Risk Premia and Coordinated Monetary Policy in a Two-country World

Hsuan Fu

Imperial College London

January 2, 2018

Abstract

I study the optimal monetary policy and the implications for equity risk premia in a two-country world. In particular, I explore the motivation for a large country to participate in monetary policy coordination. A sticky-price model with endogenous monetary actions from both countries is constructed to quantify the gains in consumption and excess equity returns. The coordinative equilibrium is generally associated with higher expected consumption and lower risk premia relative to the non-coordinative equilibrium. The smaller the country is, the larger stabilization gains from coordination would be achieved with respect to her larger neighbour. Nevertheless, monetary policy coordination is still beneficial to the large country because of the international risk sharing.

Keywords: Macro-finance, International Monetary Policy, Price Rigidities, Policy Coordination, Equity Risk Premia, Equity Home Bias

---

Hsuan Fu is from the Business School, Imperial College London, London, United Kingdom. I am grateful to Harjoat Bharma, Pasquale Della Corte, Marcin Kacperczyk, Alexander Michaelides, Tarun Ramadorai and Savitar Sundaresan for their constant supports and invaluable guidance throughout. I will present a poster of this paper in the AFA 2018 Annual Meeting in Philadelphia, Pennsylvania. I also thank Carol Alexander, Guofu Zhou, and Andrea Barbon (discussant) along with participants at the Young Finance Scholar Conference in 2016, the FMA 2016 Annual Conference, and the SFI Finance Workshop in 2016. All remaining errors are mine.

1 Introduction

Central banks of major economies, except for the Fed, have been calling for international coordination in the aftermath of financial crisis. The main concern shared by both researchers and practitioners[1] is that spillovers of the expansionary monetary policy from a large economy[2] may affect macroeconomic stability in other countries through greater risk-taking in equity market. Despite the Fed has not been supporting the proposal of monetary policy coordination, it shares the same concerns with regard to international spillovers from another large economy China.[3] The monetary policy coordination across countries, as many policymakers believe, could potentially limit the spillovers but it requires the bilateral participation of both small and large countries.

A well-known feature of USA is its enormous scale of economy. It is undoubtedly a large country even in the list of the world's top 10 economies by gross domestic product.[4] Considerable gains from monetary policy coordination were not found in the conventional model in which two countries are usually symmetric in size, among other characteristics. Country size becomes an important feature to be considered in the study of monetary policy coordination. If there exists any gain from coordination, it is intuitive that larger shares would be distributed to the small country rather than the large country. Therefore, it is essential to explore the motivation especially for a relatively large economy to get involved in monetary policy coordination.

The need to understand the scope of monetary policy coordination shall be addressed by a theoretical framework that can jointly study the dimensions of macroeconomic stability and equity risk premia. In order to establish the theoretical foundation for the support of international monetary coordination, I follow Clarida, Galí, and Gertler (2002) and propose

[1] See Stein (2014) and *the Bloomberg* (5 May 2016): "supporting stock prices is the U.S. central bank's unspoken third mandate, after full employment and stable inflation..."

[2] See Taylor (2013) and Rajan (2015).

[3] See Fischer (2015) and Yellen's speech to lawmakers in February 2016.

[4] The gross domestic product of U.S. or China is about 4.5 times larger than Japan based on the report of International Monetary Fund and World Bank in the year of 2015 and 2016.

a New Keynesian model with endogenous monetary policy and equity market in small and large countries.

My model works roughly as follows. Households and firms endogenously determine the output at country level from the tradeoff between consumption and work. International trade is needed as a small fraction of household consumption can not be perfectly substituted by locally-produced goods. The monetary policy action is correlated to exchange rate in real terms. An expansionary monetary policy that stimulates the corresponding output results in depreciation of real exchange rate. The rule of optimal monetary policy is constructed to achieve the stabilization objectives. No exchange rate policy is implemented by any central bank. Monetary policy coordination can improve the welfare in both small and large countries through internalizing the negative externality stemming from terms of trade.

Under the reasonable choice of parameter values, I show that monetary policy coordination achieves non-negligible improvements in both small and large countries.

The economic gains from monetary policy coordination can be evaluated by an increase in expected consumption and a decline in risk premia. I compare the equilibrium outcomes under coordination with non-coordination and quantify coordination gains as the first-order difference in expected consumption and equity excess return. Policy coordination is associated with larger gains in the small country with respect to the large country. The gains are decreasing in the relative country size and the degree of risk aversion. Nevertheless, participating in monetary policy coordination is still beneficial to the large country because of international risk sharing. The monetary policy coordination causes large country's terms of trade to improve so the large country can consume more units of imported goods than in the equilibrium of non-coordination.

My baseline calibration shows that coordination gains in consumption are 1.12% and 1.25% per annum, respectively for the large and small countries. In addition, policy coordination smooths out approximately 8 basis points in expected excess returns from non-coordination. These findings are quantitatively comparable to recent empirical studies. The model is calibrated to match relevant properties of U.S. data in recent 30 years. Parameters

describing shocks are chosen to match the standard deviation of real GDP, which is normally a small number compared with volatilities of financial returns. Hence, extremely high risk aversion is a common problem in macroeconomic model that occurs when one tries to match the moment of excess equity returns. A medium value of relative risk aversion (approximately 3.23) is important for having sensible interpretation of my model and can generate reasonable quantities for economic gains from monetary policy coordination.

A related question is: How monetary policy coordination influences household's investment decision. I extend the model to analyse the cross-border equity holdings in steady state. The home bias in trade, preventing two countries from perfect risk-sharing, leads to home bias in equity holdings. The degree of equity home bias depends on the correlation between exchange rate and labour income. Policy coordination makes exchange rate more negatively correlated to labour income because each policymaker responds to both home and foreign shocks. Policy coordination enhances the hedging role of local equity against with exchange rate risk. Consequently, investors enjoy higher (lower) returns on local (foreign) equities so their portfolio rebalance will results in elevated market participation.

The contribution of the paper can be evaluated in three different aspects. First, I endogenize foreign policy actions into the policy function of each country and demonstrate the distorted steady state under policy competition. I show that policy coordination can generate positive, first-order consumption gains, echoing recent call from major policymakers for policy coordination. Second, I bridge the theoretical gap between optimal monetary policy and equity risk premia in an international context. This can extend the closed-economy implications already discussed in the literature and help us to understand better the real effect of monetary transmission to risk premia. In particular, lower excess returns and higher market participation implied by policy coordination provide important policy implications for all countries. Third, I study the effects of multiples shocks on macroeconomic and financial variables in a calibrated framework. Additional shocks and frictions can be added to improve the quantitative performance.

This paper joins the macroeconomic literature of international monetary policy coordination. The conventional view of sticky-price models suggested limited welfare gains from

policy coordination, such as Obstfeld and Rogoff (2002), Benigno and Benigno (2003), Pappa (2004), Woodford (2007), and Haberis and Lipinska (2012), among others. A few papers documented the existence of coordination gains after introducing additional frictions, including mark-up shocks in Benigno and Benigno (2006), imperfect exchange-rate pass-through in Corsetti and Pesenti (2001), hedging demand due to higher risk aversion in Clarida, Galí, and Gertler (2002), and asymmetric trading structure in Liu and Pappa (2008).

This paper also contributes to the literature that studies the impact of monetary policy on asset prices. The empirical evidence on multiple asset classes has been documented with both single- and multiple-country data, such as Bernanke and Kuttner (2005), Bekaert, Hoerova, and Duca (2013), Bruno and Shin (2014), Stein (2014), Lucca and Moench (2015), Rogers, Scotti, and Wright (2014), and Mueller, Tahbaz-Salehi, and Vedolin (2017). Yet, the most related theory papers still focus on the models with closed economy and pre-determined policy rules, e.g., Jermann (1998), Bhamra, Fisher, and Kuehn (2011), Li and Palomino (2014), Weber (2015), Diercks (2015), Drechsler, Savov, and Schnabl (2017), Cochrane (2016), and Coimbra and Rey (2017). Recent efforts to rationalise the international risk premia are either bearing restrictive assumption such as no cross-border investment in Engel (2016) or using Real Business Cycle models without the input of monetary policy. See Devereux and Sutherland (2011), and Coeurdacier and Rey (2013).

Last but not least, a particular dimension of international policy coordination is discussed in this paper. Other related issues have been explored in the literature, specifically in the tradeoff between flexibly exchange rte and monetary autonomy in Devereux and Engel (2003), currency war at zero lower bound in Caballero, Farhi, and Gourinchas (2008), currency war between advanced and emerging economies in Svensson (2003), Eichengreen (2013), unconventional and coordinated monetary actions in Gertler and Karadi (2011), Mohan and Kapur (2014), fiscal policy coordination in Aguiar, Amador, Farhi, and Gopinath (2015), and the credit market dynamic in Cúrdia and Woodford (2016).

2 Model

My two-country production economy is similar to that in Clarida, Galí, and Gertler (2002). Each country has three players, including a representative household, a continuum of firms, and one central bank. The exchange rate is under floating regime. The financial markets are complete to the national level. Risk-sharing across two countries is efficient but not perfect due to home bias and heterogeneity in country size. One may find Figure 1 useful for visualising my New Keynesian model.

A Households

I study a two-country model with production economy. I assign numbers $i = \{1, 2\}$ to subscribe the economic variables related to consumers and alphabets $j = \{H, F\}$ to those variables related to production sectors. In country i, the utility function per capita (household) takes the form of

$$U_{i,t} = \log C_{i,t} - \frac{N_{i,t}^{1+\varphi}}{1+\varphi}.$$

where N_i is labour supply, and Frisch elasticity φ is the rate of substitution between wage rate and labour hours. Households maximize the utility function subject to the following intertemporal budget constraint,

$$E(S_{i,t+1}) \leq S_{i,t}[1 + E(R_{i,t+1})] + \frac{W_{i,t}}{P_{i,t}} N_{i,t} - C_{i,t}. \tag{1}$$

W_i is nominal wage rate, and P_i is the consumer price index (CPI) which is aggregated to the national level and representing the value of each consumption bundle in local currency. S_i is the financial wealth held by each household and R_i is its rate of return. I will describe the financial market in later sections.

