What Is Learned from a Currency Crisis, Fear of Floating, or Hollow Middle? Identifying Exchange Rate Policy in Crisis Countries*

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This paper develops a new methodology to infer the de facto exchange rate regime, based on a structural VAR model with sign restrictions. The methodology is applied to data from eleven emerging markets that experienced a currency crisis. The main findings are as follows: (i) to be consistent with the "hollow middle" hypothesis, many countries moved toward hard pegs, such as dollarization and a currency board, or more flexible exchange rate arrangements that are close to the free float in the post-crisis period; and (ii) the cases where a country overstates its exchange rate flexibility (including the case of "fear of floating") are found in all samples, but such cases tend to be less frequently found in the post-crisis period than in the pre-crisis period.

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1. Introduction

Many countries have experienced a currency crisis and economic turbulence, including Europe (1992), Mexico (1994–95), East Asia

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(1997), Russia (1998), and Argentina (2002). With the onset of a currency crisis, most of these countries adopted highly managed exchange rate arrangements. As a result, there is the notion that the tight exchange rate arrangements adopted in each country are at least partly responsible for the currency crisis. Consequently, lively discussions on the choice of the exchange rate regime have followed.

Eichengreen (1994) suggests that highly managed exchange rate arrangements are vulnerable to international capital flows. Thus, intermediate regimes, including a soft peg, would disappear in a world with integrated capital markets. The only viable choices would be two extreme exchange rate arrangements: free float and "hard peg." These choices would include currency boards, dollarization, and a currency union. This view is known as the "hollow middle" hypothesis (Eichengreen 1994) or the "bipolar view" (Fischer 2001).[1]

European monetary unification confirms the bipolar view since a currency union can be regarded as a polar regime. However, experience of emerging markets is more diversified, and it does not uniformly support this bipolar view. Although changes toward polar regimes are seemingly observed based on what each country officially states or the country's de jure classification of the exchange rate regime (for example, see Fischer 2001), each country's official statement may be different than what the country actually does. Calvo and Reinhart (2002) find that by inferring the exchange rate policies in each country from the actual data on the exchange rate and policy instruments (that is, de facto arrangements), most countries that say they allow their exchange rate to float do not. Calvo and Reinhart (2002) conclude that there seems to be an epidemic case of "fear of floating."[2] This possible discrepancy between de jure and de facto exchange rate arrangements has been well represented in previous debates. For example, McKinnon (2000) and Mussa et al. (2000) argue that a few years after a crisis, Asian countries that had the crisis reverted back to highly managed exchange rate arrangements (although they claimed free float) and these countries raised concerns of possible repetition of the crisis.

[1]See also Obstfeld and Rogoff (1995) and Krueger (2000) for this view.

[2]Levy-Yeyati and Sturzenegger (2005) also confirm "fear of floating" by classifying the de facto exchange rate regime of each country based on the data.

This paper contributes to the literature on the transition of exchange rate arrangements and de facto exchange rate arrangements in two aspects. First, this paper develops a de facto measure of exchange rate arrangements by using a structural VAR (vector autoregression) model, which resolves a few problems with previous methods. Second, this method is applied to countries that experienced a crisis during the 1990s and the 2000s in order to investigate how these countries change the exchange rate arrangement after the crisis and to shed some light on various issues concerning de facto exchange rate arrangements and the transition of exchange rate arrangements.

While past studies often investigated not only crisis countries but also non-crisis countries, this study has focused on countries that have experienced a severe crisis. These countries are the main victims of the crisis. They are the ones who have been deliberating on the exchange rate regime choice. These countries have made choices regarding the exchange rate regimes after realistically considering the possibility of a future crisis. On the other hand, the choices of other countries are likely to be more superficial. Other countries may simply keep their current exchange rate arrangements, or their choice may involve consideration of some aspects other than the crisis. In other words, it would be interesting to see what these countries learned about exchange rate arrangements after their experience of a severe crisis. As examples, did these crisis countries move to polar regimes that were less vulnerable in integrated capital markets? Were these countries reluctant to publicly announce their highly managed exchange rate arrangements? This study also has focused on relatively recent crisis episodes, since various views on exchange rate regimes (such as the vulnerability of the soft peg) have become widely known in relatively recent years. Eleven cases are considered. These cases include five Asian crisis countries.

Following Calvo and Reinhart (2002), a number of previous studies construct de facto regime classifications (e.g., Baig 2001; Bubula and Ötker-Robe 2002; Ghosh, Gulde, and Wolf 2003; Hernandez and Montiel 2003; Levy-Yeyati and Sturzenegger 2005; and Reinhart and Rogoff 2002). Many previous studies, including Calvo and Reinhart (2002), rely on information on the volatility of the exchange rate (changes) and the policy instruments (changes) such as foreign exchange reserves (changes) and the interest rate (changes).

