Macroeconomic Impacts of Foreign Exchange Reserve Accumulation: A Theory and Some International Evidence [*]

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Abstract

Recently, a dramatic accumulation of foreign exchange reserves has been widely observed among developing countries. The purpose of this paper is to explore what macroeconomic impacts accumulated foreign reserves have in developing countries. In the first part, we analyze a simple open economy model where increased foreign reserves reduce costs of liquidity risk. Given the amount of foreign reserves, the utility-maximizing representative agents decide consumption and the amounts of liquid and illiquid foreign debts. The equilibrium values of these macro variables depend on the amount of foreign reserves. When the government increases its foreign reserves, not only liquid debt but also total debt increases, while the debt maturity becomes shorter. The increased foreign reserves also lead to permanent decline of consumption, depreciation of real exchange rate, and temporal improvement of current account. In the second part, we show several empirical supports to the theoretical implications. We provide several supportive evidences by using the panel data of the Penn World Table. We also explore how foreign debt maturity structures changed in East Asia. We find that many East Asian economies reduced short-term borrowings temporarily after the crisis but increased short-term borrowings in the early 2000s. Since short-term debt is liquid debt, the instantaneous change after the crisis is consistent with the case where only private agents responded to increased aversion to liquidity risk. However, accompanied by substantial rises in foreign exchange reserves, the change in the early 2000s is consistent with our model implications.

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1. Introduction

Recently, a dramatic accumulation of foreign exchange reserves has been widely observed among developing countries. Some developing countries had accumulated significant amount of foreign reserves even before the late 1990s. However, foreign reserves started to show a dramatic increase after the late 1990s and are now record-breaking in many developing countries, especially in Asian and Middle Eastern countries (Figure 1). During the crisis, East Asian economies with smaller liquid foreign assets had hard time in preventing panics in financial markets and sudden reversals in capital flows (see, for example, Corsetti, Pesenti, and Roubini [1999] and Sachs and Radelet [1998]). Many developing countries thus came to recognize that increased liquidity is an important self-protection against crises. Among the strategies for the self-protection, replacing liquid short-term debt by illiquid long-term debt was initially one popular advice that many economists suggested. However, what most Asian economies have taken more seriously was raising foreign reserves (see, for example, Aizenman and Lee [2005]). The recent rapid rises in reserves were accelerated by policymakers' desire to prevent the appreciation of their currencies and maintain the competitiveness of their tradable sectors. The aggressive intervention could maintain the competitiveness of their tradable sectors and manifest itself in the massive accumulation of foreign reserves by Asian central banks. The argument may be particularly relevant in explaining China's reserve accumulation, where *de facto* dollar peg had been maintained for a long time.

In this paper, we explore what macroeconomic impacts the accumulated foreign reserves had on developing countries. In the first part, we analyze a simple open economy model where increased foreign reserves reduce costs of liquidity risk. In the model, each representative agent maximizes the utility function over time. A key feature in the model is that relative size of net foreign liquid debt to foreign reserve reduces the utility. This is one of the simplest forms that capture costs from holding liquid foreign debts. Given the amount of foreign reserves, the utility-maximizing representative agents decide consumption and the amounts of liquid and illiquid foreign debts. The equilibrium values of these macro variables, thus, depend on the amount of foreign reserves. When the government increases its foreign reserves, not only liquid debt but also total debt increases, while the debt maturity becomes shorter. The increased foreign reserves also lead to permanent decline of consumption, depreciation of real exchange rate, and temporal improvement of current account.

In the second part, we provide several empirical supports to the theoretical implications. We show several supportive evidences by using the panel data of the Penn World Table. We also explore how foreign debt maturity structures changed in East Asia. We find that many East Asian economies reduced short-term borrowings temporarily after the crisis but increased short-term borrowings in the early 2000s. Since short-term debt is liquid debt, the change soon after the crisis is consistent with the case where only private agents responded to increased aversion to liquidity risk. However, accompanied by substantial rises in foreign exchange reserves, the change in the early 2000s is consistent with our model implications.

In previous literature, Rodrik (2005) noted that a very rapid rise since the early 1990s in foreign reserves held by developing countries had climbed to almost 30 percent of developing countries' GDP. He then pointed out that reasonable spreads between the yield on reserve assets and the cost of foreign borrowing caused the income loss amounts to close to 1 percent of GDP in these developing countries. He, however, provided no theoretical

model that explains why developing countries have not tried harder to reduce short-term foreign liabilities in order to achieve the same level of liquidity (thereby paying a smaller cost in terms of reserve accumulation).

Aizenman and Lee (2005) compared the importance of precautionary and mercantilist motives in accounting for the hoarding of international reserves by developing countries. Their empirical results suggested that precautionary motives played a more prominent role behind reserve accumulation by developing countries. Like our study, their empirical studies were based on panel data of developing countries. However, unlike ours, they focused on what determines foreign reserve accumulation rather than what foreign reserve accumulation determines. Moreover, they did not focus on interaction of illiquid debt and foreign reserves in preventing liquidity crisis in the empirical study.

The paper proceeds as follows. Section 2 sets up our small open economy model and section 3 discusses the impacts of increased foreign reserves. Section 4 presents the simulation results. Section 5 provides supportive evidences by using the panel data of the Penn World Table. Section 6 shows some evidence in East Asia. Section 7 discusses implications for real exchange rates. Section 8 summarizes our main results and refers to their implications.

2. A Small Open Economy Model

The main purpose of our theoretical model is to investigate what macroeconomic impacts accumulated foreign reserves had on developing countries. We consider a small open economy that produces two composite goods, tradables and nontradables. For analytical simplicity, we assume that outputs of tradables and nontradables, y^T and y^N, are fixed and constant overtime. Each representative agent in the economy maximizes the following utility function:

$$(1) \quad \Sigma_{j=0}^{\infty} \beta^j \, [\, U(c^T_{t+j}, c^N_{t+j}) - C\,(b^A_{t+j}, R_{t+j})],$$

where c^T_t = consumption of tradable good, c^N_t = consumption of nontradable good, b^A_t = net liquid debt, b^B_t = net illiquid debt, and R_t = foreign reserve. The parameter β is a discount factor such that $0 < \beta < 1$. Subscript t denotes time period. The utility function $U(c^T_{t+j}, c^N_{t+j})$ is increasing and strictly concave in c^T_{t+j} and c^N_{t+j}, while the disutility function $C\,(b^A_{t+j}, R_{t+j})$ is strictly increasing and strictly convex in b^A_{t+j} but strictly decreasing in R_{t+j}.

