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EXCHANGE-RATE REGIMES AND INTERNATIONAL RESERVES

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In this paper, we use the new classification of exchange-rate arrangements developed by Reinhart and Rogoff (2004) to test whether reserve holdings decrease with increasing exchange-rate flexibility. Using pooled data for 127 countries over the period 1980–2000, we find several new results. First, the degree of exchange-rate flexibility has an inverted-U relationship with the country's reserve holdings. Exchange-rate regimes with intermediate flexibility need more reserves than polar regimes (hard pegs and freely floating). Second, reserve holdings are smaller under hard pegs than under freely floating, implying that current large stockpiles of reserves in East Asian countries can be significantly reduced if they adopt a single currency. Finally, per capita GDP and reserve holdings have an inverted-U relationship, too, reflecting that their correlation would be negative for industrial countries, but positive for developing countries.

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I. INTRODUCTION

One of the unresolved issues in international finance is whether exchange-rate regimes matter for countries' international reserve

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accumulation. Theory suggests that countries with fixed or heavily managed exchange rates should hold more reserves to defend their currency values than countries with more flexible regimes. However, this standard view is not supported by all empirical results of previous studies. Moreover, as countries have shifted from pegs to floating-exchange-rate regimes following the currency and financial crises of the 1990s, world reserve holdings have continued to rise. In this paper, we empirically reexamine the relationship between exchange-rate regimes and countries' reserve holdings with updated data and new exchange-rate arrangements developed by Reinhart and Rogoff (2004).

Previous empirical studies on the relationship between exchange-rate regimes and international reserve holdings concentrated primarily on testing whether there was a change in reserve behavior in March 1973, when the international monetary system moved from a pegged-rate system to a floating-rate regime. Williamson (1976) presents the first attempt to test the standard view and found no strong evidence of any difference between countries' reserve use in the pre- and post-1973 periods. He argues that demand and supply curves for foreign exchange may be variant with respect to the exchange-rate system, and that more reserves may be required due to destabilizing capital flows after departing from a par-value system.

Frenkel (1978, 1980, 1983) explicitly uses the buffer-stock model to test the stability of the demand for international reserves between the pegged exchange-rate period (1963-1972) and the flexible exchange-rate period (1973-1979).[1] Based on estimated results from the cross-sectional and pooled regressions for both periods, he concludes that while there was some evidence of a leftward structural change in reserve demand by both developed and developing countries after moving to the latter period, greater flexibility of exchange rates had not fundamentally changed the general patterns of reserve holdings. The reasoning he suggested is that the exchange rate has been adjustable rather than fixed during the pegged-rate regime, while it has been managed rather than free during the floating-rate regime.

Heller and Khan (1978) further investigate the question raised by

[1] The flexible exchange rate period is 1973–1975 for Frenkel (1978, 1980).

Frenkel (1978), for which they estimate ARIMA models for reserves of six country groupings with quarterly data over the period 1964-1976. The results show that industrial countries reduced the demand for reserves as exchange rates became more flexible, but the reverse held true for non-oil developing countries. Their explanation for this is that non-oil developing countries were concerned more about the greater degree of uncertainty and the variability of their payment balances resulting from being pegged to a floating currency.

On the other hand, Grimes (1993) theoretically verifies that the same reserves might be held under a floating-rate regime as under a fixed-rate regime if the opportunity cost of holding reserves is negligible or that central banks are extremely risk-averse regarding reserve shortfalls.

Some other studies have noted that countries may not behave the same way with respect to their demand for reserves even under a pegged exchange-rate system. Edwards (1983) divides 41 developing countries into two groups: the first maintained a fixed exchange rate during 1964-1972 (that is, they adjusted their parities by less than 1% per year), and the second had devaluations of at least 10% during this period. The estimation results prove that devaluation countries held, on average, less reserves than fixed-rate countries, suggesting that countries with more flexible exchange-rate policies required smaller reserves.

More recent empirical results on this issue are mixed. Flood and Marion (2002) and Aizenman and Marion (2002, 2004) show, using panel data, that volatility of nominal effective exchange rates significantly reduces the level of reserves, suggesting that greater exchange-rate flexibility lowers reserve holdings. On the other hand, Lane and Burke (2001) use cross-sectional data for 102 countries over the period 1981–1995, and find no significant relationship between the exchange-rate regime and the level of reserves.

Overall, previous empirical results testing the standard view are inconclusive. The reason may be that all studies relied upon countries' officially declared classifications of exchange rates, which do not often describe actual country practice. Reinhart and Rogoff (2004) reclassified exchange-rate regimes based on historical chronology and data on market-determined rates going back to 1946 for 153 countries. Using their

new exchange-rate arrangements and pooled data for 127 countries over the period 1980-2000, we identify the determinants of the country's reserve holdings and re-estimate the effect of the exchange-rate system on the demand for reserves.

We find several new results. First, the exchange-rate regime has an inverted-U relationship with the country's reserve holdings. Intermediate regimes need more reserves than polar regimes (hard pegs and freely floating). Second, reserve holdings are smaller under hard pegs than under freely floating, implying that countries using a single regional currency can significantly reduce their optimal reserve holdings. The third, minor result is that per capita GDP and reserve holdings also have an inverted-U relationship.

In section 2, we describe the empirical specification and data, and analyze the regression results. Section 3 discusses reserve implications for a single currency from an East Asian perspective. The final section summarizes the paper's main findings.

