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"Currency Swap Agreements and Financial Crises in Small Open Economies"

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Currency Swap Agreements and Financial Crises in Small Open Economies

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Abstract

This paper studies the effects of an international currency swap agreement, or an exchange of hard currencies between countries, on the probability of financial crises. The analysis is based on a small open economy model with a financial constraint. A currency swap is described as a mutual provision of collateral goods between two countries. The results show that there are cases where a currency swap agreement can lower the probability of financial crises. Whether it can benefit both member countries depends on their difference in the size or probability of recessions, as well as the amount of collateral goods exchanged. Contracts of currency swaps should be designed in consideration of these factors.

Keywords: Emerging economy, Financial crisis, Currency swap

JEL classification: E32, F41, F44

1 Introduction

In response to the Asian financial crisis of 1997–98, several countries in East Asia have adopted international agreements for currency swaps. The Chiang-Mai Initiative (CMI) is an example. It started in 2000 as an initiative that promotes bilateral currency swaps between the member countries of the Association of Southeast Asian Nations (ASEAN) and China, Japan, and South Korea (ASEAN Plus Three). Continuous improvements have been made to the mechanism,

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such as multilateralization of the initiative (Chiang-Mai Initiative Multilateralization: CMIM) in 2009 (see, e.g., Aizenman et al., 2011; Ito, 2017).

Swap agreements are considered to be effective in lowering the probability of financial crises by preventing depreciation of the local currencies. Currency depreciation has caused several crises in emerging economies under liability dollarization, as pointed out by Calvo (1998), Mendoza (2002, 2005), and Eichengreen and Hausmann (2005). To prevent depreciation, many countries have adopted foreign reserve accumulation for foreign exchange intervention. Meanwhile, since foreign reserve accumulation can be costly for countries under current account deficits, a currency swap agreement has been proposed as an alternative. It is a kind of insurance that enables member countries to share the risk of currency depreciation, and thus the cost for each country can be lower than foreign reserve accumulation (Aizenman and Pasricha, 2010; Aizenman et al., 2011). However, despite its importance in the actual policy, only a few attempts have been made to study swap agreements with theoretical models.

This paper investigates the effect of a currency swap agreement on the probability of financial crises, and examines its desirable designs. The model is based on a simple small open economy model that incorporates collateral constraints, which has been widely used for analyzing currency and financial crises (e.g., Mendoza, 2002, 2005, 2010; Bianchi, 2011). As shown in Figure 1, the model is a two-country setting where both countries borrow from foreign lenders. A currency swap is described as an exchange of tradable goods, which represents hard currencies such as dollars. The transfer of tradable goods compensates for the reduction of collateral in a recession, thereby preventing local currency depreciation and mitigating the influence of the recession. I conduct stochastic simulations with this model and show that swap agreements can indeed lower the probability of financial crises. However, it is also shown that whether swap agreements benefit both member countries depends on the difference in the size or probability of recessions, as well as the amount of tradable goods exchanged. Therefore, contracts of currency swaps should be designed in consideration of these factors.

Analyzing financial crises in such a real model is common in recent small open economy literature. Bianchi (2011), Jeanne and Korinek (2010), and Mendoza (2002, 2005, 2010) are examples of these studies. In the models of these studies, currency depreciation is also analyzed by considering the prices of nontradable goods as the proxy of the real exchange rate. Further,

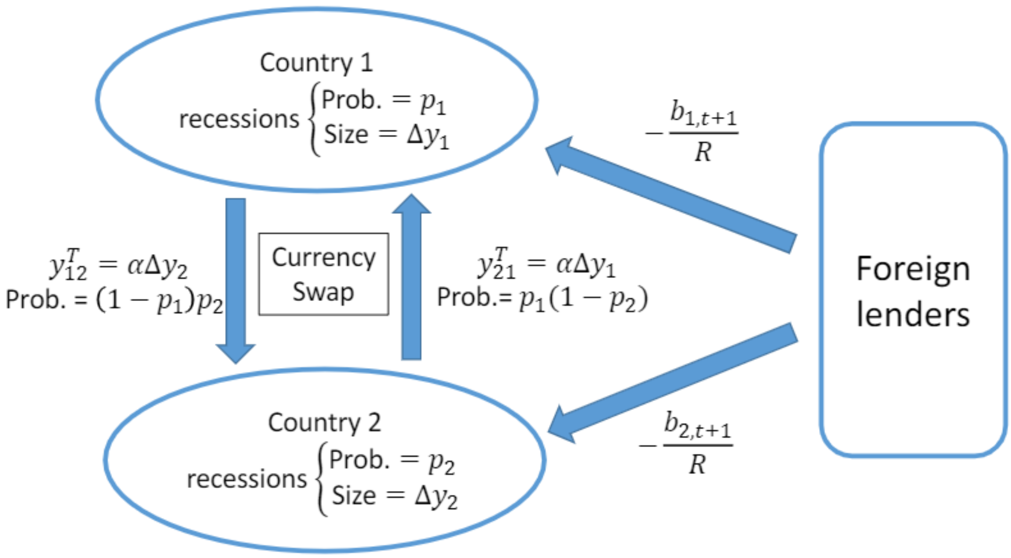

Figure 1: Model of currency swap

Note: Countries 1 and 2 exchange tradable goods, y^T_{12} or y^T_{21}, when either of them is in a recession.

Benigno et al. (2016) examine the effects of exchange rate intervention using a real model. In their model, an exchange rate policy is described as a taxation or subsidy on the consumption of tradable or nontradable goods. This paper follows their methods to analyze currency swaps in real settings.

This study is related to two strands of the literature. The first includes studies on currency swap agreements. Aizenman and Pasricha (2010) is one of the few theoretical studies in this field. Their model is based on Diamond and Dybvig's (1983) finite horizon model and considers a currency swap as a measure to prevent banking crises. In contrast, the model in this paper abstracts from banking sectors and incorporates a currency swap in infinite horizon settings. For this purpose, I introduce a collateral constraint in the model following Kiyotaki and Moore (1997) and Bianchi (2011). Aizenman and Pasricha (2010) also conduct empirical analyses on currency swaps. They show that the swap agreements conducted by the Federal Reserve promoted appreciation of the currencies of emerging countries. Another example of an empirical work is Obstfeld et al. (2009), who state that the swap agreements by the Federal Reserve did not actually work but served as a signal for preventing further crises. Aizenman et al. (2011) show that currency swap agreements are not as important as foreign reserve accumulation by each country. Considering that Korea relied on the bilateral foreign swap agreement with the Federal Reserve instead of the CMI, they assert that the effect of a currency agreement varies.

The second strand is the literature on financial crises ("Sudden Stops") in small open economies. In this literature, Kiyotaki and Moore's (1997) collateral constraint is often introduced as the engine for amplifying the negative economic shocks that cause financial crises (e.g., Bianchi, 2011; Jeanne and Korinek, 2010; and Mendoza, 2002, 2005, 2010). While these studies propose capital controls as a policy measure to prevent crises, international cooperation has not been discussed widely. In this paper I adopt their model for examining a currency swap as an example of international cooperation. An international currency swap agreement is closely related to its domestic counterpart, foreign exchange accumulation, which is studied by Aizenman and Lee (2007), Aizenman and Hutchison (2012), Benigno and Fornaro (2012), and Chamon et al. (2019).

The rest of the paper is organized as follows. Section 2 presents the model and optimality conditions. Section 3 presents the simulation results and the implications. Section 4 concludes the paper.