The budget constraint of the representative agent is

$$(2) \quad b^A_{t+1} + b^B_{t+1} = (1+r_A)\, b^A_t + (1+r_B)\, b^B_t - y^T - p^N_t y^N + c^T_t + p^N_t c^N_t + T_t.$$

where T_t is lump-sum tax, p^N_t is the price of nontradable good, r_A is real interest rate of liquid debt, and r_B is real interest rate of illiquid debt. We assume that $r_A < r_B = (1/\beta) - 1$. The assumption that $r_A < r_B$ reflects a liquidity premium that makes real interest rate of liquid debt lower than that of illiquid debt. The assumption that $r_B =$

$(1/\beta) - 1$, where the real interest rate of illiquid debt is equal to the rate of time preference, simplifies our analysis through excluding endogenous time trend in consumption and current account. Since the numeraire is the traded good, the real interest rates and the price of nontradable good are defined in terms of tradables.

A key feature in equation (1) is that net liquid debt and foreign reserve are in the utility function. In our model, net supply of domestic debt is always zero, so that b^A_t denotes net liquid foreign debt. We assume that relative size of net liquid foreign debt to foreign reserve reduces the utility. This is one of the simplest forms that capture potential costs from holding liquid foreign debts. Panics in financial markets and sudden reversals in capital flows are more likely to happen when the country has higher (net) levels of liquid foreign debts but are less likely when it has higher levels of foreign reserves. As b^A_t becomes relatively larger to R_t, the borrowing agent thus needs to pay larger costs to prevent the potential liquidity crisis. Assuming that $\partial C(b^A_{t+j}, R_{t+j})/\partial b^A_{t+j} > 0$ and $\partial C(b^A_{t+j}, R_{t+j})/\partial R_{t+j} < 0$, the function $C(b^A_{t+j}, R_{t+j})$ is a reduced form that captures the disutility from such potential costs.

One may interpret the function $C(b^A_{t+j}, R_{t+j})$ as a shopping time model where either a decline of b^A_t or a rise of R_t saves labor hours for reducing liquidity risk. In a closed economy, a fiat money provides such liquidity services in the money-in-the-utility function model. In a small open economy that has a potential liquidity risk, either a decrease of liquid foreign debt or an increase of foreign reserve may provide a similar service. In the following analysis, we assume that $\partial^2 C(b^A_{t+j}, R_{t+j})/\partial b^A_{t+j}\partial R_{t+j} < 0$. The assumption reflects the fact that a foreign reserve accumulation relieves the marginal disutility from increased liquid foreign debt.

The amounts of foreign reserves R_t and lump-sum tax T_t are exogenously given for the representative agent. The first-order conditions are thus derived by maximizing the following Lagrangian:

$$(3)\quad L = \sum_{j=0}^{\infty} \beta^j \left[U(c^T_{t+j}, c^N_{t+j}) - C(b^A_{t+j}, R_{t+j}) \right]$$

$$+ \sum_{j=0}^{\infty} \beta^j \mu_{t+j} \left[b^A_{t+1+j} + b^B_{t+1+j} - (1+r_A) b^A_{t+j} - (1+r_B) b^B_{t+j} + y^T + p^N_{t+j} y^N - c^T_{t+j} - p^N_{t+j} c^N_{t+j} - T_{t+j} \right].$$

Under the assumption of perishable goods, it holds that $c^N_t = y^N$ in equilibrium. Assuming interior solutions, the first-order conditions thus lead to

$$(4a)\quad \partial U(c^T_t, y^N)/\partial y^N = \mu_t p^N_t,$$
$$(4b)\quad \partial U(c^T_t, y^N)/\partial c^T_t = \mu_t,$$
$$(4c)\quad \partial C(b^A_{t+1}, R_{t+1})/\partial b^A_{t+1} = (r_B - r_A)\mu_{t+1}.$$

Since the numeraire is the traded good, the price of nontradable good p^N_t denotes the real exchange rate of this small open economy at time t, where a decline of p^N_t means depreciation of the real exchange rate. Equation (4a) implies that the real exchange rate depreciates when $(\partial U/\partial y^N)/(\partial U/\partial c^T_t)$ declines. Given the Lagrangian multiplier, equation (4b) determines the amount of consumption of tradable good. Equation (4c) shows that the

amount of liquid foreign debt b^A_t is positively related with the amount of foreign reserves R_t. This is because foreign reserves, which reduce liquidity risk, allow the representative agent to hold more liquid foreign debt.

Under the assumption that $r_B = (1/\beta) - 1$ where the real interest rate of illiquid debt is equal to the rate of time preference, the Lagrangian multiplier μ_t is constant over time and equals to $\mu > 0$. This implies that all of the macro variables c^T_t, p^N_t, b^A_t, and $b^A_t + b^B_t$ are constant over time without unanticipated external shocks.[1] However, an unanticipated change of foreign reserves affects the equilibrium values of these variables.

3. The Macroeconomic Impacts of Increased Foreign Reserves

The main purpose of the following analysis is to explore the impacts when the government suddenly increased its foreign reserves. To achieve this goal, we explore what impacts an unanticipated change of R_t has on various macroeconomic variables. When increasing the amount of foreign reserves, the government has alternative methods to finance it. However, because of the Ricardian equivalence, the government method of finance does not affect resource allocation. We thus focus on the case where the increases of the foreign reserves are solely financed by lump-sum tax increases. In this case, the government budget constraint at period t is written as

$$(5) \quad T_t = G^* + R_{t+1} - (1+r) R_t,$$

where G^* is exogenous government expenditure and r is real interest rate of the foreign reserves. We assume that the rate of returns from foreign reserves is very low in international capital market so that $r < r_A < r_B$.

Suppose that there was an unanticipated increase of $R_{\tau+1}$ at period τ. Then, both c^T_t and p^N_t instantaneously jump to the new steady state at period τ, while both b^A_t and $b^A_t + b^B_t$ move to the new steady state at period $\tau+1$. Since $c^N_t = y^N$, the budget constraints before and after the shock are

$$(6a) \quad 0 = r_B (b^A_0 + b^B_0) - (r_B - r_A) b^A_0 - y^T + c^T_0 + T_0,$$
$$(6b) \quad b^A_1 + b^B_1 = (1+r_B)(b^A_0 + b^B_0) - (r_B - r_A) b^A_0 - y^T + c^T_1 + T_0 + \Delta R,$$
$$(6c) \quad 0 = r_B (b^A_1 + b^B_1) - (r_B - r_A) b^A_1 - y^T + c^T_1 + T_0 - r\Delta R.$$

where the variables with subscript 0 are those in the old steady state and the variables with subscript 1 are those in the new steady state. Denoting the change of a variable x by Δx, these equations lead to

$$(7) \quad \Delta(b^A + b^B) = [(r_B - r_A)/(1+r_B)] \Delta b^A + [(1+r)/(1+r_B)] \Delta R = \Delta c^T + \Delta R.$$

In contrast, equations (4a), (4b), and (4c) respectively imply that

[1] When $r_B \neq (1/\beta) - 1$, Lagrangian multiplier μ_t changes over time and consequently some macro variables such as c^T_t have a time trend. However, even when $r_B \neq (1/\beta) - 1$, a basic message in the following analysis is essentially the same.