II. EMPIRICAL EVIDENCE: EXCHANGE-RATE SYSTEM AND RESERVE HOLDINGS

2.1 The Empirical Specification

To analyze the effect of the exchange-rate system on international reserve holdings, we set up an estimating equation as follows:

$$\begin{aligned}\ln\left(RES_{it}\right) = {} & \beta_0 + \beta_1 \ln\left(PGDP_{it}\right) + \beta_2 \ln\left(GDP_{it}\right) + \beta_3 \ln\left(TOPEN_{it}\right) \\ & + \beta_4 \ln\left(FOPEN_{it}\right) + \beta_5 \ln(INTEREST_{it}) \\ & + \beta_6 \ln(VOLATILITY_{it}) + \beta_{7j} DUMMY_{j,it} + e_{it}\end{aligned} \tag{1}$$

where *RES* is actual holdings of reserves, *PGDP* is per capita GDP, and *GDP* is the Gross Domestic Product. *TOPEN* is trade openness, measured as the ratio of exports plus imports to GDP. *FOPEN* is financial openness, defined as the ratio of gross private capital flows to GDP. *INTEREST* means lending interest rates used as a proxy for the opportunity cost of holding reserves, and *VOLATILITY* is export volatility. $DUMMY_j$ is the

dummy for exchange-rate regime *j*. The subscripts, *i* and *t*, denote country *i* and year *t*, respectively.

The RHS variables are chosen as potential determinants of reserves on the basis of previous empirical studies.[2] Per capita GDP is included as a general control variable for the level of development. Regarding the standard of living, richer countries may accumulate larger reserves. However, richer countries are less subject to speculative attacks and financial crises so that they can survive with smaller reserves. Thus, the sign of β_1 is not unambiguous. Next, reserve holdings should increase with the size of international transactions, generally represented by GDP or population size. The regression results shown later are similar for either of the two variables, so we use GDP as the scaling factor. The sign of β_2 is expected to be positive.

Reserves should also be built up with vulnerability to both real and financial external shocks such as terms-of-trade shocks and currency and financial crises. To the extent that a country is more open on the real side as well as on the financial side, it is more vulnerable to such shocks. Thus real- and financial-side openness both should be positively correlated with reserve holdings, that is, $\beta_3 \rangle 0$ and $\beta_4 \rangle 0$.

The demand for reserves should decrease as the opportunity cost of holding them increases ($\beta_5 \langle 0$). The opportunity-cost variable is difficult to measure exactly. Recently, Flood and Marion (2002) defined it as the spread between the country's own bond yield (or lending, deposit, money market rates) and the return on U.S. Treasury Bills. Instead, we use the country's lending interest rate directly as a proxy for the opportunity cost. The reason is that the estimation results show little difference between the lending rate only and its spread over the return on Treasury Bills.

Reserve holdings should be positively correlated with reserve volatility, represented here by the volatility of export earnings, if they are intended to minimize adjustment costs caused by reserve shortfalls. So, we expect $\beta_6 \rangle 0$. Finally, we add the dummies for historical exchange-rate regimes

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[2] Determinants of reserves used here are based on the buffer-stock model. Another view is the monetary approach to balance of payments where the disequilibrium of the money market reflects changes in international reserves. See Frenkel (1983), Edwards (1983), 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.

classified by Reinhart and Rogoff (2004). The hypothesis to be tested in this section is that reserve holdings should decrease with exchange-rate flexibility.

2.2 Data

The data set consists of reserve information from the period 1980–2000 for the 127 countries listed in Table 1. The countries are chosen based on the availability of reserve data and other explanatory variables for estimation. The total reserves minus gold (.1L.DZF) series, in millions of US dollars, from the IFS CD-ROM from the International Monetary Fund (IMF) are used as a measure of international reserves. GDP, per capita GDP, lending interest rate, trade openness, and financial openness are taken from the World Development Indicators CD-ROM from the World Bank. GDP and per capita GDP are measured in current US dollars. Lending interest rate is the rate charged by banks on loans to prime customers. Trade openness is defined as the ratio of merchandise exports plus imports to GDP, measured in current US dollars. Financial openness is measured as the ratio of gross private capital flows to GDP in US dollars. Export volatility is calculated as the coefficient of variation calculated from the monthly export data for the corresponding year (.70..DZF..). Table 2 reports summary statistics for the data described above.

Reinhart and Rogoff (2004) used historical chronologies and data on market-determined parallel exchange rates to develop a new system of exchange-rate regimes. They call their classification scheme a “natural” system in contrast to the official IMF classification scheme that often fails to describe actual country practice. Table 3 presents two of Reinhart and Rogoff’s natural classification schemes. The first defines 14 types of exchange-rate arrangements, and the second covers Five broader categories. There are two critical differences between this scheme and the official classification scheme. First, the natural scheme captures regime changes by month, and groups historical exchange-rate arrangements in a much finer grid of regimes in contrast with just three or four buckets for the official scheme. Second, the former has a new category, called “freely

falling," for countries whose 12-month rate of inflation is greater than 40%.

[Table 1] Country List

1 Albania	36 Estonia	71 Lithuania	106 Spain
2 Algeria	37 Finland	72 Macedonia, FYR	107 Sri Lanka
3 Antigua and Barbuda	38 France	73 Madagascar	108 St. Kitts and Nevis
4 Argentina	39 Gabon	74 Malawi	109 St. Lucia
5 Armenia	40 Gambia, The	75 Malaysia	110 St. Vincent and Grens.
6 Australia	41 Georgia	76 Mali	111 Suriname
7 Austria	42 Germany	77 Malta	112 Swaziland
8 Azerbaijan	43 Ghana	78 Mauritania	113 Sweden
9 Belarus	44 Greece	79 Mauritius	114 Switzerland
10 Belgium	45 Grenada	80 Mexico	115 Tanzania
11 Benin	46 Guatemala	81 Moldova	116 Thailand
12 Bolivia	47 Guinea	82 Mongolia	117 Togo
13 Botswana	48 Guinea-Bissau	83 Morocco	118 Tunisia
14 Brazil	49 Guyana	84 Nepal	119 Turkey
15 Bulgaria	50 Haiti	85 Netherlands	120 Uganda
16 Burkina Faso	51 Honduras	86 New Zealand	121 United Kingdom
17 Burundi	52 China, P.R.: Hong Kong	87 Nicaragua	122 Ukraine
18 Cameroon	53 Hungary	88 Niger	123 Uruguay
19 Canada	54 Iceland	89 Nigeria	124 United States
20 Central African Rep.	55 India	90 Norway	125 Venezuela, Rep. Bol.
21 Chad	56 Indonesia	91 Pakistan	126 Zambia
22 Chile	57 Ireland	92 Panama	127 Zimbabwe
23 China, P.R.: Mainland	58 Israel	93 Paraguay	
24 Colombia	59 Italy	94 Peru	
25 Costa Rica	60 Jamaica	95 Philippines	
26 Côte d'Ivoire	61 Japan	96 Poland	
27 Croatia	62 Jordan	97 Portugal	
28 Cyprus	63 Kazakhstan	98 Romania	
29 Czech Republic	64 Kenya	99 Russia	
30 Denmark	65 Korea	100 Saudi Arabia	
31 Dominican Republic	66 Kuwait	101 Senegal	
32 Ecuador	67 Kyrgyz Republic	102 Singapore	
33 Egypt	68 Lao People's Dem. Rep	103 Slovak Republic	
34 El Salvador	69 Latvia	104 Slovenia	
35 Equatorial Guinea	70 Lesotho	105 South Africa	