Assumption 1 *Assume labour immobility. Labour market is cleared when labour supply equates demand, $N_i = N_j$. For brevity, I drop the notation of N_i from now on.*

Note that the consumption bundle C_i for each representative agent is expressed as Cobb-Douglas functions of domestic and imported goods,

$$C_{1,t} = C_{1,H,t}^{\alpha_1} C_{1,F,t}^{1-\alpha_1} \qquad C_{2,t} = C_{2,F,t}^{\alpha_2} C_{2,H,t}^{1-\alpha_2}.$$

As there are two consumers and two production sectors, four types of consumption goods are of different quantities. Correspondingly, there shall be four types of prices paid in local currency. CPI of each country serves as a Cobb-Douglas aggregator of prices of different goods but denominated in the same currency. Households choose the consumption bundle in their maximisation problems and allocate the quantities to two types of goods according to their preferences. The home bias parameter capturing household preference is denoted as $\alpha_i \geq 1/2$. In the macroeconomic literature, $(1-\alpha_i)$ indicates the openness of each country.

B Firms

I assume there is a continuum of firms in each country. Each firm, indexed by $k \in [0,1]$, produces differentiated goods by linear technology $Y_{j,t}(k) = A_{j,t} N_{j,t}(k)$. The profit-maximisation problem for a fraction of flexible-price firms is

$$\max_{P_{j,t}^*(k)} \sum_{l=0}^{\infty} \theta^l E_t \left\{ \Lambda_{i,t,t+l}^{\$} \left[P_{j,t}^*(k) Y_{j,t+l|t}(k) - (1-\Phi) \frac{W_{j,t+l|t}(k)}{A_{j,t}} \right] \right\}$$
$$\text{s.t. } Y_{j,t}(k) = \left[\frac{P_{j,t}(k)}{P_{j,t}} \right]^{-\epsilon} Y_{j,t},$$

where the stochastic discount factor is aligned with household i because the firms aggregated to country level are owned by the representative household.

Monopolistic competition and price rigidity a la Calvo are standard New Keynesian frictions that ultimately lead to price distortion.[5] Note that the average price markup is increasing in the degree of imperfect competition and decreasing in ϵ. In addition, price

[5] See Galí (2015) Ch.3 for more information regarding friction specifications in New Keynesian models.

rigidity is increasing in θ, a fraction of firms are assumed to keep their prices unchanged in any period t.

Assumption 2 *Each fiscal authority chooses a rate of subsidy* Φ[6] *in order to correct the distorted output due to monopolistic competition. I assume that both fiscal authorities have access to lump-sum taxes and pursue a Ricardian fiscal policy at all time.*

There are at least two potential advantages of introducing the subsidy. First, the distortion from flexible-price equilibrium can be mostly restored. However, I am unable to fully recover competitive equilibrium as both Home and Foreign policies generate negative spillovers transmitted via terms of trade. Second, it separate the details of the fiscal policy from monetary policy-making process, as suggested by Sims (1994), Woodford (1994), Christiano, Eichenbaum, and Evans (2005), etc.

C Terms of Trade

The terms of trade is defined as the unit price of Home goods in terms of the unit price of the Foreign goods. I follow Backus and Smith (1993) in computing a competitive equilibrium as the solution to a social planning problem. With Assumption 3, Corollary 2, and nominal exchange rate to be defined as efficient in risk-sharing, I can pin down terms of trade as

$$Q_t = \frac{\eta}{1-\eta}\frac{\Psi_1}{\Psi_2}\frac{Y_{F,t}}{Y_{H,t}}. \tag{2}$$

The constant Ψ_i for $i = \{1,2\}$ are size-weighted preferences of two households towards each goods. The detailed expression will be addressed by market clearing condition in Corollary 2.

[6]To keep my notation clean, I ignore the country-specific subscription for Φ, ϵ, and θ. However, the calibrated parameters vary across countries.

Assumption 3 *Law of one price assumes the same type of goods must have the same price if denoted in the same currency,*

$$P_{1,H} = \mathscr{E}P_{2,H} \qquad P_{1,F} = \mathscr{E}P_{2,F}.$$

If a cross country allocation is Pareto optimal, it is a standard result that the marginal utilities are proportional to the weights in a social planner's optimisation problem.[7] In my model, these weights are interpreted as country size or share of economic body as in Pavlova and Rigobon (2007).

$$\eta U_1' = (1-\eta)U_2'. \tag{3}$$

As shown by Backus and Smith (1993), one can derive efficient risk-sharing condition below by using market clearing conditions in Corollary 2 and the definition of terms of trade (2). The real exchange rate under efficient risk-sharing can be pinned down as

$$E = \frac{1-\eta}{\eta}\frac{C_1}{C_2}.$$

Nominal exchange rate can be denoted with aggregate price levels of both countries, i.e., $\mathscr{E} = EP_1/P_2$. Note that risk-sharing is perfect only for certain choice of size or home bias parameters that I will explain further in Corollary 1. Abstracting from perfect risk-sharing, I find PPP generally fails and the large country has stronger purchasing power than the small counterparty.

Corollary 1 *Perfect risk-sharing occurs only when the preference parameters of two countries related to local goods, i.e., the home bias paratmeters, are binding at the case of no home bias,* $\alpha_1 = \alpha_2 = \alpha = 1/2$.

The sharing rule under competitive equilibrium is

$$\frac{C_2}{C_1} = \frac{1-\eta}{\eta}Q^{\alpha_1+\alpha_2-1}.$$

[7] See Chapter 7 in Back (2010).

The no home bias condition $\alpha_1 + \alpha_2 = 1$ neutralises the variation in terms of trade, leading to Pareto optimality (3). By construction, home bias parameters are assigned values no less than 1/2. Therefore, the only possibility to completely neutralise the terms-of-trade variation is to set both home bias parameters binding at 1/2. Otherwise, when home bias arises $\alpha > 1/2$, the variation in terms of trade would prevent the risk-sharing from being perfect.[8]

Corollary 2 *When international market is cleared for each type of goods, I can express country-specific output as a function of time-varying consumption and terms of trade as well as constant including weighted preferences and home bias,*

$$Y_H = C_1 Q^{-(1-\alpha)} \Psi_1 \qquad Y_F = C_2 Q^{1-\alpha} \Psi_2$$ [9]

Market clearing condition is the last element to pin down terms of trade (2). Aggregate supply in each country shall be cleared by demands of two households. Heterogeneous size of country plays an important role, e.g., Home aggregate supply is $Y_H = C_{1,H} + \frac{1-\eta}{\eta} C_{2,H}$ and in Foreign country $Y_F = \frac{\eta}{1-\eta} C_{1,F} + C_{2,F}$. The size effect is largely reduced when households have high-order risk aversion. It follows that the trade balance is zero within each country, $P_j Y_j = P_i C_i$.[10]

[8] Home bias in trade, firstly documented by McCallum (1995), is one of the six major puzzles in international macroeconomics, discussed by Obstfeld and Rogoff (2000) and has been used to explain the equity home bias puzzle in Hau and Rey (2008), and Coeurdacier and Rey (2013).

[9] The constant Ψ contains two parts. The first part comes from the aggregate price and is completely determined by country-specific home bias,

$$\tau(\alpha) = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}.$$

Note that τ is decreasing in home bias (α). The second part is weighted preferences of both households towards the same goods,

$$\Psi_1 = \left[\alpha_1 + (1-\alpha_2)\left(\frac{1-\eta}{\eta}\right)^2\right]\tau(\alpha_1) \qquad \Psi_2 = \left[\alpha_2 + (1-\alpha_1)\left(\frac{\eta}{1-\eta}\right)^2\right]\tau(\alpha_2),$$

where Ψ is decreasing in relative size of local country. More derivation details can be found in Internet Appendix.

[10] It would be more realistic to consider international borrowing as in De Paoli (2009b) and banking sectors as in Gertler and Kiyotaki (2010).

D Equilibrium

Three-Equation Model is the well-known results for log-linearised New Keynesian Model. My model aims to approximate the non-linear version. Below I construct the general equilibrium of my model by listing six building blocs in each country. Below I express logarithm variables in lowercase letters, e.g. $x = \log X$, and I use tilde to denote log deviations from the flexible price equilibrium, e.g. $\tilde{x} = \log(X/X^n)$.

► **1. Investment-Saving (IS) Curve**

The nominal discount factor is the optimal condition from by households' maximisation problem,

$$\Lambda_{i,t,t+1} = e^{\delta_i} \Pi_{i,t+1} \frac{C_{i,t+1}}{C_{i,t}}, \tag{4}$$

where $\Pi_{i,t+1} = P_{i,t+1}/P_{i,t}$ is the inflation of consumer price index (CPI).

