Portfolio-Flow Volatility and Demand for International Reserves

Changkyu Choi and Seung-Gwan Baek*

This paper examines the importance of portfolio-flow volatility as a determinant of the demand for international reserves over the 1980-99 period. Using panel data, we find that portfolio-flow volatility significantly raises the level of reserve holdings. Especially reserve accumulation is most sensitive to the volatility of portfolio balance (net flows). Capital account liberalization has increased uncertainty in the world economy, thereby making open economies more vulnerable to international financial crises. The regression results imply that monetary authorities have accumulated more precautionary reserve balances against increased uncertainty in portfolio flows as capital account liberalization progresses. As in previous studies, real openness is an important explanatory factor in determining the demand for reserves.

Keywords: Portfolio-flow volatility, International reserves, Precautionary demand

JEL Classification: C23, F32

Many governments still judge the adequacy of their [international] reserves to the value of imports. But a reserve goal of "six months of imports" ignores the fact that currency crises are about capital flows, not trading financing. What matters is the value of reserves relative to the amount of the currency that speculators might sell when the country's fundamental economic conditions do not warrant a currency decline.

Feldstein (1999, p.16)

*Associate Professor, Department of Economics, Myongji University, 50-3, Namgajwa-dong, Seodaemun-gu, Seoul 120-728, Korea, (Tel) +82-2-300-0687, (Fax) +82-2-300-0654, (E-mail) ckchoi@mju.ac.kr; Professor, Department of Economics, Hongik University, 72-1 Sangsu-dong, Mapo-gu, Seoul 121-791, Korea, (Tel) +82-2-320-1802, (Fax) +82-2-322-8845, (E-mail) sbaek @wow.hongik.ac.kr, respectively. We are grateful to the editor of this journal and anonymous referees for helpful comments and suggestions.
[**Seoul Journal of Economics** 2006, Vol. 19, No. 2]

I. Motivation

Singapore and Taiwan held the largest international reserves leading up to the 1997 Asian financial crisis, and they were the least affected by its speculative pressures. Hardest hit were countries, such as Korea, with inadequate holdings of international reserves. Since the crisis Korea has built up large stockpiles of reserves and has become the world's fourth largest reserve holder today.

This state of affairs is closely associated with two trends of the 1990s in the international economy that may affect the determinants of reserve holdings. The first one is that capital mobility across countries becomes greater as more countries liberalize their capital accounts and remove capital controls. The second is that more countries face currency and financial crises with the increasing frequency of speculative attacks. In this paper, we seek to identify empirically whether these trends have affected central bank reserve holdings.

Previous studies on the demand for international reserves are based on the buffer stock model introduced by Heller (1966) and Frenkel and Jovanovic (1981). The model suggests that a nation's optimal holdings of reserves are associated with two costs: The first is the opportunity cost of holding reserves. The second is the expected macroeconomic adjustment cost incurred in the absence of reserves. The adjustment cost is defined generally as the output forgone by taking expenditure-reducing or -switching policies to generate the external payments surplus necessary for reserve accumulation. A higher level of reserves reduces the probability of having to make adjustments and thus lowers the expected cost of adjustment. But this benefit comes at the cost of higher foregone earnings, which is the opportunity cost of holding reserves. At the optimal level of reserve holdings the sum of these two costs are minimized.

As a result, the main determinants of the demand for reserves used by previous empirical studies have been associated with the adjustment cost, the opportunity cost, and reserve volatility.[1] Since

[1] For example, see Heller and Kahn (1978), Edwards (1983), Frenkel (1983), and Lizondo and Mathieson (1987). Another view is the monetary approach to balance of payments where the disequilibrium of money market reflects

the international financial crises in the 1990s, however, empirical studies on reserve holdings have added other determinants or used new measures of the explanatory variables employed in the previous studies (Lane and Burke 2001; Aizenman and Marion 2002, 2004; Flood and Marion 2002). Lane and Burke (2001) use a large number of potential determinants of reserves in their empirical study. Their empirical results suggest that trade openness is the most important factor in explaining cross-country variation in reserve accumulation. The other statistically significant variables are financial development and the level of total external debt.

