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(Citation)
International Journal of Economic Theory,18(4):624-642

(Issue Date)
2022-12

(Resource Type)
journal article

(Version)
Version of Record

Received: 31 March 2020 | Accepted: 23 October 2021

DOI: 10.1111/ijet.12331

SPECIAL FEATURE ARTICLE

International Journal of Economic Theory IJET WILEY

Financial market incompleteness and international cooperation on capital controls

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Funding information

Japan Society for the Promotion of Science, Grant/Award Numbers: 20H05633, 20K01744

Abstract

We examine how the degree of financial market incompleteness affects welfare gains from international cooperation on capital controls. When financial markets are incomplete, international risk sharing is disturbed. However, the optimal global policy significantly reverses the welfare deterioration due to inefficient risk sharing. We show that when financial markets are more incomplete, the welfare gap between the optimal global policy and the Nash equilibrium increases, and the welfare gains from international cooperation on capital controls then become larger.

KEYWORDS

capital controls, financial markets, incomplete markets, open-loop Nash game, optimal policy, policy cooperation, Ramsey policy, welfare

JEL CLASSIFICATION

D52, E61, F32, F38, F42, G15

1 | INTRODUCTION

Many studies discuss the gains from monetary policy coordination. Among them, several employ two-country models with complete financial markets, which implies that international risk sharing is perfect (e.g. Benigno & Benigno, 2003, 2006; Clarida et al., 2001, 2002; Corsetti &

Pesenti, 2001, 2005; Fujiwara & Teranishi, 2017). On the contrary, some studies employ two-country models with incomplete financial markets, and recent studies extend this literature in several directions. Corsetti et al. (2010) show that incomplete markets break an open-economy version of divine coincidence and cause policy trade-offs. Benigno (2009) shows that gains from the optimal monetary policy increase with cross-country asymmetries in initial net international positions. Rabitsch (2012) studies welfare gains from monetary policy cooperation under three types of international financial market structures: complete markets, financial autarky, and incomplete markets.

Although many studies examine gains from monetary policy coordination from many different perspectives, as mentioned above, few authors analyze the gains from policy coordination in capital controls.[1] Noteworthy exceptions are De Paoli and Lipinska (2013) and Heathcote and Perri (2016). De Paoli and Lipinska (2013) show that capital controls can be beggar-thy-neighbor policies, and policy coordination in capital controls can yield gains. This is because individual countries have incentives to manage their terms of trade to stabilize their own output fluctuations, but the uncoordinated use of capital controls disturbs international consumption risk sharing and deteriorates global welfare. Using a two-country model augmented with capital accumulation, Heathcote and Perri (2016) show that for certain parameterizations, capital controls can lead to better international risk sharing. Through this improved risk sharing, symmetric capital controls can be welfare improving for both countries compared to free international capital mobility, which implies that capital controls can be Pareto-improving.

In this study, we also examine the welfare gains from policy coordination on capital controls. However, we focus on how the degree of financial market incompleteness affects welfare gains from international cooperation on capital controls. Incomplete markets disturb international risk sharing, whereas the optimal global policy mitigates risk-sharing inefficiency. We find that when financial markets are more incomplete, global welfare deteriorates under the Nash equilibrium; however, the optimal global policy mitigates the welfare loss because of financial market inefficiencies. When financial markets are more incomplete, we find that the welfare gap between the optimal global policy and the Nash equilibrium increases, and welfare gains from international cooperation on capital controls then become larger. To the best of our knowledge, no previous work addresses this relationship between the gains from policy coordination in capital controls and the degree of financial market incompleteness in the related literature.

The remainder of the paper proceeds as follows. In Section 2, we present a standard two-country model with incomplete asset markets. In Section 3, we characterize optimal global policy and Nash equilibrium. In Section 4, we perform a comparative analysis of welfare for the two cases. In Section 5, we conduct robustness check. We present our conclusions in Section 6.

2 | MODEL

We consider a familiar two-country model populated with a continuum of agents of unit mass, in which the population in segment $[0, n]$ belongs to country H and that in segment $(n, 1]$ belongs to country F. Our model is a standard two-country model with incomplete asset

[1]If we do not restrict our attention to policy coordination, there is a vast literature on theoretical studies of capital controls. See, for example, Kitano and Takaku (2018), Kitano and Takaku (2020), and references therein. For empirical studies of capital controls, see, for example, Boero et al. (2019) and references therein.

markets, which is similar to those in previous studies (e.g. Benigno, 2009; Corsetti et al., 2010; De Paoli & Lipinska, 2013; Kim & Kim, 2018; Rabitsch, 2012).[2]

2.1 | Model Setup

The household in country H maximizes the following expected life utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \{u(C_t) - v(L_t)\}, \tag{1}$$

where E_0 denotes the mathematical expectations operator conditional on the information available at time 0, and $\beta \in (0, 1)$ is the discount factor. The functions u and v are increasing in the composite consumption index C_t and the labor supply L_t, respectively. We assume that the household's utility functions $u(C_t)$ and $v(L_t)$ are iso-elastic functions:

$$u(C_t) = \frac{C_t^{1-\sigma} - 1}{1 - \sigma}, \tag{2}$$

and

$$v(L_t) = \frac{L_t^{1+\chi}}{1 + \chi}. \tag{3}$$

We define the home composite consumption index C_t as

$$C_t = \left[\nu^{\frac{1}{\theta}} (C_{H,t})^{\frac{\theta-1}{\theta}} + (1 - \nu)^{\frac{1}{\theta}} (C_{F,t})^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \tag{4}$$

where $1 - \nu = (1 - n)\lambda$. The parameter λ indicates the degree of openness. The corresponding home consumption-based price index is

$$P_t = [\nu(P_{H,t})^{1-\theta} + (1 - \nu)(P_{F,t})^{1-\theta}]^{\frac{1}{1-\theta}}. \tag{5}$$

Similarly, the foreign composite consumption index C_t^* is

$$C_t^* = \left[\nu^{*\frac{1}{\theta}} (C_{H,t}^*)^{\frac{\theta-1}{\theta}} + (1 - \nu^*)^{\frac{1}{\theta}} (C_{F,t}^*)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}, \tag{6}$$

where $\nu^* = n\lambda$. The corresponding foreign consumption-based price index is

$$P_t^* = \left[\nu^*(P_{H,t}^*)^{1-\theta} + (1 - \nu^*)(P_{F,t}^*)^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{7}$$

[2]The two-country models in Benigno (2009), Corsetti et al. (2010), and Rabitsch (2012) incorporate nominal rigidities into their models. The two-country model in Kim and Kim (2018) incorporates capital.

