1$	0.3207	0.2263	0.1725
Taylor	0.0110	0.0256	0.0000

Table 12: Welfare Gains from Cooperating in Implementable Rules (%)

Note: The three panels from the top to the bottom report cooperation gains for Home, Foreign, and world's joint welfare, respectively. The rows (columns) indicate the rules adopted by Home (Foreign). The Nash equilibrium is underlined.

the two countries follow the Taylor rules (24) and (25). Thus, this is the cooperative equilibrium if the two countries cooperate by choosing a combination of simple rules to maximise the world's joint welfare.

Relative to this cooperative equilibrium with implementable rules, Table 12 reports gains from cooperation relative to the other eight non-cooperative scenarios. I rearrange these gains in the form of the pay-off matrices. The three panels from the top to the bottom report cooperation gains for Home, Foreign, and world's joint welfare, respectively. The rows (columns) indicate the rules adopted by Home (Foreign). The results indicate that cooperation still fails to improve both countries' welfare compared to non-cooperative scenarios if both countries adopt implementable rules.

Moreover, there is a simple strategy Nash equilibrium where each country's policy rule is the optimal response to the rule of the other country among the eight non-cooperative equilibriums. This Nash equilibrium is achieved when Home adopts the Taylor rule (24) and Foreign fully stabilises the CPI inflation. Compared to this non-cooperative Nash equilibrium, Home benefits from cooperation by 0.191%, whereas Foreign loses 0.1396% of steady-state consumption.

Another interesting question in this environment is whether central banks should respond to the movements of external variables such as the nominal exchange rate. To answer this question, I expand the strategy space for implementable rules in consideration by allowing central banks to implement the following augmented Taylor rules:

$$\frac{1+i_t}{1+\bar{i}} = (\frac{1+i_{t-1}}{1+\bar{i}})^{\rho_m}[(\frac{\pi_{H,t}}{\bar{\pi}_H})^{\varphi_\pi}(\frac{e_t}{e_{t-1}})^{\varphi_e}]^{1-\rho_m} \quad (28)$$

$$\frac{1+i^*_t}{1+\bar{i}^*} = (\frac{1+i_{t-1}}{1+\bar{i}^*})^{\rho_m}[(\frac{\pi^*_{F,t}}{\bar{\pi}^*_F})^{\varphi_\pi}(\frac{e_t}{e_{t-1}})^{\varphi^*_e}]^{1-\rho_m}, \quad (29)$$

where $\frac{e_t}{e_{t-1}}$ is the change in nominal exchange rate. The values of ρ_m and φ_π are kept the same as in (24) and (25). The value of φ_e is allowed to vary within the range $[0, 5]$ and φ^*_e within the range $[-5, 0]$.[12]

Within this expanded policy space, the optimal cooperative policy requires both national central banks to adopt the augmented Taylor rule and respond to exchange rate movements with $\varphi_e = 0.2$, $\varphi^*_e = -0.1$. Compared to the optimal cooperative Ramsey equilibrium described in section 4.1, this cooperative equilibrium in implementable rules achieves 0.077% lower joint welfare, 0.3325% lower Home welfare, and 0.1778% higher Foreign welfare in consumption-equivalent measures.

If the two national central banks do not cooperate, given each other's policy rule, both central banks are motivated to countervail the exchange rate fluctuations to improve national welfare in most cases. Table 13 reports the optimal responses of Home (Foreign) when Foreign (Home) adopts complete PPI or CPI stabilisation rules. If one of the countries adopts such a policy rule, it is always optimal for the other country to respond to the exchange rate fluctuations. Figure 3 plots the optimal response functions for the two countries when they both implement the Taylor rules (28) and (29). Here, responding to the exchange rate is a dominant strategy for Home as the financial periphery. For Foreign as the financial centre, reacting to the exchange rate is also optimal unless Home is already responding strongly with $\phi_e \geq 3.3$.

Scenario	Optimal Response of the Other Country
Given $\pi^*_{F,t} = 1$ in Foreign	Taylor Rule (28) with $\varphi_e = 0.7$ in Home
Given $\pi^*_t = 1$ in Foreign	Taylor Rule (28) with $\varphi_e = 0.6$ in Home
Given $\pi_{H,t} = 1$ in Home	Taylor Rule (29) with $\varphi^*_e = -1.3$ in Foreign
Given $\pi_t = 1$ in Home	Taylor Rule (29) with $\varphi^*_e = -1.2$ in Foreign

Table 13: The optimal responses for Stabilising Exchange Rate Movements I

According to the same figure, there is a simple strategy Nash equilibrium (black dot), which is also the only Nash equilibrium in my extended policy space that includes PPI and CPI targeting rules. In this non-cooperative Nash equilibrium, the Home central bank adopts the augmented Taylor rule (28) with $\varphi_e = 0.7$, and the Foreign central bank adopts the augmented Taylor rule (29) with $\varphi^*_e = -1.7$. Relative to this non-