(8a) $\Delta p^N = [U_{12} - (U_2/U_1)U_{22}]\,\Delta c^T$,

(8b) $\Delta \mu = U_{11}\,\Delta c^T$,

(8b) $C_{11}\,\Delta b^A + C_{12}\,\Delta R = (r_B - r_A)\,\Delta \mu$,

where $U_{11} \equiv \partial^2 U(c^T, y^N)/\partial c^{T2} < 0$, $C_{11} \equiv \partial^2 C/\partial b^A{}_{t+1}{}^2 > 0$, and $C_{12} \equiv \partial C/\partial b^A{}_{t+1}\partial R_{t+1} < 0$. We therefore obtain

(9a) $$\frac{\Delta b^A}{\Delta R} = -\frac{1}{\Omega}\left[\frac{(r_B - r_A)(r_B - r)}{1 + r_B}U_{11} + C_{12}\right] > 0,$$

(9b) $$\frac{\Delta(b^A + b^B)}{\Delta R} = \frac{r_B - r_A}{1 + r_B}\frac{\Delta b^A}{\Delta R} + \frac{1 + r}{1 + r_B} > 0,$$

(9c) $$\frac{\Delta c^T}{\Delta R} = \frac{r_B - r_A}{1 + r_B}\frac{\Delta b^A}{\Delta R} - \frac{r_B - r}{1 + r_B} = \frac{1}{\Omega}\left[\frac{r_A - r}{1 + r_B}C_{12} - \frac{r_B - r}{1 + r_B}(C_{11} + C_{12})\right],$$

(9d) $$\frac{\Delta p^N}{\Delta R} = (U_{12} - \frac{U_2}{U_1}U_{22})\frac{\Delta c^T}{\Delta R},$$

where $\Omega \equiv C_{11} - [(r_B - r_A)^2/(1+r_B)]\,U_{11} > 0$.

Since there is no net supply of domestic debt, $b^A{}_t$ and $b^B{}_t$ denote net liquid foreign debt and net illiquid foreign debt respectively. Equations (9a) and (9b) imply that an unexpected rise of foreign reserves increases not only liquid foreign debt but also the sum of liquid and illiquid foreign debts. Equations (9a) and (9b) also lead to

(10) $$\frac{\Delta(b^A - b^B)}{\Delta R} = \frac{1}{\Omega}\left[-\frac{(r_B - r_A)(r_B - r)}{1 + r_B}\phi\frac{\partial^2 U}{\partial c^{T^2}} - \frac{2 + r_B + r}{1 + r_B}\frac{\partial^2 C}{\partial b^A \partial R} + \frac{1 + r}{1 + r_B}\frac{\partial^2 C}{\partial b^{A^2}}\right] > 0,$$

where $\phi \equiv (1+r)(r_A - r) + (1+r_B)(r_B - r) > 0$. Equation (10) indicates that an unexpected rise of foreign reserves always increases the share of liquid foreign debt to total foreign debts. This happens because foreign reserves reduce liquidity risk, so that the value of holding illiquid debt declines. Unfortunately, equations (9a) and (9b) cannot pin down the sign of $\Delta b^B/\Delta R$ because

(11) $$\frac{\Delta b^B}{\Delta R} = -\frac{1 + r_A}{1 + r_B}\frac{\Delta b^A}{\Delta R} + \frac{1 + r}{1 + r_B}.$$

The ambiguous sign reflects the fact that an unexpected rise of foreign reserves not only has a substitution effect that replaces illiquid foreign debt by liquid debt but also has an income effect that increases total foreign debt.

Equations (9c) and (9d) determine the impacts of increased foreign reserves on consumption and real exchange rate respectively. In general, we cannot see whether the derivatives are positive or negative in (9c) and (9d). This is because while low rate of return of foreign reserve and increased total foreign debt reduces permanent income, a shift from illiquid debt to liquid debt may relieve interest rate burden of foreign debt. However, when $|C_{11}| \geq |C_{12}|$, we can show that $\Delta c^T/\Delta R < 0$. This implies that an unanticipated increase in foreign reserve has a negative impact on consumption when $|C_{11}| \geq |C_{12}|$. We can also show that $\Delta p^N/\Delta R > 0$ when $|C_{11}| \geq |C_{12}|$ and $U_{12} - (U_2/U_1)U_{22} > 0$. The inequality $\Delta p^N/\Delta R > 0$ implies depreciation of the real exchange rate. Therefore, when $|C_{11}| \geq |C_{12}|$, an unanticipated increase in the foreign reserve leads to decline of consumption as well as depreciation of the real exchange rate.

The economy's current account balance in period *t* is defined by

(12) $CA_t \equiv [(b^A_t + b^B_t) - (b^A_{t+1} + b^B_{t+1})] + (R_{t+1} - R_t)$.

The current account is balanced in the steady state. However, when foreign reserves change unexpectedly, the current account changes temporarily. That is, when there is an unexpected change of foreign reserves from period τ to period $\tau+1$, it holds that

(13) $$\Delta CA_\tau/\Delta R = -\Delta(b^A + b^B)/\Delta R + 1,$$

$$= -\frac{r_B - r_A}{1 + r_B}\frac{\Delta b^A}{\Delta R} + \frac{r_B - r}{1 + r_B} = -\frac{\Delta c^T}{\Delta R}.$$

This indicates that to the extent that $\Delta c^T/\Delta R < 0$, an unanticipated increase of foreign reserves improves the current account temporarily.

4. Some numerical examples

In the last section, we explored what impacts increased foreign reserves have on several macro variables. A comparative static shows the signs of the changed macro variables when foreign reserves increased. But it was not clear how large impacts the increased foreign reserve had. We cannot see how large impacts a dramatic change of foreign reserves has on these variables without using specific functional forms. The purpose of this section is to explore the quantitative impacts by specifying the functional forms in the model.

In the experiment, we use the following functional forms:

(14a) $U(c^T_t, c^N_t) \equiv ln\,[(c^T_t)^\alpha (c^N_t)^{1-\alpha}]$, where $0 < \alpha < 1$,

(14b) $C(b^A_t, R_t) \equiv \lambda (b^A_t - R_t)^2$, when $b^A_t > R_t$,

$\equiv 0$, otherwise.

In (14a), the utility from consumption represents the case where an elasticity of substitution in consumption between the tradable good and the nontradable good equals to one. Under (14a), it always holds that $U_{12} - (U_2/U_1)U_{22} > 0$. The disutility function (14b) implies that the difference between liquid debt and foreign reserves increases disutility when $b^A_t > R_t$. To the extent that $b^A_t > R_t$, (14b) implies that $\partial C/\partial b^A_t > 0$, $\partial C/\partial R_t < 0$, $\partial^2 C/\partial b^A_t \partial R_t < 0$, and that $|C_{11}| = |C_{12}|$.