All goods are traded and the law of one price holds:

$$P_{H,t} = S_t P^*_{H,t}, \tag{8}$$

and

$$P_{F,t} = S_t P^*_{F,t}, \tag{9}$$

where S_t denotes the nominal exchange rate. However, purchasing power parity does not hold because of the home bias specification given by (5) and (7). We define the real exchange rate as

$$q_t = \frac{S_t P_t^*}{P_t}, \tag{10}$$

which can deviate from one. It follows from Equations (5), (7), and (10) that the international relative prices satisfy

$$p_t^{H\theta-1} = \nu + (1-\nu)\left(\frac{p_t^F}{p_t^H}\right)^{1-\theta}, \tag{11}$$

and

$$\left(\frac{p_t^H}{q_t}\right)^{\theta-1} = \nu^* + \left(1-\nu^*\right)\left(\frac{p_t^F}{p_t^H}\right)^{1-\theta}, \tag{12}$$

where $p_t^H \equiv \frac{P_t^H}{P_t}$ and $p_t^F \equiv \frac{P_t^F}{P_t}$. We define the terms of trade as

$$ToT_t = \frac{p_t^F}{p_t^H}. \tag{13}$$

The production technology is given by

$$Y_t = A_t^{\frac{\chi}{1+\chi}} L_t, \tag{14}$$

and

$$Y_t^* = A_t^{*\frac{\chi}{1+\chi}} L_t^*. \tag{15}$$

The budget constraint for a household in country H is

$$C_t + (1+\tau_{t-1})\, R^*_{t-1}\, \frac{q_t}{q_{t-1}}\, D_{t-1} + \frac{\delta}{2}\, D_t^2 = D_t + p_t^H\, Y_t + T_t, \tag{16}$$

where D_t denotes the external debt position, R_t^* denotes the gross interest rate on external debt, τ_t denotes the tax rate of the external debt, and T_t denotes a lump-sum transfer from the government. Following many previous two-country studies (Benigno, 2009; De Paoli & Lipinska, 2013; Kim & Kim, 2018), we introduce quadratic adjustment costs, $\frac{\delta}{2} D_t{}^2$, to characterize incomplete financial markets.

The tax revenue from capital controls in Equation (16) is transferred to the household

$$T_t = \tau_{t-1} R_{t-1}^* \frac{q_t}{q_{t-1}} D_{t-1}, \tag{17}$$

such that capital controls have no effect on the economy's resource constraint.

Maximizing the lifetime utility (1) with respect to D_t (and C_t) subject to the budget constraint (16) yields the Euler equation in country H:

$$1 - \delta D_t = \beta (1 + \tau_t) R_t^* \frac{q_{t+1}}{q_t} \frac{u_C(C_{t+1})}{u_C(C_t)}. \tag{18}$$

Maximizing the lifetime utility (1) with respect to Y_t (and C_t) subject to the budget constraint (16) (and considering [2], [3], and [14]), we also obtain

$$p_t^H C_t{}^{-\sigma} = A_t{}^{-\chi} Y_t{}^{\chi}. \tag{19}$$

The household in country F maximizes the following expected life utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \{u(C_t^*) - v(L_t^*)\}. \tag{20}$$

The budget constraint for a household in country F is

$$C_t^* + B_t^* = (1 - \tau_{t-1}^*) R_{t-1}^* B_{t-1}^* + p_{F_t}^* Y_t^* + T_t^*, \tag{21}$$

where B_t^* denotes the external asset position in country F, τ_t^* denotes the tax rate of the external asset, and T_t denotes a lump-sum transfer from the government. The transfer policy in country F, which implies that the government returns the tax on interest income to households, is

$$T_t^* = \tau_{t-1}^* R_{t-1}^* B_{t-1}^*. \tag{22}$$

Maximizing the lifetime utility (20) with respect to B_t^* (and C_t^*) subject to the budget constraint (21) yields the Euler equation in country F:

$$1 = \beta^* (1 - \tau_t^*) R_t^* \frac{u_C(C_{t+1}^*)}{u_C(C_t^*)}. \tag{23}$$

Maximizing the lifetime utility (20) with respect to Y_t^* (and C_t^*) subject to the budget constraint (21) (and considering the equivalent functional forms to [2], [3], Equations [10], and [15]), we also obtain

$$\frac{p_t^F}{q_t} C_t^{*-\sigma} = A_t^{*-\chi} Y_t^{*\chi}. \tag{24}$$

2.2 | Risk-Sharing Gap

Following Viani (2010), we define the "risk-sharing gap," which is a key variable in our study, as

$$gap_t = log\left(\frac{SDF_t}{SDF_t^*}\right). \tag{25}$$

Herein, SDF_t denotes the "stochastic discount factor" of country H:

$$SDF_t = \beta \frac{u_C(C_{t+1})}{u_C(C_t)} \frac{q_{t+1}}{q_t}. \tag{26}$$

SDF_t^* denotes the "stochastic discount factor" of country F:

$$SDF_t^* = \beta^* \frac{u_C(C_{t+1}^*)}{u_C(C_t^*)}. \tag{27}$$

In complete asset markets, agents have access to complete array of state-contingent claims. Under complete markets, the risk-sharing gap is zero, because perfect cross-border risk sharing makes the stochastic discount factors of the two countries equal. However, in this model, households of two counties have access to only a single risk-free bond traded internationally, which implies that asset markets are incomplete. Under incomplete markets, the gap deviates from zero. Because the gap indicates a deviation from the allocation under complete markets, we can measure the lack of risk sharing (i.e. risk-sharing inefficiency) with the risk-sharing gap in Equation (25). In other words, the risk-sharing gap indicates the degree of market incompleteness.