Source: Selected from Reinhart and Rogoff (2004).

[Table 2] Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Reserves (*RES*)	2141	8141.177	19047.48	0.04	286916
GDP (GDP) (million US dollars)	2141	184,000	689,000	56.6	9,240,000
Per capita GDP (*PGDP*)	2141	6843.023	6723.3	344	32200
Lending interest rate (*INTEREST*)	1760	95.7093	2910.329	2.16	122000
Trade openness (*TOPEN*)	2141	75.45624	48.18624	6.32	439
Financial openness (*FOPEN*)	2141	14.30884	26.57248	0.062	649
Export volatility (*VOLATILITY*)	1654	0.176119	0.130706	0.021258	1.381729

Source: authors' calculation from IFS CD-ROM (IMF) and WDI CD-ROM (World Bank).

[Table 3] Exchange Rate System classified by Reinhart and Rogoff (2004)

Natural Classification Bucket	Fine Grid (mcode; FINE)	Coarse Grid (mgcode; SYSTEM)
No separate legal tender	1	1
Pre-announced peg or currency board arrangement	2	1
Pre-announced horizontal band that is narrower than or equal to ±2%	3	1
De facto peg	4	1
Pre-announced crawling peg	5	2
Pre-announced crawling band that is narrower than or equal to ±2%	6	2
De facto crawling peg	7	2
De facto crawling band that is narrower than or equal to ±2%	8	2
Pre-announced crawling band that is wider than or equal to ±2%	9	2
De facto crawling band that is narrower than or equal to ±5%	10	3
Moving band that is narrower than or equal to ±2% (i.e., allows for both appreciation and depreciation over time)	11	3
Managed floating	12	3
Freely floating	13	4
Freely falling	14	5

Source: Reinhart and Rogoff (2004) Table V.

Tables 4 and 5 show frequency and share of each category for the fine and coarse grid classifications, respectively, for the pooled data used in the regression. For the fine grid, which is coded from 1 to 14 (we call it 'mcode'), a dummy variable, FINEj is 1 if 'mcode' belongs to j and 0 otherwise (j = 1, 2, 3, …., 14). For the coarse grid, which is coded from 1

to 5 (we call it 'mgcode'), a dummy variable SYSTEMj is 1 if 'mgcode' belongs to *j* and 0 otherwise (*j* = 1, 2, …., 5). Here, the exchange-rate regime becomes more flexible as j increases. For example, mcode 1-4 in a fine grid are grouped into mgcode 1 in a coarse grid from Table 3.

[Table 4] Statistics for fine grid classification

mcode (FINE)	Frequency	Percent	Cumulative Percent
1	40	1.87	1.87
2	441	20.6	22.47
3	2	0.09	22.56
4	197	9.2	31.76
5	13	0.61	32.37
6	20	0.93	33.3
7	201	9.39	42.69
8	412	19.24	61.93
9	8	0.37	62.31
10	187	8.73	71.04
11	28	1.31	72.35
12	208	9.72	82.06
13	127	5.93	88
14	257	12	100
Total	2,141	100	

Source: authors' calculation from Reinhart and Rogoff (2004).

[Table 5] Statistics for coarse grid classification

mgcode (SYSTEM)	Frequency	Percent	Cumulative Percent
1	680	31.76	31.76
2	647	30.22	61.98
3	430	20.08	82.06
4	127	5.93	88
5	257	12	100
Total	2,141	100	

Source: authors' calculation from Reinhart and Rogoff (2004).

2.3 Regression Results

Using pooled data from 1980 to 2000 for 127 countries, we estimated equation. (1) by ordinary least squares, with Huber-White-sandwich

corrected standard errors. Table 6 shows the results with the five types of exchange-rate arrangements (SYSTEM1–SYSTEM5); [3] SYSTEM4 (freely floating) is used as a reference group.

All explanatory variables in equation. (1) are included in column (a).[4] Regarding traditional control variables, first, the estimated coefficient of per capita GDP is positive but insignificant. However, the coefficients of GDP, trade openness, and financial openness are positive and significant at 1%. Larger countries hold more reserves. Countries more open to external trade on the real and financial side have greater chances of facing external shocks and thus demand greater international reserves. Lane and Burke (2001) also confirm that real openness is the most important determinant of cross-country variation in reserve accumulation. Flood and Marion (2002) show that both real and financial openness are positively correlated with reserve holdings.

