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DILUTION OF OPPORTUNITY COST EFFECT ON THE DEMAND FOR INTERNATIONAL RESERVES IN THE HIGH RESERVE ERA

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This study investigates the possible links between the international reserve accumulation by developing countries and an endogenous decrease in the magnitude of the opportunity cost effect. If the opportunity cost of reserve holdings is determined endogenously in relation to the reserve holdings themselves, the estimated coefficients of opportunity costs from a conventional OLS regression will be biased downward. An increase in the reserves decreases the risk of liquidity problems imposed by a sudden capital outflow, which results in a decrease in the opportunity cost of holding reserves. Thus, a high level of reserves may make the negative opportunity cost effect smaller. Generally, empirical results from pooled data for 17 developing countries covering the 1994 to 2002 time period support this interpretation.

JEL Classification: E52, F31, G21
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I. INTRODUCTION

The purpose of this study is to investigate the possible links between the rapid accumulation of international reserves (reserves hereafter) by developing countries and a reduction in the magnitude of opportunity cost

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effects. There has been a massive increase in reserve holdings by developing countries in recent years; debate on this rapid reserve accumulation is now under way (Flood and Marion, 2002; Aizenman and Marion, 2003; Lee, 2004; Dooley, Folkerts-Landau, and Graber, 2005; Rodrik, 2005).[1]

Opportunity cost is regarded as one of the key factors that determine the demand for reserves. For central banks, the opportunity cost of holding current reserves is the best alternative that is given up; for example, reserves are usually invested in US treasury bonds, with a yield much lower than the expected return on local investments, giving a net opportunity cost of the difference between the two. Theory predicts a negative marginal effect on the demand for reserves. The higher the net opportunity cost, the less incentive a central bank has to hold reserves. Thus, if a proper measure for opportunity cost is used for estimation, it is expected to display a negative effect on reserve holdings.

However, if the opportunity cost of the reserve holdings is determined endogenously in relation to the reserve holdings themselves, the estimated coefficients of opportunity cost from conventional Ordinary Least Squares (OLS) regression will be biased downward. In other words, the magnitude of the estimated opportunity cost effects would get smaller when we correct for endogeneity bias.[2] For a central bank, the opportunity cost of holding reserves can be measured by the difference between the yield it pays on its own debt and the yield it receives on its reserve assets, which is the spread (Grimes, 1993; Rodrik, 2006). However, a high level of reserves may decrease the cost of borrowing from foreign creditors, especially for emerging economies, as these reserves reassure foreign creditors. Thus, we propose that spreads are determined endogenously in relation to the reserve holdings. Based on the rapid reserve accumulation by developing countries in the 1990s, this

[1] For example, reserves have risen from a range of 6-8 percent of the GDP during the 1970s and 1980s to almost 30 percent of the GDP by 2004. Also, prior to 1990, developing country reserves fluctuated between three and four months of imports but increased to over eight months by 2004 (Rodrik, 2005). The debate includes the perspective of modern mercantilism (Lee, 2004; Dooley, Folkerts-Landau, and Graber, 2005) and self-insurance/precautionary motives in the presence of sudden-stop risks (Flood and Marion, 2002; Aizenman and Marion, 2003; Rodrik, 2005).

[2] Note that when the opportunity cost effects get smaller or weaker, the coefficients would approach zero.

study investigates the validity of this proposition.[3]

We introduce a spread equation and use system estimation methods, such as two-stage least squares (2SLS), to verify and correct for the bias. We compare the results from the system estimation method with the results from the conventional single equation method, OLS. Our empirical results from the pooled sample show that, if we consider the endogeneity in estimation for the reserve demand, the negative opportunity cost effects are weaker. To our knowledge, ours is the first study to confirm the downward bias of conventional measures of opportunity cost effects on reserve holdings, especially dusing the high-reserve era of the 1990s.

In the next section, we review relevant literature on the opportunity cost measures of reserve holdings, spread determination, and endogeneity. Then, we discuss methodology and data in Section 3. Section 4 presents estimation results. Finally, Section 5 summarizes the main findings and discusses areas of future research.

II. LITERATURE REVIEW

As mentioned above, opportunity cost plays an important role in all theoretical models for reserve holdings (Kenen and Yudin, 1965; Heller, 1966; Clark, 1970; Hamada and Ueda, 1977; Frenkel and Jovanovic, 1981; Ben-Bassat and Gottlieb, 1992). Theoretically, it is defined as the difference between the highest possible marginal productivity forgone from an alternative investment in fixed assets and the yield on reserves.

Overall, despite its important role in theory, many empirical studies in 1960s and 1970s fail to find a significant opportunity cost effect or even exclude the opportunity cost measure from estimation.[4] This may be due

[3] See Appendix 1 for the trends of each country's reserves.