► **2. Price Dispersion and Aggregation**

Since I consider stickiness only in prices not wages, I can easily incorporate the dynamics of price dispersion into price aggregation. Price dispersion is equal to aggregate price level divided by rest price, $DS_{j,t} = P_{j,t}/P^*_{j,t}$ and its evolution is

$$DS_{j,t} = (1-\theta)\left(\frac{P^*_{j,t}}{P_{j,t-1}}\right)^{-\epsilon} + \theta\left(\frac{1}{\Pi_{j,t}}\right)^{-\epsilon} DS_{j,t-1}. \tag{5}$$

Aggregate price level divided by that of previous period can be expressed in two parts: a fraction θ of firms who couldn't adjust their prices and the other fraction $1-\theta$ who could reset prices to P^* in order to maximise their profits.

$$P^{1-\epsilon}_{j,t} = \theta P^{1-\epsilon}_{j,t-1} + (1-\theta) P^{*1-\epsilon}_{j,t}. \tag{6}$$

► **3. Phillips Curve (NKPC)**

The profit-maximised price set by each firm k in country j is denoted as $P^*_{j,t}(k)$. With the aggregate price index $P^*_{j,t} = \int_0^1 P^*_{j,t}(k)dk$, I can re-write it recursively by the following three equations

$$\begin{aligned} P^*_{j,t}X_{j,t} =& \mu_{\epsilon_j}\frac{W_{j,t}}{A_{j,t}}Z_{j,t}e^{u_{j,t}}, \\ X_{j,t} =& 1+\theta_j e^{-\delta_i}\Pi^{\epsilon_j-1}_{j,t+1}X_{j,t+1}, \\ Z_{j,t} =& 1+\theta_j e^{-\delta_i}\frac{W_{j,t+1}}{W_{j,t}}\frac{A_{j,t}}{A_{j,t+1}}\Pi^{\epsilon_j-1}_{j,t+1}Z_{j,t+1}. \end{aligned}$$

► **4. Real marginal cost (RMC)**

Real marginal cost that can also be viewed as real wage per unit of productivity plays an important role between household and firms. The tradeoff between household consumption and labour supply yields the equilibrium condition,

$$\frac{W_{i,t}}{P_{i,t}} = N^{\varphi}_{i,t}C_{i,t} \quad \Rightarrow \quad \frac{W_{j,t}}{P_{j,t}A_{j,t}} = N^{1+\varphi}_{j,t},$$

I make use of labour immobility that leads to $N_i = N_j$ and $W_i = W_j$ and zero trade balance $P_iC_i = P_jY_j$s from Corollary 2.

► **5. Exogenous Shocks**

The optimal design of monetary policy is analysed in environments where central bank is faced with tradeoff between stabilisation targets. It is impossible for central bank to target output gap at zero period by period. I assume central bank can only target output gap within the neighbourhood of zero. The distance to zero output

gap is time-varying and known in literature as cost-push shock.[11] The log cost-push shock[12] is assumed to follow an AR(1) process,

$$u_{j,t} = \rho_u u_{j,t-1} + \varepsilon_t^u.$$

► **6. Discretionary Monetary Policy**

To close the model, I shall describe the optimal policy rule in each country. A welfare-based analysis is conducted to develop a *flexible inflation targeting*[13] rule of monetary policy. By Corollary 2, I can re-express the IS curve (4) in log terms with outcome variables from New Keynesian model,

$$i_{i,t} = \delta_i + (\tilde{y}_{j,t+1} - \tilde{y}_{j,t}) + \pi_{j,t+1} + \nu_{i,t}, \tag{7}$$

where ν_t is monetary policy shock. Abstracting from the simple, pre-determined Taylor rules, here the optimal policy is a forward-looking Taylor rule containing time-varying inflation and output targets.

The caveat of discretionary policy is the (inefficiently high) inflation bias discussed in Kydland and Prescott (1977), among others. The policy with commitment could fix this bias because a credible commitment to fight inflation in the future time can improve the current welfare level. The commitment gain was demonstrated in the classical paper by Clarida, Galí, and Gertler (1999) as well as in the continuous-time model by Werning (2011). However, how realistic it is to presume full credibility of central banks' commitment remains still a ongoing debate. It is less intuitive to impose such presumption in the context of international policy coordination. In addition, high inflation has not been a concern

[11] See Li and Palomino (2014) for permanent economic shock and Diercks (2015) for long run risk specified in technology shock. I do not incorporate the permanent shocks in the model as the asset pricing implication is drawn from equity excess returns. The permanent component of macroeconomic shocks would eventually be priced in the nominal bond returns which are subtracted from the excess return calculation.

[12] The productivity shocks have the same formulation as the cost-push shock, following Ch. 5 in Galí (2015).

[13] The term *flexible inflation targeting* was coined by Lars Svensson, to refer to the monetary policies that result from the minimization of a central bank loss function. More details will be presented in later sections.

for advanced economies in the aftermath of the recent financial crisis. In this paper, I will discuss the policy rules only with discretion.

3 Optimal Monetary Policy Regimes

To achieve optimal policy, each policy-maker choose endogenous variables $\{i, \tilde{y}, \pi\}$ to minimise its domestic welfare loss subject to the log-linearised constraints of IS curves and NKPCs. Under competition, policy-makers only maximise welfare of their own countries. Alternatively, policy-makers under coordination agree to maximise global welfare weighted by country size.

I focus on deriving *discretionary* optimal policy where central banks are lack of commitment on monetary policy.[14] Policy-makers thus need to figure out the optimal targets of inflation and output gap period by period. The policy effect cannot be carried on to the next period regardless of competition or coordination. Therefore, I expect to find very similar quantities in risk premia under coordination and competition.

Corollary 3 *The implementation of optimal policy can be described as a flexible-inflation targeting rule as in Cúrdia and Woodford (2016)*

$$i_t = r_t^e + \underbrace{(1-\epsilon)}_{(-)} \pi_{t+1}^{OP} + \underbrace{(\epsilon-\phi)}_{(+)} \pi_t^{OP} + \phi \pi_t, \tag{8}$$

where efficient risk free rate is $r_t^e = \delta - (1-\rho_a) \cdot a_t$ *and* δ *is time discount rate. Note that the accommodative degree of policy-making increases in Taylor coefficient and decreases in the market power of production sectors.*

The nominal rate follows a forward-looking Taylor rule in (7). However, the structural equations do not guarantee a unique solution because the condition proposed in Blanchard and Kahn (1980) is not satisfied. Following Galí (2015) Ch.5, an additional term

[14] There are papers focusing on the welfare improvement brought by policy with commitment as opposed to discretion, such as Galí (2015) and Werning (2011). In this paper, I only discuss on discretionary policy and focus the comparison across equilibria of competition and coordination.

$\phi\left(\pi_t - \pi_t^{OP}\right)$ is appended to the policy rule. Taylor principle requires $\phi > 1$ in order to guarantee a unique equilibrium.[15]

A Non-coordinative Monetary Policy (NC)

The standard approach to explore optimal monetary is to minimize a quadratic loss function. The optimal targeting rule carries opposite signs for the paths of output gap and inflation. The welfare function is formulated to be the deviation from efficient allocation measured as a fraction of steady state consumption basket, $\mathscr{W} = \frac{U_t - U^n}{U_C C}$.[16]

In a Nash equilibrium, I minimise the objective function of each country separately. The welfare function in each country is derived by the "timeless perspective" proposed by Woodford (1999),

$$\mathscr{W}_{j,t} \approx \underbrace{(1-\alpha)\tilde{y}_{j,t}}_{\text{terms-of-trade component}} \underbrace{-\frac{1+\varphi}{2}\left[\frac{\epsilon}{\kappa}\pi_{j,t}^2 + \tilde{y}_{j,t}^2\right]}_{\text{quadratic components}} + t.i.p., \tag{9}$$

where $\kappa = (1-\theta)(1-e^{-\delta}\theta)(1+\varphi)/\theta$ is a constant term from Phillips curves and $t.i.p.$ collect those terms independent of national policy-making, including Foreign output gap and inflation. Note that the quadratic components from the same equation has the standard quadratic formulation as in the closed or small open economy. The linear component in equation (9) comes from Corollary 2. It is novel from existing literature as policy-makers in my setup have to deal with international spillovers.

The optimal condition under competitive equilibrium has identical formula for each country

$$\tilde{y}_{j,t}^{OP} = -\frac{1-\alpha_i}{1+\varphi_i} - \epsilon_i \pi_{j,t}^{OP}. \tag{10}$$

[15] The BK condition can hold when the household preferences are assumed as Power utility ($\gamma > 1$). Thus the additional term is no longer needed when households have higher degree of risk aversion. I introduce Taylor coefficient only in the case of myopic household ($\gamma = 1$).

[16] By taking the advantage of logarithm utility, I can drop the denominator $U_C C = 1$. This advantage continues to exist in the welfare function of the social planner.

Each policy-maker aims to target the output lower than its steady state ($\tilde{y}_t < 0$) because the consumption of imported goods is exacerbated by stimulation to domestic production sector. Terms of trade depreciates when Home output rises. This mechanism does not exist in any closed economy nor small open economy. The deviation from targeting zero gap of output is mitigated when home bias is larger and market power of production sectors is weaker. As a consequence, the equilibrium inflation would be on average negative for both countries. Competitive equilibrium leads to a global recession.

B Coordinative Monetary Policy (C)

Next, I derive the welfare loss function for a social planner in order to study the pareto-optimal allocation across countries. The maximisation of a social planner's welfare function is a standard way to study policy coordination across countries. In this particular case, Home and Foreign countries agree to maximize the global welfare weighted by country sizes, following the literature such as Clarida, Galí, and Gertler (2002).

The social planner also has a logarithm utility function. It is convenient to interpret the social planner's utility function which is an aggregate utility function across two countries, $\ln C = \eta \ln C_1 + (1-\eta)\ln C_2$. From the timeless perspective, the loss function for social planner is

$$\begin{aligned}\mathscr{W}_{g,t} \approx \lambda_q(\tilde{y}_{H,t} - \tilde{y}_{F,t}) - \frac{\eta(1+\varphi_1)}{2}\left[\frac{\epsilon_1}{\kappa_1}\pi_{H,t}^2 + \tilde{y}_{H,t}^2\right] \\ - \frac{(1-\eta)(1+\varphi_2)}{2}\left[\frac{\epsilon_2}{\kappa_2}\pi_{F,t}^2 + \tilde{y}_{F,t}^2\right] + t.i.p.,\end{aligned}$$

where the coefficient captures the adjusted difference of terms-of-trade exposure,

$$\lambda_q = (1-\alpha_1) - \frac{1-\eta}{\eta}(1-\alpha_2).$$

The aggregate optimisation problem can achieve at least the same or higher globally aggregate welfare than the Nash problems. It is always beneficial to coordinate from

a global perspective. The relevant question becomes whether it remains beneficial or incentive compatible from perspective of each country.