To explore the impacts of unanticipated changes of foreign reserves, we set the structural parameters as $\alpha = 0.7$, $\beta = 0.9$, and $\lambda = 0.2$. We also assume that $r_B - r_A = 0.05$, $r = 0.01$, $G^* = 20$, $y^T = 100$, and $y^N = 50$. These parameters and variables remain constant throughout the period. Before period τ, total foreign debts and foreign reserves had initial values such that $b^A_t + b^B_t = 100$ and $R_t = 50$ for all $t < \tau$. However, at period τ, there was an unanticipated rise of foreign reserves that increases increased R_t.

Table 1 summarizes the equilibrium values of macro variables when R_t takes alternative values of. 50 (initial value), 75, 100, 125, 150, 175, and 200 for all $t \geq \tau$. For each R_t, the table reports the equilibrium values of c^T_t, p^N_t, b^A_t, b^B_t, and $b^A_t + b^B_t$. It also reports temporal utility when these values are realized. As we discussed in the last section, there was some ambiguity concerning the impacts on c^T_t, p^N_t, and b^B_t. However, the table indicates that under the parameter set and exogenous variables specified above, an unexpected rise of R_t increases b^A_t and $b^A_t + b^B_t$ and decreases c^T_t, p^N_t, and b^B_t. Not surprisingly, the changes of these macro variables are more substantial as the change of R_t is larger. For example, c^T_t declines by 1.6% when R_t rises to 75 but declines by 9.6% when R_t rises to 200. The changes of b^A_t and $b^A_t + b^B_t$ are, however, substantial even when the change of R_t is moderate.

It is noteworthy that the utility of the representative agent declines monotonically as R_t increases. The change is moderate when the change of R_t is small. But the decline becomes substantial when the change of R_t is large. This is mainly because c^T_t declines monotonically as R_t increases. The value of $b^A_t - R_t$ also increases as the change of R_t is larger, which is also responsible for the monotonic decline of the utility.

Except for b^A_t and $b^A_t + b^B_t$, the changes of the macro variables and the utility are sensitive to how to set the interest rate differences among r_A, r_B, and r. In the above benchmark case, we set that $r_B - r_A = 0.05$ and $r_A - r = 0.051$. But we can see that the changes of c^T_t, p^N_t, b^B_t, and the utility are larger when $r_B - r_A$ is small, while they are larger when $r_A - r$ is small. Tables 2-(1) and 2-(2) respectively summarize the equilibrium values of macro variables when the interest rate difference between r_B and r_A is smaller (that is, $r_B - r_A = 0.01$ and $r_A - r = 0.051$) and when the interest rate difference between r_A and r is smaller (that is, $r_B - r_A = 0.05$ and $r_A - r = 0.011$). It is easy to see that when the interest rate difference between r_B and r_A is smaller, c^T_t declines substantially, that is, by 2.9% even when R_t rises to 75 in Table 2-(1). This reflects the fact that a rise of foreign reserves has a beneficial effect on permanent income in that it shifts illiquid debt with higher interest rate to liquid debt with lower interest rate. The costs from increasing foreign reserves thus become smaller when $r_B - r_A$ is larger. In contrast, when the interest rate difference between r_A and r is smaller, c^T_t declines only by 2.0% even when R_t rises to 200 in Table

2-(2). A rise of foreign reserves has a negative effect on permanent income because the interest rate of foreign reserves is very low. The costs from increasing foreign reserves thus become smaller when r_A-r is smaller.

5. Some International Evidence

The main implications of our theoretical analysis are that an increase in foreign reserves has significant impacts on several macroeconomic variables. The purpose of this section is to test these implications empirically. Specifically, we examine what relationship foreign reserves have with consumption, debt maturity, and current account by using .the panel data in developing countries. We estimated the following three equations:

(15) $Maturity_{j,t}$ = constant term + $a_1 \cdot Foreign\ Reserve_{j,t}/\ GNI_{j,t} + a_2 \cdot log\ GNI_{j,t}$,

(16) $Consumption_{j,t}/GNI_{j,t}$ = constant term + $b_1\ Foreign\ Reserve_{j,t}/\ GNI_{j,t} + b_2 \cdot log\ GNI_{j,t}$,

(17) $Current\ Account_{j,t}/GNI_{j,t}$ = constant term + $c_1\ \Delta(Foreign\ Reserve_{j,t}/\ GNI_{j,t}) + c_2 \cdot log\ GNI_{j,t}$,

where *Consumption* = consumption, *GNI* = gross national income, *Foreign Reserve* = foreign reserve, *Maturity* = average maturity of new commitments (years), and *Current Account* = current account. Subscript j denotes country j, while subscript t denotes year. To avoid heteroscedasticity problem, consumption, foreign reserves, and current account are divided by *GNI*. However, to allow scale effects, we include *log GNI* in all equations. Since the impact of increased foreign reserves on the current account is temporary, we use the first-difference of foreign reserve as an explanatory variable in equation (17).

The data of consumption, GNI, and current account are from the Penn World Table (PWT 6.2). The data of foreign reserve is from IMF, while average maturity of new commitments is from Global Development Finance issued by the World Bank. The data is unbalanced panel data of 135 countries. The sample period is 1980 to 2004. The method of estimation is OLS. To allow a structural break after the crisis, we include the post-crisis dummy in some regressions. The post-crisis dummy is a time dummy that takes one from 1998 to 2003 and zero otherwise.

Table 3-(1), 3-(2), and 3-(3) report the results of our regressions with and without the post-crisis dummy. The coefficients of foreign reserves are statistically significant and are consistent with our theoretical results. That is, foreign reserve is negatively correlated with consumption and with maturity, which implies that an increased foreign reserve decreases consumption and makes debt maturity shorter. In contrast, a change of foreign reserve is positively correlated with the current account, which implies that an increased foreign reserve improves the current account temporarily.

6. Some Evidence in East Asia

When looking at the recent remarkable reversal in global capital flows, East Asian economies have been one of the major net lenders since the late 1990s. In particular, the accumulation of foreign reserves is now

record-breaking in Asian countries. Table 4 reports the ratios of foreign exchange reserves to GDP for ten East Asian economies (Japan, China, Hong Kong, Indonesia, Korea, Malaysia, the Philippines, Singapore, Thailand, and Taiwan) from 1990 to 2004. It shows that the ratios went up substantially after the Asian crisis and showed further increases in the early 2000s except for Indonesia. The ratios are now over 10% in all East Asian economies and over 20% except for Japan, Indonesia, and the Philippines. It is highly possible that the accumulated foreign reserves discouraged the private agents to replace liquid short-term debt by illiquid long-term debt in these economies.