[4] Kenen and Yudin (1965) and Kelly (1970) use per capita income as a proxy, but find the wrong (positive) sign. Flanders (1971) uses an economy's growth rate, but finds the wrong sign also. Courchene and Youssef (1967) and Frenkel and Jovanovic (1981) use the domestic discount rate as a proxy. Courchene and Youssef find that the coefficients have correct (negative) signs, but are insignificant in most cases, while Frenkel and Jovanovic find correct signs and significant coefficients. Several studies argue that previous studies ignore the yield on reserves and estimate only the opportunity cost effects using the proxy for the rate of return on capital (Shinkai, 1979; Edward, 1985; Landell-Mills, 1989). These studies emphasize the importance of net opportunity cost and attempt to measure the yield differential for it. Other studies (Clark, 1970; Frenkel, 1974, 1980; Bilson and Frenkel, 1979; Heller and Kahn, 1978; Edwards, 1983) simply drop the

to the failure to measure opportunity cost in accordance with its theoretical definition. It may also be due to the lack of reliable data on the real rate of return to capital and alternative yields on reserves, because, in many developing countries, the domestic capital market is not fully developed (Edward, 1985; Landell-Mills, 1989; Aizenman and Marion, 2004).

However, recent studies in the 1980s and 1990s continue to find that demand for reserves is significantly related to measures of the opportunity costs (Edwards, 1985; Landell-Mills, 1989; Ben-Bassat and Gottlieb, 1992; Islam and Khan, 1994; Huang, 1995). These studies attempt to find an adequate measure for opportunity cost, because it is believed that the insignificant results of opportunity cost effects are due to inadequate measurement. For example, Ben-Bassat and Gottlieb (1992) show that, when opportunity cost is measured properly, the estimated effect on Israeli reserve holdings is significant and correctly signed. Their study estimates net opportunity cost effects on reserve holdings using annual data for Israel over the 1968-1988 period.[5] Islam and Kahn (1994) confirm that a rising alternative yield, proxied by the US three-month Treasury Bill rate, causes El Salvador's central bank to economize on reserves. Huang (1995) finds that even the central bank of China behaves as if reserves are a scarce resource and reduced its reserve demand as interest rates rose during 1980-1990.

Briefly, although early studies in 1960s and 1970s were not successful in finding significant and negative opportunity cost effects on reserve demand, studies in the 1980s and 1990s show that reserve holdings are significantly related to the measures of opportunity cost. Therefore, it is now standard to once again include opportunity cost measures in reserve demand equations. Also, the opportunity cost effects seem to present the expected negative sign in empirical analysis.

However, most of the previous studies adopt single equation methods to estimate reserve demand equations. We propose that inadequate

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opportunity cost measure from the analysis, because reliable opportunity cost measures for estimation are not available.

[5] The net opportunity cost is the real return on capital minus the real return on an average of US dollar reserves and Deutschemark reserves held—the study asserts this measurement is close to the theoretical definition.

estimation methods also might be responsible for the bias in opportunity cost effects as well. For example, in the case of using spreads (the most commonly used opportunity cost measure in recent studies) as proxies for net opportunity cost, the conventional single estimation method possibly results in a bias problem due to the endogenous determination of spread in relation to reserve holdings. Thus, to validate the negative opportunity cost effects, we need to adopt a simultaneous equation method to overcome the bias problem of the single equation method.

Various studies on spread determination propose that reserve holdings are one of the factors that determine the size of the spread (Edwards, 1984; Min, 1998; Kamin and Karsten, 1999; Mauro *et al.*, 2002). Variables are generally categorized under several topics, for example: (i) liquidity and solvency variables; (ii) macroeconomic fundamentals; (iii) external shocks; and (iv) dummy variables (i.e., regional dummies). Reserve holdings (reserves-to-GDP ratio) are included in the first group of variables, which reflects the liquidity position of the country. It is expected that the ratio of reserves to GDP should have a negative effect on spread. In other words, an increase in the reserves-to-GDP ratio decreases the risk of liquidity problems imposed by a sudden capital outflow, which results in a decrease in the spread. Generally, empirical studies find supporting evidence for this.

Even though we have theoretical and empirical foundations on reserve demand and spread determination, few studies put two equations into one system and deal with the endogeneity problem of opportunity cost measure. To our knowledge, only Edwards (1985) discusses this issue and suggests 2SLS and joint generalized least squares (GLS) methods to correct the bias.[6] However, in the study, the direction of the bias, upward or downward is not identified. This study may contribute to the literature showing that the bias is downward in terms of econometric theory. Our empirical evidence supports the proposition.

Briefly, to this point, the estimation of reserve demand equation, including the investigation of the opportunity cost effect on reserve holdings, has been driven by the process of devising more adequate measures for opportunity cost. However, there are very few studies

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[6] We discuss the study in section 3.2.

discussing the bias in the estimated opportunity cost effects. Thus, we suggest the adoption of system estimation methods—incorporating the spread determination equation into the reserve demand—to account for this.