The estimated coefficients of the opportunity-cost variable and export volatility are not significant at all. Most empirical studies have been unable to find a significant opportunity-cost effect.[5] When we re-estimated equation. (1) with an opportunity cost measure from Flood and Marion (2002)—the spread between the country's lending interest rate and the return on U.S. Treasury Bills—the estimated opportunity-cost coefficient was still insignificant with little change in the estimated values of the other explanatory variables. In contrast to other studies, on the other hand, export volatility does not significantly affect reserve holdings. An exception was Lane and Burke (2001), where export volatility has the opposite sign and its coefficient is insignificant in the full-sample regression. Ben-Bassat and Gottlieb (1992) do not use volatility as an explanatory factor in their empirics. Their theoretical model indicates an ambiguous relationship between reserve (or export) volatility and reserve

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[3] Reinhart and Rogoff (2004) use this coarse grid classification to match with the official four-bucket classification: SYSTEM1 (peg), SYSTEM2 (limited flexibility), SYSTEM3 (managed floating), and SYSTEM4 (independent floating).

[4] We also used the ratio of reserves to GDP as a dependent variable after excluding GDP from the RHS, but the estimation results for the other control variables were left almost intact.

[5] 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.

holdings, but cannot explain why. The reason may be that monetary authorities have been more concerned about increased uncertainty on the financial side during the 1980s and 1990s as capital mobility across countries has become greater with capital account liberalization.

For exchange-rate regimes, SYSTEM2 and SYSTEM3 have positive estimated coefficients at the 1% significance level, but no significance is found in SYSTEM1 or SYSTEM5. This result implies that a country's reserve holdings are larger under limited flexibility and managed floating regimes than under a freely floating regime.

Turning back to the relationship between per capita GDP and reserve holdings, the regression results of previous studies are not conclusive. For example, Aizenman and Marion (2002, 2004) show that the coefficient of per capita GDP is positive and highly significant. For Lane and Burke (2001), however, it is negative and insignificant for industrial countries, while it is positive and significant for several cases within the sample to developing countries. Thus, we add the square of per capita GDP to equation. (1), assuming that per capita GDP may have an inverted-U relationship with reserve holdings. The results are presented in column (b). As expected, PGDP and the squared term are positive and negative, respectively, and at the 1% significance level. The estimated figures imply that reserve holdings should increase with the standard of living from low-income to mid-income level, but thereafter decrease as income moves up to a high level. Thus, the relationship between per capita GDP and reserve holdings would be negative for the industrial-country sample, but positive for the developing-country sample. The income level which reserve holdings are maximized is roughly US $ 4,832.[6] The estimates for the other control variables are almost the same as those presented in column (a). The exceptions are that the estimate of SYSTEM1 becomes negative, but remains insignificant, and SYSTEM5 becomes significant at the 15% level.

In regressions (a) and (b), the opportunity cost and export volatility are insignificant. We did an F-test to see whether the coefficients of both variables are zero. The *p*-value of the F-test is 0.4776, suggesting that the null hypothesis should not be rejected. Thus, these two variables are

[6] 1.527-2*0.09*ln(PGDP) = 0, ln(PGDP) = 8.483, PGDP = 4,832

[Table 6] Coarse Grid Exchange Rate Arrangements and Demand for International Reserves[1,2,3]

Dependent Variable	ln(*RES*)		
	(a)	(b)[4]	(c)[5]
Constant	-18.975***	-24.833***	-22.291***
	(0.506)	(1.295)	(1.231)
ln(*PGDP*)	0.040	1.527***	0.824***
	(0.029)	(0.315)	(0.278)
ln(*PGDP*) * ln(*PGDP*)		-0.090***	-0.043**
		(0.019)	(0.017)
ln(*GDP*)	0.940***	0.946***	0.947***
	(0.017)	(0.017)	(0.015)
ln(*TOPEN*)	0.760***	0.734***	0.664***
	(0.058)	(0.059)	(0.053)
ln(*FOPEN*)	0.148***	0.157***	0.144***
	(0.035)	(0.036)	(0.031)
ln(*Interest*)	0.039	-0.017	
	(0.034)	(0.036)	
ln(*Volatility*)	0.045	0.058	
	(0.051)	(0.051)	
SYSTEM1	0.038	-0.043	-0.202**
	(0.082)	(0.080)	(0.083)
SYSTEM2	0.218***	0.139**	0.204***
	(0.070)	(0.070)	(0.072)
SYSTEM3	0.297***	0.249***	0.287***
	(0.075)	(0.075)	(0.076)
SYSTEM5	-0.111	-0.148[#]	-0.079
	(0.098)	(0.096)	(0.084)
R^2	0.868	0.868	0.845
F-statistics	965.15	965.15	1495.89
Probability > F	0.0000	0.0000	0.0000
No of observations	1376	1376	2141

Source: authors' calculation

Notes:

1. *RES* stands for the international reserves, *PGDP* is per capita GDP, *GDP* is the Gross Domestic Product, *TOPEN* is trade openness, *FOPEN* is financial openness, *Interest* is lending interest rate, *Volatility* is the export volatility.
2. [#], *, **, and *** denote significance at the 15%, 10%, 5%, and 1% levels, respectively.
3. Huber-White-sandwich corrected standard errors in parentheses.
4. From column (b), F-test for ln(Interest) = ln(Volatility) = 0, F(2, 1364) = 0.74, Prob > F = 0.4776.
5. From column (d), F-test for SYSTEM2 = SYSTEM3, F(1, 2131) = 2.61, Prob > F = 0.1062.

dropped in regression (c). What differs from regression (b) is that the coefficient of SYSTEM1 is negative and highly significant, while SYSTEM5 loses its significance. The estimated figures imply that countries with SYSTEM1 (peg) hold 18% less reserves than those with SYSTEM4 (freely floating).[7] On the other hand, countries having SYSTEM2 and SYSTEM3 hold 23% and 33% more, respectively.[8] Furthermore, we did an F-test to see whether there is a difference between SYSTEM2 and SYSTEM3. The *p*-value for the F-statistics is 0.1062, indicating that the null hypothesis that both coefficients are the same cannot be rejected at the 10% significance level.