[12]Intuitively, the interest rates should respond to countervail changes in the exchange rate. Thus, φ_e should be positive whilst φ^*_e should be negative.

cooperative Nash equilibrium with implementable rules, the cooperative equilibrium with implementable rules discussed above ($\varphi_e = 0.2$, $\varphi_e^* = -0.1$) increases the Home welfare by 0.281%, decreases the Foreign welfare by 0.119%, and increases the world's joint welfare by 0.081% of the steady state consumption. Figures C.1 - C.2 in Appendix C plot the cooperation gains relative to all possible combinations of rules in the extended policy space. The uneven distribution of cooperation gains is robustly prevalent in all cases.

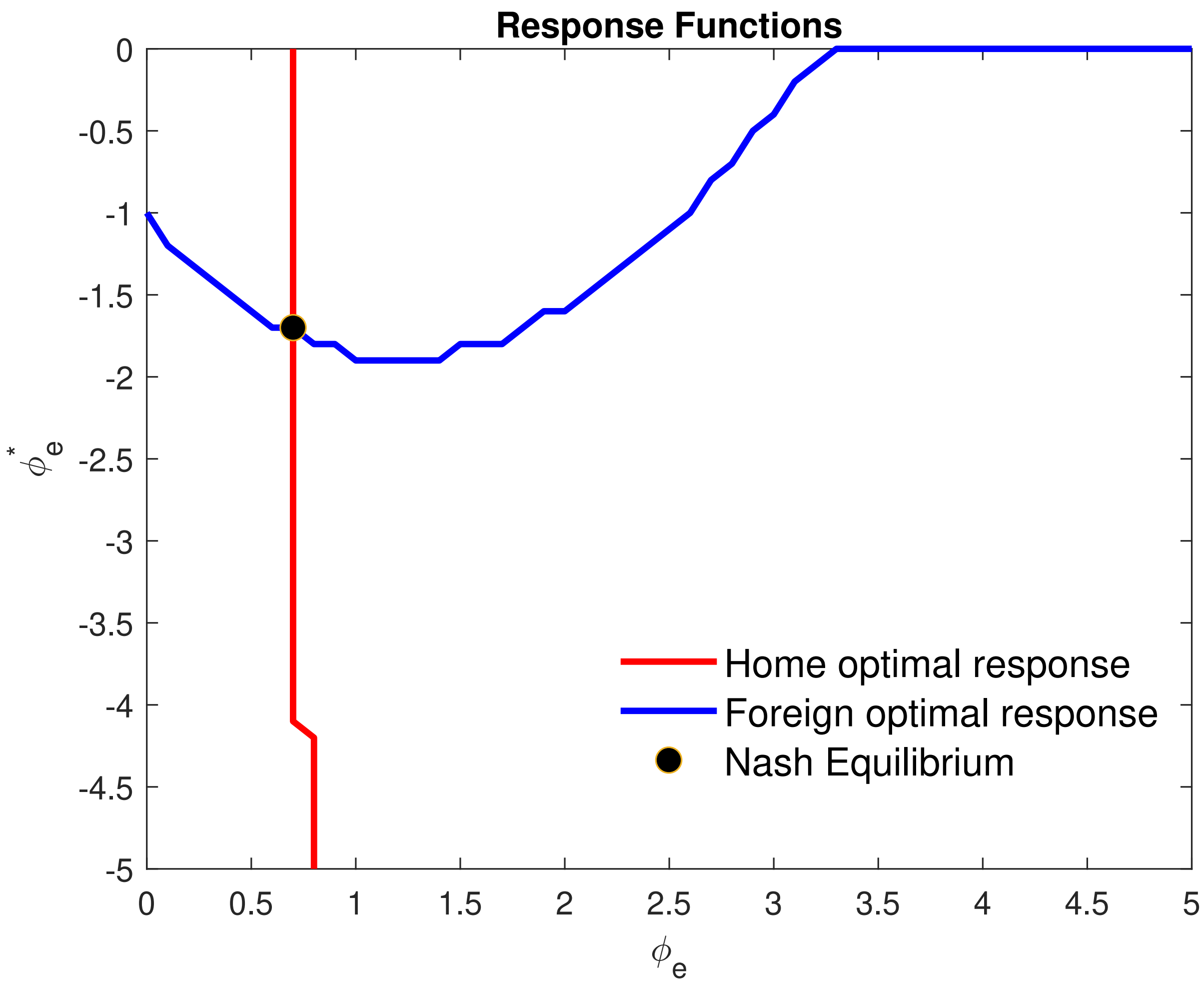

Figure 3: The Optimal Responses for Stabilising Exchange Rate Movements II

Note: The two countries adopt the augmented Taylor rules (28) and (29), respectively.