Aizenman and Marion (2002a, b) interpret the build-up of large international reserves in some Asian countries after the 1997 financial crisis as representing precautionary holdings.[2] Traditional determinants suggested by the buffer stock model cannot fully explain the behavior of precautionary reserve holdings. The additional variables that may lead to large precautionary reserves are sovereign risk, costly tax collection to cover fiscal liabilities, and loss aversion against a future crisis. On the other hand, countries with high discount rates, political instability or political corruption may hold smaller precautionary balances. Aizenman and Marion's estimated results support the idea that political corruption and instability significantly reduce reserve holdings.

Flood and Marion (2002) use a new measure of reserve volatility and re-estimate Frenkel and Javanovic's (1981) model with more recent panel data for 36 developed and developing countries over the 1980-97 period. Traditional volatility measures used in the previous studies have been the volatility of export receipts or actual reserve volatility. The new measure of reserve volatility, called fundamentals volatility, corrects positive or negative skewness to the reserve increment measure that can occur after financial and

changes in international reserves. See Frenkel (1983), Edwards (1984), Elbadawi (1990), Ford and Huang (1994), and Huang and Shen (1999). Also see Bahmani-Oskooee and Brown (2002) for a recent review of the literature on international reserves.

[2] Aizenman and Lee (2005) present a model of financial intermediation and adjustment to liquidity shocks, where hoarding international reserves emerges as part of the optimal financial intermediation. Using cross-section data of 53 countries for the period of 1980-2000, they reconfirm that precautionary demand is consistent with high levels of reserves. Using the precautionary approach, Aizenman, Lee, and Rhee (2004) investigate changes in reserve holdings in Korea in the aftermath of 1997-8 crisis.

currency crises. The estimated coefficients on the new measure of volatility are statistically significant, but their sizes become much smaller than those of Frenkel and Jovanovic (1981). Their conclusion is that the buffer stock model of reserve holdings works as well in an era of increased exchange-rate flexibility and high capital mobility as it did when capital was less mobile.

Our study is close to Flood and Marion (2002), but it uses portfolio-flow volatility as an alternative volatility measure.[3] The purpose of this paper is to test whether portfolio-flow volatility is a significant determinant of the demand for international reserves. The rationale for using this volatility measure is that the extent of portfolio-flow volatility rather than trade flow volatility should matter for reserve holdings in the world of high capital mobility associated with capital account liberalization. Moreover, portfolio flows, not trade flows, have been relevant to recent currency and financial crises.

We describe the empirical specification and data in section II, and analyze the regression results in section III. The final section summarizes the paper's main findings.

II. Model and Data

A. The Empirical Specification

To analyze the effect of portfolio-flow volatility on the demand for international reserves, we set up an estimating equation as follows:

$$\ln(RES_{it}) = \beta_0 + \beta_1 \ln(VOL_{it}) + \beta_2 \ln(GDP_{it}) + \beta_3 \ln(OPEN_{it}) + e_{it} \quad (1)$$

where *RES* stands for the reserves/GDP ratio, *VOL* is the volatility of portfolio flows, *GDP* is the Gross Domestic Product, and *OPEN* is the ratio of exports plus imports to GDP. The subscripts, i and t, denote country i and year t, respectively.

[3] Flood and Marion (2002) concern about the skewness of reserve increments induced by periodic adjustments by the reserve authority, which may violate the assumption of Frenkel and Javanovic (1981) that reserves follow a Wiener process up until they hit the upper barrier. But we assume that the reserve authority does not set such barrier for portfolio flows. Thus the problem of skewness is ignored when we calculate portfolio-flow volatility.