As a second attempt, we used the dummies for 14 types of arrangements, ranging from FINE1 to FINE14. The results are presented in Table 7 where FINE13 (freely floating) is used as a reference group. The regression results for the other control variables are very similar to those of Table 6. Regarding exchange-rate regimes, FINE12 (managed floating) is the only variable for which the coefficient is insignificant for all regressions. Focusing on regressions (b) and (c), all the coefficients of the other regimes are significant at least at the 10% level, except FINE5 in (c). The estimated coefficients are negative for FINE1–FINE3, FINE5, and FINE14, but positive for the other regimes.

Reserve implications for the estimation results can be summarized as follows; compared to a freely floating regime, first, countries hold fewer reserves under hard peg regimes such as currency union, dollarization, currency board, and pre-announced horizontal band. However, more reserves are held under de facto peg (FINE 4). A possible explanation for this result is that under hard pegs, monetary authorities should hold reserves more for the transactional motive, but less for the precautionary motive since they are less subject to speculative attacks. As capital account liberalization progresses with greater capital mobility, the latter motive, becomes the more important factor for the country's reserve accumulation. Among hard pegs, FINE1 has the least value; for regression (c), countries with FINE1 (a single currency) hold 53%[9] less reserves than those with FINE13 (freely floating).

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[7] $RES_{SYSTEM1}/RES_{SYSTEM4} = e^{-0.202} = 0.82$

[8] $RES_{SYSTEM2}/RES_{SYSTEM4} = e^{0.204} = 1.23$, $RES_{SYSTEM3}/RES_{SYSTEM4} = e^{0.287} = 1.33$

[9] $RES_{FINE1}/RES_{FINE13} = e^{-0..746} = 0.47$

[Table 7] Fine Grid Exchange Rate Arrangements and Demand for International Reserves[1,2,3]

Dependent Variable	ln(*RES*)		
	(a)	(b)[4]	(c)[5]
Constant	-18.258***	-23.483***	-20.180***
	(0.503)	(1.238)	(1.240)
ln(*PGDP*)	0.008	1.337***	0.615**
	(0.029)	(0.302)	(0.274)
ln(*PGDP*) * ln(*PGDP*)		-0.081***	-0.032*
		(0.018)	(0.017)
ln(*GDP*)	0.931***	0.936***	0.910***
	(0.018)	(0.018)	(0.017)
ln(*TOPEN*)	0.672***	0.648***	0.573***
	(0.058)	(0.058)	(0.056)
ln(*FOPEN*)	0.206***	0.215***	0.176***
	(0.032)	(0.032)	(0.032)
ln(*Interest*)	0.034	-0.013	
	(0.034)	(0.035)	
ln(*Volatility*)	0.037	0.049	
	(0.049)	(0.049)	
FINE1	-0.675**	-0.748***	-0.746***
	(0.131)	(0.129)	(0.143)
FINE2	-0.175[#]	-0.252***	-0.496***
	(0.115)	(0.117)	(0.106)
FINE3	-0.299***	-0.329***	-0.316***
	(0.096)	(0.096)	(0.098)
FINE4	0.376***	0.306***	0.298***
	(0.088)	(0.085)	(0.080)
FINE5	-0.548*	-0.654**	-0.047
	(0.293)	(0.297)	(0.169)
FINE6	0.531***	0.418***	0.583***
	(0.112)	(0.114)	(0.118)
FINE7	0.301***	0.203**	0.232***
	(0.087)	(0.087)	(0.083)
FINE8	0.195**	0.136*	0.151**
	(0.076)	(0.076)	(0.074)
FINE9	0.631***	0.543**	0.626***
	(0.229)	(0.231)	(0.232)
FINE10	0.369***	0.319***	0.295***
	(0.089)	(0.091)	(0.085)
FINE11	1.117***	1.054***	1.111***
	(0.140)	(0.131)	(0.135)
FINE12	0.082	0.047	0.063
	(0.087)	(0.087)	(0.082)
FINE14	-0.124	-0.162*	-0.146*
	(0.098)	(0.097)	(0.081)
R^2	0.745	0.741	0.854
F-statistics	658.37	649.66	918.00
Probability > F	0.0000	0.0000	0.0000
No of observations	1376	1376	2141

Source: authors' calculation.

Notes:

1. *RES* stands for the international reserves, *PGDP* is per capita GDP, *GDP* is the Gross

Domestic Product, *TOPEN* is trade openness, *FOPEN* is financial openness, *Interest* is lending interest rate, *Volatility* is the export volatility.

2. #, *, **, and *** denote significance at the 15%, 10%, 5%, and 1% levels, respectively.
3. Huber-White-sandwich corrected standard errors in parentheses.
4. From column (b), F-test for ln(Interest) = ln(Volatility) = 0, F(2, 1355) = 0.55, Prob > F = 0.5743.
5. From column (c),
   F-test for FINE1 = FINE2, F(1, 2122) = 2.67, Prob > F = 0.1026,
   F-test for FINE2 = FINE3, F(1, 2122) = 1.97, Prob > F = 0.1605
   F-test for FINE1 = FINE3, F(1, 2122) = 9.62, Prob > F = 0.0020.

Second, as expected, countries with intermediate regimes such as crawling pegs or bands demand larger reserves. FINE11—moving band ($\leq \pm 2\%$)—has the highest value; FINE11 needs 203%[10] more reserves compared to FINE13. A surprising result is, however, that a managed floating regime (FINE 12) does not differ from a freely floating regime (FINE 13) in reserve holdings. As Calvo and Reinhart (2002) assert, the reason may be that, in many cases, the authorities subject to freely floating regimes have been attempting to stabilize the exchange rate through direct intervention in the foreign exchange market.