2.3 | Equilibrium and Exogenous Shocks

From the households' preferences, we can derive the demand for domestic and foreign goods:

$$Y_t = \left(p_t^H\right)^{-\theta}\left[\nu\ C_t + \frac{1-n}{n}\ \nu^* \left(\frac{1}{q_t}\right)^{-\theta} C_t^*\right], \tag{28}$$

and

$$Y_t^* = \left(p_t^F\right)^{-\theta}\left[\frac{n(1-\nu)}{1-n}C_t + (1-\nu^*)\left(\frac{1}{q_t}\right)^{-\theta} C_t^*\right]. \tag{29}$$

The equilibrium in the asset market requires that

$$D_t = B_t^*. \tag{30}$$

The productivity shocks in countries H and F are, respectively,

$$\log A_t = \rho \log A_{t-1} + \epsilon_t, \tag{31}$$

and

$$\log A_t^* = \rho \log A_{t-1}^* + \epsilon_t^*. \tag{32}$$

The equilibrium of this economy is a set of stationary stochastic processes: $\{C_t, C_t^*, Y_t, Y_t^*, L_t, L_t^*, R_t^*, D_t, B_t^*, q_t, p_t^H, p_t^F, ToT_t, T_t, T_t^*, gap_t, SDF_t, SDF_t^*\}_{t=0}^{\infty}$ satisfying Equations (10), (11), (12), (13), (14), (15), (17), (18), (19), (22), (23), (24), (25), (26), (27), (28), (29), and (30), given the exogenous stochastic processes A_t, A_t^*, and an initial value for D_{-1}.

2.4 | Welfare

We perform numerical experiments using a second-order approximation of the model with the perturbation method following Schmitt-Grohé and Uribe (2004).[3] Following Schmitt-Grohé and Uribe (2006), we measure the conditional welfare of country H by computing the expected welfare conditional on the initial non-stochastic steady state:

$$\begin{aligned}\mathcal{W}_0 &\equiv E_0 \sum_{t=0}^{\infty}\beta^t U(C_t, L_t)\\ &= E_0 \sum_{t=0}^{\infty}\beta^t U((1+\eta)C, L),\end{aligned} \tag{33}$$

where

$$U(C_t, L_t) = u(C_t) - v(L_t), \tag{34}$$

and C and L denote their non-stochastic steady-state levels. With η, we evaluate and compare conditional welfare levels under different parameters or policies.

[3]Kim and Kim (2003) show that second-order solutions are necessary because conventional linearization may generate spurious welfare reversals when long-run distortions exist in the model.

Similarly, we compute conditional global welfare by defining

$$\begin{aligned}\mathcal{W}_0^W &\equiv E_0 \sum_{t=0}^{\infty} \beta^t U^W(C_t, C_t^*, L_t, L_t^*) \\ &= E_0 \sum_{t=0}^{\infty} \beta^t U^W((1+\eta)C, L),\end{aligned} \tag{35}$$

where $U^W(C_t, C_t^*, L_t, L_t^*) = nU(C_t, L_t) + (1-n)U(C_t^*, L_t^*)$. The transition from the first line to the second follows from the fact that $C = C^*$ and $L = L^*$ in their non-stochastic steady states by structure.

3 | OPTIMAL GLOBAL POLICY AND NASH EQUILIBRIUM

3.1 | Optimal Global Policy

We characterize the optimal global policy by analyzing welfare-maximizing Ramsey policies with commitment. Under the optimal global policy, a global policy maker optimizes capital controls to maximize global welfare, considering the private sector's response to the implemented policies. Setting up a Lagrangian problem in which the global policy maker maximizes global welfare subject to the first-order conditions of the private agents and the market-clearing conditions of the two economies, we obtain the first-order conditions for the global policy maker. The first-order conditions for the global policy maker, the first-order conditions of the private agents, and the market-clearing conditions of the two economies characterize the cooperation equilibrium.

In Section 4.2, we examine the optimal global capital controls policy. Under the optimal global policy, we include τ_t (or τ_t^*) as a policy instrument.[4] We let x_t denote the $N \times 1$ vector of endogenous variables. Except for the policy instrument, the remaining $N-1$ endogenous variables in x_t satisfy the $N-1$ structural conditions, which are

$$E_t f(x_t, x_{t+1}, \zeta_t) = 0, \tag{36}$$

where the vector ζ_t denotes the exogenous variables. We obtain the global policy maker's first-order conditions by setting up a Lagrangian problem in which the global policy maker maximizes global welfare subject to the first-order conditions of the private agents and the market-clearing conditions of the two economies. More specifically, we derive the optimal Ramsey policy from the maximization problem:

$$\begin{aligned}\max_{\{x_t\}_{t=0}^{\infty}} \quad & E_0 \sum_{t=0}^{\infty} \beta^t U^W(x_t, \zeta_t) \\ s.t. \quad & E_t f(x_t, x_{t+1}, \zeta_t) = 0.\end{aligned} \tag{37}$$

[4]Following De Paoli and Lipinska (2013), we include only one policy instrument.

We set up the Lagrangian problem:

$$\mathcal{L}_0 = E_0 \sum_{t=0}^{\infty} \beta^t \{U^W(x_t, \zeta_t) + \lambda_t' f(x_t, x_{t+1}, \zeta_t)\}, \tag{38}$$

where λ_t denotes the Lagrange multipliers associated with the first-order conditions of the private agents and the market-clearing conditions of the economy in (36). Taking the derivatives of $\mathcal{L}_0$ with respect to the N endogenous variables, we obtain the N first-order conditions, which are characterized by the following equation[5]:

$$U_1^W(x_t, \zeta_t) + E_t \lambda_t' f_1(x_t, x_{t+1}, \zeta_t) + \beta^{-1} \lambda_{t-1}' f_2(x_{t-1}, x_t, \zeta_{t-1}) = 0. \tag{39}$$

Taking the derivatives of $\mathcal{L}_0$ with respect to λ_t, we obtain the $N-1$ equilibrium conditions in the private sector in (36). The first-order conditions of the private agents, the market-clearing conditions of the two economies, and the global policy maker's first-order conditions characterize the cooperation equilibrium. The Ramsey equilibrium process is therefore characterized by the $N-1$ Equations (36) and the N Equations (39). For the variables, we have N elements of x and $N-1$ multipliers of λ. In total, we therefore have $2N-1$ variables and $2N-1$ equations.