2 Model

2.1 Model setup

The basic structure of the model follows Bianchi (2011). Consider two small open economies, Country 1 and 2, in infinite discrete time $t = 0, 1, 2, ...$ Each economy contains the tradable goods sector and nontradable goods sector. Only tradable goods can be traded internationally; nontradable goods are consumed domestically. Country $i \in \{1, 2\}$ is populated by a continuum of identical, infinitely lived households of measure unity with preferences given by

$$U_{i,t} = E_t \sum_{s=t}^{\infty} \beta^{s-t} u(c_{i,s}),$$

where $E_t(\cdot)$ is the time t expectation operator, and $\beta \in (0, 1)$ is the discount factor. The period utility function $u(c)$ is assumed to be common in the two economies and takes the form, $c^{1-\sigma}/(1 - \sigma)$, and $\sigma > 0$. Let $c_{i,t}$ denote a CES (constant elasticity of substitution) composite of tradable and nontradable goods consumption, $c^T_{i,t}$ and $c^N_{i,t}$, respectively, given by

$$c_{i,t} = [\omega(c^T_{i,t})^{-\eta} + (1-\omega)(c^N_{i,t})^{-\eta}]^{-\frac{1}{\eta}},$$

where $\eta > -1$, and $\omega \in (0,1)$ is the share of tradable goods in consumption. In each period t, households receive an endowment of tradable goods $y^T_{i,t}$ and an endowment of nontradable goods $y^N_{i,t}$. I assume that the vector of endowments given by $y = (y^T, y^N)$ follows an identical and independent process. These endowment shocks are the only source of uncertainty in this model.

The only foreign asset available is a one period, non-state contingent bond denominated in units of tradable goods that pays a fixed interest rate R, determined exogenously in the world market. I examine the equilibrium in which the household borrows from foreigners with constant gross interest rate R, where $\beta R < 1$. For simplicity, I also assume that there is no trade between these two countries, while I assume that they trade with the rest of the world. I normalize the price of tradable goods to 1 and denote the price of nontradable goods by $p^N_{i,t}$.

A swap agreement is modeled as an exchange of tradable income, $y^T_{i,t}$, between the two countries. Therefore, the introduction of a swap agreement affects both budget and collateral constraints. Let y^T_{ij} denote a transfer of tradable goods from Country i to j, where $j \in \{1,2\}$ and $i \neq j$. Then, the budget constraint for Country i is

$$b_{i,t+1}/R + c^T_{i,t} + p^N_{i,t}c^N_{i,t} = b_{i,t} + y^T_{i,t} + p^N_{i,t}y^N_{i,t} - y^T_{ij,t} + y^T_{ji,t}, \tag{1}$$

where the borrowings are expressed as negative numbers of bond holdings, $b_{i,t}$. Compared with Bianchi (2011), the last two terms on the right hand side, $-y^T_{ij,t}$ and $y^T_{ji,t}$, are added to incorporate a currency swap.

Following Bianchi (2011), I assume that creditors restrict loans so that the amount of debt does not exceed a fraction κ_i of total income. Thus the credit constraint is given by

$$b_{i,t+1}/R \geq -\kappa_i(y^T_{i,t} + p^N_{i,t}y^N_{i,t} - y^T_{ij,t} + y^T_{ji,t}). \tag{2}$$

As in the case of the budget constraint above, the last two terms in parentheses on the right hand side, $-y^T_{ij,t}$ and $y^T_{ji,t}$, are added to Bianchi's (2011) credit constraint.

I describe a currency swap agreement as a policy rule as follows. A transfer of tradable goods from Country i to j occurs only when Country j is in a recession but Country i is not. I also assume that the amount of the transfer is proportional to the drop in tradable output. That is, the amount of the transfer is written as $\alpha \Delta y_j$, where $\alpha > 0$ and $\Delta y_j > 0$ is the size of drop in tradable output. I call parameter α as the swap size and assume that the value is determined by the member countries as a factor of the contract of a currency swap agreement.

Given the above settings, a currency swap is described as a sequence $\left\{(y^T_{ij,t}, y^T_{ji,t})\right\}_{t=0}^{\infty}$, where

$$y^T_{ij,t} = \begin{cases} y^T_{ij,t} = \alpha \Delta y_j > 0 & \text{if Country } j \text{ is in a recession while Country } i \text{ is not} \\ y^T_{ij,t} = 0 & \text{otherwise,} \end{cases}$$

and vice versa for $y^T_{ji,t}$. The definition of a recession in the model is given in the calibration part of the next section.

2.2 Equilibrium

A competitive equilibrium for Country i is a set of allocations $\{(b_{i,t+1}, c^T_{i,t}, c^N_{i,t})^{\infty}_{t=0}\}$ such that (i) the household maximizes $U_{i,t}$ subject to budget constraint (1) and collateral constraint (2) given $b_{i,0}$, R, and $\{(y^T_{i,t}, y^N_{i,t})^{\infty}_{t=0}\}$; (ii) consistency conditions $c^T_{i,t} = C^T_{i,t}, c^N_{i,t} = C^N_{i,t}$, and $b_{i,t} = B_{i,t}$, where the capital letters are aggregate variables for each country; and (iii) market clearing conditions $c^T_{i,t} + B_{i,t+1}/R = y^T_{i,t} + B_{1,t} - y^T_{ij,t} + y^T_{ji,t}$, and $c^N_{i,t} = y^N_{i,t}$ are satisfied for all t. The household's first-order conditions for Country i are

$$\begin{aligned} & u_T(c_{i,t}) = \beta R E_t(u_T(c_{i,t+1})) + \mu_{i,t}, \\ & \mu_{i,t} \left[b_{i,t+1}/R + \kappa \left(y^T_{i,t} + p^N_{1,t} y^N_{i,t} - y^T_{ij,t} + y^T_{ji,t} \right) \right] = 0, \\ & \mu_{i,t} \geq 0, \\ & p^N_{i,t} = \frac{u_N(c^T, y^N)}{u_T(c^T, y^N)} = \frac{1-\omega}{\omega} \left(\frac{c^T_{i,t}}{y^N_{i,t}} \right)^{1+\eta}, \end{aligned} \tag{3}$$

where u_T and u_N denote $\equiv \partial u/\partial c^T$ and $\equiv \partial u/\partial c^N$, respectively, and μ_t^i is the Lagrange multiplier for (2). The equilibrium is similarly defined for the other country j.

3 Quantitative analyses

In this section, I describe the calibration of the model and evaluate the quantitative implications of the currency swap agreement. I numerically solve for the competitive equilibrium shown above using nonlinear methods proposed by Bianchi (2011).

3.1 Calibration

In the quantitative analyses with the models above, I assume $\beta = 0.91$, $R = 1.04$, $\sigma = 2$, $1/(1+\eta) = 0.83$, and $\kappa = 0.32$, following Bianchi (2011) and Bianchi, Liu, and Mendoza (2016). Following Korinek and Mendoza's (2014) observation, I assume a binary endowment process $y_{i,t}^T = y_{i,t}^N \in \{y^H, y_i^L\}$, where y^H is normalized to 1 and $y_i^L = y^H - \Delta y_i$, in which $\Delta y_i \in [0,1]$ with an i.i.d. probability p_i for $i \in \{1,2\}$. I call state L a "recession" and later define a "crisis" as an extreme case of a recession. I adopt Korinek and Mendoza's (2014) baseline calibration, $\Delta y_i = 3\%$ and $p_i = 5\%$. Parameter values for Country j are calibrated similarly.