Finally, the level of reserves is lower under freely falling regimes relative to freely floating regimes. Most countries that experienced a freely falling regime have transition economies[11] and developing countries that have been exposed to large fiscal deficits, high foreign debt, political corruption, or political instability. The reason that countries with a freely falling regime hold smaller reserves may be that foreign debt substitutes for reserves as a means of financing external transactions (Lane and Burke, 2001). As Aizenman and Marion (2002, 2004) argue, furthermore, countries with high discount rates, political instability, or political corruption may hold smaller precautionary reserve balances.

In Table 8, we used only the dummies of FINE1–FINE3 to focus on a currency union. FINE1 indicates "No separate legal tender," a currency union such as the euro, dollarization, etc.; FINE2, "Pre announced peg or currency board arrangement"; and FINE3, "Pre announced horizontal

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[10] $RES_{FINE11}/RES_{FINE13} = e^{1.111} = 3.03$

[11] In the 1990s, freely falling accounts for 41 percent of the observations for the transition economies (Reinhart and Rogoff, 2004).

[Table 8] Exchange Rate System (FINE1–FINE3) and Demand for International Reserves[1,2,3]

Dependent Variable	ln(RES)		
	(a)	(b)[4]	(c)[5]
Constant	-17.793***	-24.332***	-21.123***
	(0.505)	(1.249)	(1.304)
ln(PGDP)	0.030	1.681***	1.087***
	(0.029)	(0.308)	(0.305)
ln(PGDP) * ln(PGDP)		-0.100***	-0.059***
		(0.018)	(0.018)
ln(GDP)	0.912***	0.919***	0.881***
	(0.018)	(0.017)	(0.018)
ln(TOPEN)	0.725***	0.684***	0.639***
	(0.055)	(0.056)	(0.063)
ln(FOPEN)	0.202***	0.213***	0.140***
	(0.033)	(0.033)	(0.038)
ln(Interest)	-0.044	-0.102***	
	(0.031)	(0.034)	
ln(Volatility)	0.026	0.041	
	(0.050)	(0.050)	
FINE1	-0.948***	-0.967***	-0.794***
	(0.119)	(0.118)	(0.129)
FINE2	-0.423***	-0.447***	-0.883***
	(0.092)	(0.093)	(0.096)
FINE3	-0.488***	-0.463***	-0.382***
	(0.087)	(0.086)	(0.089)
R2	0.871	0.873	0.860
F-statistics	1218.9	1156.0	1636.3
Probability > F	0.0000	0.0000	0.0000
No of observations	1376	1376	1760

Source: authors' calculation.

Notes:

1. *RES* stands for the international reserves, *PGDP* is per capita GDP, *GDP* is the Gross Domestic Product, *TOPEN* is trade openness, *FOPEN* is financial openness, *Interest* is lending interest rate, *Volatility* is the export volatility.
2. #, *, **, and *** denote significance at the 15%, 10%, 5%, and 1% levels, respectively.
3. Huber-White-sandwich corrected standard errors in the parentheses.
4. From column (c),
   F-test for FINE1 = FINE2, F(1, 1750) = 0.31, Prob > F = 0.5779,
   F-test for FINE2 = FINE3, F(1, 1750) = 12.0, Prob > F = 0.0005,
   F-test for FINE1 = FINE3, F(1, 1750) = 8.34, Prob > F = 0.0039.

band that is narrower than or equal to ±2%". The results confirm that all three dummies are negative and significant at the 1% level with little change in the estimates for the other control variables. In the case of regression (c), FINE1 and FINE2 need fewer reserves than the benchmark (FINE4-FINE14) by 55% and 59% respectively.[12] We also performed F-tests to see the equality of FINE1 and FINE2, FINE2 and FINE3, and FINE1 and FINE3. The *p*-values are 0.5779, 0.0005, and 0.0039, respectively. This means that the null hypothesis for the equality of FINE1 (or FINE2) and FINE3 could be rejected, while the equality of FINE1 and FINE2 holds. The figures indicate that the demand for reserves decreases by 34%[13] when the regime changes from FINE3 to FINE1.

The regression results obtained up to this point suggest that the exchange-rate regime is nonlinearly correlated with a country's reserve holdings. Based on the estimated values for the dummies, we assume an inverted-U relationship between reserves and the exchange-rate regime. In columns (a)–(c) of Table 9, we replaced the regime dummies with mcode and its squared term, where mcode represents the numbers ranging from 1 to 14 in the fine grid. The results show that mcode and the squared term are positive and negative, respectively, at the 1% significance level, thus verifying the inverted-U relationship.

We also tried to draw a graph for this inverted-U relationship and identify a regime that holds the largest reserves. To do this, we first extracted the residuals obtained from regressing reserves on the other control variables in column (d). Next, we regressed the estimated residuals on mcode and the squared term. The results are shown in column (e) and drawn in Figure 1, where the residuals and mcode are juxtaposed at the vertical and horizontal axes, respectively. The figure clarifies, first, that reserve holdings are smaller under extreme exchange-rate regimes (hard pegs and freely floating) than under intermediate regimes. Second, hard pegs demand fewer reserves than freely floating. Third, we can roughly derive an mcode number of holding maximum reserves, approximately 8.9.