III. MODEL AND DATA

3.1 Reserve demand and spread equations

Most previous theoretical and empirical studies on demand for reserves rely on the buffer stock model (Heller, 1966; Frankel and Jovanovic, 1981; Flood and Marion, 2002; Aizenman and Marion, 2004). This model is based on the inventory management principle, which optimizes the trade-off between flow holding costs and fixed restocking costs. It assumes that the central bank chooses an initial level of reserves that minimizes its total expected costs. Two costs are considered: the opportunity cost of holding reserves, and the adjustment cost that is incurred when reserves reach some lower bound.[7] The two costs are interrelated because a higher stock of reserves reduces the probability of having to adjust, which reduces the expected cost of adjustment, but at the cost of higher forgone earnings. Thus, the optimal level of reserves is determined when the expected cost is minimized. Also, the size of transactions and the economy's openness are suggested as the arguments to decide the reserve demand. Then, the basic model of demand for reserves turns out to be a stable function of adjustment cost, opportunity cost, scale variables, and the degree of openness. Using a conventional log-linear specification (Frankel and Jovanovic, 1981; Flood and Marion, 2002; Aizenman and Marion, 2004), the reserve demand equation follows as:[8]

[7] The adjustment cost is interpreted as the output or welfare forgone by having to take other policy measures to generate the external payments surplus necessary for reserve accumulation in times of actual reserves reaching some lower limit. An example of this kind of policy is the increase of domestic interest rate that results in a decrease in investment and reduction in GDP.

[8] Here we use reserve-to-GDP ratio instead of reserves to normalize the size of reserves among countries.

$$\log\left(\frac{R}{Y}\right)_{it} = \alpha_0 + \alpha_1 \log\sigma_{it} + \alpha_2 \log(\rho - r^*)_{it} + \alpha_3 \log\left(\frac{IM}{Y}\right)_{it} + \upsilon_{it}^1 \tag{1}$$

where, σ_{it}, $(\rho - r^*)_{it}$ and $\left(\frac{IM}{Y}\right)_{it}$ are the variables of adjustment cost, net opportunity cost (ρ denotes the real rate of return on capital and r^* denotes the yield on reserves), and degree of openness of country i at time t, respectively. Generally, right-hand-side variables are assumed to be determined exogenously. Here, α_1, the coefficient of σ_{it}, is expected to be positive; α_2, the coefficient of $(\rho - r^*)_{it}$, is expected to be negative; and α_3, the coefficient of $\left(\frac{IM}{Y}\right)_{it}$, is expected to be positive.

Also, to allow for possible endogeneity of the opportunity cost, we introduce the spread determination equation. The equation includes the level of reserve holdings as one of its arguments.[9] The past empirical results show that strong macroeconomic fundamentals, such as low domestic inflation rates, improved terms of trade, and increased net foreign assets, are associated with a lower level of spreads. In contrast, weak liquidity variables, such as high debt-to-GDP ratios, low foreign reserves-to-GDP ratios, low (high) export (import) growth rates, and high debt-service ratios are associated with a higher level of spreads. At the same time, external shocks matter in the determination of spreads (Edwards, 1984; Min, 1998; Kamin and Karsten, 1999; Mauro *et al.*, 2002). Then, adopting a conventional specification from these studies, the spread determination equation follows as:

$$\log(\rho - \rho^*)_{it} = \beta_0 + \beta_1 \log\left(\frac{R}{Y}\right)_{it} + \sum_{k=2}^{n} \beta_k Z_{it}^k + \upsilon_{it}^2 \tag{2}$$

Spread $(\rho - \rho^*)$ is the differential between the real rate of expected return on investment in the home country (ρ) and the same rate in the foreign country (ρ^*). The optimal spread of country i at time t is assumed

[9] We use scaled reserves $\left(\frac{R}{Y}\right)$, rather than reserves, R, following the conventional method.

to be determined by some relevant economic variables, ($Z_{it}^{1},...,Z_{it}^{k}$), including scaled reserves, $\left(\frac{R}{Y}\right)_{it}$.

3.2 System estimation

Edwards (1985) suggests 2SLS and joint GLS methods to deal with the endogeneity problem of opportunity cost measure.[10] We show below that theory predicts that the direction of bias will be downward. Based on Edwards's reasoning, we introduce system estimation methods, including 2SLS, with an explicit functional form to correct for the bias. Also, we extend our analysis to both the individual country and the pooled data, and compare the results with those of OLS.

We assume that there is free capital movement in international capital markets, and that the yield on reserves (r^*) is equal to the real rate of expected return on investment in the foreign country (ρ^*). This assumption follows the principle that a country borrows in international capital markets as long as the cost of borrowing is equal to or lower than the domestic marginal productivity of capital.[11] To deal with the endogeneity problem—to correct the bias—we put two equations into one system and introduce 2SLS to get the unbiased coefficient of spread.[12]