3.2 | Nash Equilibrium

Under a Nash equilibrium, the Home policy maker optimizes capital controls in country H to maximize country H's welfare level, whereas the Foreign policy maker optimizes capital controls in country F to maximize country F's welfare level. Thus, the strategic interaction between the two countries' policy makers leads to different outcomes from those under the welfare-maximizing cooperative policy. Specifically, we consider an open-loop Nash equilibrium in which the actions of each country's policy maker are best response to the other policy maker's best response.

Setting up two Lagrangian problems in which the Home and Foreign policy makers maximize their own country's welfare subject to the first-order conditions of the private agents and the market-clearing conditions of the two economies, we obtain the first-order conditions for each country's policy maker. The first-order conditions for each country's policy maker, the first-order conditions of the private agents, and the market-clearing conditions of the two economies characterize an open-loop Nash equilibrium.

In Section 4.2, we also examine a Nash equilibrium in which the Home policy maker optimizes τ_t to maximize country H's welfare level, whereas the Foreign policy maker optimizes τ_t^* to maximize country F's welfare level. Specifically, we consider an open-loop Nash equilibrium in which each country's policy maker chooses the optimal allocation given the evolution of the other country's policy instrument. We let x_t denote the $N \times 1$ vector of endogenous variables in this case.[6] Except for the two policy instruments, the remaining $N-2$ endogenous variables in x_t satisfy the $N-2$ structural conditions, which we again express with

$$E_t f(x_t, x_{t+1}, \zeta_t) = 0. \tag{40}$$

[5] The first-order necessary condition for optimality at $t = 0$ is (39) with $\lambda_{-1} = 0$.
[6] N in Section 3.1 is not identical to N in Section 3.2.

We obtain the first-order conditions for the each country's policy maker by setting up two Lagrangian problems in which the Home and Foreign policy makers maximize their own welfare subject to the first-order conditions of the private agents and the market-clearing conditions of the two economies. More specifically, we set up a Lagrangian problem for country i (1 or 2):

$$\mathcal{L}_{i,0} = E_0 \sum_{t=0}^{\infty} \beta^t \{U^i(x_t, \zeta_t) + \lambda_{i,t}' f(x_t, x_{t+1}, \zeta_t)\}. \tag{41}$$

Taking the derivatives of $\mathcal{L}_{i,0}$ with respect to the $N-1$ variables (except for the policy instrument of the other country), we obtain the $2N-2$ first-order conditions characterized by

$$U_1^i(x_t, \zeta_t) + E_t \lambda_{i,t}' f_1(x_t, x_{t+1}, \zeta_t) + \beta^{-1} \lambda_{i,t-1}' f_2(x_{t-1}, x_t, \zeta_{t-1}) = 0. \tag{42}$$

Taking the derivatives of $\mathcal{L}_{i,0}$ with respect to $\lambda_{i,t}$, we obtain the $N-2$ equilibrium conditions in the private sector in (40), which are common for both countries. The first-order conditions for each country's policy maker, the first-order conditions of each country's private agents, and the market-clearing conditions of the two economies characterize an open-loop Nash equilibrium. The Nash equilibrium process is therefore characterized by the $N-2$ Equations (40) and the $2N-2$ Equations (42). For the variables, we have $N-2$ elements of x and $2N-2$ multipliers of λ. In total, we therefore have $3N-4$ equations and $3N-4$ variables.

We obtain the relevant first-order conditions that characterize the optimal global policy and Nash equilibrium problems using Bodenstein et al. (2018)'s Matlab procedures.[7]

4 | PARAMETERIZATION AND NUMERICAL ANALYSIS

4.1 | Parameterization

We choose standard parameter values from the relevant literature, which we summarize in Table 1. However, we vary the parameter value of δ to examine how the asset market incompleteness affects the dynamics of the two economies in Section 4.2. We also choose a different value for the elasticity of substitution between domestic and imported goods θ to show the robustness of our analysis results in Section 5.

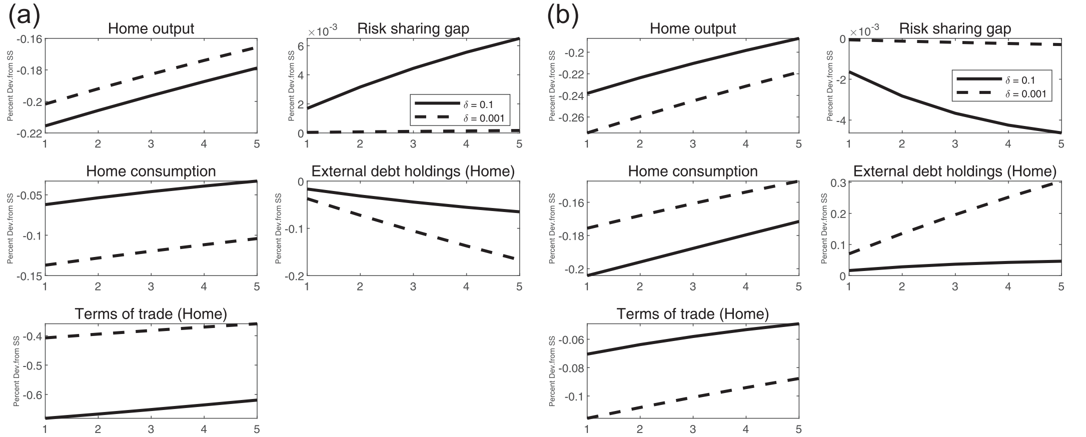
4.2 | Results

Figure 1 compares the impulse responses of the main variables to a negative home productivity shock. Figure 1a is the case when $\theta = 0.5$, which implies that the home and foreign goods are complements. Figure 1b is the case when $\theta = 3$, which implies that the home and foreign goods are imperfect substitutes. In both cases, the solid and dotted curves indicate the case with high ($\delta = 0.1$) and low frictions ($\delta = 0.001$), respectively. As Corsetti et al. (2010) and De Paoli and Lipinska (2013) argue, the elasticity of substitution

[7]Bodenstein et al. (2018)'s program reads a Dynare model file and generates the first-order conditions of policy makers under the optimal global policy and the Nash equilibrium. See Adjemian et al. (2011) for details on Dynare.