Proposition 1 *International policy coordination is welfare-improving for both countries when considering international spillovers and imperfect risk-sharing. In particular, country of smaller size and smaller home bias benefits more from the policy coordination.*

Next, I use asterisk to indicate the optimal output gaps under coordination. The optimal output gap without asterisk is from the equilibrium of policy competition.

$$\tilde{y}_{H,t}^{OP^*} = \tilde{y}_{H,t}^{OP} + \underbrace{\frac{1-\eta}{\eta}(1-\alpha_2)}_{(+)} \qquad \& \qquad \tilde{y}_{F,t}^{OP^*} = \tilde{y}_{F,t}^{OP} + \underbrace{\frac{\eta}{1-\eta}(1-\alpha_1)}_{(+)}.$$

Similar to Clarida, Galí, and Gertler (2002), I show that the FOCs under coordination are different from that under competition. The target of output gap is improved for both countries. The degree of improvement is determined by country size and home bias. Small country benefits more than large country and country with large home bias has lower incentive to participate in coordination. Empirical estimates indicate the U.S. as large country with high home bias relative to other large economic bodies in the world. It is consistent with my model that the Fed is not prone to policy coordination.

I must be more careful about the comparison of different equilibria. As mentioned in Benigno and Benigno (2006), the steady states may vary between competitive and coordinative equilibria. Therefore, one has to coincide both equilibria in order to have a meaningful comparison. To avoid such concern, I choose to focus on the comparison of per-capita welfare or consumption levels.

C Power Utility Specification

It is challenging to match the moments of equity risk premia under the assumption of logarithm preferences. Thus, I must consider higher relative risk aversion $\gamma > 1$ in the baseline calibration. In this subsection, I will briefly explain the main impact which occurs to the weights of social planner's loss function.[17]

Relative risk aversion plays an important role in mitigating the difference in weights that originally comes from difference in country size. Note that the definition of welfare loss function is expressed as a fraction of aggregate consumption which is generally of different values at country and global levels.[18] Therefore, I adjust the total consumption at country level to global level when aggregating loss functions across countries.

$$\mathscr{W}_{g,t} = \underbrace{\eta \frac{U'(C_1^n)C_1^n}{U'(C_g^n)C_g^n}}_{\Theta_1} \mathscr{W}_{H,t} + \underbrace{(1-\eta) \frac{U'(C_2^n)C_2^n}{U'(C_g^n)C_g^n}}_{\Theta_2} \mathscr{W}_{F,t}.$$

To further simplify the social planner's loss function, I normalise the Home weight to 1.

$$\mathscr{W}_{g,t} \equiv \mathscr{W}_{H,t} + \Theta \mathscr{W}_{F,t}, \quad \text{where} \quad \Theta = \frac{(1-\eta)\Theta_2}{\eta\Theta_1} = \left(\frac{1-\eta}{\eta}\right)^{1/\gamma}.$$

The normalised Foreign weight is important in allocating the coordination gains despite that weighting issue becomes trivial[19] $\Theta \to 1$ in the limiting case of extremely high risk aversion $\gamma \to \infty$. Figure 2 shows normalised Foreign weight remains non-trivial with high risk aversion especially when there is large difference in country size.

[17] See more details in Appendix D where I demonstrate how to modify the current structural models when households are assumed to have power utility.

[18] I use a CES aggregator to sum up the consumption of both countries as $C_g = f(C_1, C_2)$. The specification of global consumption does not play any significant role as it will be eliminated when I normalise weights between two countries later.

[19] The case of equally-sized countries is trivial but it is a common assumption in open economy literature, e.g., Obstfeld and Rogoff (2002), Benigno and Benigno (2003), Pappa (2004),etc. Conventionally, the relative weights are always at unity regardless of the degree of risk aversion.

4 Financial Market

There are four securities available for trading in my two-country economy, including equity and bond in each country. Since the total number of shocks are equal to the number of traded securities, the financial market is potentially dynamically complete. For any given dividend process, there exists an optimal portfolio choice process that satisfies the intertemporal budget constraint in (1) and drives the evolution of financial wealth process. Since the optimality of portfolio choice is considered implicitly in stochastic discount factor $\Lambda_{i,t,t+l}$, it is sufficient to focus on evaluating real price of optimal wealth process[20] by means of no arbitrage principle

$$S_{i,t} = E_t\left(\sum_{l=1}^{\infty}\Lambda_{i,t,t+l}D_{i,t+l}\right). \tag{11}$$

The real dividend flows $D_{i,t}$ in (11) is the CPI-deflated value of nominal dividends which are generated by one goods but household-investors use them to exchange for a combination of two goods. Therefore, real dividends are obtained by using CPIs to deflate nominal dividends from each production sector, $D_1 = P_H Y_H\left(1-\frac{W_H}{P_H^* A_H}\right)/P_1$ and $D_2 = P_F Y_F\left(1-\frac{W_F}{P_F^* A_F}\right)/P_2$.

The gross return of the wealth process includes capital gain and dividend yield. Following Li and Palomino (2014), I calculate excess return by netting the gross return of nominal interest rate in Equation (8)

$$XR_{i,t} = \frac{S_{i,t+1}+D_{i,t+1}}{S_{i,t}} - (1+i_{i,t}).$$

Proposition 2 *Policy coordination can smooth out the excess risk premia for risk-averse household-investors. The consumption gain from coordination as opposed to competition results in lower risk premia. The calibrated quantity is comparable to the empirical evidence of monetary policy from event studies.*

[20] See Back (2010) Ch. 8.

A Cross-border Equity Holdings

In order to understand the role of macroeconomic risks in asset pricing, I have to further investigate the cross-border equity holdings. I follow Coeurdacier and Rey (2013) in deriving the "zero-order" portfolio, meaning the mean equity holdings around the steady state.[21] For $i, j = \{1, 2\}$ and $i \neq j$, the budget constraint at steady state can be re-arranged from (1)

$$C_i = (W_i/P_i)N_i + \chi D_i + (-\chi)D_j,$$

where χ is the parameter of local equity holdings and I drop the country subscription due to ex-ante symmetry assumption. D_i and D_j are dividends generated by local and foreign production sectors. The foreign equity holding is $(-\chi)$ as each equity market has zero net supply. Since I do not prevent any investor from international investment, the financial wealth is the sum of domestic and foreign investment, $S_i = \chi D_i + (-\chi)D_j$. It is also the real price of equity (11) at steady state.

In what follows, I define a notation $\hat{x}$ as the difference of Home relative and Foreign variables in terms of log deviations, i.e. $\hat{x} = \tilde{x}_H - \tilde{x}_F$. The difference of output gaps can be re-expressed in terms of trade gap

$$\hat{y} = -\left[\frac{2\alpha - 1}{\gamma} + 2(1-\alpha)\right]\tilde{q} = -\lambda\tilde{q}.$$

Note that $0 < \lambda \leq 1$ when $\alpha \geq 1/2$. The negative relation as in Coeurdacier and Rey (2013) implies that terms of trade worsens when the relative supply of Home goods increases as Foreign goods become scarcer. When $\lambda < 1$, the change in the relative supply causes larger variation in real exchange rate. This property makes investors reduce their exposure to international investment.

[21] There are two recent papers, Devereux and Sutherland (2011) and Coeurdacier and Rey (2013), studying the equity holding decomposition respectively in an endowment economy and with a Real Business Cycle model. The first step to derive the equity holdings in Devereux and Sutherland (2011) is to perturb equity returns to at least the second order. The first-order equity holdings require a third-order approximation on stock returns and so on. The perturbation is more challenging in case of flexible inflation targeting policy. I leave it for future studies and focus on deriving "zero-order" portfolio in this paper.

The optimal holdings are solved as $\chi = (1-\text{EHB})/2$. Note that equity home bias (EHB) term takes negative value due to negative covariance between terms of trade and relative labour income.

$$\text{EHB} = \left(\frac{1}{\gamma} + \frac{1+\varphi}{2\alpha-1} \underbrace{\frac{\sigma^2_{\hat{n}}}{\sigma_{\tilde{q},\hat{n}}}}_{(-)} \right)^{-1},$$

where the first component $1/2$ is the fully diversified benchmark as in Lucas (1982). The negative covariance dominates the sign of the second component especially when the degree of risk aversion is high. I also show that investors shall depart from full diversification in respond to exchange rate risk and labour income risk. The result is aligned with Coeurdacier and Rey (2013). Policy coordination reduces the labour income risk and makes relative labour income more negatively correlated to terms of trade. In consequence, it encourages domestic investors to increase the degree of equity home bias with a larger long position in local equity and short position in foreign equity.

5 Calibration

The calibration at quarterly frequency matches the properties of US data ranging from the year of 1982 to 2011. Most models in the literature are calibrated to match several second moments as the main interests lie in economic uncertainty. Matching some of the first moments in my model is essential because the average consumption and equity return can also generate economic implications with sensible quantities.

Table 1 presents the values for the baseline calibration[22]. Following Pavlova and Rigobon (2007), the country-size parameter is set as $\eta = 0.867$, representing the size of US economy while the total size of US and UK is normalised to unity. The home bias parameter is chosen as $\alpha = 0.7$ for both countries.[23]

[22] Except for the excess return series downloaded from French's website, all other parameters are selected from the literature.

[23] Note that Pavlova and Rigobon (2007) calibrated the home bias parameters for the US and UK to be 0.863 and 0.601 respectively. Similarly, Hau and Rey (2008) documented the home bias in the US to be higher than other countries and a great heterogeneity across advanced and emerging economies.

The parameter value of relative risk aversion γ is set as 31.65 to match the mean[24] return of 6.5% in the US equity market. This value is still higher than the choice of 10 implied by long run risk model in Bansal and Yaron (2004), and is twice the value estimated from the experimental evidence by Barsky, Juster, Kimball, and Shapiro (1997). Nevertheless, it is significantly lower than required by sticky-price models. For instance, risk aversion parameter is 84.5 in Li and Palomino (2014) and around 1,000 in Tallarini (2000). In the production economy, a fraction of consumption risk could be self-hedged by adjusting the labour supply. Therefore, γ alone is overestimating the degree of risk aversion, as argued by Swanson (2012). A comparable coefficient of relative risk aversion shall incorporate the labour- and firm-related parameters,

$$\frac{\gamma}{1+\frac{\gamma}{\varphi\mu_\epsilon}} \approx 3.23$$

which is indeed a popular choice in the conventional asset pricing models of endowment economy. As for the subjective discount factor, I transform the quarterly value reported by Li and Palomino (2014) into quarterly value as $\delta = 2.16\%/4$.