Reserve holdings should increase with the volatility of portfolio flows if they are to be held under a precautionary motive in an economy where financial openness is high. So we expect $\beta_1 > 0$. GDP measures the country's size or standard of living. Reserve holdings should increase with the size of international transactions; so GDP may be positively correlated with reserves. However, a larger country is less subject to speculative attack and financial crises so that it can survive with smaller reserves relative to its GDP. Thus, the sign of β_2 is not unambiguous.

Reserve holdings should be associated with the vulnerability of real external shocks such as terms-of-trade shocks. Since an open economy that trades more with other economies could face more frequent and larger adjustment costs, real openness may be positively correlated with reserve holdings. On the other hand, Heller (1966) uses the marginal propensity to import (m) as an openness measure and adopts a Keynesian view where the adjustment cost for an economy is equal to the inverse of its m. He concludes that greater openness, by reducing the adjustment cost, would be related to lower reserve holdings. Thus, the sign of β_3 is not certain either.

In contrast to Flood and Marion (2002), we exclude the opportunity cost as an explanatory variable in (1). As Aizenman and Marion (2002, 2004) admit, previous studies have found that it is an insignificant explanatory factor.[4] There are few reliable proxies for the opportunity cost variable. Moreover, interest-rate data have not been available especially for many developing countries.

B. Data

The data set consists of reserve information from the period 1980-99 for 46 countries, listed in Table 1. The countries are chosen based on the availability of reserve data and other variables for estimation. The total reserves minus gold (.1L.DZF) series in U.S. Dollars from the *IFS* CD-ROM from the International Monetary Fund (IMF 2001) are used as a measure of international reserves

[4] The exceptions are Edwards (1985), Landell-Mills (1989), and Ben-Bassat and Gottlieb (1992). In their literature survey, Bahmani-Oskooee and Brown (2002) conclude that the measure of opportunity cost is significant when countries are considered individually, but insignificant when data are pooled.

TABLE 1
COUNTRY LIST

1	ARGENTINA	17	HUNGARY	33	PHILIPPINES
2	AUSTRALIA	18	ICELAND	34	PORTUGAL
3	AUSTRIA	19	IRELAND	35	RUSSIA
4	BELARUS	20	ISRAEL	36	SLOVAK REPUBLIC
5	BRAZIL	21	ITALY	37	SLOVENIA
6	BULGARIA	22	JAPAN	38	SOUTH AFRICA
7	CANADA	23	KOREA	39	SPAIN
8	CHILE	24	LATVIA	40	SRI LANKA
9	COLOMBIA	25	LITHUANIA	41	SWEDEN
10	CZECH REPUBLIC	26	MALTA	42	THAILAND
11	DENMARK	27	MEXICO	43	TURKEY
12	ESTONIA	28	NETHERLANDS	44	UNITED KINGDOM
13	FINLAND	29	NEW ZEALAND	45	UNITED STATES
14	FRANCE	30	NORWAY	46	VENEZUELA, REP. BOL.
15	GERMANY	31	PAPUA NEW GUINEA		
16	GUATEMALA	32	PERU		

at the end of the period. The gold series in ounces is from the IFS CD-ROM and is multiplied by 35 (=gold in SDR), and then converted to U.S. Dollars using the end-of-period $/SDR exchange rate (111..AA.ZF) following Flood and Marion (2002). Portfolio-flow data are the quarterly portfolio investment assets (78BFDZF) and the liabilities (78BGDZF) series from the *IFS* CD-ROM. Import, export, and GDP are measured in current U.S. Dollars and are taken from the *World Development Indicators* CD-ROM from the World Bank (2001).