Lastly, I consider the conditional welfare gains as I did in section 5 for the cooperative and non-cooperative equilibriums with implementable rules. Starting from the non-cooperative Nash equilibrium, if the two central banks cooperate to implement the cooperative policy rules, both countries gain from cooperation. Home gains 0.0703%, Foreign gains 0.0711%, and the world's joint welfare increases by 0.0707% of the steady-state consumption along this transition. By contrast, if the two countries are already cooperating but decide to move to the Nash equilibrium, both countries lose out. Along the transition, Home loses 0.0492%, Foreign loses 0.0730%, and the world's joint welfare decreases by 0.0611% of the steady-state consumption.

7 Conclusion

This paper discusses the desirability of central banks of the financial centre and periphery countries cooperating in their monetary policy within a model consistent with global financial cycles. The dominance of the financial centre countries' currencies in the global banking system generates a currency mismatch on banks' balance sheets in the financial periphery countries. This friction leads to asymmetric policy trade-offs across borders. As a result, the distribution of the gains from monetary policy cooperation is highly uneven.

Compared with the optimal non-cooperative Nash equilibrium, one of the countries suffers significant losses in the optimal cooperative Ramsey equilibrium whilst the other country extracts significant welfare gains. This asymmetry in cooperation gain distribution diminishes with the degree of currency mismatch friction in the financial periphery. The asymmetry is robust to the type and origin of the shock, relative country size, and the policy instruments used under non-cooperation. The financial periphery is more likely to gain from cooperation if it raises low levels of foreign currency debt or is relatively small. In addition, transiting from non-cooperation to cooperation or vice versa still fails to benefit both countries simultaneously. Overall, my findings suggest that even with global financial cycles, it does not follow that it is beneficial or practical for the financial periphery to cooperate with the financial centre.

This asymmetry of cooperation gains distribution still holds if both countries adopt implementable rules. Moreover, within the range of policy rules considered, counteracting the effects of exchange rate movements is beneficial for the financial periphery, regardless of the policy rules of the financial centre. The same is true for the financial centre unless the financial periphery responds strongly to exchange rate fluctuations. Lastly, both countries can gain by moving from the non-cooperative Nash equilibrium to the cooperative equilibrium with implementable rules. By contrast, both lose out if they break their existing cooperation.

Future research may consider extending this analysis for more specific quantitative assessments. For example, the model can be calibrated with country-specific data for country-specific policy recommendations. Likewise, one can extend my model to study how the currency mismatch friction interacts with other frictions relevant to specific countries to influence the cooperation gains. It is also interesting to consider other implementable rules, such as rules responding to credit spreads and the UIP deviation. Lastly, one can explore how cooperative and non-cooperative macroprudential tools help stabilise the international transmission of shocks and how these tools interact with monetary policy.

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Appendices

A The No-mismatch Model

In the no-mismatch model, I assume that Home banks can raise debt d^G_{t-1} from international wholesale funds providers in the Home currency in period $t-1$ and pay back $R_t d^G_{t-1}$ in period t. Therefore, the net worth of a typical Home bank becomes

$$n^i_t = (R^K_t + (1-\delta)q_t)K^i_{t-1} - R_t d^{Gi}_{t-1} - \widetilde{R}_t d^i_{t-1}.$$

The balance sheet constraint becomes

$$q_t K^i_t = n^i_t + d^i_t + d^{Gi}_t$$

and the incentive compatibility constraint remains the same.

The optimality conditions for leverage ratio Γ^i_t and foreign-currency debt ratio x^i_t remain unchanged. However, the definition for $\mu_{1,t}$ changes to

$$\mu_{1,t} = \mathbb{E}_t\{\Omega_{t,t+1}(\widetilde{R}_{t+1} - R_{t+1})\} = \mathbb{E}_t\{\Omega_{t,t+1}\tau^r_{t+1}\}.$$

The evolution of aggregate net worth and the balance sheet constraint are thus

$$n_t = (\omega + \xi)(R^K_t + (1-\delta)q_t)K_{t-1} - \omega R_t d^G_{t-1} - \omega \widetilde{R}_t d_{t-1},$$

and

$$q_t K_t = n_t + d_t + d^G_t.$$

Meanwhile, the international wholesale funds providers raise d^{G*}_{t-1} in the Foreign currency from Foreign households in period $t-1$ and promise to pay back $R^*_t d^{G*}_{t-1}$ in period t. The wholesale banks can hedge away any exchange rate risks on their balance sheets as in Cesa-Bianchi et al. (2018). In particular, I assume that the hedging is such that

$$d^{G*}_t \varepsilon_t = d^G_t.$$

Therefore, the profit for the wholesale bank is

$$\Pi^{wb}_t = (R_t - R^*_t)d^{G*}_{t-1} - \Phi,$$

where Φ is a constant hedging cost. Thus, the balance of payments equation becomes:

$$d^{G*}_t = R_t d^{G*}_{t-1} + \frac{P^*_{F,t}}{P^*_t} y_{F,t} - \frac{P^*_{H,t}}{P^*_t} y^*_{H,t}.$$

Other equations of the model remain unchanged.