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[12] $RES_{FINE1}/RES_{other} = e^{-0.794} = 0.45$, $RES_{FINE2}/RES_{other} = e^{-0.883} = 0.41$

[13] $RES_{FINE1}/RES_{FINE3} = e^{-0.794-(-0.382)} = e^{-0.412} = 0.66$

[Table 9] Exchange Rate System (MCODE) and Demand for International Reserves[1,2,3]

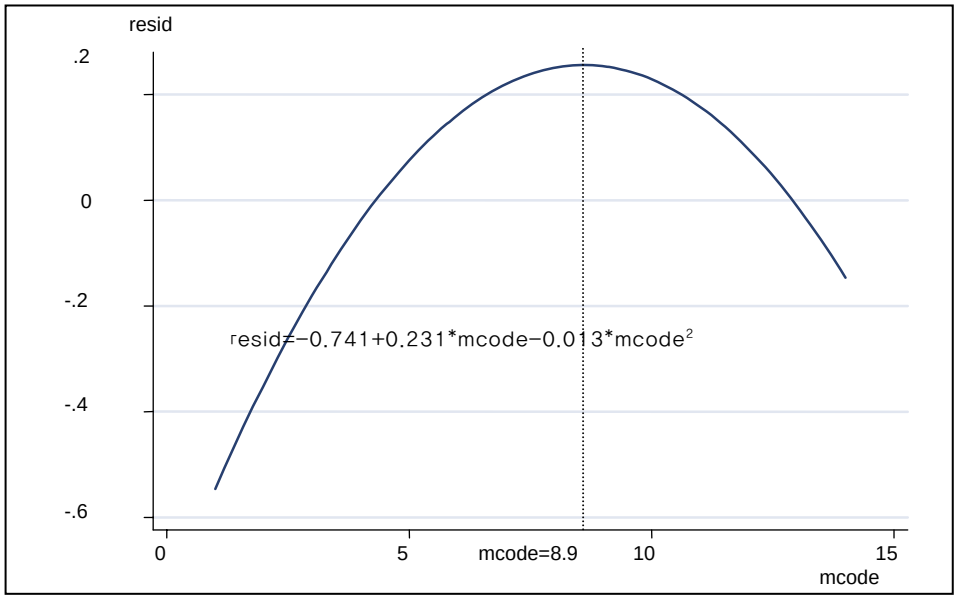
Dependent Variable	ln(RES)				Residual from (d)[4]
	(a)	(b)	(c)	(d)	(e)
Constant	-18.938***	-24.465***	-21.758***	-23.705***	-0.741***
	(0.485)	(1.272)	(1.167)	(1.185)	(0.092)
ln(PGDP)	0.018	1.408***	0.670**	1.042***	
	(0.029)	(0.308)	(0.259)	(0.267)	
ln(PGDP) * ln(PGDP)		-0.084***	-0.034**	-0.056***	
		(0.018)	(0.016)	(0.016)	
ln(GDP)	0.928***	0.935***	0.924***	0.969***	
	(0.017)	(0.017)	(0.015)	(0.014)	
ln(TOPEN)	0.713***	0.687***	0.613***	0.688***	
	(0.057)	(0.057)	(0.053)	(0.053)	
ln(FOPEN)	0.192***	0.199***	0.177***	0.113***	
	(0.032)	(0.033)	(0.030)	(0.032)	
ln(Interest)	0.023	-0.034			
	(0.031)	(0.034)			
ln(Volatility)	0.037	0.048			
	(0.050)	(0.049)			
MCODE	0.209***	0.204***	0.270***		0.231***
	(0.024)	(0.024)	(0.024)		(0.023)
MCODE*MCODE	-0.013***	-0.012***	-0.016***		-0.013***
	(0.001)	(0.001)	(0.001)		(0.001)
R^2	0.871	0.873	0.849	0.839	0.054
F-statistics	1264.67	1181.53	1978.43	2584.49	50.79
Probability > F	0.0000	0.0000	0.0000	0.0000	0.0000
No of observations	1376	1376	2141	2141	2141

Source: authors' calculation

Notes:

1. *RES* stands for the international reserves, *PGDP* is per capita GDP, *GDP* is the Gross Domestic Product, *TOPEN* is trade openness, *FOPEN* is financial openness, *Interest* is lending interest rate, *Volatility* is the export volatility.
2. #, *, **, and *** denote significance at the 15%, 10%, 5%, and 1% levels, respectively.
3. Huber-White-sandwich corrected standard errors in the parentheses.
4. The dependent variable is the residual calculated from column (d).

[Figure 1] Exchange Rate Regimes (mcode) and Reserve Holdings



III. RESERVE IMPLICATIONS FOR AN EAST ASIAN CURRENCY UNION

The empirical results in section 2 verify that FINE1 needs the smallest reserve holdings among exchange-rate regimes. This implies that the member countries of a currency union hold fewer reserves than countries working independently. As discussed above, they may have smaller precautionary balances since they are less affected by currency crises and speculative pressures. For instance, Spain put a lot of money in Argentina and was heavily hit by the 2001 Argentine crisis. However, the Spanish peseta was safe from speculative attacks. The main reason is that Spain was a member of the European Economic and Monetary Union (EMU).

Since the 1997 Asian Financial Crisis, East Asian countries have accumulated large stocks of reserves. The world's top five holders of reserves are all in the Far East. Aizenman and Marion (2004) interpreted the build-up of large reserves in East Asian countries as representing precautionary holdings, particularly due to loss aversion against a future crisis. However, some argue that such large stockpiles are excessive, suggesting that the reserves would be more profitably invested in assets

overseas; others criticize these East Asian countries of mercantilism. On the other hand, the successful launch of the euro in 1999 initiated academic and political interest in the possibility of monetary integration in the East Asian region. Based on our empirical analysis, we will discuss reserve implications for an East Asian currency union in this section.

[Table 10] Current and Hypothetical Reserve Holdings in East Asian Countries: The Coarse Grid

Country	SYSTEM (mgcode) (a)	$RES_{SYSTEM1}/RES_{SYSTEM*}$ (b)	Current Reserves[3] (c)	Hypothetical Reserves (d) = (b) * (c)
China	1	1	215,605	215,605
Korea	4	0.82[1]	102,753	84,257.5
Japan	4	0.82[1]	395,155	324,027.1
Indonesia	4	0.82[1]	27,246.2	22,341.9
Malaysia	1	1	30,474.4	30,474.4
Philippine	3	0.61[2]	13,442.4	8,199.9
Singapore	3	0.61[2]	75,374.8	45,978.6
Thailand	3	0.61[2]	32,354.8	19,736.4
Total		0.84	892,405.6	750,620.8

Source: authors' calculation from Reinhart and Rogoff (2004), IFS CD-Rom (IMF) and column (c) in Table 6.