As a robustness check, we use four types of portfolio-flow volatility: (a) Liability, (b) asset, (c) balance, and (d) sum. To get the volatility of portfolio liability and portfolio asset, we use the standard deviation of each country's current and past two years' quarterly portfolio-liability (asset) data. For example, to get the 1980 portfolio-liability (asset) volatility, we use the standard deviation of quarterly portfolio-liability (asset) data from the first quarter of 1978 to the fourth quarter of 1980 divided by GDP in 1980. Portfolio-balance volatility where balance is defined as portfolio liability minus portfolio asset is obtained in the same way

TABLE 2

SUMMARY STATISTICS

Variable	Obs.	Mean	Std. Dev.	Min	Max
Foreign Reserves (Million USD)	417	22,628.43	30,080.99	96.06	286,916.00
Volatility of Portfolio Liability	417	3,294.38	5,415.81	2.41	38,677.76
Volatility of Portfolio Assets	412	2,330.52	4,618.00	3.58	25,960.19
Volatility of Portfolio Balance	417	3,812.58	6,219.60	9.61	45,287.45
Volatility of Portfolio Sum	417	5,624.91	9,634.06	22.34	61,109.06
GDP (Million USD)	417	711,788.52	1,336,386.39	3,340.00	8,699,200.00
Per Capita GDP (USD)	409	14,980.00	6,357.96	2,450.00	30,400.00
Openness	417	0.62	0.32	0.15	1.82
Gold (Million USD)	416	1,333.25	2,630.08	0.00	13,647.66

Source: Authors' calculation from *IFS* CD-ROM, IMF (2001) and *WDI* CD-ROM, World Bank (2001).

as described above. Portfolio-sum volatility is calculated as the sum of portfolio-liability volatility and portfolio-asset volatility. Summary statistics for the variables used in the regression are listed in Table 2.

III. Empirical Evidence: Portfolio-Flow Volatility and Reserve Holdings

Using pooled data, we estimate (1) by OLS (ordinary least squares). The dependent variable is the natural log of foreign reserves excluding gold scaled by GDP. The regression results for the four types of portfolio-flow volatility are shown in Table 3. All types of portfolio-flow volatility significantly raise the level of reserve holdings. The estimated coefficient on asset volatility is positive and significant at 10%, but the other volatility measures have positive coefficients at the 1% significance level. The coefficient of portfolio-balance volatility has the highest value, 0.167, while that of portfolio asset volatility is the smallest value, 0.069. This means that when portfolio-balance volatility increases by 1%, the reserves/GDP ratio increases by 0.167%. This result is consistent with our presumption that monetary authorities' reserve accumulation could be sensitive most to portfolio-balance volatility, but least to portfolio asset (outflows) volatility.

The estimated coefficients on GDP are all negative and significant

TABLE 3
PORTFOLIO-FLOW VOLATILITY AND DEMAND FOR FOREIGN RESERVES

Dependent Variable	ln(*RES*)			
Estimation Method	Pooled OLS			
Portfolio Volatility Type	Liability	Asset	Balance	Sum
Constant	1.021*	0.877	1.328***	1.104*
	(0.543)	(0.617)	(0.497)	(0.565)
ln(*VOL*)	0.122***	0.069*	0.167***	0.140***
	(0.042)	(0.042)	(0.041)	(0.047)
ln(*GDP*)	-0.248***	-0.254***	-0.257***	-0.253***
	(0.037)	(0.040)	(0.036)	(0.038)
ln(*OPEN*)	0.371***	0.384***	0.317***	0.341***
	(0.096)	(0.108)	(0.093)	(0.099)
Adjusted R^2	0.48	0.47	0.49	0.48
No. of obs.	417	417	417	417

Notes: 1) *RES* stands for the reserves/GDP ratio, *VOL* is the volatility of portfolio flows, *GDP* is the Gross Domestic Product, and *OPEN* is the ratio of exports plus imports to GDP.
2) *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.
3) Newey and West's (1987) heteroscedasticity- and autocorrelation-consistent covariance matrix assuming a lag length of one is used for standard errors.

at 1%.[5] Larger countries may need larger reserves for international transactions, but actually hold smaller reserves relative to their economic size. The results imply that precautionary reserve holdings are less important for larger countries.