Under this two-state setting, I assume that the amount of transfer (i.e., a currency swap agreement), $y_{ij,T}^T$, is given by

$$y_{ij,t}^T = \begin{cases} y_{i,j}^T = \alpha \Delta y_j & \text{if } y_{i,t}^T = y_{i,y}^N = y_H \text{ and } y_{j,t}^T = y_{j,y}^N = y_L, \\ y_{i,j}^T = 0 & \text{otherwise.} \end{cases}$$

Since I assume the recession probabilities in the two countries to be independent, the probability of each case can be summarized as in Table 2. For instance, when none of the two Countries 1 and 2 is in a recession (state (H,H)), no transfer is conducted, namely, $(y_{12,t}^T, y_{21,t}^T) = (0,0)$. This occurs with probability $(1-p_1)(1-p_2)$. In contrast, when Country 2 is in a recession and Country 1 is not (state (H,L), with probability $(1-p_1)p_2$), Country 1 conducts a transfer $\alpha\Delta y_2$ to Country 2, following the swap agreement. In the table, this situation is described as $(y_{12,t}^T, y_{21,t}^T) = (\alpha\Delta y_2, 0)$. No transfer is conducted when both of the two countries are in a

Table 1: Calibration

Parameter	Description	
R	Gross interest rate	1.04
σ	Risk aversion	2
ω	Weight on tradable goods in CES	0.32
η	Elasticity of substitution	0.20
β	Discount factor	0.91
κ_i	Credit coefficient	0.32
π	Probability of a recession	5%
Δy_i	Output drop in a recession	3%

Note: Baseline calibration of Bianchi (2011). Subscript $i \in \{1, 2\}$ is the country index.

Table 2: Contract design of a currency swap $(y^T_{12,t}, y^T_{21,t})$

		Country 2	
		H	L
Country 1	H	$(0, 0)$ w.p. $(1 - p_1)(1 - p_2)$	$(\alpha\Delta y_2,\ 0)$ w.p. $(1 - p_1)p_2$
	L	$(0,\ \alpha\Delta y_1)$ w.p. $p_1(1 - p_2)$	$(0, 0)$ w.p. $p_1 p_2$

Note: Sizes and probability of transfers in each case, where H and L represent the normal and recession times, respectively.

recession (state (L, L)), which is written as $(0, 0)$ in the table.

Following Bianchi (2011), I define a financial crisis as a case where (i) the credit constraint binds ($\mu_{i,t} > 0$), and which (ii) accompanies an increase in net capital outflows that exceeds one standard deviation of net capital outflows in the ergodic distribution of the case without a currency swap agreement. To calculate the probability, I conduct 10,000 simulations with the policy function obtained from the above equilibrium conditions, and burn in the first 2,000 iterations.

3.2 Borrowing decisions

Figure 2 is the policy function of $b_{1,t+1}$ for the case without a currency swap, namely, $\alpha = 0$. This is similar to the policy functions shown in Bianchi (2011) or Korinek and Mendoza (2014). As they point out, each policy function has downward-sloping and upward-sloping regions. The upward-sloping region represents a case where the collateral constraint is not binding. When the current borrowing is high (i.e., $b_{1,t}$ is highly negative), the household needs to borrow

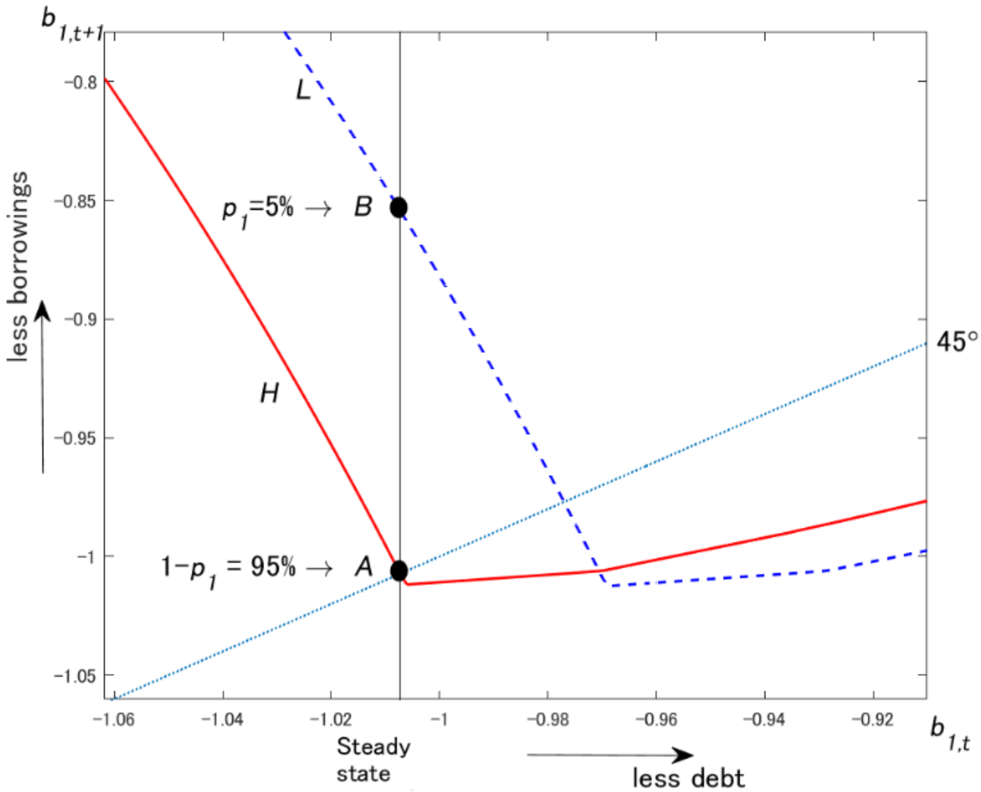

Figure 2: Policy functions without a currency swap (bond holdings)

Notes: This figure shows the policy functions of bond holdings in the next period, $b_{1,t+1}$, when the swap size α is 0. The horizontal axis is the amount of current bond holdings (borrowings when negative). The red solid line is for case H, and the blue dotted line is for case L.

more to reimburse them, yielding low $b_{1,t+1}$. Therefore, the relationship between $b_{1,t}$ and $b_{1,t+1}$ is positive. The downward-sloping area is where the collateral constraint is binding. In this area, borrowing is limited to a certain level. Therefore, when the level of $b_{1,t}$ is low, $b_{1,t+1}$ cannot be reduced because of the resource constraint (1); that is, the household cannot increase borrowings. Instead, the household is forced to reduce tradable goods consumption, $c_{1,t}^T$. This lowers the price of nontradable goods $p_{1,t}^N$ through the first order condition (3), which decreases the borrowings (i.e., increases the value of $b_{1,t+1}$). This process yields a negative relationship between $b_{1,t}$ and $b_{1,t+1}$.

The dots shown in the figures represent the levels of debt and borrowings in state H or L. When the economy is not in a recession, $(b_{1,t}, b_{1,t+1})$ is at point A, where the policy function of state H ($y_{1,t}^T = y_{1,t}^N = y^H$) and the 45 degree line cross. Once a recession occurs, point $(b_{1,t}, b_{1,t+1})$ jumps up to point B, where the household borrows less (i.e., larger $b_{1,t+1}$). This corresponds to what is called a "Sudden Stop" in the literature, where foreign borrowings are restricted extensively. Under the current parameter values, the economy is at point A with probability 95% and at point B with probability 5%.[1]

Figure 3 shows the policy functions when a swap agreement is introduced, with swap size $\alpha = 0.5$. With a swap agreement, there are four, instead of two, policy functions. That is, there are policy functions that correspond to states (H, H), (H, L), (L, H), and (L, L), respectively. Assuming $p_1 = p_2 = 5\%$, the probability of being at each point is 90.25%, 4.75%, 4.75%, and 0.25%, respectively.