After the Asian crisis, most Asian economies came to recognize that economic growth that relies on liquid external borrowings is not desirable, given their vulnerability to a sudden reversal of capital flows. Soon after the crisis, they thus started to increase liquidity as an important self-protection against crises. However, they had alternative strategies for the self-protection. Among the strategies for the self-protection, replacing liquid short-term debt by illiquid long-term debt was what most Asian economies had taken initially. However, since the early 2000s, what most Asian economies have taken more seriously was raising foreign reserves. The purpose of this section is to explore what impacts the recent increases of foreign reserves had on the maturity structure of foreign debt of these Asian economies.

Based on the data in BIS Quarterly Review, Figure 2 reports the changes of short-term, medium-term, and long-term borrowings in seven East Asian economies before and after the crisis. Reflecting dramatic capital inflows into East Asia before the crisis, we can observe large increases of all types of debts in 1995 and 1996. We can also observe that there were substantial declines of short-term borrowings not only during the crisis but for some periods after the crisis. The declines of short-term borrowings during the crisis clearly happened because of capital flight under the panicking crisis. It is, however, noteworthy that the declines of short-term borrowings continued even in 1998 when East Asian economies started their economic recovery. At the same time, there were dramatic increases of medium-term borrowings and some increases of long-term borrowings in several East Asian economies after the crisis.

These results indicate that many East Asian economies shifted their borrowings from liquid short-term debt to illiquid long-term debts soon after the crisis. However, the shift from liquid debt to illiquid debt did not persist. Instead, liquid short-term debt increased again in the early 2000s. Korea was the only East Asian country that had significant increases of short-term borrowings since the late 1990s. But several East Asian economies also experienced increases of their short-term borrowings in the early 2000s. In contrast, in the East Asian economies, medium-term debts and long-term debts slowed down their growth and sometimes declined during the same period. This indicates that many East Asian economies might have reversed their maturity structures shifting their borrowings from illiquid long-term debt to liquid short-term debt.

An essentially similar result can be obtained from the alternative data set in Global Development Finance issued by the World Bank. Table 5 summarizes average maturities of private credits to six East Asian countries from 1995 to 2004. In the East Asian countries, the average maturity increased during the crisis and remained high until the late 1999. This indicates significant shifts from liquid short-term debt to illiquid long-term debt soon after the crisis. However, as in Figure 2, Korea reduced the average maturity in the late 1990s. The other

East Asian countries also gradually reduced the maturity in the early 2000s. This alternative data set also supports the view that many East Asian economies might have reversed their maturity structures in the early 2000s.

Since short-term borrowing is liquid debt and medium-term and long-term borrowings are illiquid debts, shifting their debt from short-term to long-term is consistent with the case where only private agents responded to the increased aversion to liquidity risk. In contrast, increasing their short-term borrowings and decreasing long-term borrowings are consistent with the case where the government increased its foreign reserves. The above evidence suggests that in East Asia, the former case prevailed soon after the crisis but the latter became dominant in the early 2000s.

7. Implications for Real Exchange Rates

One of the byproducts in our theoretical analysis is the impacts of increased foreign reserves on the real exchange rate. If recent current account surpluses in East Asia primarily reflect either an increase in the U.S. demand for East Asian products or increased productivity of East Asian exports, they would naturally lead to currency appreciation of East Asian currencies in a world of floating exchange rates. However, when the government increases its foreign reserves, large current account surpluses could persist for long years accompanied by the real exchange rate depreciation. This is particularly true for current account surplus against the United States the currency of which has been widely held as an international reserve currency. The purpose of this section is to investigate these implications empirically. Figure 3 reports real exchange rates of eight East Asian economies from 1990 to 2004. In the figure, lower values mean depreciation. It shows that except for China, the real exchange rates depreciated substantially against the U.S. dollar after the crisis and remained low even after the economies recovered from the crisis. The rate of depreciation from 1996 to 2004 is more than 20% in Korea, Thailand, Malaysia, and the Philippines.

The basic result still remains true even when we use absolute PPP data to evaluate the real exchange rates. By using the balanced panel data of the Penn World Table (PWT 6.2) from 1980 to 2004, we estimated the simple following logarithmic equation over the observations of 135 countries:

$$(18) \quad \log P_j/P_{U.S.} = \text{constant} + d_1 \, \textit{Foreign Reserve}_{j,t}/\, GNI_{j,t} + d_2 \cdot \log Y_j/Y_{U.S.},$$

where $P_j/P_{U.S.}$ is the price level of country j relative to the United States, and $Y_j/Y_{U.S.}$ is country j's relative income level to the United States. We included log $Y_j/Y_{U.S.}$ in the regression because Rogoff (1996) found that the Balassa-Samuelson effect leads to a clear positive association between relative price levels and real incomes.

Table 6 reports the results of our regressions with and without the three extra dummies. Like the Rogoff's result, the coefficient of the relative income level always takes significantly positive, showing a clear positive association between relative price levels and real incomes. What is noteworthy is that the coefficient of the foreign reserves is significantly negative for the sample period from 1990 to 2004. The negative coefficient is

consistent with our theoretical implication, implying that current account surpluses could persist for long years accompanied by the real exchange rate depreciation when foreign reserves are kept accumulating. However, the coefficient of the relative income level is not significant for the sample period from 1980 to 2004. This implies that a negative association between relative price levels and foreign reserves became clear only after 1990.

8. Concluding Remarks

Recent foreign reserve accumulations are record-breaking in many developing countries, especially in Asian and Middle Eastern countries This paper investigated what macroeconomic impacts the accumulated foreign reserves have in developing countries. In the first part, we analyzed a simple open economy model where increased foreign reserves reduce costs of liquidity risk. When the government increases its foreign reserves, not only liquid debt but also total debt increases, while the debt maturity becomes shorter. The increased foreign reserves also lead to permanent decline of consumption, depreciation of real exchange rate, and temporal improvement of current account. In the second part, we showed several empirical supports to the theoretical implications.

During the last decade, financial globalization has been accompanied by frequent and painful financial crises. During the crises, countries with smaller liquid foreign assets had hard time in preventing panics in financial markets and sudden reversals in capital flows. Many developing countries thus came to recognize that increased liquidity is an important self-protection against crises. Raising foreign reserves is a popular strategies that many economists advised. However, accumulation of foreign reserves is accompanied by social costs. It is important to reconsider what is the optimal accumulation of foreign reserves in developing countries.