B Steady State

I approximate the model around a non-stochastic steady state with zero inflation in both countries. I also normalise all relative price terms to one so that the price dispersion terms $s = s^* = 1$. In addition, the nominal exchange rate is normalised to one, which implies that the real exchange rate is also one.

I set the steady state Home labour hours $L = \frac{1}{3}$. The inter-temporal Euler equations imply $R = R^* = \frac{1}{\beta}$. Therefore, $i = i^* = \frac{1}{\beta} - 1$. $\widetilde{R}$ and R^{G*} are determined by R, R^*, and the relevant targeted interest rate spreads for calibration. Moreover, the optimal pricing of capital implies $q = q^* = 1$.

From the optimal pricing equation of firms, $mc = \frac{\varphi-1}{\varphi}$. Similarly, $mc^* = \frac{\varphi^*-1}{\varphi^*}$. The values of R^K and R^{K^*} are pinned down by R, R^*, and the targeted credit spreads in the steady state. Productivity is normalised to one in both countries.

From the first-order condition (FOC) with respect to labour for Home firms,

$$w = [\frac{mc}{(R^K)^\alpha}]^{\frac{1}{1-\alpha}}.$$

Substituting w back to the FOC for capital,

$$K = \frac{\alpha}{1-\alpha}\frac{wL}{R^K}.$$

From the capital accumulation equation, $I = \delta K$. By equation equation (20) and (22), the total output produced by Home firms

$$Y_H = \frac{wL}{(1-\alpha)mc}.$$

Moreover, from equation (3), the steady state consumption

$$C = \frac{w}{\zeta L^\chi}.$$

Meanwhile, from the evolution of foreign assets (23), we obtain

$$Y_F^* = [\frac{(1-a)m}{(a-a^*)(1-m)}Y_H + (R^{G*}-1)d^{G*}]\frac{(a-a^*)}{a^*}.$$

Then from the Foreign counterpart equation of (22),

$$L^* = (1-\alpha)Y_F^*(\frac{R^{K*}}{w^*})^\alpha.$$

Then, the values of K^*, I^*, and C^* are pinned down similarly as their counterparts for Home.

From the definitions of output Y_H and Y_F^* and demands for goods y_H, y_H^*, y_F, and y_F^*, the aggregate demand in the two countries are

$$C + I + G = \frac{(1-a^*)Y_H - a^* \frac{1-m}{m} Y_F^*}{a - a^*}$$
$$C^* + I^* + G^* = \frac{aY_F^* - (1-a)\frac{m}{1-m} Y_H}{a - a^*}.$$

Then the demands y_H, y_H^*, y_F, y_F^* and government spending G and G^* are determined accordingly.

Given K and the targeted leverage ratio Γ, the net worth of Home banks is given by $n = \frac{K}{\Gamma}$. Then, given the targeted foreign-currency-debt-to-asset ratio x, the cross-border lending $d^{G*} = xK$. From the aggregate balance sheet of banks, we can solve

$$d = K - n - d^{G*}.$$

By the evolution of the aggregate net worth (15), the value of ξ is

$$\xi = \frac{n + \omega R^{G*} d^{G*} + \omega \widetilde{R} d}{(R^K + 1 - \delta)K} - \omega.$$

Inserting the values of interest rates back to equations (7) $-$ (9) and (14), the corresponding values of the spread measures are determined. Then from equation (13),

$$\kappa_b = \frac{2\mu}{x^2\mu + 2x}.$$

By inserting these values back to (12), the value of θ is

$$\theta = \frac{\beta(1-\omega)\widetilde{R} + \beta(1-\omega)\Gamma(R^K + 1 - \delta - \widetilde{R}) + \beta\Gamma(1-\omega)x(\widetilde{R} - R^{G*})}{\Gamma(\frac{\kappa_b}{2}x^2 + 1)[1 - \beta\omega\widetilde{R} - \beta\omega\Gamma(R^K + 1 - \delta - \widetilde{R}) - \beta\omega\Gamma x(\widetilde{R} - R^{G*})]}.$$