All the coefficients on real openness (*OPEN*) are positive and significant at 1%. Countries more open to external trade have more chances to face external shocks and thus demand greater international reserves. Lane and Burke (2001) also confirm that trade openness is the most important determinant of cross-county variation in reserve accumulation. In their extended empirical work, Flood and Marion (2002) show that real openness is positively

[5] Lane and Burke (2001) use population size and *per capita* GDP here. In their regression results, population size significantly lowers reserve holdings relative to GDP while the estimated coefficients for *per capita* GDP are positive but statistically insignificant. On the other hand, the coefficients of both variables are positive and significant for Aizenman and Marion (2002, 2004) where the dependent variable is defined as the ratio of reserves to external debt or to *M2*.

TABLE 4

FOREIGN RESERVES INCLUDING GOLD

Dependent Variable	ln(*RES*)			
Estimation Method	Pooled OLS			
Portfolio Volatility Type	Liability	Asset	Balance	Sum
Constant	0.598	0.502	0.870*	0.674
	(0.514)	(0.583)	(0.468)	(0.534)
ln(*VOL*)	0.079**	0.044	0.120***	0.095**
	(0.037)	(0.038)	(0.035)	(0.042)
ln(*GDP*)	-0.226***	-0.230***	-0.233***	-0.229***
	(0.036)	(0.038)	(0.035)	(0.036)
ln(*OPEN*)	0.417***	0.426***	0.371***	0.394***
	(0.091)	(0.101)	(0.087)	(0.093)
Adjusted R^2	0.49	0.49	0.50	0.49
No. of obs.	416	416	416	416

Notes: 1) *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

2) Newey and West's (1987) heteroscedasticity- and autocorrelation-consistent covariance matrix assuming a lag length of one is used for standard errors.

correlated with reserve holdings, too.[6]

Flood and Marion (2002) assert that gold should be included in the reserves measure. As a robustness check, we use international reserves including gold and re-estimate (1). The results, shown in Table 4, indicate that all the regression results are pretty robust when international reserves including gold are used, although the coefficient for each of the volatilities decreases slightly and asset volatility loses its significance.

We are also interested in whether the significance of portfolio-flow volatility varies depending upon estimating periods. Compared with the 1990s, capital accounts were less open in the 1980s, international capital mobility was lower, and financial crises were less frequent. Table 5 presents the portfolio-balance estimation results for the 1980s and 1990s. As expected, the coefficient on volatility is positive and significant in the 1990s, but insignificant in the 1980s. The role of real openness in determining reserve

[6] They also show a positive relationship between financial openness and reserve holdings. We tried to add financial openness as an explanatory variable, but its estimated coefficients were not significant. The main reason would be that it is highly correlated with portfolio-flow volatility.

TABLE 5

PORTFOLIO-BALANCE VOLATILITY AND DEMAND FOR FOREIGN RESERVES: BY PERIOD

Dependent Variable	ln(*RES*)	
Estimation Method	Pooled OLS	
Period	1980-1989	1990-1999
Constant	1.426*	0.989*
	(0.789)	(0.594)
ln(*VOL*)	0.059	0.136**
	(0.068)	(0.064)
ln(*GDP*)	-0.314***	-0.242***
	(0.066)	(0.040)
ln(*OPEN*)	0.495***	0.239**
	(0.185)	(0.101)
Adjusted R^2	0.56	0.43
No. of obs.	137	280

Source: Authors' calculation

Notes: 1) *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

2) Newey and West's (1987) heteroscedasticity- and autocorrelation-consistent covariance matrix assuming a lag length of one is used for standard errors.

holdings is greater in the 1980s, and, importantly, the explanatory power increases with only two significant control variables, country size and openness. This implies that real trade impacts central bank reserve accumulation more in the 1980s than in the 1990s.

Table 6 examines the case for two separate country groups, rich and poor countries. A rich country is defined as a country whose *per capita* GDP is greater than 10,000 U.S. Dollars in each observation.[7] For the rich-country sample, the estimated coefficients of all portfolio-flow volatilities are significant at 1%. For the poor-country sample, on the other hand, real openness is the only variable that keeps its significance in determining the demand for international reserves. The coefficient of openness for poor countries is almost twice that for rich countries. Moreover, the adjusted

[7] A country belongs to a group of poor countries in some years, and the same country also belongs to the rich group in other years according to the variations of the *per capita* GDP. It may be more exact if the classification refers to high-income period and low-income period rather than rich countries and poor countries.