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Table 1. The Impacts of an Increase in R: Numerical Examples

	$R_t = 50$	$R_t = 75$	$R_t = 100$	$R_t = 125$	$R_t = 150$	$R_t = 175$	$R_t = 200$
c^T_t	71.91	70.76	69.61	68.46	67.31	66.17	65.02
p^N_t	0.62	0.61	0.60	0.59	0.58	0.57	0.56
b^A_t	50.49	75.49	100.50	125.51	150.52	175.53	200.54
b^B_t,	49.51	48.36	47.20	46.04	44.88	43.72	42.56
$b^A_t+b^B_t$	100.00	123.85	147.70	171.55	195.40	219.25	243.10
U_t	65.29	64.49	63.68	62.87	62.07	61.26	60.45

Table 2. Interest Rate Differences and the Impacts of an Increase in R

(i) When r_B-r_A = 0.01 and r_A-r = 0.051

	$R_t = 50$	$R_t = 75$	$R_t = 100$	$R_t = 125$	$R_t = 150$	$R_t = 175$	$R_t = 200$
c^T_t	69.91	67.86	65.82	63.77	61.72	59.67	57.62
p^N_t	0.60	0.58	0.56	0.55	0.53	0.51	0.49
b^A_t	52.50	77.58	102.66	127.74	152.84	177.93	203.04
b^B_t,	47.50	45.37	43.24	41.11	38.97	36.82	34.67
$b^A_t+b^B_t$	100.00	122.95	145.90	168.85	191.80	214.75	237.70
U_t	62.69	61.18	59.66	58.13	56.59	55.05	53.49

(ii) When r_B-r_A = 0.05 and r_A-r = 0.011

	$R_t = 50$	$R_t = 75$	$R_t = 100$	$R_t = 125$	$R_t = 150$	$R_t = 175$	$R_t = 200$
c^T_t	73.91	73.66	73.41	73.16	72.91	72.66	72.41
p^N_t	0.63	0.63	0.63	0.63	0.62	0.62	0.62
b^A_t	50.47	75.48	100.48	125.48	150.48	175.48	200.48
b^B_t,	49.53	49.27	49.02	48.77	48.52	48.27	48.02
$b^A_t+b^B_t$	100.00	124.75	149.50	174.25	199.00	223.75	248.50
U_t	66.69	66.52	66.34	66.17	65.99	65.82	65.64

Table 3 International Evidence Based on the Penn World Table

(1) $Maturity_{j,t}$ = constant term + $a_1 \cdot Foreign\ Reserve_{j,t}/\ GNI_{j,t}$ + $a_2 \cdot log\ GNI_{j,t}$

regression	1		2		3	
constant	40.1028	***	22.7722	***	40.1968	***
	(33.42)		(55.58)		(33.41)	
reserve/GNI	-0.0566	***	-0.0292		-0.0618	***
	(-2.60)		(-1.26)		(-2.77)	
log(GNI)	-2.0137	***			-2.0387	***
	(-15.37)				(-15.31)	
after98-dummy			-1.0081		0.6272	
			(-1.64)		(1.05)	
adj.R^2	0.0889		0.0014		0.0889	

(2) $Consumption_{j,t}/GNI_{j,t}$ = constant term + b_1 $Foreign\ Reserve_{j,t}/\ GNI_{j,t}$ + $b_2 \cdot log\ GNI_{j,t}$

regression	1		2		3		4		5	
constant	74.0506	***	92.8138	***	92.7998	***	48.2009	***	51.6480	***
	(150.40)		(60.53)		(60.53)		(10.14)		(10.83)	
reserve/GNI	-0.0462	*	-0.0761	***	-0.0687	**	-0.0626	**	-0.0508	*
	(-1.69)		(-2.86)		(-2.52)		(-2.40)		(-1.95)	
log(GNI)			-2.1614	***	-2.1370	***	8.7082	***	7.5728	***
			(-12.88)		(-12.65)		(7.84)		(6.74)	
{log(GNI)}^2							-0.6277	***	-0.5426	***
							(-9.89)		(-8.35)	
after98-dummy					-0.9464					
					(-1.24)					
asia-dummy									-9.4266	***
									(-5.49)	
adj.R^2	0.0007		0.0604		0.0606		0.0942		0.1042	

Table 3 International Evidence Based on the Penn World Table (continued)

(3) $Current\ Account_{j,t}/GNI_{j,t}$ = constant term + $c_1\ \Delta(Foreign\ Reserve_{j,t}/\ GNI_{j,t})$ + $c_2 \cdot log\ GNI_{j,t}$

regression	1		2		3		4		5	
constant	-19.8757	***	-19.8826	***	-29.3268	***	-29.3784	***	-30.4685	***
	(-25.71)		(-25.72)		(-11.46)		(-11.38)		(-11.81)	
dR/GNI	0.4104	***	0.4141	***	0.4175	***	0.4173	***	0.4130	***
	(9.87)		(9.93)		(10.04)		(10.03)		(9.97)	
log(GNI)	1.6350	***	1.6528	***	3.9350	***	3.9511	***	4.2505	***
	(18.72)		(18.69)		(6.60)		(6.52)		(7.02)	
{log(GNI)}^2					-0.1304	***	-0.1316	***	-0.1490	***
					(-3.87)		(-3.80)		(-4.30)	
after98-dummy			-0.5068		-0.5450		-0.5412		-0.9661	**
			(-1.30)		(-1.40)		(-1.38)		(-2.42)	
asia-dummy							0.1350		-2.2510	**
							(0.15)		(-2.24)	
after98*asia									8.8499	***
									(4.93)	
adj.R^2	0.1569		0.1571		0.1620		0.1616		0.1696	

Notes)

1) Number of observation. = 2411 (134 countries and 25 periods, unbalanced panel). The sample includes developing countries only.

2) The method of estimation is pooled-OLS. t-statistics are in parentheses.

3) Asia-dummy takes 1 for 5 Asian countries (China, Indonesia, Malaysia, Philippines, and Thailand).

Table 4. The Ratios of Foreign Exchange Reserves to GDP in East Asia

	Japan	China	Hong Kong	Indonesia	Korea
1990	2.7	9.7	32.8	7.0	5.8
1991	2.2	12.6	33.5	8.0	4.7
1992	2.0	5.6	35.0	8.3	5.6
1993	2.3	5.5	36.4	7.1	5.6
1994	2.6	9.8	37.0	6.9	6.1
1995	3.5	10.8	39.1	6.8	6.3
1996	4.6	13.0	40.8	8.0	6.1
1997	5.1	15.8	53.4	7.7	3.9
1998	5.5	15.6	54.2	23.8	15.0
1999	6.4	15.8	59.9	18.9	16.6
2000	7.5	15.6	65.1	17.3	18.8
2001	9.5	18.1	68.3	16.6	21.3
2002	11.6	22.3	69.9	15.5	22.2
2003	15.4	27.8	76.3	14.7	25.5
2004	17.9	37.3	75.8	13.6	29.3

	Malaysia	Philippines	Singapore	Thailand	Taiwan
1990	22.8	2.1	76.0	15.6	45.2
1991	23.1	7.2	80.7	17.8	45.9
1992	29.9	8.3	82.2	18.3	38.8
1993	40.7	8.6	82.9	19.6	37.3
1994	34.1	9.4	82.4	20.3	37.8
1995	26.8	8.6	81.8	21.4	34.1
1996	26.8	12.1	83.4	20.7	31.5
1997	20.8	8.9	74.7	17.3	28.8
1998	35.4	14.2	91.3	25.8	33.8
1999	38.6	17.4	93.1	27.8	36.9
2000	32.7	17.2	86.6	26.1	34.4
2001	34.6	18.9	87.8	28.0	43.7
2002	36.0	17.7	92.7	30.0	57.4
2003	42.9	17.6	103.7	28.7	72.2
2004	56.4	15.5	105.1	29.8	79.2

Sources) Except for Taiwan, International Financial Statistics, IMF. For Taiwan, Key Indicators, ADB.