Given the values of Γ^* and K^*, n^* and d^* are accordingly determined similarly to those for Home. The values of μ_0^*, μ_1^*, and ψ^* can be obtained by substituting the relevant variables into their respective definitions. Then, the values of θ^* and ξ^* are given by

$$\theta^* = \frac{\beta(1-\omega)[(R^{K*} + 1 - \delta - R^*)\Gamma^* + R^*]}{\Gamma^* - \beta\omega(\Gamma^*)^2(R^{K*} + 1 - \delta - R^*) - \beta\omega\Gamma^* R^*}$$
$$\xi^* = \frac{n^* + \omega R^* d^*}{(R^{K*} + 1 - \delta)K^*} - \omega.$$

C Additional Figures and Tables

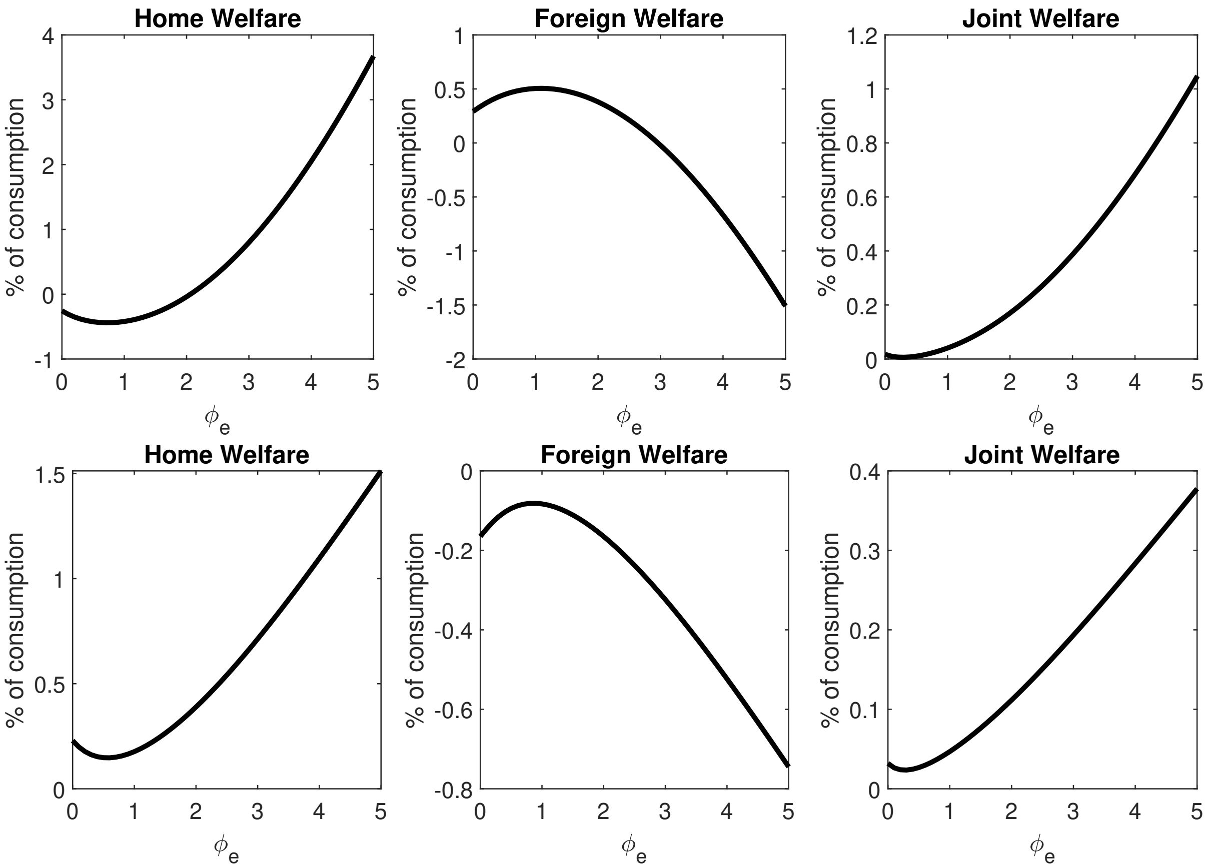

Figure C.1: Welfare Gains from Cooperation in Implementable Rules I

Note: The cooperative welfare is compared to equilibria with non-cooperative implementable rules. Upper panel: Home implements the augmented Taylor rule with varying ϕ_e, and Foreign implements PPI targeting without cooperation. Lower panel: Home implements the augmented Taylor rule with varying ϕ_e, and Foreign implements CPI targeting without cooperation.