TABLE 1 Parameterization

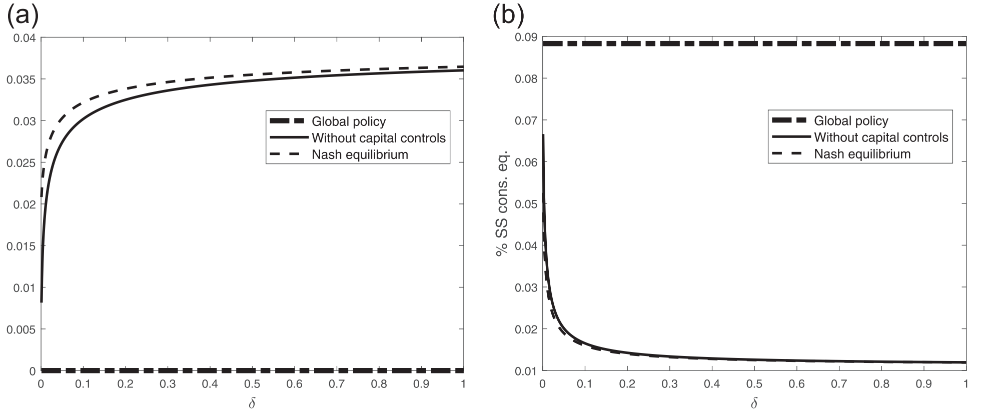
	Description	Value
β	Discount factor	0.99
σ	Inverse intertemporal elasticity of substitution	1
χ	Inverse elasticity of labor supply	0.47
δ	Bond adjustment cost parameter	0.01 [0.001, 0.1]
λ	Degree of openness	0.5
n	Home country size	0.5
θ	Elasticity of substitution between domestic and imported goods	3
ρ	Persistence of productivity shock	0.95
σ_ϵ	Standard deviation of productivity shock	0.0071



$\theta = 0.5.$ $\theta = 3.$

FIGURE 1 Responses to a negative (one standard deviation) home productivity shock. (a) $\theta = 0.5$. (b) $\theta = 3$

between the home and foreign goods, θ, is a critical parameter to dynamics in the two-country models. In Figure 1a,b, the position of the solid and dotted curves critically depends on the parameter θ. For example, in the case of "Home output," the solid curve is lower than the dotted curve in (a), but the solid curve is higher than the dotted curve in (b). However, in the "Risk-sharing gap" case, although the position of the two curves is still reversed between (a) and (b), we should note that the solid curve deviates from zero further than the dotted curve does in either case. In the high-friction case ($\delta = 0.1$), the "Risk-sharing gap" deviates further from zero compared to the low-friction case ($\delta = 0.001$). In other words, in the high-friction case, international risk sharing is more disturbed and the international financial markets are more incomplete compared to the low-friction case. Related to this, in the "External debt holdings" case, the solid curve remains closer to zero than the dotted curve does in either case. This is again because in the high-friction case, the international financial markets are more incomplete and



Standard deviation of the risk-sharing gap (%).

Conditional global welfare.

FIGURE 2 Standard deviations of the risk-sharing gap and global welfare levels under the optimal global policy, the Nash equilibrium, and no capital controls for different values of δ

international risk sharing is more disrupted compared to the low-friction case. The disruption of international risk sharing restricts changes in external debt holdings.

In Figure 1, we find that in both cases (a) and (b), a higher degree of friction causes the impulse response of the "Risk-sharing gap" to deviate further. Figure 2a plots the standard deviation of the risk-sharing gap defined by Equation (25) under different degrees of friction. The solid curve in Figure 2a depicts the case without capital controls. Consistent with Figure 1, the solid curve in Figure 2a indicates that the standard deviation of the risk-sharing gap increases as the degree of friction increases. Figure 2b depicts the associated conditional global welfare level, which we measure as a percentage of steady-state consumption. The solid curve in Figure 2b depicts the case without capital controls, which indicates that the conditional global welfare decreases as the degree of friction increases because the two countries suffer from more insufficient risk sharing as the degree of friction increases.

In Figure 2a, the dashed curve plots the standard deviations of the risk-sharing gap under the Nash equilibrium, in which the standard deviation of the risk-sharing gap increases when the degree of friction increases, as well as in the case without capital controls. However, comparing the dashed and solid curves, we see that the standard deviation of the risk-sharing gap under the Nash equilibrium is higher than that in the case without capital controls. In Figure 2b, the dashed curve plots the global welfare level under the Nash equilibrium. Consistent with the dashed curve in Figure 2a, the dashed curve in Figure 2b indicates that global welfare deteriorates as the degree of friction increases because of the resulting insufficient risk sharing. Comparing the dashed and solid curves in Figure 2b, we see that the global welfare level under the Nash equilibrium is lower than that in the case without capital controls, which is consistent with the comparison between the solid and dashed curves in Figure 2a.