TABLE 6

PORTFOLIO-FLOW VOLATILITY AND DEMAND FOR FOREIGN RESERVES: BY RICH AND POOR COUNTRY

Dependent Variable	ln(*RES*)			
Estimation Method	Pooled OLS			
Country Group	Rich Country (*Per Capita* GDP>$10,000)			
Portfolio Volatility Type	Liability	Asset	Balance	Sum
Constant	1.703***	2.303***	1.878***	1.903***
	(0.583)	(0.603)	(0.579)	(0.575)
ln(*VOL*)	0.136***	0.151***	0.176***	0.174***
	(0.042)	(0.040)	(0.043)	(0.045)
ln(*GDP*)	-0.298***	-0.336***	-0.299***	-0.307***
	(0.043)	(0.043)	(0.043)	(0.043)
ln(*OPEN*)	0.300***	0.202**	0.261***	0.247**
	(0.099)	(0.101)	(0.098)	(0.098)
Adjusted R^2	0.55	0.57	0.56	0.56
No. of obs.	308	308	308	308
Country Group	Poor Country (*Per Capita* GDP<$10,000)			
Portfolio Volatility Type	Liability	Asset	Balance	Sum
Constant	-1.308	-1.723*	-0.898	-1.418
	(1.327)	(0.989)	(1.210)	(1.266)
ln(*VOL*)	0.064	-0.016	0.116	0.063
	(0.096)	(0.076)	(0.088)	(0.106)
ln(*GDP*)	-0.056	-0.059	-0.070	-0.048
	(0.100)	(0.087)	(0.099)	(0.096)
ln(*OPEN*)	0.690**	0.733***	0.630**	0.704***
	(0.274)	(0.247)	(0.269)	(0.266)
Adjusted R^2	0.27	0.26	0.28	0.27
No. of obs.	101	101	101	101

Notes: 1) *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

2) Newey and West's (1987) heteroscedasticity- and autocorrelation-consistent covariance matrix assuming a lag length of one is used for standard errors.

coefficient of determination ($\bar{R}^2$) is about 56% for the rich countries' reserve holdings, but only about 27% for poor countries. These results suggest that poor countries hold reserves mostly by the transactions motive and their capital accounts are less open than those of rich countries.[8] Though Lane and Burke (2001) used

[8] Correlation coefficient of log of *per capita* GDP and log of financial openness, which is defined as the ratio of gross private capital flows to

TABLE 7
PORTFOLIO-FLOW VOLATILITY AND DEMAND FOR FOREIGN RESERVES: INDIVIDUAL RANDOM EFFECTS

Dependent Variable	ln(*RES*)			
Portfolio Volatility Type	Liability	Asset	Balance	Sum
Constant	-0.937	-1.737***	-0.831	-1.102*
	(0.594)	(0.594)	(0.602)	(0.616)
ln(*VOL*)	0.089***	0.035*	0.098***	0.079***
	(0.027)	(0.021)	(0.028)	(0.028)
ln(*GDP*)	-0.080*	-0.030	-0.088*	-0.074
	(0.036)	(0.045)	(0.045)	(0.047)
ln(*OPEN*)	0.574***	0.671***	0.553***	0.577***
	(0.116)	(0.115)	(0.118)	(0.121)
Adjusted R^2	0.84	0.84	0.84	0.84
No. of obs.	417	417	417	417

Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

export volatility as a volatility measure, they also confirmed that volatility lost its significance with wrong signs for their developing-country sample while openness remained a significant explanatory factor.