Table 5. Average Maturity of New Commitments in Private Credit to East Asia

Unit = years

	China	Indonesia	Korea	Malaysia	Philippines	Thailand
1995	7.3	11.0	5.8	16.9	10.9	8.9
1996	7.0	11.5	12.3	18.1	13.9	7.9
1997	6.4	16.1	6.6	12.7	14.4	10.9
1998	11.1	n.a.	6.4	13.7	6.3	6.8
1999	10.9	14.3	5.1	10.3	13.5	8.8
2000	10.5	6.9	4.6	7.6	11.4	7.3
2001	10.2	8.0	4.1	11.6	4.7	5.9
2002	10.1	9.4	.	10.2	9.4	4.3
2003	8.7	7.9	.	6.1	8.3	4.7
2004	9.0	8.2	.	8.3	8.5	5.0

Source) Global Development Finance, The World Bank.

Table 6. International Evidence Based on the Penn World Table: The Case of Real Exchange Rate

(1) Sample Period: 1990-2004

regression	1		2		3	
constant	-0.7231	***	-0.6793	***	-0.6793	***
	(-22.69)		(-20.55)		(-20.54)	
R/GNI	0.0017	**	0.0022	***	0.0022	***
	(2.06)		(2.69)		(2.69)	
log(Yj/Yusa)	0.1701	***	0.1705	***	0.1704	***
	(13.81)		(13.92)		(13.88)	
after98-dummy			-0.1054	***	-0.1055	***
			(-4.64)		(-4.64)	
asia-dummy					-0.0061	
					(-0.11)	
adj.R-squared	0.1026		0.1136		0.1130	

(2) Sample Period: 1980-2004

regression	1		2		3	
constant	-0.7231	***	-0.6793	***	-0.6793	***
	(-22.69)		(-20.55)		(-20.54)	
R/GNI	0.0017	**	0.0022	***	0.0022	***
	(2.06)		(2.69)		(2.69)	
log(Yj/Yusa)	0.1701	***	0.1705	***	0.1704	***
	(13.81)		(13.92)		(13.88)	
after98-dummy			-0.1054	***	-0.1055	***
			(-4.64)		(-4.64)	
asia-dummy					-0.0061	
					(-0.11)	
adj.R-squared	0.1026		0.1136		0.1130	