The dashed dotted curve in Figure 2a plots the standard deviations of the risk-sharing gap under the optimal global policy. Compared with the Nash equilibrium case and the no capital controls case, the optimal global policy keeps the standard deviation of the risk-sharing gap close to zero. In Figure 2b, we see that compared to the other two cases, the optimal global

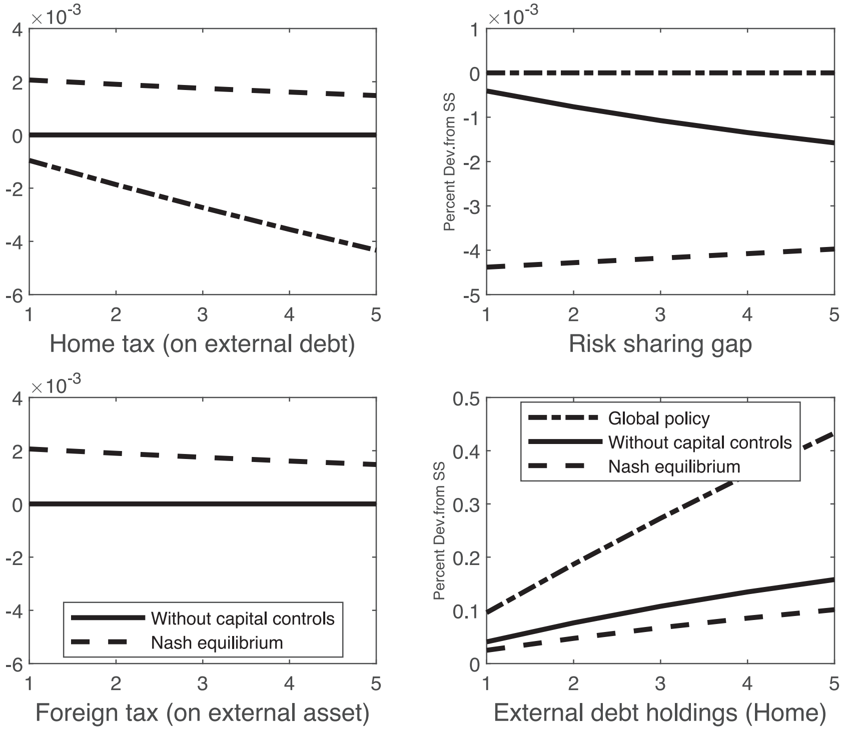


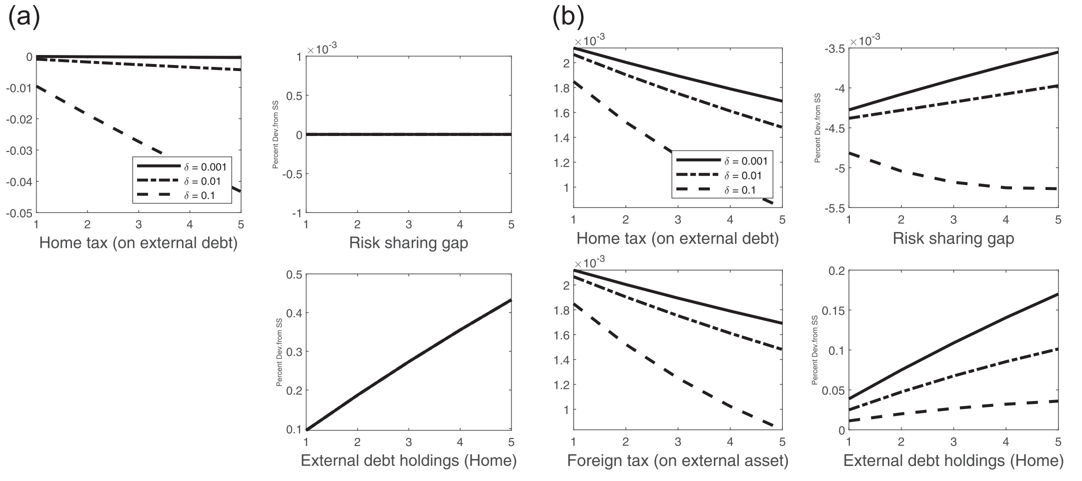
FIGURE 3 Responses of tax rates, risk-sharing gap, and external debt holdings to a negative home productivity shock under the optimal global policy, the Nash equilibrium, and no capital controls ($\delta = 0.01$)

policy prevents global welfare from deteriorating, even when the degree of friction is high, which is consistent with the dashed dotted curve in Figure 2a.

Figure 3 depicts how the tax rates of the external debt and asset (i.e. capital controls), which are different under different regimes (optimal global policy and Nash equilibrium), respond to a negative home productivity shock. In Figure 3, the solid curve, the dashed curve, and the dashed dotted curve depict the case without capital controls, the Nash equilibrium case, and the optimal global policy case, respectively. The optimal global policy reduces the rate of "Home tax (on external debt)" (left upper panel) and encourages Home's external borrowing (right lower panel) in response to a Home negative productivity shock. Because the optimal global policy improves international risk sharing, the "Risk-sharing gap" becomes zero (right upper panel).[8] In contrast, in the Nash equilibrium case, the Home policy maker raises the rate of "Home tax (on external debt)" (left upper panel) and discourages Home's external borrowing (right lower panel) compared to the other two cases. At the same time, the Foreign policy maker raises the rate of "Foreign tax (on external asset)" (left lower panel), which also disturbs international risk sharing. As international risk sharing is disturbed under the Nash equilibrium, the "Risk-sharing gap" deviates further from zero (right upper panel) even compared to the case without capital controls.

Related to Figure 3, Figure 4a depicts how the responses of tax rates, risk-sharing gap, and external debt holdings to a negative home productivity shock differ under different

[8]In the optimal global policy case, only one policy instrument is included (De Paoli & Lipinska, 2013).