Notes: Hypothetical reserves are defined as reserve balances required if a country adopts SYSTEM1.

1. $RES_{SYSTEM1}/RES_{SYSTEM4} = e^{-0.202} = 0.82$.

2. $RES_{SYSTEM1}/RES_{SYSTEM3} = e^{-0.202-(0.287)} = e^{-0.489} = 0.61$.

3. Millions of US dollars (2001).

We first consider the coarse grid of exchange-rate regimes for eight East Asian countries (China, Korea, Japan, Indonesia, Malaysia, the Philippines, Singapore, and Thailand), shown in Table 10. Columns (a) and (c) represent each country's current exchange-rate system (mgcode) and actual reserve balances in 2001, respectively. Column (b) shows the ratio of hypothetical reserves—shown in column (d)—to current reserve balances, where the former is defined as reserve balances required if a country adopts SYSTEM1, and calculated from column (c) in Table 6.

The figures in the table indicate that if all countries choose SYSTEM1, reserve balances can decrease by 39% for SYSTEM3 (Philippines, Singapore, and Thailand) and 18% for SYSTEM4 (Korea, Japan, and Indonesia). The total reserves of eight East Asian countries would fall from US $ 892,405.6 to 750,620.8 million, thus decreasing by 16%.

[Table 11] Current and Hypothetical Reserve Holdings in East Asian Countries: The Fine Grid

Country	FINE(mcode) (a)	RES_{FINE1}/RES_{FINE*} (b)	Current Reserves[5] (c)	Hypothetical Reserves (d) = (b) * (c)
China	4	0.35[1]	215,605	75,461.8
Korea	13	0.51[2]	102,753	50,404.0
Japan	13	0.51[2]	395,155	201,529.1
Indonesia	13	0.51[2]	27,246.2	13,895.6
Malaysia	2	0.78[3]	30,474.4	23,770.0
Philippine	12	0.51[4]	13,442.4	6,855.6
Singapore	12	0.51[4]	75,374.8	38,441.1
Thailand	12	0.51[4]	32,354.8	16,500.9
Total		0.48	892,405.6	426,858.1

Source: Authors' calculation from Reinhart and Rogoff (2004), IFS CD-Rom (IMF), and column (c) in Table 7.

Notes: Hypothetical reserves are defined as reserve balances required if a country adopts FINE1.

1. $RES_{FINE1}/RES_{FINE4} = e^{-0.746-0.298} = e^{-1.044} = 0.35$.
2. $RES_{FINE1}/RES_{FINE13} = e^{-0.675} = 0.51$.
3. $RES_{FINE1}/RES_{FINE2} = e^{-0.746-(-0.496)} = e^{-0.250} = 0.78$.
4. $RES_{FINE1}/RES_{FINE12} = e^{-0.746-(0.063)} = e^{-0.683} = 0.51$.
5. Millions of US dollars (2001).

Table 11 shows the case of the fine grid of exchange-rate regimes for the same East Asian countries. The estimates derived from column (c) in Table 7 imply that if all East Asian countries adopt a single currency, China (FINE4) would save international reserves by 65%. Likewise, reserve holdings would be reduced by 49% for Korea, Japan, and Indonesia (FINE13), and for Philippines, Singapore, and Thailand

(FINE12), and by 22% for Malaysia (FINE2). Total reserves in this region can decrease by 52%, more than US $ 426 billion. These figures suggest that an East Asian currency union can contribute to significantly reducing currently excessive holdings of reserves in this region and allow them to be invested more profitably.

IV. CONCLUDING REMARKS

Using Reinhart and Rogoff's new exchange-rate arrangements, we find in this study that reserve holdings are significantly and nonlinearly correlated with the exchange-rate system. In contrast to the previous empirical results, which depended mostly upon the official IMF classification, our model of exchange-rate regime has an inverted-U relationship with reserves. First, reserve holdings are smaller under polar regimes (hard pegs and freely floating) than under intermediate regimes. Second, hard pegs demand less reserves than freely floating.

Regarding the other determinants of the demand for reserves, country size, real openness, and financial openness all raise reserve holdings while the opportunity cost and export volatility are not significant variables. Unlike previous studies, however, in our model per capita GDP and reserve holdings have an inverted-U relationship, reflecting that their correlation would be negative for industrial countries, but positive for developing countries.

The first implication of our empirical results is that the exchange-rate system matters for the country's reserve holdings. In the official classification, freely floating accounts for more than 30% of observations in the past decade. In the new classification, however, the share of freely floating is only 5.9% of the total observations as shown in Tables 4 and 5. Limited flexibility—dominated by *de facto* crawling peg and crawling narrow-band in the new scheme—has been the second most important grouping over the past decade, just behind pegs. On the other hand, its share is very small under the official scheme. That is, *de facto* intermediate regimes still dominate world currency arrangements even though more countries have shifted to *de jure* floating exchange rates in the 1990s. This fact is one of the main reasons that world reserve holdings continued to rise through the period.

The second implication is related to the choice of a monetary regime. A currency union enhances trade among members and growth via trade (Frankel and Rose 2002). Our study shows that one more benefit can be added to those of a currency union. That is, demand for reserves can be reduced if a currency union is adopted in East Asian countries. Therefore, a central bank can save the cost of holding reserves by reducing excessive reserves. Some research[14] found that East Asian countries almost meet the economic preconditions of EMU countries before the Maastricht Treaty was signed in 1991. In contrast with the EMU, however, significant gaps remain between East Asian countries in noneconomic factors. In East Asia, political cooperation and institutionalization may be the prerequisites for discussions on the plausibility of a single currency based on economic conditions.

[14] Among them are Bayoumi and Mauro (1999), Eichengreen and Bayoumi (1999), and Baek and Song (2002).

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