[10] The specification is not reported explicitly in Edwards (1985). Thus, we need to arrange the specification for the model. The system implied in his study could be interpreted as:

$$\log R_{it}^{D} = \alpha_0 + \alpha_1 \log \sigma_{it} + \alpha_2 \log r_{it} + \alpha_3 \log Y_{it} + \alpha_4 \log\left(\frac{IM}{Y}\right)_{it} + \varepsilon_{it}^{1} \qquad (3)$$

$$\log r_{it} = \beta_0 + \beta_1 \log R_{it}^{D} + \sum_{k=2}^{n} \beta_k Z_{it}^{k} + \varepsilon_{it}^{2} \qquad (4)$$

where, R_{it}^{D} is demand for reserves; σ_{it} is the standard error of trend adjusted export earnings of country i at time t; r_{it} is the net opportunity cost of holding reserves of country i at time t; Y_{it} is the income of country i at time t; $\left(\frac{IM}{Y}\right)_{it}$ is the average propensity of imports of country i at time t; and Z variables are some economic variables that determine the spread of country i at time t.[10] Here, it is expected that $\alpha_1 > 0$, $\alpha_2 < 0$, $\alpha_3 > 0$, $\alpha_4 > 0$, and $\beta_1 < 0$. The expected signs of β_k depend on the specification chosen.

[11] Here, r^* and ρ^* would be the borrowing cost and the domestic marginal productivity of capital of the foreign country, respectively.

[12] Note that the reserve demand equation is overidentified. 2SLS provides a useful estimation procedure for obtaining the parameters in the case of overidentification.

Then, we expand the analysis to the other system estimation methods. Our system to be estimated follows as:

$$\log\left(\frac{R}{Y}\right)_{it} = \gamma_0 + \gamma_1 \log\sigma_{g\,it} + \gamma_2 \log S_{it} + \gamma_3 \log\left(\frac{IM}{Y}\right)_{it} + \varepsilon_{it}^1 \quad (5)$$

$$\log S_{it} = \delta_0 + \delta_1 \log\left(\frac{R}{Y}\right)_{it} + \sum_{k=2}^{n} \delta_k Z_{it}^k + \varepsilon_{it}^2 \quad (6)$$

Here, we denote the spread, $(\rho - \rho^*)$ as S. In the system, we follow the notation from Equation (1), defining σ_{git} as the volatility of the change in reserves from the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) process,[13] S_{it} as the spread, and $\left(\frac{IM}{Y}\right)_{it}$ as the ratio of imports to GDP of country i at time t. Also, regarding the spread equation, we follow existing studies that link the spread to a number of macroeconomic variables (Z_{it}), as mentioned above. We expect $\gamma_1 > 0$, $\gamma_2 < 0$, $\gamma_3 > 0$, $\delta_1 < 0$, and δ_k to depend on the variable Z^k.[14] Then, the expected value of the opportunity cost coefficient, $E(\hat{\gamma}_2)$, simplifies to:

[13] We model the volatility by the GARCH process because the change in reserves is related to its variance, which is not constant over any period of time (Engel, 1982; Bollerslev, 1986). It is preferred to the conventional standard deviation in payments and receipts (Flood and Marion, 2002). Assuming that the conditional variance depends on an infinite number of lags of reserve changes, we test various GARCH (p, q) specifications. To measure the volatility, we estimate the following basic regressions:

$$\Delta R_t = \omega_t + \sqrt{\sigma_t^2}\,\upsilon_t \quad (7)$$

$$\sigma_t^2 = \alpha_0 + \alpha(L)\,\varepsilon_t^2 + \phi(L)\,\sigma_t^2 \quad (8)$$

where, ΔR is the change in reserves, ω is the constant term, σ^2 is the conditional variance, υ is normally distributed, L is the lag operator, and $\alpha(L)$ and $\phi(L)$ are the lag polynomials with orders p and q, respectively. Then, the conditional standard deviation, $\sigma_{g_{it}}$, can be used for the volatility of payments and receipts. Due to the massive quantity of output, the results are not reported, but are available from the author upon request.

[14] In this study, as Z variables we use debt to GDP ratio (*DBTY*), Z^2; net foreign assets to GDP ratio (*NFAY*), Z^3; current account flows to exports ratio (*CAEXP*), Z^4; inflation rate (*INF*), Z^5; fiscal deficit to GDP ratio (*GOVY*), Z^6; and export growth rate (*EXPGR*), Z^7. Then, we expect $\delta_2 > 0$, $\delta_3 < 0$, $\delta_4 < 0$, $\delta_5 > 0$, $\delta_6 > 0$, and $\delta_7 < 0$.

$$E(\hat{\gamma}_2) = \gamma_2 + E[\sum(\log S_{it} - \overline{\log S_i})(\varepsilon_{it}^1) / \sum(\log S_{it} - \overline{\log S_i})^2] \qquad (9)$$

where, $\overline{\log S_i}$ is the average of $\log S_i$ across time *t*.