As a methodology robustness check, we ran a regression with individual random effects. The results are listed in Table 7. Compared with the basic results in Table 3, the coefficients on portfolio-flow volatilities, with the exception of portfolio-asset volatility, are still highly significant, but they become smaller. Openness has a stronger effect on reserve holdings. However, the role of GDP significantly decreases, and the GDP coefficient becomes insignificant for two cases out of four.

Lastly, a panel GMM method is used in Table 8. We use robust standard errors, which are heteroscedasticity- and autocorrelation-consistent up to a moving average of 1 lag *via* GMM. Instrumental variables used are constant, ln *VOL*(−1), ln *GDP*(−1), ln *OPEN*(−1), and ln *OPEN*(−2). Furthermore, we test the null hypothesis that the expected error is zero according to the *J*-statistic proposed by Hansen (1982). The null hypothesis cannot be rejected, meaning that the model specification is appropriate. The estimated results

GDP, was 0.58. This supports the argument that in general capital accounts are less open in poor countries than in rich countries.

TABLE 8

PORTFOLIO-FLOW VOLATILITY AND DEMAND FOR FOREIGN RESERVES: PANEL GMM

Dependent Variable	ln(*RES*)			
Estimation Method	Pooled OLS			
Portfolio Volatility Type	Liability	Asset	Balance	Sum
Constant	1.038*	0.720	1.470***	1.109*
	(0.611)	(0.690)	(0.552)	(0.630)
ln(*VOL*)	0.129**	0.048	0.169***	0.142**
	(0.053)	(0.050)	(0.048)	(0.057)
ln(*GDP*)	-0.246***	-0.251***	-0.269***	-0.253***
	(0.038)	(0.042)	(0.038)	(0.040)
ln(*OPEN*)	0.349***	0.376***	0.288***	0.320***
	(0.010)	(0.114)	(0.096)	(0.104)
Adjusted R^2	0.47	0.46	0.50	0.47
No. of obs.	395	395	357	395
J-Specification(1)	0.52	0.0009	0.40	0.34
Significance Level of *J*	0.47	0.98	0.53	0.56
Instrumental Variables	Constant, ln*VOL*(−1), ln*GDP*(−1), ln*OPEN*(−1), ln*OPEN*(−2)			

Notes: 1) *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

2) Newey and West's (1987) heteroscedasticity- and autocorrelation-consistent covariance matrix assuming a lag length of one is used for standard errors.

are very similar to the basic results in Table 3. The exception is that portfolio-asset volatility loses its significance.

IV. Conclusion

This paper has examined whether portfolio-flow volatility is an important determinant of the demand for international reserves over the last two decades. The regression results show that portfolio-flow volatility significantly raises the level of reserve holdings. The volatility of portfolio balance (net flows) turned out to be more sensitive than other types of portfolio flow volatility in determining reserve holdings. The results imply that monetary authorities have accumulated more precautionary reserve balances against increased volatility of capital flows as capital account liberalization progresses and more frequent international financial crises occur. We can

confirm this argument from the estimation results that portfolio-flow volatility loses its significance for the 1980s and for poor-country samples, for which capital account liberalization is limited. As in previous studies, real openness proved to be an important explanatory factor in determining the demand for reserves.

Recently researchers have tried to test whether capital account liberalization positively affects economic growth (for example, Edison *et al.* (2002)) and financial development (Chinn and Ito 2002). While beneficial in many respects, capital account liberalization has increased uncertainty, thereby making open economies more vulnerable to financial crises.

(Received 26 August 2005; Revised 24 November 2005)

References

Aizenman, J., and Lee, J. International Reserves: Precautionary *versus* Mercantilist Views, Theory, and Evidence. NBER Working Paper No. 11366, 2005.

Aizenman, J., and Marion, N. P. "The High Demand for International Reserves in the Far East: What's Going On?" *Journal of the Japanese and International Economies* 17 (No. 3 2002): 370-400.

_____. "International Reserve Holdings with Sovereign Risk and Costly Tax Collection." *The Economic Journal* 114 (July 2004): 569-91.