Note that the probability of being at point B is now $p_1 p_2 = 0.25\%$, which is much smaller than that in Figure 2 ($p_1 = 5\%$). This is because the probability of a joint recession in the two countries (i.e., state (L, L)) is smaller than the probability of a recession in a single country. Therefore, the two countries can hedge the risk by swapping tradable goods to prevent a large reduction in borrowings. In addition, when a recession occurs in Country 1 but not in 2 (state (L, H), point B' in Figure 3), the reduction in borrowings is less than that of state (L, L) (point B), since the drop is now compensated by the transfer $y_{12,t}^T$ from Country 2.

Because of the alleviation in the drop in borrowings, the drop in consumption and currency

[1]The steady state of case L is the intersection of the 45 degree line and the policy function for case L. However, the economy reaches this point only when the recession continues for many periods, which is a rare event with $p_1 = 0.5$. Therefore, in most cases, the economy jumps up to point B in the recession, and soon moves back to point A as the endowment recovers.

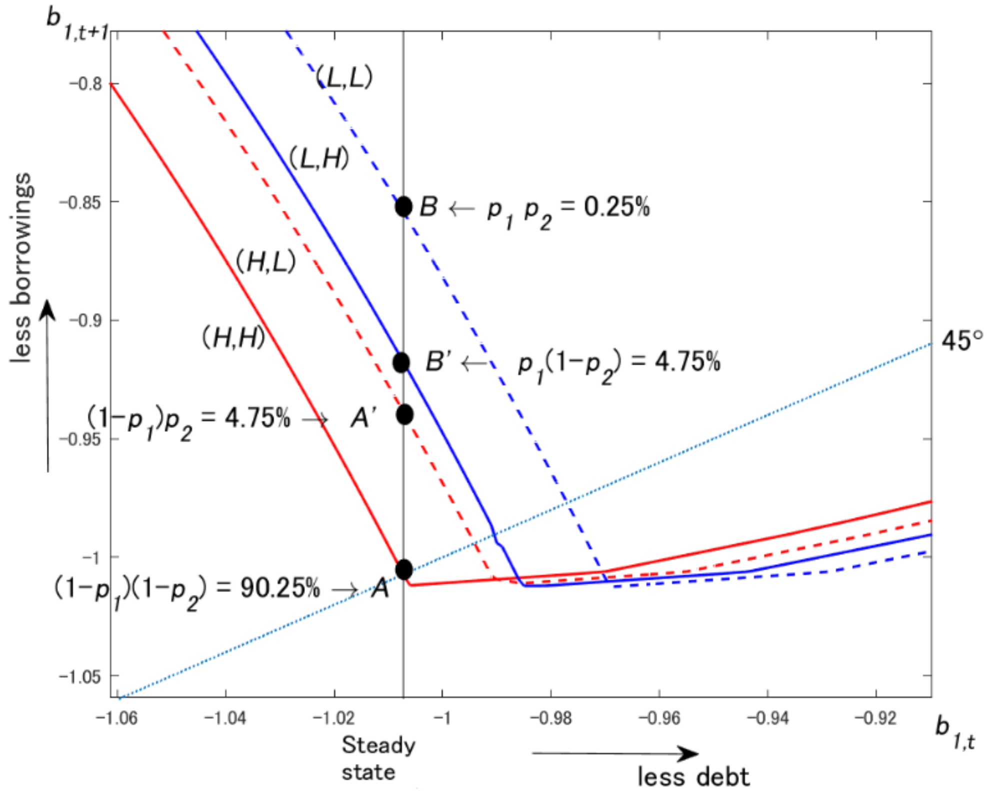

Figure 3: Policy functions with a currency swap (bond holdings)
Notes: This figure shows the policy functions of bond holdings in the next period, $b_{1,t+1}$, when the swap size α is 0.5. The horizontal axis is the amount of current bond holdings (borrowings when negative). The red solid line is for case (H, H), the red dotted line for case (H, L), the blue solid line for case (L, H), and the blue dotted line for case (L, L).

depreciation are also mitigated, as shown in their policy functions. Figures 4 and 5 show the policy functions of tradable goods consumption $c^T_{1,t}$ and nontradable goods price $p^N_{1,t}$. In Figure 4, the level of tradable goods consumption is at point B' when Country 1 is under a recession, but Country 2 is not (state (L, H)). Without a currency swap, it would be at point B, which shows that the existence of a currency swap mitigates the drop in tradable goods consumption. The probability of the worst case (point B) is also smaller ($p_1p_2 = 0.25\%$) than in the case without a currency swap ($p_1 = 5\%$). As shown in Figure 5, this alleviation of the drop in tradable goods consumption also mitigates the drop in the prices of nontradable goods, namely, a large depreciation of the local currency. In Figure 5, the price of nontradable goods, $p^N_{1,t}$, for state (L, H), shown as point B', is above that of state (L, L), shown as point B. This higher price leads to a higher value of the collateral, $y^T_{1,t} + p^N_{1,t} y^N_{1,t} - y^T_{12,t} + y^T_{21,t}$, in constraint

(2) and prevents serious financial crises. Finally, Figure 6 shows the policy functions of the Lagrange multiplier of credit constraint, $\mu_{1,t}$. When $\mu_{1,t} > 0$, the credit constraint is binding. The larger is the value of $\mu_{1,t}$, the more tightly binding it is. Just as in Figures 4 and 5, the probability of the worst case (L, L) is smaller and the collateral constraint is less binding at state (L, H), where the country receives a transfer.

However, introducing a currency swap agreement also entails some costs. Because of its mutual nature, Country 1 needs to transfer $\alpha\Delta y_2$ in state (H, L). As a result, the probability of the best case (state (H, H), shown as point A in Figures 3–6) becomes lower (i.e., $(1-p_1)(1-p_2) = 90.25\%$) than in the case without a swap agreement. Therefore, it is not clear whether a currency swap is beneficial for Country 1. Further, more conditions might be required for a currency swap to be beneficial for both member countries. I discuss such conditions in the next subsection.