In a non-simultaneous equation, where $\log S_{it}$ and ε_{it}^1 are not correlated, the expected value of $\hat{\gamma}_2$ equals the true value of γ_2, because the expected value of the term $\sum(\log S_{it} - \overline{\log S_i})(\varepsilon_{it}^1)$ is 0. If $\log S_{it}$ and ε_{it}^1 are positively correlated (δ_1 is positive), then the expected value of $\hat{\gamma}_2$ is greater than the true value of γ_2, because the expected value of the term $\sum(\log S_{it} - \overline{\log S_i})(\varepsilon_{it}^1)$ is positive. Here, $\log S_{it}$ and ε_{it}^1 are negatively correlated because δ_1 is negative. Then, the expected value of $\hat{\gamma}_2$ is less than the true value of γ_2, which results in an underestimation or downward bias.

3.3 Data

For this analysis, we use JP Morgan's Emerging Market Bond Index (EMBI) Global Composite of 19 emerging economies during 1994-2002 for the spread data.[15] Since the EMBI is composed of daily data, we calculate the monthly average of the spread for our estimation. We exclude Egypt and Ukraine from the analysis because of a lack of sufficient data for individual country analysis.[16]

The data for the other explanatory variables—volatility of reserves (σ_g), import to GDP ratio (*IMY*), debt to GDP ratio (*DBTY*), net-foreign-assets-to-GDP ratio (*NFAY*), current-account-flows-to-exports ratio (*CAEXP*), inflation rate (*INF*), fiscal-deficit-to-GDP ratio (*GOVY*), and export growth rate (*EXPGR*)—are obtained or derived from the IMF International Financial Statistics (IFS). Here, we transform the quarterly GDP data to monthly data by dividing the quarterly GDP by 3.

[15] The EMBI Global Composites are weighted averages of the spreads of US dollar-denominated individual bonds issued by a particular emerging market country. Some studies have selected a benchmark bond for each country studied and used its spread; others have looked at the spreads of several individual bonds. Since, in this study, we are looking for the general proxy of opportunity cost, the EMBI Global Composites suit our purpose better than using individual bonds. The set of countries is as follows: Argentina, Brazil, Bulgaria, Columbia, Ecuador, (Egypt), Korea, Malaysia, Mexico, Morocco, Nigeria, Panama, Peru, Philippines, Poland, Russia, Turkey, (Ukraine), and Venezuela.

[16] Only annual GDP data is available for Egypt, and we have only 12 observations for Ukraine.

IV. EMPIRICAL RESULTS

After running the standard OLS regression, we perform Hausman specification tests for individual countries to establish the endogeneity between the reserve holdings and the spread in the system. Based on the results, we perform system estimation methods, such as 2SLS, to get unbiased estimated coefficients of opportunity cost measures and compare them with the coefficients of opportunity cost measures of OLS. We expect that we can confirm the downward bias in the opportunity cost effects.

4.1 Hausman tests

From Table 1, Hausman specification test statistics are significant for 15 (not Malaysia and Turkey) of our 17 countries, which means the spreads are determined endogenously for the 15 countries. The two countries that do not present endogeneity problems seem to have small numbers of observations for estimation: Malaysia has only 12 observations, and Turkey just 41. We do not perform the 2SLS for Malaysia and Turkey, because the two countries do not present the endogeneity problem at the Hausman specification test.

[Table 1] Hausman specification test on the endogeneity of spread

Country	*Z* variables	Hausman specification test Statistics	Observations	Endogeneity
Argentina	*NFAY, CAEXP, INF, GOVY,EXPGR*	0.214** (0.088)	95	YES
Brazil	*NFAY, CAEXP, INF, GOVY,EXPGR*	-0.467*** (0.158)	107	YES
Bulgaria	*DBTY, NFAY, CAEXP, INF, GOVY,EXPGR*	1.859*** (0.212)	84	YES
Columbia	*DBTY, NFAY, CAEXP, INF, GOVY,EXPGR*	-0.464*** (0.138)	43	YES
Ecuador	*DBTY, NFAY, CAEXP, INF, GOVY,EXPGR*	1.160*** (0.140)	84	YES
Korea	*NFAY, CAEXP, INF, GOVY,EXPGR*	0.295*** (0.085)	31	YES

Malaysia	*NFAY, CAEXP, INF, EXPGR*	-0.106 (0.356)	12	NO
Mexico	*DBTY, NFAY, CAEXP, INF, GOVY,EXPGR*	0.381*** (0.090)	105	YES
Morocco	*DBTY, NFAY, CAEXP, INF, GOVY,EXPGR*	2.362*** (0.260)	57	YES
Nigeria	*NFAY, CAEXP, INF, EXPGR*	-3.484*** (0.628)	78	YES
Panama	*NFAY, CAEXP, INF, EXPGR*	1.947** (0.086)	95	YES
Peru	*DBTY, NFAY, CAEXP, INF, GOVY,EXPGR*	-0.285*** (0.058)	48	YES
Philippines	*DBTY, NFAY, CAEXP, INF, GOVY,EXPGR*	0.544*** (0.177)	88	YES
Poland	*DBTY, NFAY, CAEXP, INF, GOVY,EXPGR*	-0.789*** (0.153)	72	YES
Russia	*DBTY, NFAY, CAEXP, INF, GOVY,EXPGR*	0.674*** (0.211)	60	YES
Turkey	*NFAY, CAEXP, INF, EXPGR*	-0.170 (0.123)	41	NO
Venezuela	*NFAY, CAEXP, INF, GOVY,EXPGR*	0.771*** (0.071)	93	YES

Notes: 1) Significance levels are 10% *, 5% **, and 1% ***.