Parameter values of New Keynesian variables are selected from Galí (2015). I set the inverse of Frisch elasticity equal to 3.[25] The monopoly power in each country is set as $\epsilon = 6$ which implies a 20% average markup[26] in steady state. The price rigidity measure is $\theta = 0.67$ implying an average price duration of three quarters. The Taylor coefficient $\phi = 1.5$ is aligned with Taylor (1999) original estimate by using US data[27] during post-Breton Woods Era. Following Smets and Wouters (2007), I choose the autoregressive parameter for the production and cost-push shocks as $\rho_a = 0.95$ and $\rho_m = 0.8$ respectively.

[24] An attempt to match the second moment of excess returns during the sample period requires smaller $\gamma = 12.8$ but the calibrated mean of excess returns would be too small quantitatively. Alternatively, the attempt to match the Sharpe ratio as in Li and Palomino (2014) requires much larger γ where the calibrated means would be unreasonably large for economic interpretation. The reasonable γ is likely to fall between 12.8 and 31.65.

[25] My choice falls within the range $\varphi \in [2.5, 3.33]$ estimated by Vissing-Jørgensen (2002) from the group of stockholders.

[26] Weber (2015) calibrated the monopolistic power to be smaller, $\epsilon \in [8, 12]$.

[27] Clarida, Galí, and Gertler (1998) reported the estimated inflation coefficient by German is between 1.10 and 1.37 and by US is between 1.05 and 2.20. My calibration does not require Taylor coefficient anymore to guarantee a unique solution when the risk aversion parameter is chosen to be higher than 1.

The quarterly standard deviation of productivity shock is set as 0.0085 following Weber (2015). As for the cost-push shocks and monetary policy shocks, I use the same standard deviation as instructed by Galí (2015).

A Quantitative Results

Table 2 summarises the model-implied results together with empirical data. In column (1) the risk aversion parameter is chosen to match the first moment of equity excess return, and column (4) is to match its second moment. Columns (2)–(4) in the table allow me to test the sensitivity of the choice of risk aversion parameter. The volatilities of calibrated macroeconomic variables decrease in the degree of risk aversion. My model calibration generates more volatilities in the macroeconomic variables when households are less risk averse. Conversely, the financial variables increase in the degree of risk aversion. The intuition is aligned with the asset pricing literature that higher risk aversion is associated with higher required rate of returns in risky assets (equity).

B Impulse Response Functions

Cost-push shock and monetary policy shock are the main uncertainty in policy-making. Studying impulse response function (IRF)[28] is an intuitive approach to understand how these shocks propagate to other economic variables. Figure 3 shows the IRF of Home policy shock. Although the paths are not exactly the same, the directions of each IRF are consistent under different equilibria. The contractionary policy shock leads to currency appreciation in Home country. Then, a fall in Home consumption is followed but it is a good news for Foreign consumption growth. In consequence, I observe a fall in Home risk premium and a boom in Foreign counterpart. For both countries, it is consistent to find higher consumption (Proposition 1) and lower risk premia (Proposition 2) under coordinative equilibrium. Though the IRF under coordination for Home consumption is

[28] IRFs are widely shown in the macroeconomic literature, e.g., Benigno and Benigno (2003), Haberis and Lipinska (2012), Li and Palomino (2014), among others.

observed to be below its counterpart under competition, I must stress the steady state consumption[29] under the same equilibrium has much higher value. Therefore, the findings in Figure 3 sustain Proposition 1.

Figure 4 demonstrate a different pattern of propagation by Home cost-push shock. It is a type of shock that strikes the pricing behaviour within the production sector. A positive cost-push shock implies those who can adjust prices in a sticky-price production sector overprice their goods prices. Home cost-push shock implied Home goods become more expensive than Foreign ones. Therefore, the real exchange rate appreciates. The fact that Home goods become more expensive oppresses both Home and Foreign consumption under competitive equilibrium. The risk premia are quantitatively similar between policy competition and coordination. Under coordinative equilibrium, Foreign consumption slightly rises in response to Home cost-push shock as it benefits from deeper exchange rate depreciation.

6 How large are the gains from policy coordination?

The analysis of Section 3 demonstrates that there are potential gains from policy coordination although the scale of gains remains negligible in this line of literature.[30] The real exchange is endogenous in my model as I did not disconnect the link between terms of trade and the relative output of two countries. This generates the first-order gains from coordination as shown by Pappa (2004) and De Paoli (2009a) that central banks have certain incentive to increase domestic welfare via the terms of trade channel. The gains (differences) from policy coordination is reported in Table 3.

[29] The difference of steady state variables is reported in the last column of Table 3.
[30] See Obstfeld and Rogoff (2002), and Corsetti and Pesenti (2001) for instance.

A The Welfare Gains

The first finding I would like to stress is the welfare gains. I focus on the quantitative difference in consumption rather than employment, even it is the case that labour supply is higher under coordination than non-coordination. The fairly high degree of risk aversion produces much higher utility from the rise in consumption while the disutility generated by the employment growth is totally dominated in the calculation of welfare gains. The percentage of consumption gains is decreasing in the degree of risk aversion. In the limiting case of myopic households, the consumption gains are as high as 15% and 35%, respectively for Home and Foreign countries. It seems like the log utility specification implies too little motivation for Home country, yet too much temptation for Foreign country so the discussion regarding coordination participation is not plausible in column (1). The baseline calibration in column (5) shows the consumption gains per annum as 1.12% for Home and 1.25% for Foreign country. Column (6) reports the same numbers from steady state consumption. The welfare gains do not result from a more stabilised economy. Instead, they are mainly generated by a higher level of global output thanks to coordination.

B The Decline in Risk Premia

Second, the risk premia are lower if both countries participate in policy coordination. In the baseline case, the excess returns in both countries are 8 bps lower under coordination relative to non-coordination. The drop in risk premia is not always symmetric if risk aversion is lower but still within reasonable range. Column (2) in Table 3 shows that Foreign country is faced with 14 bps decline in excess return when Home country is with 11 bps. Foreign risk premium drops more as household-investors anticipate a stronger consumption growth when participating in policy coordination.

My finding is non-trivial compared with the existing empirical evidence, such as Rogers, Scotti, and Wright (2014) who documented an increase of 9 to 25 bps in risk premia following the announcement of monetary policy. However, there is other evidence showing much larger impact of monetary policy. For instance, Bernanke and Kuttner (2005) show

an increase of 44.5 bps in stock return due to monetary policy shock during their sample period.

C Understanding the Mechanism

Panel B in Table 3 reports the statistics for a number of contributors to my baseline results. Column (7) shows the results calibrated from a pair of equally-sized countries. The consumption gains become symmetric and unlike the baseline case in (5), the terms of trade remains unchanged between coordination and non-coordination regimes. Following Taylor (1999), I consider a smaller value for policy shock persistence in Column (9).

The decline in risk premia becomes much smaller when the policy shocks are less persistent. In Column (10) I switch off the monetary policy shocks. The results of consumption gains do not vary with the existence of any shock. The drop in expected excess returns can be largely explained by monetary policy shocks as in Weber (2015). The inability to implement the monetary policy exactly as described by the flexible inflation targeting rules is another important motivation for both country to coordinate their monetary actions. I switch off the cost-push shocks in Column (11). Since the short-run tradeoffs between inflation and employment are similar under coordination and non-coordination regimes, I do not find the results significantly different from the baseline calibration in Column (5).

7 Conclusion

The awareness of international coordination has been raised since 2008 financial crisis, mainly due to excessive policy spillovers and closer connection between monetary policy and equity risk premia. I propose a two-country New Keynesian asset-pricing model to analyse the strategic interaction among major economies in the world. Abstracting from conventional small-open-economy setup, I endogenize foreign policy actions into the policymaking function of each country and derive a general equilibrium model.

The international spillover of monetary policy prevents policymakers from achieving their dual mandates. A unilateral policymaking action usually causes unfavourable economic outcome in the foreign country via exchange rate channel. It is then possible to find welfare improvement and fall in risk premia for both countries if they participate in policy coordination.

Country size is the main heterogeneity studied in this paper. Together with the home bias in trade, the size effect leads to imperfect risk sharing in the foreign exchange market. When countries are of unequal size, the cross-country allocation of coordination gains is asymmetric. The social planner has to allocate more economic benefits to the small country in order to keep her participating in policy coordination. Coordination also implies monetary policy being more accommodative to global shocks and make local equity a better hedge against exchange rate risk. Therefore, household-investors are shown to increase their long (short) position in local (foreign) equity.

There are several potential extensions for future research. A more careful study of portfolio choice linked to monetary policy-making at global level will be interesting to further investigate.[31] Alternatively, allowing international borrowing could yield some space for analysing different types of policy instrument such as capital control. All of these are crucial questions to better understand the boundaries of policy coordination.

[31] Some empirical papers have documented the excess stock returns generated by the meeting cycle of monetary policy committee. See Cieslak, Morse, and Vissing-Jorgensen (2015) for example.

References

Aguiar, M., M. Amador, E. Farhi, and G. Gopinath, 2015, "Coordination and crisis in monetary unions," *Quarterly Journal of Economics*, 130(4), 1727–1779.

Back, K., 2010, *Asset pricing and portfolio choice theory*. Oxford University Press.

Backus, D. K., and G. W. Smith, 1993, "Consumption and real exchange rates in dynamic economies with non-traded goods," *Journal of International Economics*, 35(3-4), 297–316.

Bansal, R., and A. Yaron, 2004, "Risks for the long run: A potential resolution of asset pricing puzzles," *Journal of Finance*, 59(4), 1481–1509.