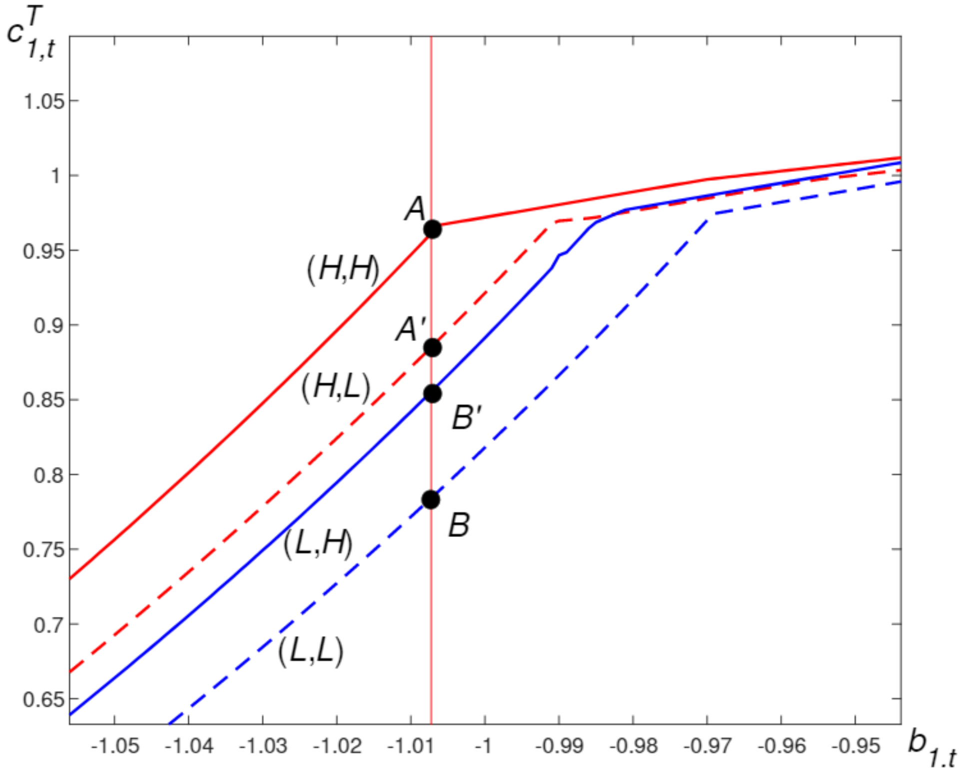

Figure 4: Policy functions of $c^T_{1,t}$

Notes: This figure shows the policy functions of tradable goods consumption, $c^T_{1,t}$, when swap size α is 0.5. The horizontal axis is the amount of current bond holdings (borrowings when negative). The red solid line is for case (H, H), the red dotted line for case (H, L), the blue solid line for case (L, H), and the blue dotted line for case (L, L).

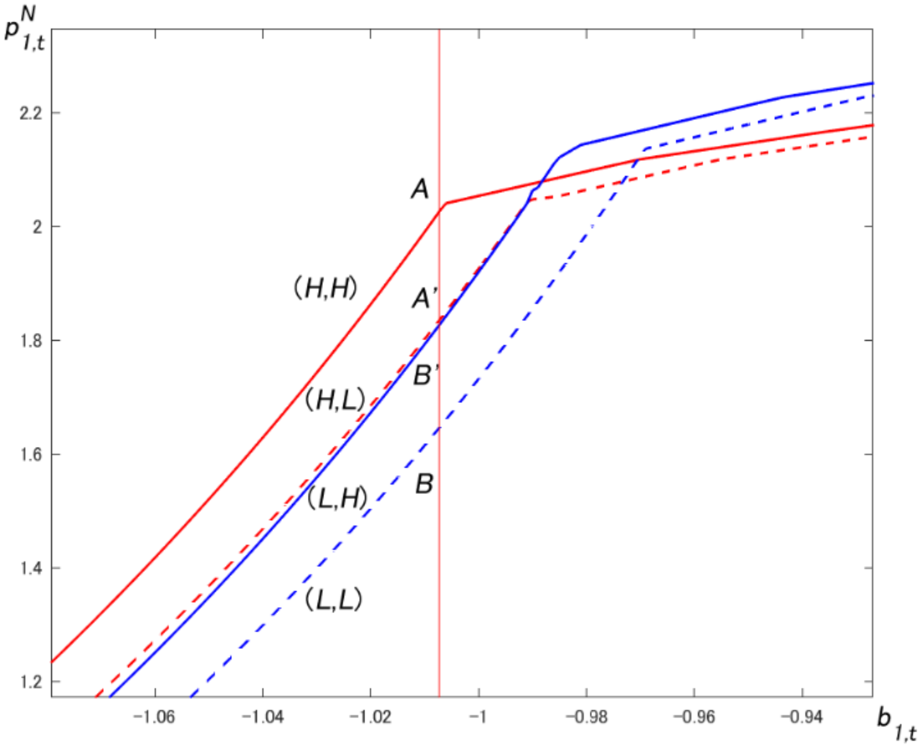

Figure 5: Policy functions of $p^N_{1,t}$

Notes: This figure shows the policy functions of nontradable goods price, $p^N_{1,t}$, when the swap size α is 0.5. The horizontal axis is the amount of current bond holdings (borrowings when negative). The red solid line is for case (H, H), the red dotted line for case (H, L), the blue solid line for case (L, H), and the blue dotted line for case (L, L).

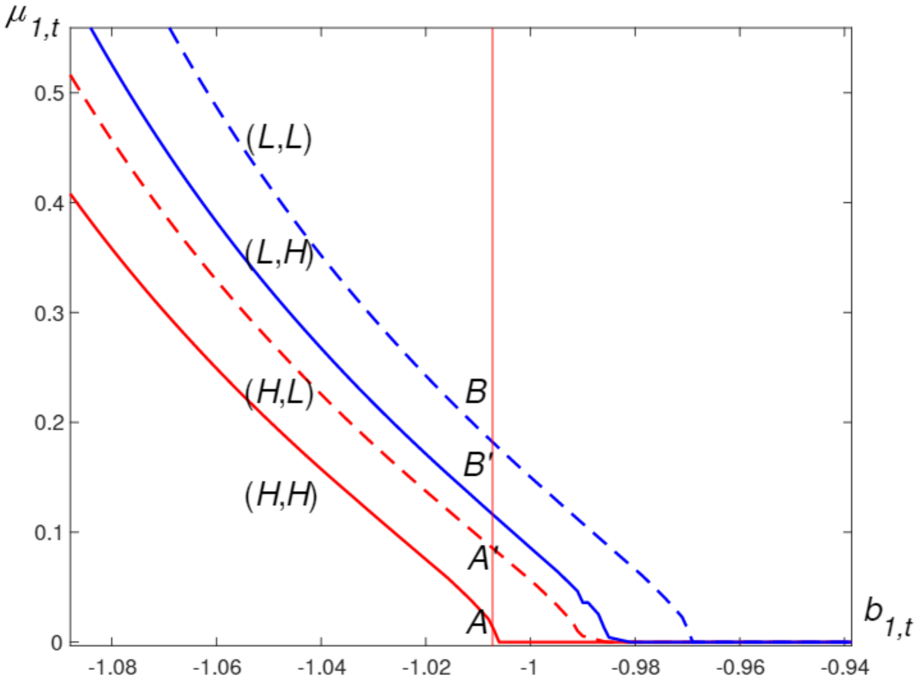

Figure 6: Policy functions of $\mu_{1,t}$

Notes: This figure shows the policy functions of the Lagrange multiplier, $\mu_{1,t}$, when the swap size α is 0.5. The horizontal axis is the amount of current bond holdings (borrowings when negative). The red solid line is for case (H, H), the red dotted line for case (H, L), the blue solid line for case (L, H), and the blue dotted line for case (L, L).