2) The number of Z variables depends on data availability. For example, Argentina has five Z variables, because debt-to-GDP ratio and *DBTY* are not available.

4.2 Estimation in levels and differenced form

Based on the Hausman specification test results, we estimate the demand equation in a two equation system for 15 countries. ADF unit root tests demonstrate that, in general, $\log\left(\frac{R}{Y}\right)$ and $\log S$ are non-stationary; $\log \sigma_g$ and $\log\left(\frac{IM}{Y}\right)$ are stationary.[17] Therefore, estimating empirical reserve demand equations in levels using OLS, consistent with theory, may result in spurious regression. To address this problem, we estimate the model in differenced form. We may lose information about a possible long-run relationship in levels when we use differenced data.

[17] Refer to the author for the statistics.

However, our estimation using the first-differenced data may be applicable since our main purpose is to examine the parameter of opportunity cost by comparing OLS with system estimations.[18] The ADF statistics for all the differenced variables reject the unit roots, implying that they are stationary.[19] Tables 2 and 3 present the results from the estimations in the differenced form of the variables for the pooled sample.[20] Overall, the results of the opportunity cost effects demonstrate a downward bias. For example, in Table 2, for OLS and 2SLS, the magnitude of the opportunity cost effects becomes weaker, from -0.104 to -0.065, when we use four *Z* variables (*NFAY*, *CAEX*, *IFL*, and *EXPGR*).

Here, the coefficients are negative but not statistically significant. However, even in that case, we may admit that the negative opportunity cost effects get smaller or weaken in the broad concept. The other coefficients of the adjustment cost and the openness present the expected signs (positive) and do not change much across the estimations. The openness is significant at the 1 percent significance level in all cases. However, the adjustment cost is generally not statistically significant. Only in the cases of 2SLS II and III is it significant at the 10 percent significance level. The adjusted R^2s are around 0.7-0.8, and the Durbin-Watson statistics do not present an autocorrelation problem. This result supports the downward bias in the estimates of the opportunity cost effects when we perform OLS.

Also, in Table 3, we add fixed effects for each country. The results are not significantly different from the results in Table 2. We get weakened negative opportunity cost effects on the reserve demand when we perform 2SLS. For example, when we compare the results of OLS with those of 2SLS, the magnitude of the opportunity cost effects becomes smaller—from -0.103 to -0.070—with four *Z* variables (*NFAY*, *CAEX*, *IFL*, and *EXPGR*). This confirms again the downward bias in the estimated

[18] The cointegration regression, such as dynamic OLS and Johansen's method, can be adopted to examine the long-run relationship. We leave cointegration estimation for future research.

[19] Refer to the author for the statistics.

[20] We also estimate OLS, 2SLS, and GMM in the differenced form of the variables for each individual country. Overall, more than half of the individual countries present the downward bias in the opportunity effects. For 2SLS and GMM, we identify the downward bias in 11 and 9 out of 15 countries, respectively, without any major econometric problems. Refer to the author for the statistics.

coefficients of the opportunity cost.

[Table 2] Results of OLS and 2SLS on the reserve demand equations[21]
(Differenced form, pooled sample without fixed effect)

	OLS	**2SLS**			
		I	**II**	**III**	**IV**
	$\Delta\log\left(\frac{R}{Y}\right)$	$\Delta\log\left(\frac{R}{Y}\right)$	$\Delta\log\left(\frac{R}{Y}\right)$	$\Delta\log\left(\frac{R}{Y}\right)$	$\Delta\log\left(\frac{R}{Y}\right)$
C	0.003 (0.005)	0.003 (0.004)	0.003 (0.004)	0.003 (0.004)	0.002 (0.004)
$\Delta\log\sigma_g$	0.018 (0.015)	0.018 (0.014)	0.020 (0.014)	0.024^{*} (0.014)	0.025^{*} (0.014)
Δ log *S*	**-0.104^{***}** **(0.039)**	**-0.065** **(0.055)**	**-0.048** **(0.054)**	**-0.065** **(0.061)**	**-0.058** **(0.061)**
$\Delta\log\left(\frac{IM}{Y}\right)$	0.789^{***} (0.015)	0.789^{***} (0.016)	0.835^{***} (0.015)	0.848^{***} (0.015)	0.849^{***} (0.015)
Adjusted R^2	0.715	0.757	0.818	0.841	0.842
Durbin-Watson	2.668	1.990	2.032	2.086	2.021
Observations	1132	1107	960	792	779

Notes: Significance levels are 10% *, 5% **, and 1% ***.
We use instrumental variables *NFAY*, *CAEX*, *IFL*, *EXPGR* for 2SLS I; *NFAY*, *CAEX*, *IFL*, *EXPGR*, *GOVY* for 2SLS II; *DBTY*, *NFAY*, *CAEX*, *IFL*, *EXPGR* for 2SLS III; and *DBTY*, *NFAY*, *CAEX*, *IFL*, *EXPGR*, *GOVY* for 2SLS IV. Δ denotes the first difference.