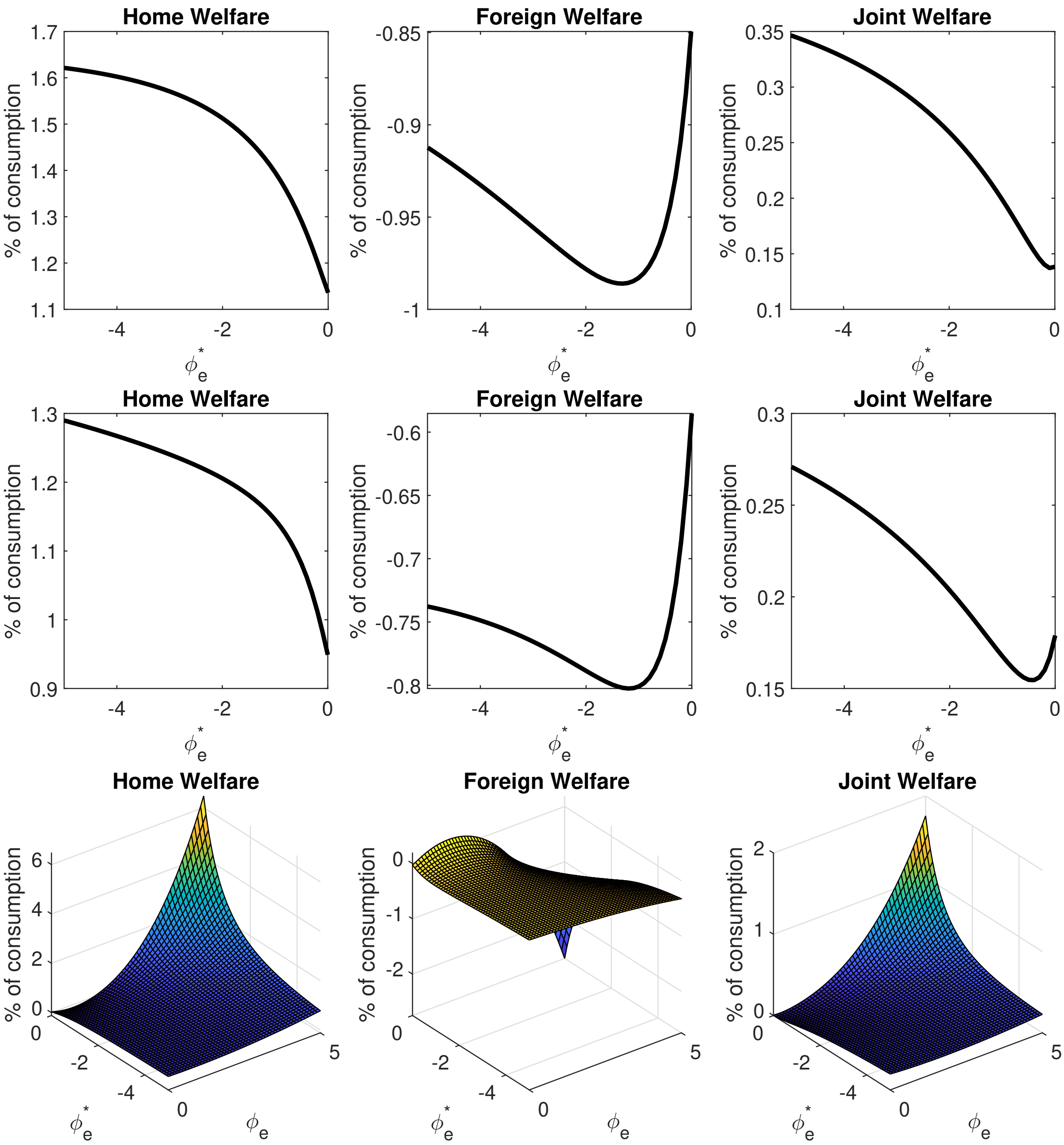

Figure C.2: Welfare Gains from Cooperation in Implementable Rules II

Note: The cooperative welfare is compared to equilibria with non-cooperative implementable rules. Upper panel: Home implements PPI targeting, and Foreign implements the augmented Taylor rule with varying ϕ_e^* without cooperation. Middle panel: Home implements CPI targeting, and Foreign implements the augmented Taylor rule with varying ϕ_e^* without cooperation. Lower panel: the two countries adopt the augmented Taylor rules (28) and (29) without cooperation, respectively.