Barsky, R. B., F. T. Juster, M. S. Kimball, and M. D. Shapiro, 1997, "Preference parameters and behavioral heterogeneity: An experimental approach in the health and retirement study," *Quarterly Journal of Economics*, 112(2), 537–579.

Bekaert, G., M. Hoerova, and M. L. Duca, 2013, "Risk, uncertainty and monetary policy," *Journal of Monetary Economics*, 60(7), 771–788.

Benigno, G., and P. Benigno, 2003, "Price stability in open economies," *Review of Economic Studies*, 70(4), 743–764.

——— , 2006, "Designing targeting rules for international monetary policy cooperation," *Journal of Monetary Economics*, 53(3), 473–506.

Bernanke, B. S., and K. N. Kuttner, 2005, "What explains the stock market's reaction to Federal Reserve policy?," *Journal of Finance*, 60(3), 1221–1257.

Bhamra, H. S., A. J. Fisher, and L.-A. Kuehn, 2011, "Monetary policy and corporate default," *Journal of Monetary Economics*, 58(5), 480–494.

Blanchard, O. J., and C. M. Kahn, 1980, "The solution of linear difference models under rational expectations," *Econometrica*, pp. 1305–1311.

Bruno, V., and H. S. Shin, 2014, "Capital flows and the risk-taking channel of monetary policy," *Journal of Monetary Economics*.

Caballero, R. J., E. Farhi, and P.-O. Gourinchas, 2008, "Financial crash, commodity prices and global imbalances," working paper, National Bureau of Economic Research.

Christiano, L. J., M. Eichenbaum, and C. L. Evans, 2005, "Nominal rigidities and the dynamic effects of a shock to monetary policy," *Journal of Political Economy*, 113(1), 1–45.

Cieslak, A., A. Morse, and A. Vissing-Jorgensen, 2015, "Stock returns over the FOMC cycle," *Available at SSRN 2687614*.

Clarida, R., J. Galí, and M. Gertler, 1998, "Monetary policy rules in practice: some international evidence," *European Economic Review*, 42(6), 1033–1067.

——— , 1999, "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, 37, 1661–1707.

——— , 2002, "A simple framework for international monetary policy analysis," *Journal of Monetary Economics*, 49(5), 879–904.

Cochrane, J. H., 2016, "Macro-finance," working paper, National Bureau of Economic Research.

Coeurdacier, N., and H. Rey, 2013, "Home Bias in Open Economy Financial Macroeconomics," *Journal of Economic Literature*, 51(1), 63–115.

Coimbra, N., and H. Rey, 2017, "Financial cycles with heterogeneous intermediaries," working paper, National Bureau of Economic Research.

Corsetti, G., and P. Pesenti, 2001, "Welfare and Macroeconomic Interdependence," *Quarterly Journal of Economics*, 116(2), 421–445.

Cúrdia, V., and M. Woodford, 2016, "Credit frictions and optimal monetary policy," *Journal of Monetary Economics*, 84, 30–65.

De Paoli, B., 2009a, "Monetary policy and welfare in a small open economy," *Journal of international Economics*, 77(1), 11–22.

——— , 2009b, "Monetary policy under alternative asset market structures: The case of a small open economy," *Journal of Money, Credit and Banking*, 41(7), 1301–1330.

Devereux, M. B., and C. Engel, 2003, "Monetary policy in the open economy revisited: Price setting and exchange-rate flexibility," *Review of Economic Studies*, 70(4), 765–783.

Devereux, M. B., and A. Sutherland, 2011, "Country Portfolios in Open Economy Macro-Models," *Journal of the European Economic Association*, 9(2), 337–369.

Diercks, A. M., 2015, "The Equity Premium, Long-Run Risk, & Optimal Monetary Policy," working paper, Finance and Economics Discussion Series 2015-087. Washington: Board of Governors of the Federal Reserve System.

Drechsler, I., A. Savov, and P. Schnabl, 2017, "A model of monetary policy and risk premia," *Journal of Finance*.

Eichengreen, B., 2013, "Currency war or international policy coordination?," *Journal of Policy Modeling*, 3(35), 425–433.

Engel, C., 2016, "Policy Cooperation, Incomplete Markets, and Risk Sharing," *IMF Economic Review*, 64(1), 103–133.

Fischer, S., 2015, "The Federal Reserve and the Global Economy," At the conference held in honor of Professor Haim Ben-Shahar, former president of Tel Aviv University, Tel Aviv University.

Galí, J., 2015, *Monetary policy, inflation, and the business cycle: an introduction to the new Keynesian framework and its applications*. Princeton University Press.

Gertler, M., and P. Karadi, 2011, "A model of unconventional monetary policy," *Journal of Monetary Economics*, 58(1), 17–34.

Gertler, M., and N. Kiyotaki, 2010, "Financial intermediation and credit policy in business cycle analysis," in *Handbook of monetary economics*. North Holland, vol. 3A, chap. 11, pp. 547–599.

Haberis, A., and A. Lipinska, 2012, "International policy spillovers at the zero lower bound," working paper, Finance and Economics Discussion Series 2012-023. Washington: Board of Governors of the Federal Reserve System.

Hau, H., and H. Rey, 2008, "Home Bias at the Fund Level," *American Economic Review*, 98(2), 333–338.

Jermann, U. J., 1998, "Asset pricing in production economies," *Journal of Monetary Economics*, 41(2), 257–275.

Kydland, F. E., and E. C. Prescott, 1977, "Rules rather than discretion: The inconsistency of optimal plans," *Journal of Political Economy*, 85(3), 473–491.

Li, E. X., and F. Palomino, 2014, "Nominal rigidities, asset returns, and monetary policy," *Journal of Monetary Economics*, 66, 210–225.

Liu, Z., and E. Pappa, 2008, "Gains from International Monetary Policy Coordination: Does it pay to be different?," *Journal of Economic Dynamics and Control*, 32(7), 2085–2117.

Lucas, R. E., 1982, "Interest rates and currency prices in a two-country world," *Journal of Monetary Economics*, 10(3), 335–359.

Lucca, D. O., and E. Moench, 2015, "The Pre-FOMC Announcement Drift," *Journal of Finance*, 70(1), 329–371.

McCallum, J., 1995, "National borders matter: Canada-US regional trade patterns," *American Economic Review*, 85(3), 615–623.

Mohan, R., and M. Kapur, 2014, "Monetary policy coordination and the role of Central Banks," .

Mueller, P., A. Tahbaz-Salehi, and A. Vedolin, 2017, "Exchange rates and monetary policy uncertainty," *Journal of Finance*, 72(3), 1213–1252.

Obstfeld, M., and K. Rogoff, 2000, *The six major puzzles in international macroeconomics: is there a common cause?*, vol. 15. MIT press, Cambridge.

——— , 2002, "Global Implications of self-oriented national policy rules," *Quarterly Journal of Economics*, 117(2), 503–505.

Pappa, E., 2004, "Do the ECB and the Fed really need to cooperate? Optimal monetary policy in a two-country world," *Journal of Monetary Economics*, 51(4), 753–779.

Pavlova, A., and R. Rigobon, 2007, "Asset prices and exchange rates," *Review of Financial Studies*, 20(4), 1139–1180.

Rajan, R., 2015, "Competitive Monetary Easing: Is it yesterday once more?," *Macroeconomics and Finance in Emerging Market Economies*, 8(1-2), 5–16.

Rogers, J. H., C. Scotti, and J. H. Wright, 2014, "Evaluating asset-market effects of unconventional monetary policy: a multi-country review," *Economic Policy*, 29(80), 749–799.

Sims, C. A., 1994, "A simple model for study of the determination of the price level and the interaction of monetary and fiscal policy," *Economic Theory*, 4(3), 381–399.

Smets, F., and R. Wouters, 2007, "Shocks and frictions in US business cycles: A Bayesian DSGE approach," *American Economic Review*, 97(3), 586–606.

Stein, J. C., 2014, "Incorporating Financial Stability Considerations into a Monetary Policy Framework," At the International Research Forum on Monetary Policy, Washington, DC.

Svensson, L. E. O., 2003, "Escaping from a Liquidity Trap and Deflation: The Foolproof Way and Others," *Journal of Economic Perspectives*, 17(4), 145.

Swanson, E. T., 2012, "Risk Aversion and the Labor Margin in Dynamic Equilibrium Models," *American Economic Review*, 102(4), 1663–1691.

Tallarini, T. D., 2000, "Risk-sensitive real business cycles," *Journal of Monetary Economics*, 45(3), 507–532.

Taylor, J. B., 1999, "A historical analysis of monetary policy rules," in *Monetary policy rules*. University of Chicago Press, pp. 319–348.

——— , 2013, "International monetary coordination and the great deviation," *Journal of Policy Modeling*, 35(3), 463–472.

Vissing-Jørgensen, A., 2002, "Limited asset market participation and the elasticity of intertemporal substitution," *Journal of Political Economy*, 110(4), 825–853.

Weber, M., 2015, "Nominal rigidities and asset pricing," working paper, University of Chicago.

Werning, I., 2011, "Managing a liquidity trap: Monetary and fiscal policy," working paper, National Bureau of Economic Research.

Woodford, M., 1994, "Monetary policy and price level determinacy in a cash-in-advance economy," *Economic Theory*, 4(3), 345–380.

——— , 1999, "Commentary: How should monetary policy be conducted in an era of price stability?," New Challenges for Monetary Policy Symposium, Jackson Hole, Wyoming.

——— , 2007, "Globalization and monetary control," working paper, National Bureau of Economic Research.

Supporting Information

Appendix S1: Internet Appendix (LINK)

Figure 1: Model overview

A two-country New Keynesian model is visualised in this Figure. These two countries are assumed to be leading economies in the world, taking the US and EU for instance. I characterise a global economy where any unexpected, unilateral monetary action would have impact on production sector of the other country. The agents include households, firms, and central banks. I use arrows and lines to indicate the direction of trade flows, both locally and internationally. Unequal size of country is an important feature of my model that affects the cross-country allocation of coordination gains. The large country has little incentive to participate in coordination because she is allocated smaller economic benefits than her neighbour country.