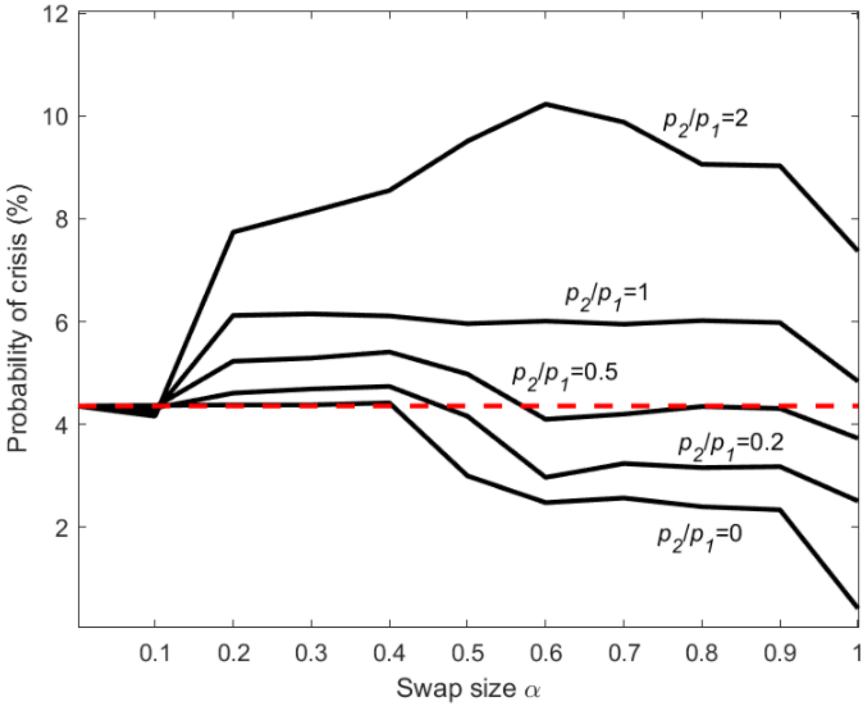

Figure 7: Swap size and and the probability of a crisis
Note: This figure shows the probability of financial crisis for each swap size α and recession probability ratios $p_2/p_1 = 0, 0.2, 0.5, 1$, and 2, respectively.

3.3 Factors that determine the effect of a currency swap

In this subsection, I consider several factors that are relevant to the effect of a currency swap agreement. These include swap size, and relative size or probability of a recession in the two member countries.

3.3.1 Swap size

Figure 7 shows the probability of financial crises in Country 1 for each swap size, α, ranging from 0 to 1, and each recession probability in Country 2 relative to that of Country 1, p_2/p_1 ($p_2/p_1 = 0, 0.2, 0.5, 1$, and 2 as examples). For each case, I conduct stochastic simulations with the model above and calculate the probability of a crisis, which is shown in the vertical axis. The horizontal red dotted line shows the probability of a crisis when no currency swap exists (i.e., $\alpha = 0$), which I treat as the benchmark case. This probability is 4.36% and common for all p_2/p_1. When probability is below this line, I evaluate a currency swap to be effective in preventing crises.

In Figure 7, the graphs exhibit similar patterns when Country 2 experiences less recessions (i.e., $p_2/p_1 = 0$, 0.2, and 0.5). The probability of a crisis in Country 1 drops by a large amount at around $\alpha = 0.5$, and again at around $\alpha = 0.9$. For instance, when Country 2 never faces a recession (i.e., $p_2/p_1 = 0$), the probability of a crisis is not affected and remains almost constant when the α is below 0.4. However, when the swap size exceeds 0.4, the probability suddenly drops by more than one percentage point. A large drop in crisis probability appears again around $\alpha = 0.9$. In the cases of $p_2/p_1 = 0.2$ and 0.5, the probability of a crisis is above the benchmark until the swap size exceeds a certain value. The probability becomes less than the benchmark at around $\alpha = 0.5$ when $p_2/p_1 = 0.2$ and at around $\alpha = 0.6$ when $p_2/p_1 = 0.5$. These results show that the swap size α should be sufficiently large for a currency swap to be beneficial for Country 1. This is because when the swap size is too small, it only raises the probability of state (H, L), where Country 1 needs to help Country 2, while the transfer received from the other country in state (L, H) is too small. After α exceeds a certain threshold, the country can receive enough transfers to prevent crises. Although the country can receive a transfer in a recession as long as α is positive, the amount should be large enough to keep the drop in borrowings over a certain value, since a crisis is an extreme case of a recession and defined by a certain quantitative criteria (see subsection 3.1).

While a currency swap is shown to be effective in reducing crises in Country 1 when $p_2/p_1 < 1$, it could be less beneficial for Country 2. For instance, $p_2/p_1 = 0.5$ means that the probability of recession in Country 1 is twice as high as in Country 2. To see the effect of the swap in the case of $p_2/p_1 = 0.5$ ($p_1/p_2 = 2$) from the viewpoint of Country 2, I also show the opposite case ($p_2/p_1 = 2$) in Figure 7. This shows that the probability of a crisis is always higher than the benchmark when α is over 0.1. The probability of a crisis is almost always over the benchmark. A similar result is obtained in the symmetric case ($p_2/p_1 = 1$), and the crisis probability becomes even larger when $p_2/p_1 = 5$ (not shown). Therefore, a swap agreement cannot benefit both the member countries when they differ only in the probability of recessions. There should be some other differences in the member countries for a swap agreement to be beneficial for both countries. In the following, I consider such cases.

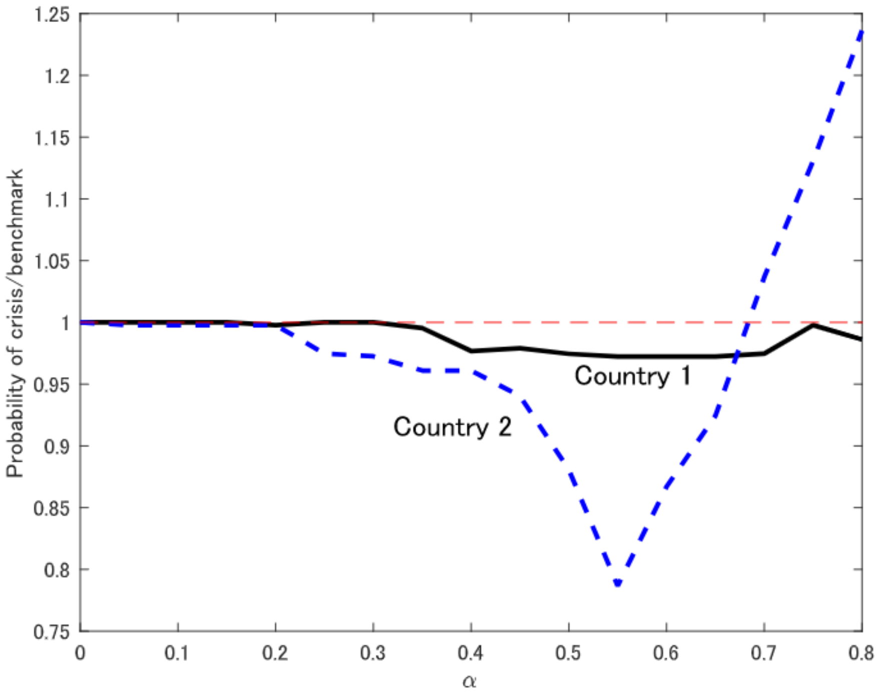

Figure 8: Crisis probability when $p_2/p_1 = 1.5$ and $\Delta y_2/\Delta y_1 = 0.2$
Notes: Probability of financial crises over that in the benchmark case ($\alpha = 0$) in Countries 1 (black solid line) and 2 (blue dotted line). Swap size, α, is set to 0.55.