Variable	All Shocks		Productivity Home		Productivity Foreign		Net Worth Home		Net Worth Foreign	
	Mean	STD	Mean	STD	Mean	STD	Mean	STD	Mean	STD
Home Variables										
Consumption	-0.1050	-0.0008	0.0722	-0.0003	-0.0963	-0.0013	-0.0962	0.0002	0.0420	0.0024
Labour	0.0238	0.0001	-0.0142	0.0003	0.0171	-0.0001	0.0193	0.0001	-0.0058	0.0001
PPI Inflation	0.0000	0.0011	0.0000	0.0011	0.0000	0.0004	0.0000	0.0005	0.0000	-0.0002
CPI Inflation	-0.0000	-0.0029	0.0000	0.0005	-0.0000	-0.0026	-0.0000	-0.0030	0.0000	0.0032
Output	0.0017	-0.0011	0.0047	-0.0012	-0.0110	-0.0000	0.0009	0.0010	0.0050	-0.0001
Credit Spread	0.6287	0.0009	-1.8671	-0.0034	0.8063	0.0000	3.4580	0.0031	-0.0005	0.0007
Currency Premium	-4.2019	0.0005	0.2822	-0.0023	-3.5224	-0.0000	-1.1041	0.0021	0.5113	0.0005
Foreign Variables										
Consumption	0.1630	0.0003	-0.0617	-0.0000	0.0969	0.0003	0.0985	-0.0008	-0.0042	0.0044
Labour	-0.0133	-0.0001	0.0131	0.0000	-0.0163	-0.0001	-0.0166	-0.0004	0.0081	0.0011
PPI Inflation	0.0000	0.0013	0.0000	0.0001	0.0000	0.0003	-0.0000	-0.0011	0.0000	0.0032
CPI Inflation	-0.0000	-0.0024	0.0000	0.0004	-0.0000	-0.0039	-0.0000	-0.0030	0.0000	0.0062
Output	0.0792	-0.0027	0.0057	0.0001	0.0110	-0.0028	0.0054	-0.0023	0.0493	0.0057
Credit Spread	-5.9816	-0.0017	-0.0175	-0.0001	-7.2652	-0.0063	-2.4856	-0.0038	6.3793	0.0096
International Variables										
Real Exchange Rate	0.0333	-0.0009	-0.0450	-0.0001	0.0426	-0.0011	0.0596	0.0001	-0.0398	0.0013

Table C.1: Differences in Unconditional Moments under Individual Shocks I

Note: This table reports the differences in unconditional means of variables under the cooperative relative to the non-cooperative equilibrium. Differences in means for all variables except inflation are scaled as the percentage change relative to the mean under the non-cooperative regime. The inflation measures are simple differences.

Variable	Mark-up Home		Mark-up Foreign		Preference Home		Preference Foreign	
	Mean	STD	Mean	STD	Mean	STD	Mean	STD
Home Variables								
Consumption	0.0092	-0.0008	-0.0136	-0.0010	0.0056	0.0001	-0.0106	-0.0003
Labour	0.0002	-0.0002	0.0027	-0.0001	-0.0008	0.0001	0.0020	-0.0000
CPI Inflation	0.0000	0.0003	-0.0000	-0.0015	0.0000	-0.0004	-0.0000	-0.0010
Output	0.0038	-0.0011	-0.0011	-0.0003	0.0008	0.0005	-0.0011	-0.0002
Credit Spread	-1.1565	-0.0026	-0.0636	-0.0012	-0.1421	-0.0006	0.0227	-0.0004
Currency Premium	-0.0997	-0.0018	-0.4402	-0.0009	0.0682	-0.0003	-0.4470	-0.0003
Foreign Variables								
Consumption	-0.0054	-0.0007	0.0175	-0.0014	-0.0042	0.0001	0.0118	-0.0005
Labour	0.0013	-0.0001	0.0010	-0.0004	0.0009	0.0000	-0.0016	0.0001
CPI Inflation	0.0000	0.0001	0.0000	0.0024	-0.0000	0.0002	-0.0000	-0.0018
Output	0.0009	-0.0006	0.0071	-0.0025	0.0004	0.0001	0.0022	0.0008
Credit Spread	-0.0242	-0.0006	-2.2587	-0.0039	0.0023	0.0001	-0.7906	-0.0024
International Variables								
Real Exchange Rate	-0.0032	-0.0002	0.0048	-0.0009	-0.0028	0.0001	0.0048	-0.0003

Table C.2: Differences in Unconditional Moments under Individual Shocks II

Note: This table reports the differences in unconditional means of variables under the cooperative relative to the non-cooperative equilibrium. Differences in means for all variables except inflation are scaled as the percentage change relative to the mean under the non-cooperative regime. The inflation measures are simple differences.