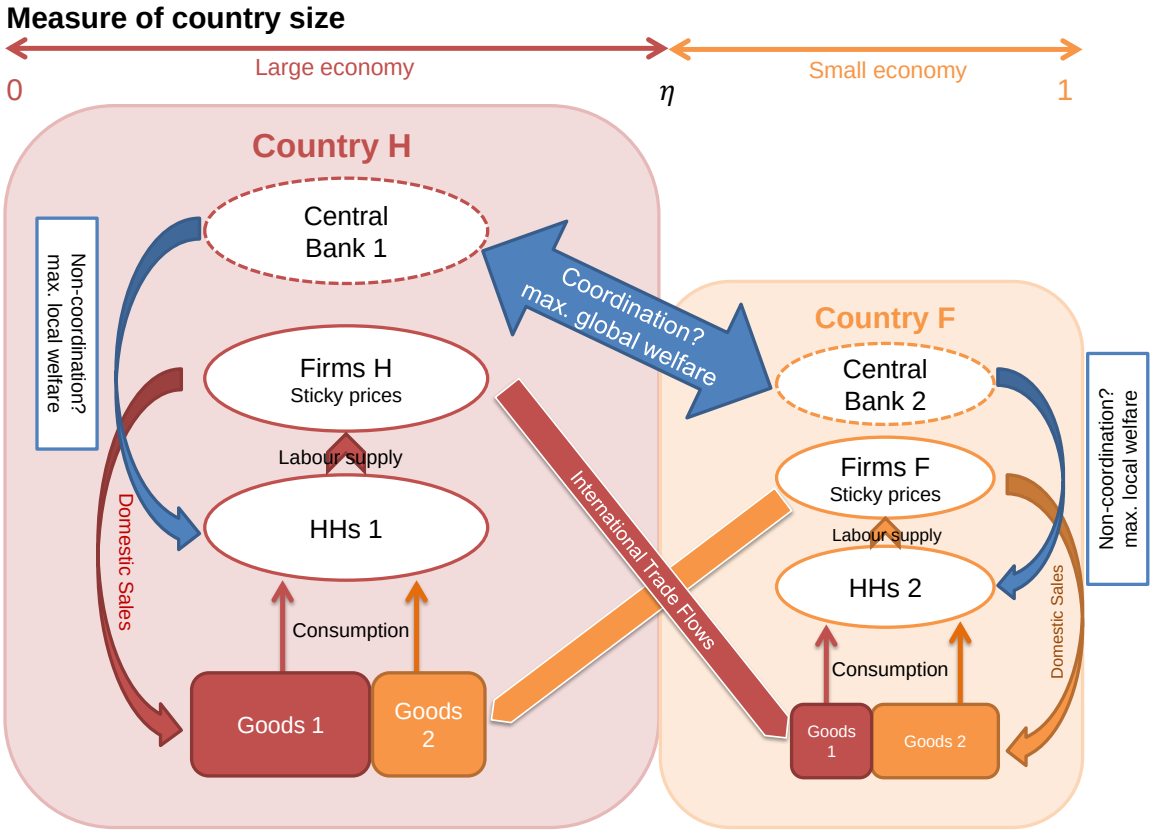

Figure 2: Relative weight of Foreign country (Θ) with non-myopic households
At coordination equilibrium, the social planner solves a size-weighted optimisation problem. I plot the relative weights of Foreign country (vertical axis) against with the size parameter of Home country (η, horizontal axis) whilst the weight of Home country is normalised to 1. The relative weights are sensitive to risk aversion. High degree of risk aversion implies relative weight converges to 1. The converging speed is increasing in the country size differential, i.e. the green dashed line is flatter than the red solid line. Nevertheless, within the range of my calibration, the choice of risk aversion and country size leads to non-trivial weight for Foreign country ($\Theta \neq 1$).

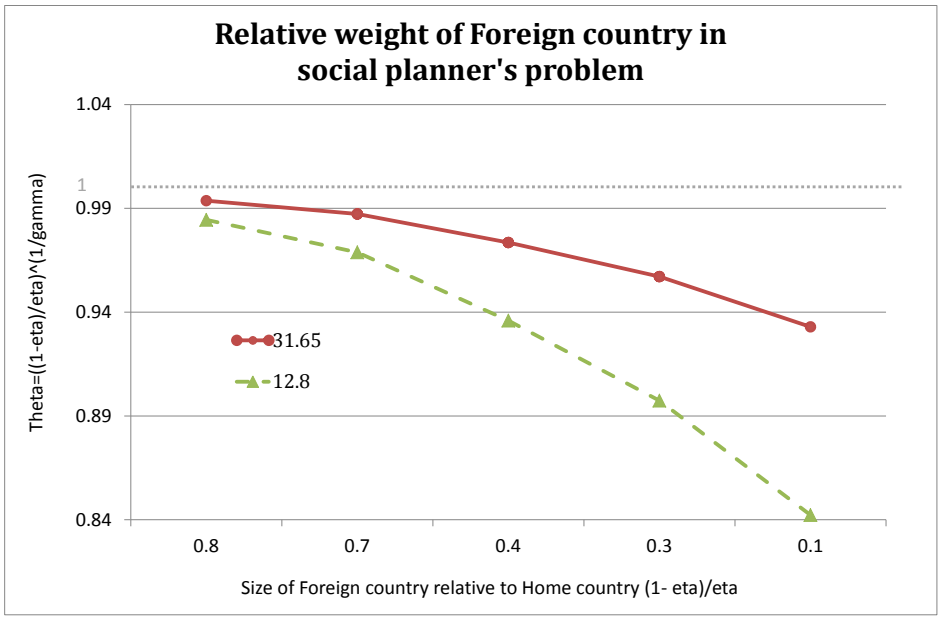

Figure 3: Impulse Respond Function to Home Policy Shock

This figure shows the transmission of Home monetary policy to other economic variables. The contractionary shock is of one standard deviation and assumed to be the same under different equilibria. The blue dashed lines are the response under competitive equilibrium and the red solid lines with circle markers are under coordinative equilibrium. All impulse response functions are plotted relative to the corresponding steady state values. Note that the steady states consumption is higher under coordinative than competitive equilibrium. More quantitative difference in steady state is presented in the last column of Table 3. All numbers are presented in percent per quarter.

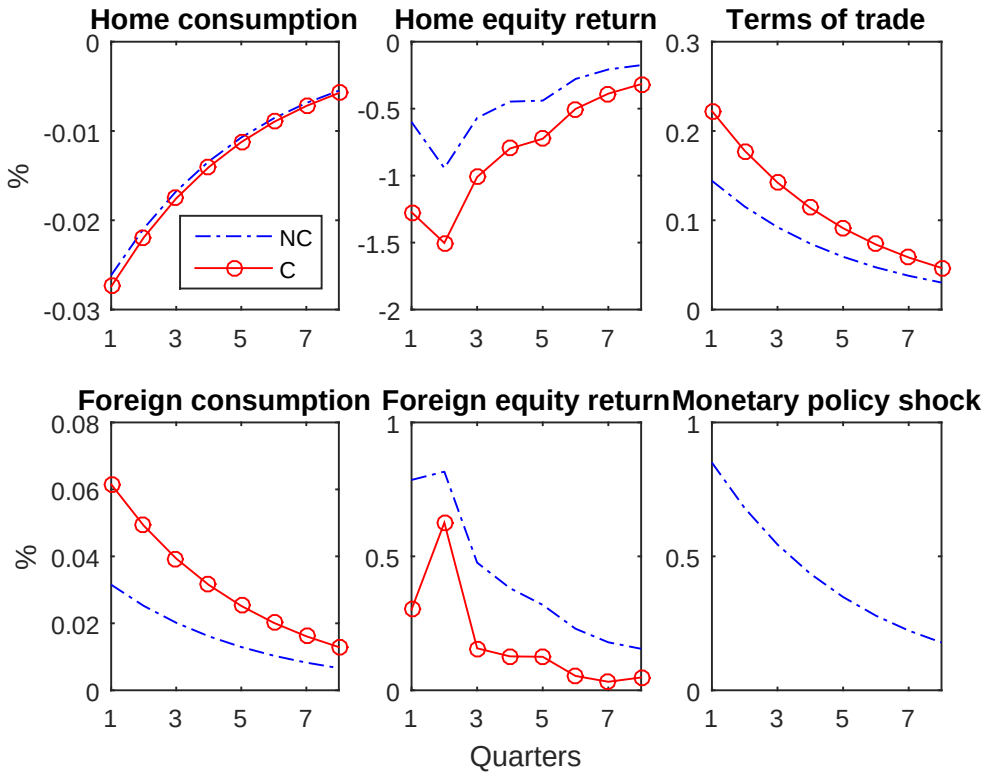

Figure 4: Impulse Respond Function to Home Cost-push Shock

This figure shows the transmission of Home cost-push shock to other economic variables. The contractionary shock is of one standard deviation and assumed to be the same under different equilibria. The blue dashed lines are the response under competitive equilibrium and the red solid lines with circle markers are under coordinative equilibrium. Foreign consumption is presented in basis point per quarter. All other variables are presented in percent per quarter.