3.3.2 Relative size and probability of recessions

Here I consider conditions that make a currency swap agreement beneficial for both member countries (win-win case). In particular, I examine the case where the two countries differ in size and probability of recessions, and calculate the probability of a crisis of each country. Figure 8 shows the results when $p_2/p_1 = 1.5$ and $\Delta y_2/\Delta y_1 = 1/5$. The horizontal axis is the swap size, α, and the vertical axis is the probability of a crisis relative to that of the benchmark case ($\alpha = 0$). The black solid line is of Country 1, and the blue dotted line is of Country 2. The figure shows that when $0.35 \leq \alpha \leq 0.65$, both countries are made better off by the currency swap. That is, in this region, the probability of a crisis relative to the benchmark is less than one in both Countries 1 and 2. The reason why Country 1 gains from the agreement is that, since the output drop in Country 2 is smaller, the transfer from Country 1 to 2 is small, although recessions occur more often in Country 2 ($p_2 > p_1$). Hence, the transfer from Country 1 to 2 is not likely to induce a crisis in Country 1. On the other hand, larger recessions

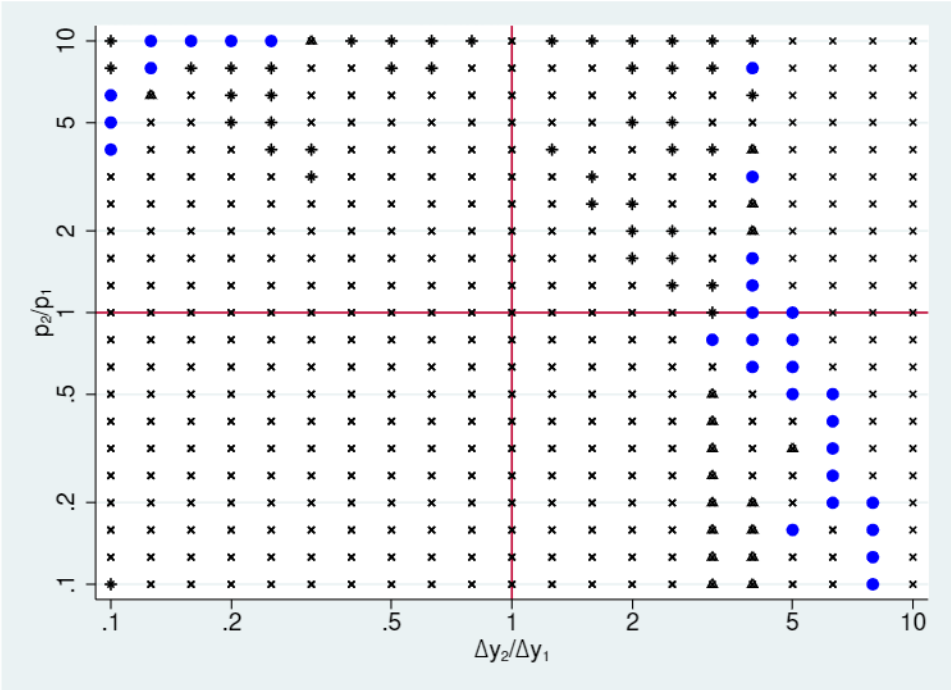

Figure 9: Cases where both countries gain from a currency swap

Notes: The horizontal axis shows recession sizes in Country 2 relative to those in Country 1, and the vertical axis shows the recession probabilities relative to those of Country 1. Both axes are logarithmic, and α is set to 0.55. The blue circles represent the win-win case, where the probability of crisis in both countries is below the benchmark case. The black crosses mean both countries are worse off, the triangles mean only Country 1 gains, and the asterisks mean only Country 2 gains from the currency swap agreement.

happen in Country 1 but less frequently than in Country 2. In addition, once Country 1 is in a recession, it can receive a large transfer from Country 2.

The example above shows that a currency swap can benefit both member countries when one of them has larger probability and smaller magnitude of recessions. Considering this point, it is possible to consider desirable partner countries in a currency swap agreement. Figure 9 shows the feature of the partner countries (Country 2), characterized by the combinations of relative size and probability of recession, $(\Delta y_2/\Delta y_1,\, p_2/p_1)$. I assume $p_1 = 5\%$ and $\Delta y_1 = 5\%$ in the home country (Country 1), which is located at point $(1, 1)$. Swap size, α, is set to 0.55 since this level leads to the lowest probability in both countries in Figure 8. Both $\Delta y_2/\Delta y_1$ and p_2/p_1 range from $10^{-1}(= 0.1)$ to $10^{0.6}(= 3.98)$, which are shown on a logarithmic graph. For each of these points, I conduct stochastic simulations with the model and examine whether the probability of a financial crisis becomes less than that in the benchmark case ($\alpha = 0$). The blue circles represent cases where both parties gain from the currency swap (win-win case), that is, the probability of a financial crisis is less than that in the benchmark case ($\alpha = 0$) in both countries. Most of the blue circles are located either in the northwest or southeast of $(1, 1)$. That is, when the output drop is sufficiently smaller and the recession probability is sufficiently larger (northwest), or when the former is sufficiently larger and the latter is sufficiently smaller (southeast), both countries can gain from the agreement. For example, when $\Delta y_2/\Delta y_1 = 0.2$, namely, when the magnitude of a recession in Country 2 is one-fifth of that in Country 1, a swap agreement benefits both countries if $p_2/p_1 = 10$. As most of the blue circles are far from $(1, 1)$, a substantial difference in size and probability of recession seems to be needed for a win-win case in this example.

3.4 Optimum swap areas

Next, I consider some ideal combinations of countries for currency swap members using actual data. Such a combination of member countries could be called an "optimum swap area," á la Mundell (1961). Based on the observations above, the area should be determined considering the relative sizes and probabilities of recessions ($\Delta y_2/\Delta y_1$ and p_2/p_1 in the model above).

In line with the model, I define a recession as a drop in real GDP per capita which exceeds 3%. I used Uribe and Schmitt-Grohé's (2017) dataset which contains output data from 1980 to 2012. I compute relative sizes of crises (corresponding to $\Delta y_2/\Delta y_1$ in the model), by dividing mean output drop in the other country (or Country 2) by that of the country of interest (home country, or Country 1). It shows how large the other country's recession size is, relative to that of the home country. Similarly, relative probability (corresponding to p_2/p_1 in the model) is the recession probability in the other country relative to that of the home country. Figures from 10 to 12 show the data values when the home country is Korea, Thailand, and Brazil, respectively. The horizontal axis is the relative size of recession, and the vertical axis is the relative probability of recession in each country. Hence, the benchmark country is at point $(1, 1)$. Both axes are logarithmic.

Quantitatively speaking, none of these three countries seems to have a desirable counterpart that corresponds to the blue circles in Figure 9. That is, the difference in recession size is not large enough to be an optimum swap area shown in Figure 9. For instance, in the case of Korea (Figure 10), the minimum value of the relative size of recession is that of Switzerland

("CHE"), which is around 0.5. In contrast, according to Figure 9, $\Delta y_2/\Delta y_1$ should be less than or equal to $10^{-0.6}(\approx 0.25)$ to be a win-win case. Hence, the actual recession size of the other countries are too close to that of Korea to be in its optimum swap area.

However, Figure 9 could still provide some qualitative guidelines or a necessary condition to be an optimum swap area. While the win-win areas (blue dots) in Figure 9 change as the size and probability of the home country (i.e., Δy_1 and p_1) take different values, the areas are in the northwest or southeast of $(1, 1)$ in most cases. Therefore, if many countries are in these regions, there is a possibility that the home country can conclude a win-win currency swap agreement with some of those countries.

In Figure 10, where Korea is the home country, it is located at point $(1, 1)$. As seen from this point, there are many countries in the northwest. In other words, many other countries have smaller and more frequent recessions compared with Korea. For instance, Malaysia ("MYS") has a probability almost four times as large as Korea's, while the mean size of its recession is around 80% of that of Korea. Therefore, it might be plausible that these two countries are member countries of a swap agreement in CMI. In contrast, as shown in Figure 11, Thailand has relatively fewer countries in the northwest or southeast of the panel. Within the data in the panel, Argentina and Turkey are the only countries in the northwest of Thailand, and there are no countries in the southeast. While Thailand is a member country of the CMI, it might be difficult for it to make a win-win swap agreement. Therefore, other policy measures, such as foreign reserve accumulation, might be a better option for the country. Finally, as shown in Figure 12, Brazil has a lot of counties in the southeast. These countries include Mexico, Chile, and Uruguay. In spite of the frequent financial and currency crises, there are few attempts to conduct currency swaps in Latin America. However, this figure suggests the possibility of some effective swap agreements in this region.