Figure2-1. Annual Growth Rates of Short-term Loans

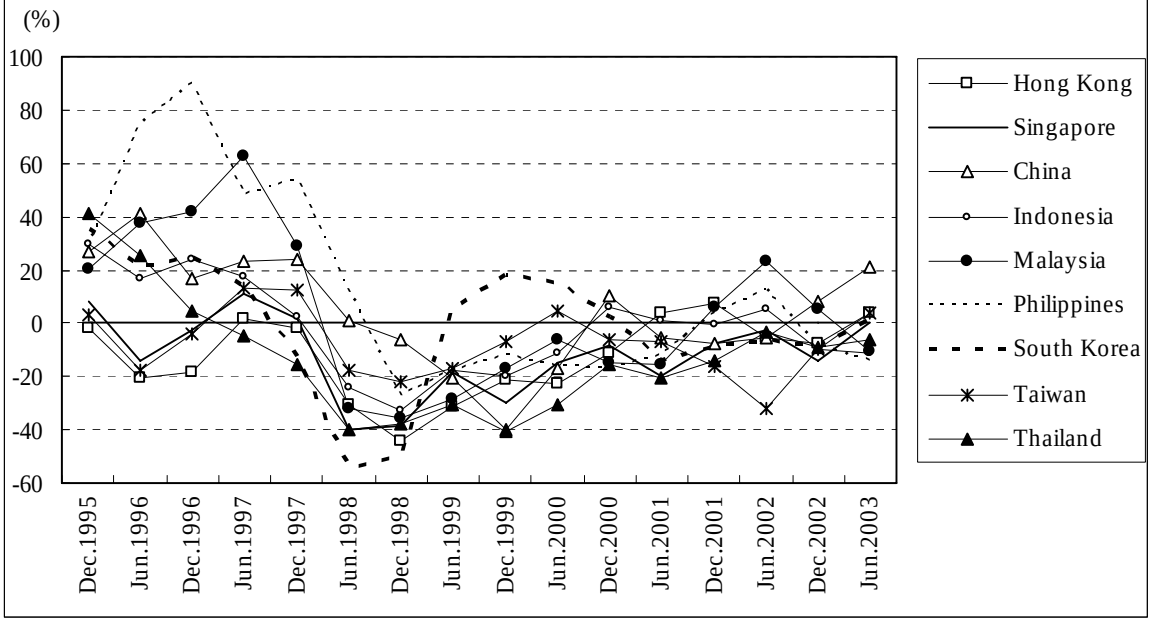


Figure2-2. Annual Growth Rates of Medium-term Loans

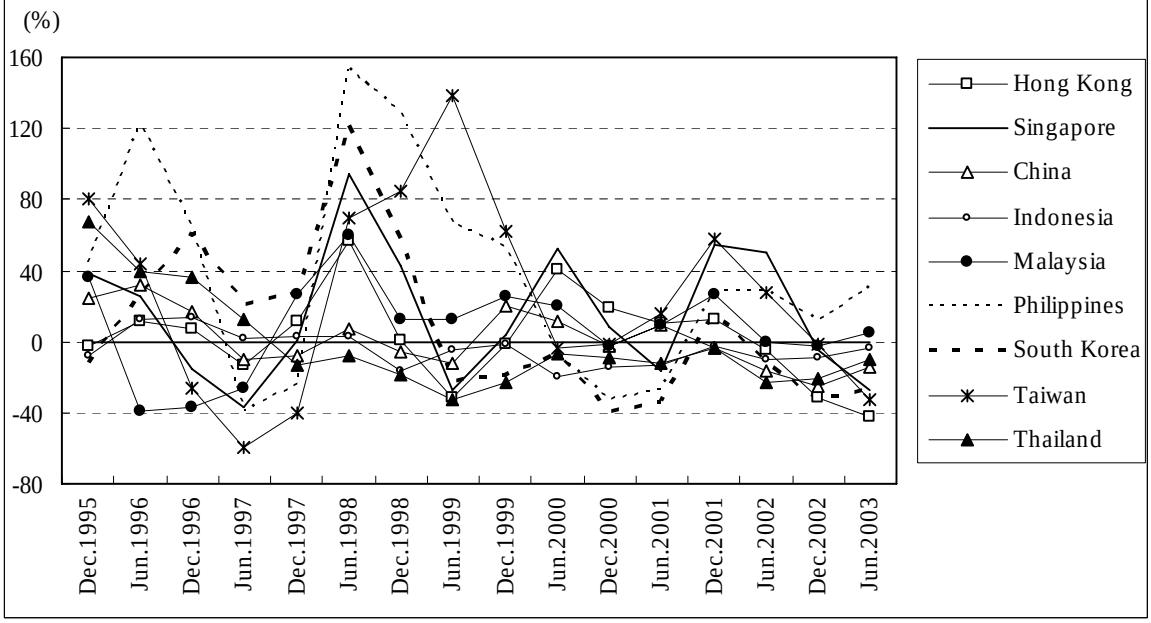
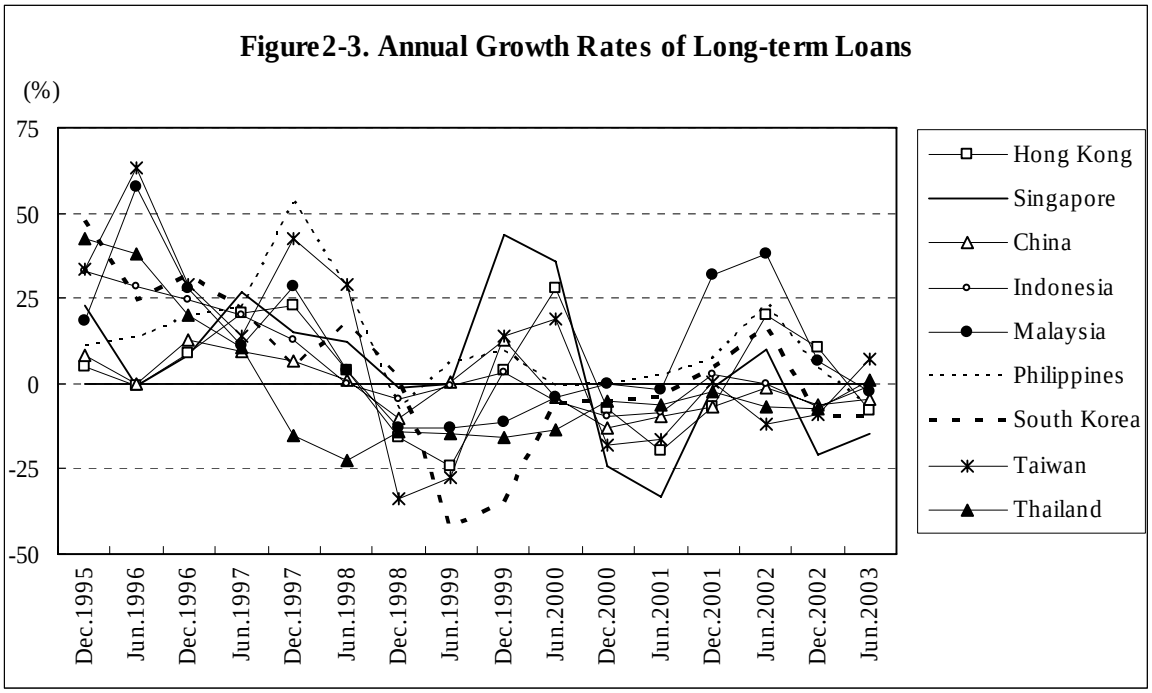


Figure2-3. Annual Growth Rates of Long-term Loans

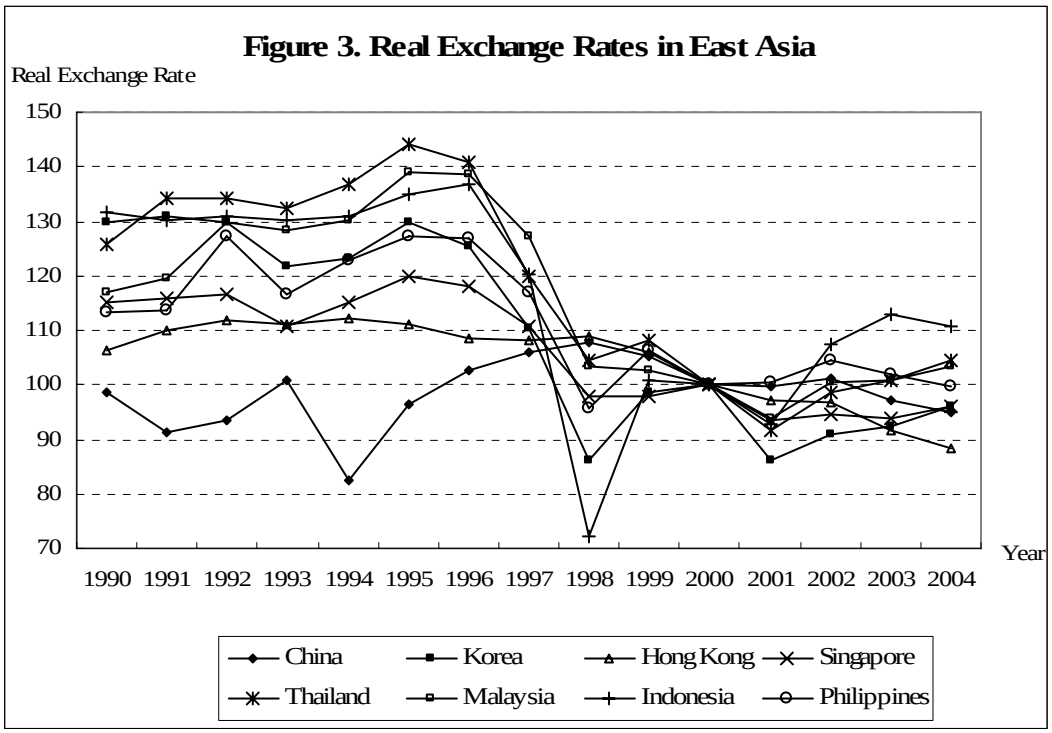


Notes

1) The data are percent changes of international claims from a year earlier in average amounts outstanding.

2) Short-term is up to and including one year, medium-term is 1 up to 2 years, and long-term is over 2 years.

Source) Table 9A in BIS Quarterly Review (June 12, 2006).



Sources) International Financial Statistics, IMF。

Notes 1) All real exchange rates are normalized to be 100 in 2000.

2) "Real Exchange Rate" of country c in year y $= \left\lfloor p_{c,y} \times \left(e_y / e_{2000}\right) \times 100 \right\rfloor / p_{USA,y}$

where e = nominal exchange rate (dollar per national currency), p = except for China, Producer Price Index (for China, Consumer Price Index).