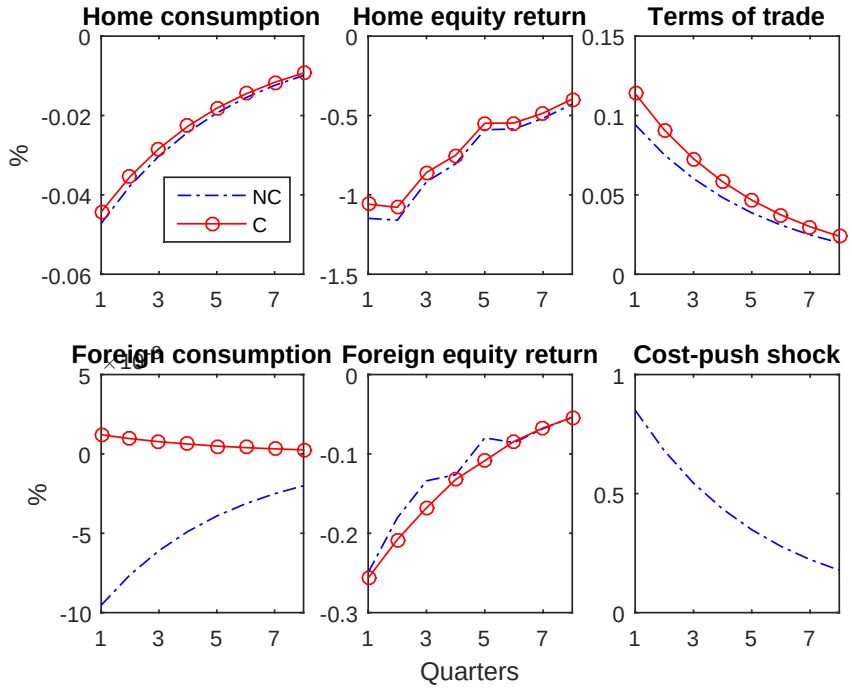

Figure 5: Risk Aversion and Impulse Respond Function

This figure shows the influence of risk aversion on impulse response to the cost-push shock by Home country. The contractionary shock strikes the production sector in Home country and has the same volatility as productivity shock. The red solid lines with circle markers plots the baseline calibration with $\gamma = 31.65$. The blue dashed lines are plotted when $\gamma = 12.8$. All numbers are presented in percent per quarter.

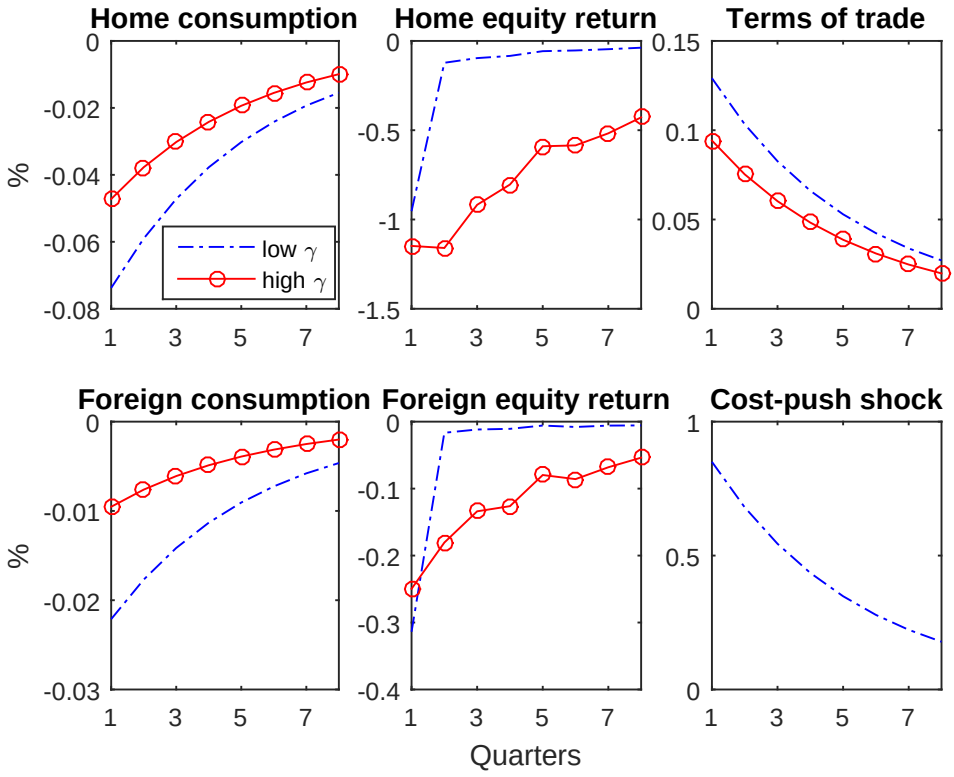

Table 1: Parameters of Baseline Calibration

This table reports the parameters for my baseline calibration from a wide range of literature. The model is calibrated at quarterly frequency to match the properties of US data during the period of 1982 to 2011. The subjective discount rate, productivity shock, and cost push shock are presented in percent per quarter.

Household Preferences		**Value**	**Reference**
Subjective discount rate	δ	0.54	Li and Palomino (2014); 1 in Galí (2015)
Elasticity of labour supply	φ	3	Galí (2015)
Home bias	α	0.7	Pavlova and Rigobon (2007)
Risk aversion	γ	31.65	84.5 in Li and Palomino (2014); 1000 in Tallarini (2000)
Home country size	η	0.867	Pavlova and Rigobon (2007)
Production Parameters			
Monopolistic power	ϵ	6	Galí (2015)
Price rigidities	θ	0.67	Galí (2015)
Exogenous Shocks			
Productivity shock	σ_a	0.90	Weber (2015)
Productivity persistence	ρ_a	0.975	Smets and Wouters (2007)
Taylor coefficient	ϕ	1.5	Taylor (1999)
Cost-push shock	σ_u	0.85	Weber (2015)
Cost-push persistence	ρ_u	0.5	Clarida, Galí, and Gertler (1998)

Table 2: Model Summary Statistics

This table contains statistics for the baseline calibration and the effect of different degrees of risk aversion. The baseline parameter values are presented in Table 1. "Baseline" indicates that γ is chosen to match the mean excess return while "$\gamma = 12.8$" is chosen to match the volatility of excess return. Detrended log consumption is denoted by $\hat{c}$. The Sharpe ratios for country i are $SR_i = \mathbb{E}(AXR_i)/\sigma(AXR_i)$. All statistics are presented in percent. The excess return and Sharpe ratio are presented per annum while other variables are per quarter. The sign "-" in the data column indicates that the statistic is not available. In order to keep the model tractable, I focus on a symmetric case and calibrates most variables, except for country size, to match the properties of US data.

			(1)	(2)	(3)	(4)
		$\gamma =$	Baseline	20	15	12.8
Description	**Statistic**	**Data**	**Panel A: Model-implied Mean**			
Home Ex. Ret.	$\mathbb{E}(AXR_1)$	6.74	6.58	2.59	1.43	1.03
Foreign Ex. Ret.	$\mathbb{E}(AXR_2)$	-	6.58	2.57	1.41	1.00
			Panel B: Model-implied Volatility			
Home Consumption Gap	$\sigma(\hat{c}_1)$	0.76	0.24	0.40	0.53	0.62
Foreign Consumption Gap	$\sigma(\hat{c}_2)$	-	0.24	0.40	0.54	0.63
Home Inflation	$\sigma(\pi_H)$	0.34	0.11	0.14	0.17	0.19
Foreign Inflation	$\sigma(\pi_F)$	-	0.11	0.14	0.17	0.19
Home Nominal Rate	$\sigma(i_1)$	0.65	1.58	1.60	1.58	1.56
Foreign Nominal Rate	$\sigma(i_2)$	-	1.65	1.73	1.75	1.74
Terms of Trade	$\sigma(q)$	2.60	3.89	3.97	4.04	4.10
Home Ex. Ret.	$\sigma(AXR_1)$	14.9	37.5	24.2	18.7	16.3
Foreign Ex. Ret.	$\sigma(AXR_2)$	-	37.7	24.7	19.2	16.9
Home Sharpe Ratio	SR_1	0.22	0.18	0.11	0.08	0.06
Foreign Sharpe Ratio	SR_2	-	0.17	0.10	0.07	0.06

Table 3: Gains from policy coordination

The presented values are the mean differential measured in percentage per annum. I obtain the differential by subtracting the expected values of outcome variables under coordination from non-coordination equilibrium. The baseline result lies in column (5) and (6). The sensitivity of risk aversion parameter (γ) is reported in Panel A. In Panel B, the sensitivity test is conducted over other parameters. Column (7) considers countries of equal size. Column (8) calibrates the relative size of USA vs. Euro area. Column (9) shows the case of lower persistence in policy shock. Columns (10) and (11) show the contribution of different exogenous shocks.

Panel A. Risk aversion						
	(1) γ=**1**	(2) **12.8**	(3) **15**	(4) **20**	(5) **31.65**	(6) **Steady State**
Consumption						
Home consumption (Ac1)	15	2.22	1.99	1.62	1.12	1.12
Foreign consumption (Ac2)	35	2.72	2.40	1.87	1.25	1.25
Terms of Trade (q)		1.26	1.00	0.66	0.33	0.32
Equity Risk Premia						
Home Ex. Ret. (AXR1)		-0.11	-0.11	-0.10	-0.08	0.00
Foreign Ex. Ret. (AXR2)		-0.14	-0.13	-0.12	-0.08	0.00
Home Sharpe Ratio (SR1)		-0.89	-0.81	-0.63	-0.39	-
Foreign Sharpe Ratio (SR2)		-1.31	-1.14	-0.90	-0.49	-
Equity Home Bias						
Local Equity Holding (χ)		0.85	0.91	0.93	0.77	-
Panel B. Sensitivity Test						
		(7) η=**0.5**	(8) η=**0.61**	(9) ρ_m=**0.5**	(10) **No policy shock**	(11) **No cost-push shock**
Consumption						
Home consumption (Ac1)		1.18	1.16	1.12	1.12	1.12
Foreign consumption (Ac2)		1.18	1.20	1.25	1.25	1.25
Terms of Trade (q)		0.00	0.08	0.33	0.33	0.33
Equity Risk Premia						
Home Ex. Ret. (AXR1)		-0.07	-0.08	-0.03	0.00	-0.07
Foreign Ex. Ret. (AXR2)		-0.09	-0.09	-0.03	0.01	-0.08
Home Sharpe Ratio (SR1)		-0.36	-0.39	-0.12	0.01	-0.37
Foreign Sharpe Ratio (SR2)		-0.52	-0.52	-0.14	0.03	-0.50