Aizenman, J., Lee, Y., and Rhee, Y. International Reserve Management and Capital Mobility in a Volatile World: Policy Considerations and a Case Study of Korea. NBER Working Paper No. 10534, 2004.

Bahmani-Oskooee, M., and Brown, F. "Demand for International Reserves." *Applied Economics* 34 (No. 10 2002): 1209-26.

Ben-Bassat, A., and Gottlieb, D. "Optimal International Reserves and Sovereign Risk." *Journal of International Economics* 33 (Nos. 3-4 1992): 345-62.

Chinn, M. D., and Ito, H. Capital Account Liberalization, Institutions and Financial Development: Cross Country Evidence. NBER Working Paper No. 8967, 2002.

Edison, H. J., Klein, M. W., Ricci, L., and Sloek, T. Capital Account

Liberalization and Economic Performance: Survey and Synthesis. NBER Working Paper No. 9100, 2002.

Edwards, S. "The Demand for International Reserves and Exchange Rate Adjustment: The Case of LDCs, 1964-1972." *Economica* 50 (August 1983): 269-80.

_____. "The Demand for International Reserves and Monetary Equilibrium: Some Evidence from Developing Countries." *The Review of Economics and Statistics* 66 (No. 3 1984): 495-500.

_____. "On the Interest Rate Elasticity of the Demand for International Reserves: Some Evidence from Developing Countries." *Journal of International Money and Finance* 4 (No. 2 1985): 287-95.

Elbadawi, I. A. "The Sudan Demand for International Reserves: A Case of a Labour-exporting Country." *Economica* 57 (No. 225 1990): 73-89.

Feldstein, M. Self-protection for Emerging Market Economies. NBER Working Paper No. 6907, 1999.

Flood, R. P., and Marion, N. P. Holding International Reserves in an Era of High Capital Mobility. *Brooking Trade Forum 2001*, Washington D.C., The Brookings Institution, pp. 1-68, 2002.

Ford, J. L., and Huang, G. "The Demand for International Reserves in China: An ECM Model with Domestic Monetary Equilibrium." *Economica* 67 (No. 243 1994): 379-97.

Frenkel, J. A. "International Liquidity and Monetary Control." In George M. von Furstenberg (ed.), *International Money and Credit: The Policy Roles*. Washington, D.C.: International Monetary Fund, pp. 65-128, 1983.

Frenkel, J. A., and Jovanovic, B. "Optimal International Reserves: A Stochastic Framework." *Economic Journal* 91 (June 1981): 507-14.

Hansen, L. P. "Large Sample Properties of Generalized Method of Moments Estimators." *Econometrica* 50 (No. 4 1982): 1029-54.

Heller, H. R. "Optimal International Reserves." *Economic Journal* 76 (June 1966): 296-311.

Heller, H. R., and Kahn, M. S. "The Demand for International Reserves under Fixed and Floating Exchange Rates." *IMF Staff Papers* (December 1978): 623-49.

Huang, T.-H., and Shen, C.-H. "Applying the Seasonal Error Correction Model to the Demand for International Reserves in

Taiwan." *Journal of International Money and Finance* 18 (No. 1 1999): 107-31.

International Monetary Fund (IMF). *International Financial Statistics (IFS)* CD-ROM. International Monetary Fund, 2001.

Landell-Mills, J. M. "The Demand for International Reserves and Their Opportunity Cost." *IMF Staff Papers* 36 (No. 3 1989): 708-32.

Lane, P. R., and Burke, D. "The Empirics of Foreign Reserves." *Open Economies Review* 12 (No. 4 2001): 423-34.

Lizondo, J. S., and Mathieson, D. J. "The Stability of the Demand for International Reserves." *Journal of International Money and Finance* 6 (No. 3 1987): 251-82.

Newey, W. K., and West, K. D. "A Simple, Positive Semi-definite, Heteroscedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica* 55 (No. 3 1987): 703-8.

World Bank. *World Development Indicators*. World Bank, 2001.