[Table 3] Results of OLS and 2SLS on the reserve demand equations[22]
(Differenced form, pooled sample with fixed effect)

	OLS	**2SLS**			
		I	**II**	**III**	**IV**
	$\Delta\log\left(\frac{R}{Y}\right)$	$\Delta\log\left(\frac{R}{Y}\right)$	$\Delta\log\left(\frac{R}{Y}\right)$	$\Delta\log\left(\frac{R}{Y}\right)$	$\Delta\log\left(\frac{R}{Y}\right)$
C	0.004 (0.005)	0.003 (0.004)	0.003 (0.004)	0.003 (0.004)	0.002 (0.004)
$\Delta\log\sigma_g$	0.018 (0.015)	0.018 (0.014)	0.020 (0.014)	0.024 (0.014)	0.025 (0.015)
Δ log *S*	**-0.103^{***}** **(0.039)**	**-0.070** **(0.056)**	**-0.047** **(0.055)**	**-0.065** **(0.062)**	**-0.058** **(0.062)**

[21] See Appendix 2, Table 4 for the spread equation results. As expected, we identify the downward bias of the reserve-to-GDP ratio estimated coefficients.
[22] See Appendix 2, Table 5 for the spread equation results. The results are not much different from the previous one.

$\Delta \log\left(\frac{IM}{Y}\right)$	0.789^{***} (0.015)	0.788^{***} (0.016)	0.834^{***} (0.015)	0.847^{***} (0.015)	0.849^{***} (0.015)
Adjusted R^2	0.711	0.754	0.816	0.840	0.841
Durbin-Watson	2.672	1.993	2.035	2.090	2.025
Observations	1132	1107	960	792	779

Notes: Significance levels are 10% *, 5% **, and 1% ***.

We use instrumental variables *NFAY*, *CAEX*, *IFL*, *EXPGR* for 2SLS I; *NFAY*, *CAEX*, *IFL*, *EXPGR*, *GOVY* for 2SLS II; *DBTY*, *NFAY*, *CAEX*, *IFL*, *EXPGR* for 2SLS III; and *DBTY*, *NFAY*, *CAEX*, *IFL*, *EXPGR*, *GOVY* for 2SLS IV. Δ denotes the first difference. Fixed effects for each country are not reported.