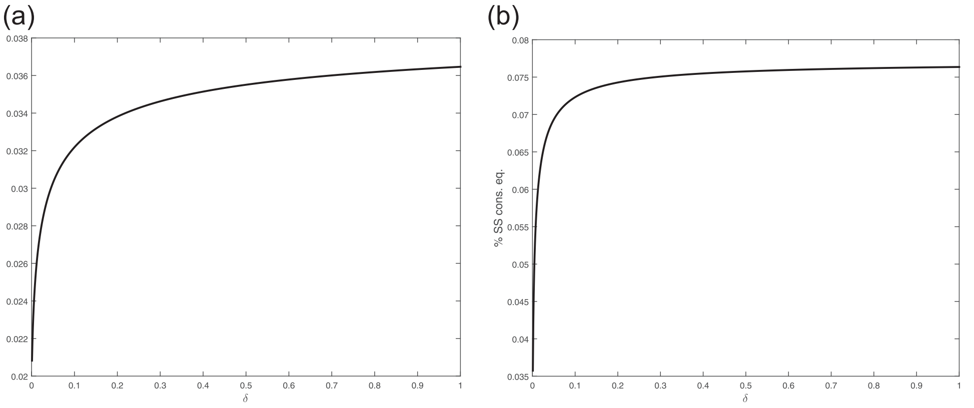


Global policy. Nash equilibrium.

FIGURE 4 Responses of tax rates, risk-sharing gap, and external debt holdings to a negative home productivity shock for different values of δ (=0.001, 0.01, and 0.1). (a) Global policy. (b) Nash equilibrium

degrees of friction (δ = 0.001, 0.01, and 0.1) in the optimal global policy case. As the degree of friction is larger, the optimal global policy reduces the rate of "Home tax (on external debt)" more aggressively (left upper panel) so as to correct the international risk-sharing inefficiency. For any degree of friction, as a result, the optimal global policy succeeds in making the "Risk-sharing gap" zero (right upper panel), and the paths of "External debt holdings (Home)" turn out identical (right lower panel). Similarly, Figure 4b depicts how the responses of the same variables to the same shock differ under different degrees of friction but in the Nash equilibrium case. Under the Nash equilibrium, the "Risk-sharing gap" is not zero and deviates further from zero as the degree of friction is higher (right upper panel). As the degree of friction is larger, international risk sharing is more disturbed, and then the path of "External debt holdings (Home)" is closer to zero (right lower panel). In contrast to the optimal global policy case, the Home policy maker raises the rate of "Home tax (on external debt)" in response to a negative home productivity shock (left upper panel). At the same time, the Foreign policy maker raises the rate of "Foreign tax (on external asset)" (left lower panel), which also disturbs international risk sharing. It is noteworthy that as the degree of friction is lower, both of the policy makers impose a higher rate of tax (left upper and lower panels) and disturbs international risk sharing further, which is in contrast to the optimal global policy's role of encouraging international risk sharing.

Figure 5 a plots the difference in the standard deviations of the risk-sharing gap between the Nash equilibrium and the optimal global policy (i.e. the difference between the dashed curve and the dashed dotted curve in Figure 2a). Figure 5a shows that as the degree of friction increases, the difference in the standard deviations of the risk-sharing gap between the Nash equilibrium and the optimal global policy increases. Figure 5b plots the difference in the (conditional) global welfare levels between the optimal global policy and the Nash equilibrium, in which the difference in global welfare levels increases when



Nash equilibrium − Global policy: Difference in the standard deviations of the risk-sharing gap (%).

Global policy − Nash equilibrium: Difference in conditional global welfare levels.

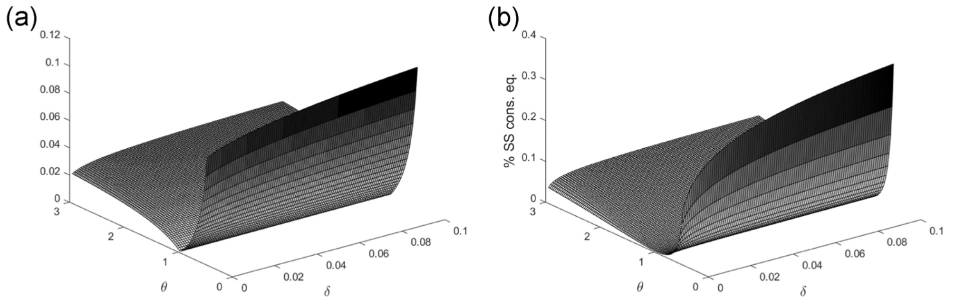
FIGURE 5 (a) Difference in the standard deviations of the risk-sharing gap between the Nash equilibrium and optimal global policy for different values of δ. (b) Difference in conditional global welfare levels between the optimal global policy and the Nash equilibrium for different values of δ

financial markets are less efficient, which is consistent with the results in Figure 5a. This implies that the gain from international cooperation on capital controls is larger when financial markets are less efficient.

In Figure 5, we set the elasticity of substitution between the home and foreign goods, θ, to 3. We next consider cases with different values of θ based on Rabitsch (2012)'s finding that welfare gains from monetary coordination critically depend on the elasticity of substitution between the home and foreign goods. Similar to Figure 5a, Figure 6a plots the differences in the standard deviations of the risk-sharing gap between the Nash equilibrium and the optimal global policy, but for different values of δ and θ. As Figure 6a shows, as θ decreases to 1, the difference in the standard deviation of the risk-sharing gap decreases, but it starts to increase for lower values of $\theta(<1)$ (for any value of δ).[9]

Similar to Figure 5b, Figure 6b plots the difference in the global welfare levels between the optimal global policy and the Nash equilibrium, but for different values of δ and θ. As Figure 6b shows, as θ decreases to 1, the difference in the global welfare levels decreases, but it starts to increase for lower values of $\theta(<1)$ (for any value of δ). In Figure 5b, we have already shown that the difference in global welfare levels between the optimal global policy and the Nash equilibrium increases as the degree of friction increases. However, Figure 6b shows that for lower values of $\theta(<1)$, the welfare gains from policy cooperation in capital controls, which we measure as the difference in global welfare levels between the optimal global policy and the Nash equilibrium, can be much larger than that in the benchmark case with $\theta = 3$.