Scenario	Welfare Gains (Baseline)		
	λ^H	λ^F	λ^W
Baseline	-0.0970	0.0878	-0.0046
Shock decomposition			
Productivity, Home	0.0025	-0.0005	0.0010
Productivity, Foreign	-0.0563	0.0455	-0.0055
Net Worth, Home	-0.0226	0.0252	0.0013
Net Worth, Foreign	0.0206	-0.0081	0.0063
Mark-up, Home	0.0004	0.0007	0.0006
Mark-up, Foreign	0.0031	-0.0006	0.0012
Preference, Home	0.0063	-0.0043	0.0010
Preference, Foreign	0.0017	-0.0012	0.0002
Financial frictions			
$x = 0.3$	-0.5764	0.4153	-0.0818
$x = 0.18$	0.0171	0.0070	0.0120
$x = 0.05$	0.0261	-0.0057	0.0102
Investment adjustment costs			
$\kappa_I = \kappa_I^* = 2.5$	-0.3668	0.2803	-0.0438
$\kappa_I = \kappa_I^* = 5$	-0.9300	0.6969	-0.1198
Country size			
$m = 0.4$	-0.0350	0.0389	0.0094
$m = 0.25$	0.0913	0.0096	0.0300
Policy Instrument			
$\pi_{H,t}$, π_t^*	-0.0921	0.0862	-0.0030
$\pi_{H,t}$, DY_t^*	-0.0988	0.0889	-0.0050
$\pi_{H,t}$, $DNER_t^*$	-0.0956	0.0877	-0.0040
π_t, $\pi_{F,t}^*$	-1.2801	0.9773	-0.1578
π_t, π_t^*	-1.5244	1.1737	-0.1845
π_t, DY_t^*	-1.2185	0.9293	-0.1504
π_t, $DNER_t^*$	-1.6848	1.2939	-0.2066
DY_t, $\pi_{F,t}^*$	-0.1033	0.0926	-0.0054
DY_t, π_t^*	-0.0987	0.0914	-0.0036
DY_t, DY_t^*	-0.1051	0.0936	-0.0058
DY_t, $DNER_t^*$	-0.1014	0.0922	-0.0046
$DNER_t$, $\pi_{F,t}^*$	-71.2938	132.6456	-18.2786
$DNER_t$, π_t^*	-43.8462	49.3970	-8.4073
$DNER_t$, DY_t^*	-93.1062	491.7800	-36.1283
$DNER_t$, $DNER_t^*$	-18.1281	15.8816	-2.5965

Table C.3: Transitional Gains: from Non-Cooperation to Cooperation (%)

Scenario	Welfare Gains (Baseline)		
	λ^H	λ^F	λ^W
Baseline	-0.0954	0.0231	-0.0362
Shock decomposition			
Productivity, Home	0.0009	-0.0019	-0.0005
Productivity, Foreign	-0.0058	-0.0052	-0.0055
Net Worth, Home	0.0238	-0.0221	0.0009
Net Worth, Foreign	-0.0080	0.0002	-0.0039
Mark-up, Home	-0.0005	-0.0007	-0.0006
Mark-up, Foreign	0.0004	-0.0009	-0.0003
Preference, Home	0.0107	-0.0078	0.0014
Preference, Foreign	0.0062	-0.0055	0.0004
Financial frictions			
$x = 0.3$	-0.7997	0.4215	-0.1910
$x = 0.18$	0.0084	-0.0198	-0.0057
$x = 0.05$	-0.0061	-0.0118	-0.0090
Investment adjustment costs			
$\kappa_I = \kappa_I^* = 2.5$	-0.4096	0.1859	-0.1123
$\kappa_I = \kappa_I^* = 5$	-0.9945	0.5332	-0.2336
Country size			
$m = 0.4$	-0.0144	-0.0188	-0.0171
$m = 0.25$	0.0423	-0.0419	-0.0209
Policy Instrument			
$\pi_{H,t}$, π_t^*	-0.0927	0.0127	-0.0400
$\pi_{H,t}$, DY_t^*	-0.0977	0.0240	-0.0369
$\pi_{H,t}$, $DNER_t^*$	-0.0889	0.0040	-0.0424
π_t, $\pi_{F,t}^*$	-0.4053	0.0804	-0.1628
π_t, π_t^*	-0.4553	0.0569	-0.1995
π_t, DY_t^*	-0.3651	0.0634	-0.1511
π_t, $DNER_t^*$	-0.4179	0.0064	-0.2060
DY_t, $\pi_{F,t}^*$	-0.0993	0.0245	-0.0374
DY_t, π_t^*	-0.0970	0.0137	-0.0417
DY_t, DY_t^*	-0.1012	0.0253	-0.0380
DY_t, $DNER_t^*$	-0.0913	0.0041	-0.0436
$DNER_t$, $\pi_{F,t}^*$	0.0251	-3.8420	-1.9275
$DNER_t$, π_t^*	-0.0701	-2.6837	-1.3856
$DNER_t$, DY_t^*	0.7140	-5.7717	-2.5828
$DNER_t$, $DNER_t^*$	-0.0577	-1.7149	-0.8897

Table C.4: Transitional Gains: from Cooperation to Non-Cooperation (%)