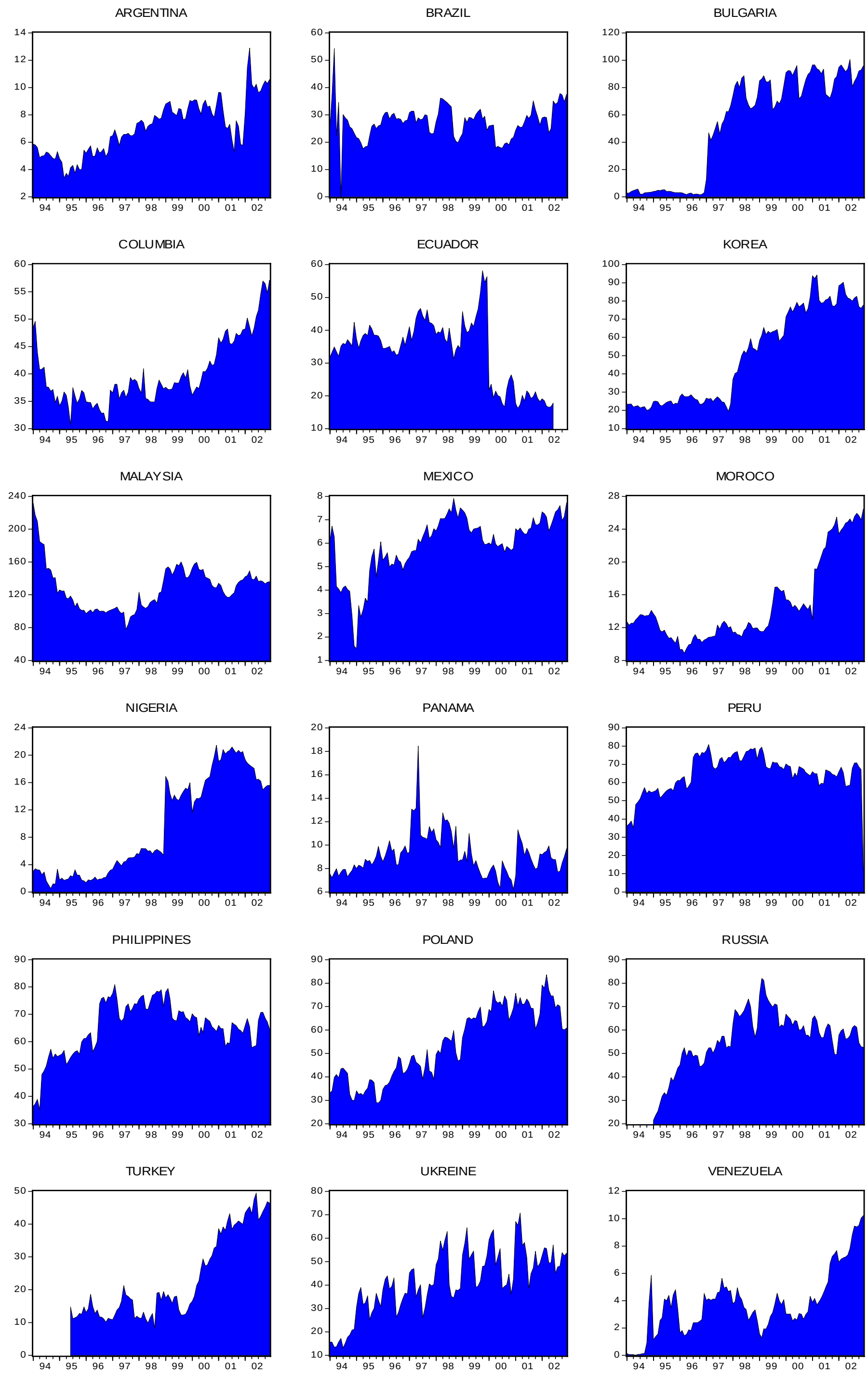
V. CONCLUSION

We develop a simultaneous model of demand for reserves to correct the bias in estimates of the opportunity cost when we use conventional methods and then examine the estimates of the opportunity cost effects from our simultaneous model. If the opportunity cost measure, which is regarded as one of the main arguments to determine the reserve demand, is determined endogenously in relation to the reserve holdings themselves, the estimated coefficients would be biased downward, especially in the high-reserve era of the 1990s.

For the pooled sample, we identify a downward bias in the opportunity cost effects on the reserve demand, implying that there is a decrease in the magnitude of the opportunity cost effects. Briefly, our empirical results show that, if we consider the endogeneity in the estimation for the reserve demand, the negative opportunity cost effects are weaker. The theoretical expectation for the opportunity cost effects becomes less influential on the reserve demand if we adopt our model.

For future study, we propose another bias problem regarding the opportunity cost effects on the reserve demand—an upward bias due to the simultaneous determination of the opportunity cost effect when we incorporate the supply side into the demand function. Our implicit assumption in this study is that the reserve supply is always elastic enough to meet the reserve demand—i.e., perfectly elastic supply. However, if the reserve supply is not elastic enough to meet demand, the opportunity cost measure is determined in relation to the reserve supply also. Then, the estimated opportunity cost effect from the conventional method would be biased. The system estimation methods can be used to deal with this problem as well.

Appendix 1: Trends of reserve-to-GDP (R/Y) ratio (%)



Appendix 2

[Table 4] Results of OLS and 2SLS on the spread equations
(Pooled sample without fixed effect)

	OLS	**2SLS**
	$\Delta \log S$	$\Delta \log S$
C	6.734*** (0.222)	6.766*** (0.240)
$\Delta \log\left(\frac{R}{Y}\right)$	**-0.022*** **(0.013)**	**-0.012** **(0.023)**
DBTY	-0.004 (0.003)	-0.004 (0.003)
NFAY	-0.004*** (0.001)	-0.005*** (0.001)
CAEXP	-0.005 (0.004)	-0.005 (0.004)
INF	-0.0002 (0.003)	-0.0002 (0.003)
GOVY	0.003 (0.003)	0.003 (0.003)
EXPGR	0.0003 (0.0003)	0.0003 (0.0003)
Adjusted R^2	0.953	0.953
D-W	1.316	1.327
Observations	746	745

Note: Significance levels are 10% *, 5% **, and 1% ***.

[Table 5] Results of OLS and 2SLS on the spread equations
(Pooled sample with fixed effect)

	OLS	**2SLS**
	$\Delta \log S$	$\Delta \log S$
C	6.708*** (0.119)	6.653*** (0.125)
$\Delta \log\left(\frac{R}{Y}\right)$	**-0.014*** **(0.009)**	**-0.002** **(0.015)**
DBTY	-0.004 (0.003)	-0.004 (0.003)
NFAY	-0.005*** (0.001)	-0.005*** (0.001)
CAEXP	-0.0002 (0.0003)	-0.0003 (0.0004)
INF	-0.0002 (0.0004)	-0.0002 (0.0004)
GOVY	0.003 (0.003)	0.003 (0.003)
EXPGR	0.0002 (0.0003)	0.0002 (0.0003)
Adjusted R^2	0.954	0.954
D-W	1.305	1.307
Observations	746	745

Note: Significance levels are 10% *, 5% **, and 1% ***.
Fixed effects for each country are not reported.

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