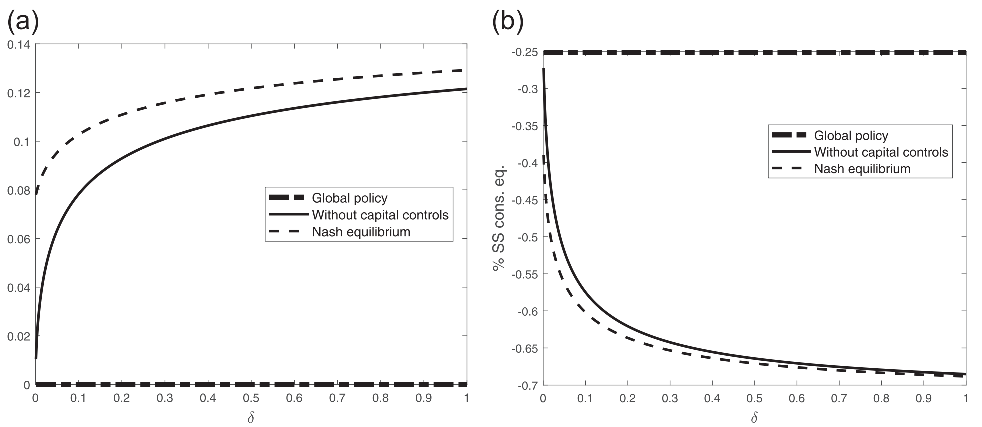
[9]The case where $\theta = 1$ corresponds to a special case in which an automatic form of risk insurance is provided (Cole & Obstfeld, 1991).



Nash equilibrium − Global policy: Difference in the standard deviations of the risk-sharing gap (%).

Global policy − Nash equilibrium: Difference in the conditional global welfare levels.

FIGURE 6 (a) Difference in the standard deviations of the risk-sharing gap between the Nash equilibrium and optimal global policy for different values of δ and θ. (b) Difference in conditional global welfare levels between the optimal global policy and the Nash equilibrium for different values of δ and θ



Standard deviation of the risk-sharing gap (%).

Conditional global welfare.

FIGURE 7 Standard deviations of the risk-sharing gap and global welfare levels under the optimal global policy, the Nash equilibrium, and no capital controls for different values of δ ($\theta = 0.5$)

5 | ROBUSTNESS

In Section 4.2, we show our results for the case in which the home and foreign goods are imperfect substitutes ($\theta = 3$), except for Figure 1a. In this section, we show that our main results remain unchanged when the home and foreign goods are complements ($\theta = 0.5$).

As Figure 7 shows, we obtain similar figures of the standard deviation of the risk-sharing gap and conditional global welfare level for different values of δ corresponding to Figure 2 in Section 4.2.

We also obtain similar figures in Figure 8 corresponding to Figure 5. We should note that when $\theta = 0.5$, the difference in the conditional global welfare levels under the optimal global

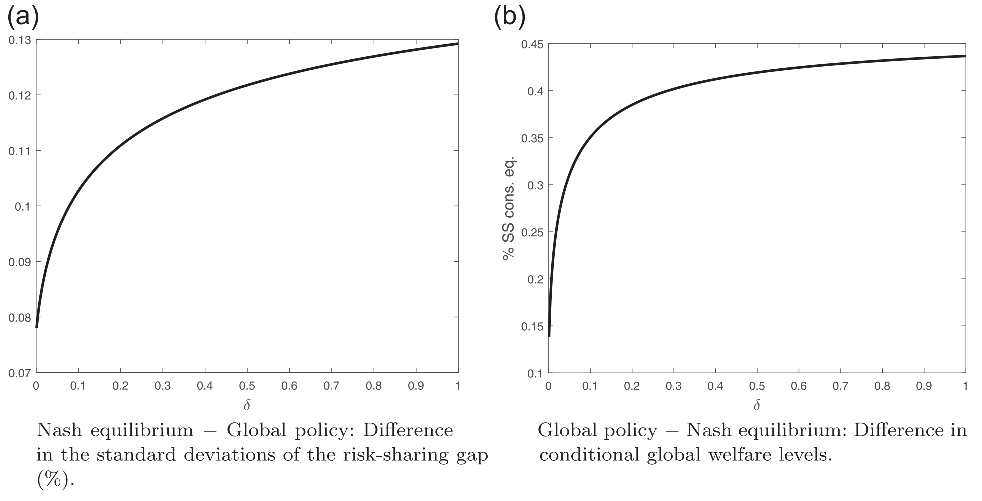


FIGURE 8 (a) Difference in the standard deviations of the risk-sharing gap under the Nash equilibrium and the optimal global policy for different values of δ. (b) Difference in the conditional global welfare levels under the optimal global policy and the Nash equilibrium for different values of δ ($\theta = 0.5$)

policy and the Nash equilibrium can reach more than 0.14 percent, up to 0.43 percent, which is higher than that in Figure 5.

6 | CONCLUSIONS

We have investigated how the degree of financial market incompleteness affects the welfare gains from international cooperation on capital controls. Under higher degrees of incompleteness, international cooperation on capital controls becomes more welfare improving compared to the Nash equilibrium case. The intuition is straightforward. When financial markets are less efficient, international risk sharing is more disturbed. However, because policy cooperation significantly reverses the welfare deterioration due to inefficient risk sharing, international cooperation on capital controls becomes more critical when financial markets are more incomplete.

ACKNOWLEDGMENTS

This work was supported by KAKENHI (20K01744 and 20H05633). The earlier versions of the paper were presented at 25th CEF conference at Carleton University, the JSME annual meeting at Gakushuin University, the seminars at Xiamen University, and Kobe University. We sincerely appreciate the referee's helpful comments and constructive suggestions that have improved our paper significantly. We are also grateful to Hao Jin, Daisuke Ida, Gilles Dufrénot, Jun Nagayasu, Yushi Yoshida, Kimiko Sugimoto, and meeting participants for their comments.

CONFLICT OF INTEREST

The authors declare that there are no conflict of interest.

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How to cite this article: Kitano, S. & Takaku, K. (2022) Financial market incompleteness and international cooperation on capital controls. *International Journal of Economic Theory*, 18, 624–642. https://doi.org/10.1111/ijet.12331