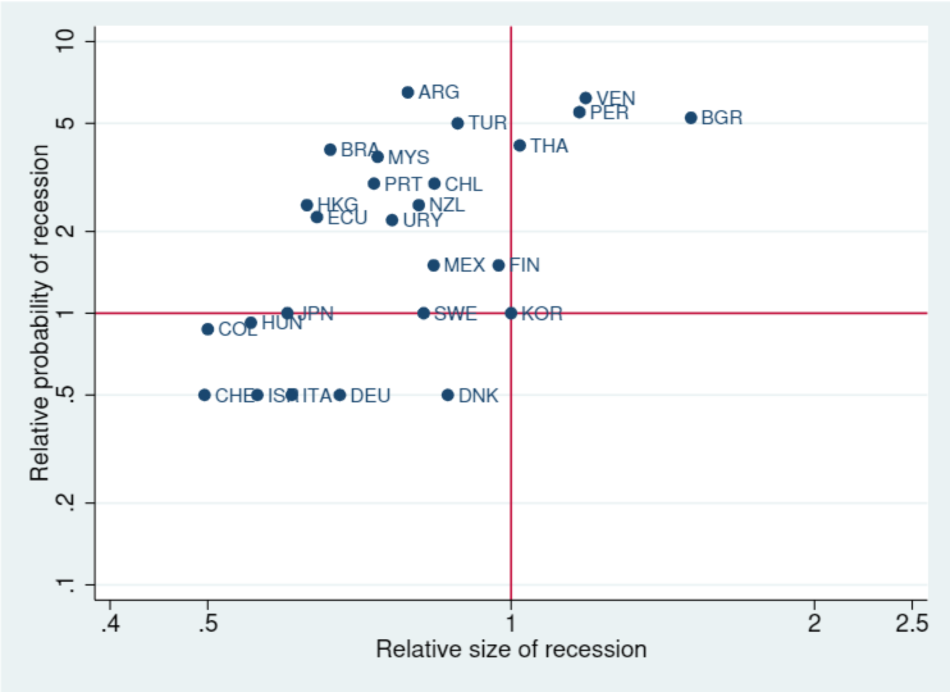

Figure 10: Optimum swap areas for Korea
Note: Size and probability of recession in each country relative to those of Korea. The axes are logarithmic.

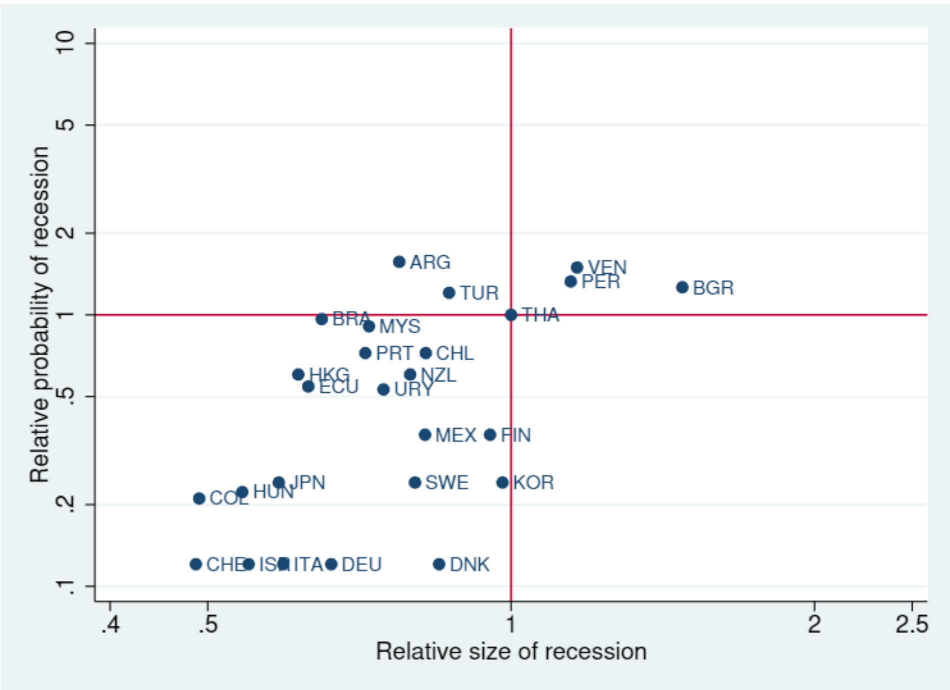

Figure 11: Optimum swap areas for Thailand
Note: Size and probability of recession in each country relative to those of Thailand. The axes are logarithmic.

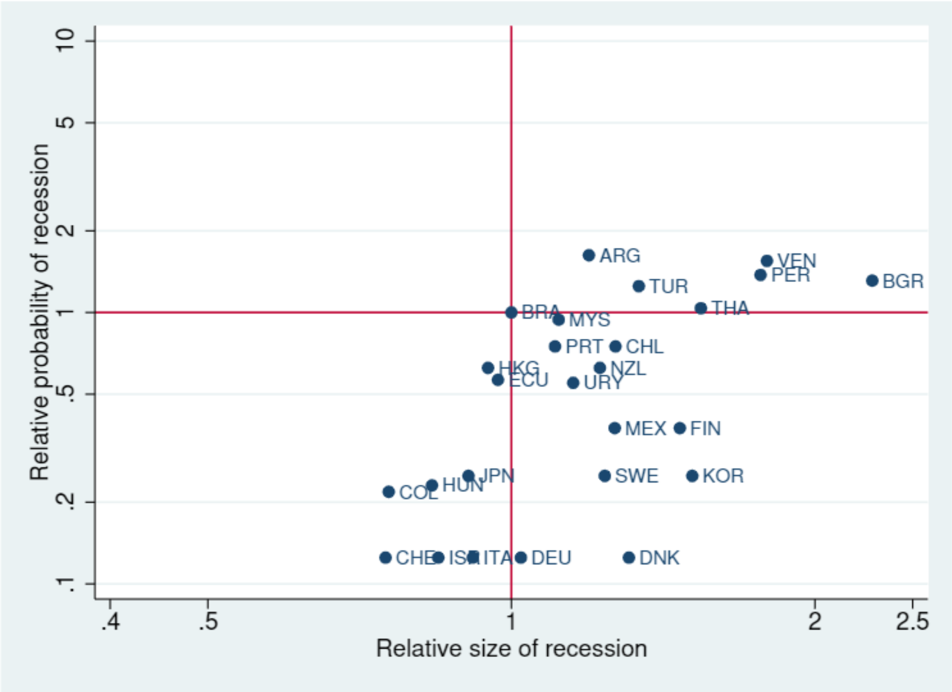

Figure 12: Optimum swap areas for Brazil

Note: Size and probability of recession in each country relative to those of Brazil. The axes are logarithmic.

4 Conclusion

In this paper, I examined the effects of currency swap agreements using a small open economy model with a financial constraint. The quantitative analyses have shown that currency swap agreements can lower the probability of financial crises in some cases. Whether they can benefit both member countries depends on the countries' difference in the size and probability of recessions, as well as the swap size, α. Contracts of currency swaps should be designed in consideration of these factors.

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