If the policy authority actively stabilizes exchange rate movements by adjusting the policy instruments, the exchange rate changes would be small while the policy instrument changes would be large. Based on this idea, past studies often classified regimes with less volatile exchange rates (changes) and more volatile policy instruments (changes) as having less flexible exchange rate arrangements.[3]

However, such classification methods have a drawback. The policy instruments may change in the absence of the policy authority's intention to stabilize the exchange rate. For example, the interest rate may be changed in support of other policy objectives rather than for just the purpose of stabilizing the exchange rate (i.e., stimulating output). Foreign exchange reserves, for instance, may change due to fluctuations in valuation, interests accrual, and passive interventions in order to fulfill government transactions or orders. Such changes in policy instruments (and the resulting changes in the exchange rate) are not relevant to exchange rate stabilization. Although past studies have included such changes, these changes should be excluded when inferring de facto exchange rate arrangements. In a sense, the problem arises from using *unconditional* data that comprises both the movements originating from shocks to the exchange rate that policy instruments react to and the movements originating from shocks to the instruments that affect the exchange rate, although only the former contains the relevant information. From another perspective, past studies have used information from both the policy reaction function (the policy authority's reaction of policy instruments to the exchange rate, in order to stabilize the exchange rate) and the foreign exchange market equation (that shows how the policy instruments affect the exchange rate). However, only the former is relevant. In other words, although there is a simultaneity problem between the policy instrument and the exchange rate (or between the reaction of

[3]Calvo and Reinhart (2002) characterized various countries based on three variables (the exchange rate, reserves, and the interest rate) without providing an exact classification of countries. On the other hand, Ghosh, Gulde, and Wolf (2003) and Reinhart and Rogoff (2002) provide an exact classification, but the inference is based on the exchange rate only. Levy-Yeyati and Sturzenegger (2005) provide an exact classification based on two variables (the exchange rate and reserves). The current paper provides the estimated reaction function and some test statistics to infer the exchange rate policy based on three variables (the exchange rate, reserves, and the interest rate) and provide a classification.

policy and the effects of policy), it is not properly accounted for in past studies.

Structural VAR models are a natural fit in addressing this problem since structural VAR models can be used to identify different types of structural shocks (and structural equations) and also to construct the *conditional* data in the presence of only one type of structural shock. To separate the two types of shocks, this study imposes sign restrictions on impulse responses by modifying Uhlig's (2005) methodology. The two shocks imply different sign restrictions on the responses of the exchange rate and policy instruments. An (exogenous) increase in the foreign exchange reserves (or a decrease in the interest rate) would lead to an exchange rate depreciation. On the other hand, an (exogenous) exchange rate depreciation would lead to a decrease in the foreign exchange reserves (or an increase in the interest rate) when the policy authority stabilizes the exchange rate. Based on the estimated impulse responses to the latter shocks, dynamic policy reaction functions are formally derived—instead of simple descriptive statistics, as used in some past studies—in order to infer de facto exchange rate arrangements in each country.

The main findings are as follows. The cases where a country overstates its exchange rate flexibility (including the case of "fear of floating") are often found, but such cases tend to be less frequently found in the post-crisis period than in the pre-crisis period. Based on de facto classification after correcting for such cases, most countries adopted intermediate regimes in the pre-crisis period, but a majority of countries adopted a hard peg or the exchange rate regime that is close to a free float such as Australia's. It is especially interesting that four Asian crisis countries achieved an exchange rate flexibility that is close to that of Australia's in its post-crisis period, although some past studies argued that these four countries reverted back to a highly managed exchange rate policy. Overall, the tendency of a country's overstating its exchange rate flexibility does not overturn the general conclusion on exchange rate regime transitions based on de jure classification; countries move to bipolar regimes.

The rest of the paper is organized as follows. Section 2 explains the methodology developed in this paper. Section 3 analyzes exchange rate arrangements and discusses various issues on exchange rate arrangements. Section 4 discusses some extended experiments and compares the methodology in this study with that of Calvo and Reinhart's (2002). Section 5 concludes with a summary of findings.

2. The Methodology

The methodology starts from the most parsimonious model, since the model is applied to short time-span data. Since the number of parameters to be estimated in VAR models increases geometrically as the number of variables increases, a large VAR model often suffers from a low degree of freedom. The most parsimonious model includes only two variables—the exchange rate changes and changes in one policy instrument. The number of parameters to be estimated in the two-variable model is relatively small, which helps ensure that the model can be successfully applied to a short time span.

As emphasized by Levy-Yeyati and Sturzenegger (2005), the textbook definition of the fixed exchange rate regime is the regime in which changes in foreign exchange reserves are aimed at reducing the volatility of the exchange rate while the flexible exchange rate regimes are characterized by substantial volatility in the exchange rate with relatively stable reserves. Therefore, the exchange rate and foreign exchange reserves are included in the model in order to infer the exchange rate arrangements.

In addition to the foreign exchange reserve, another important policy instrument, the interest rate, is also often used to control the exchange rate. Consequently, past studies, such as that of Calvo and Reinhart (2002), have also examined interest rate changes. Therefore, a two-variable model with the exchange rate and the interest rate is also constructed in order to complement the first model.

As is usual in structural VAR analysis, the structural representation is identified by imposing some restrictions on the estimated reduced form. The reduced-form VAR equations for the first model are

$$\begin{bmatrix} \Delta E_t \\ \Delta FR_t \end{bmatrix} = \begin{bmatrix} A_{11}(L) & A_{12}(L) \\ A_{21}(L) & A_{22}(L) \end{bmatrix} \begin{bmatrix} \Delta E_{t-1} \\ \Delta FR_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{E,t} \\ \varepsilon_{FR,t} \end{bmatrix}, \quad (1)$$

where E is the log of the exchange rate; ΔFR is the ratio of the changes in foreign exchange reserves to monetary base of the previous period; $A(L)$s are polynomials in the lag operator $L; \varepsilon_E$ and

ε_{FR} are the residuals in each equation, which are assumed to be Gaussian random variables; ε is a two-by-one vector of residuals, $\varepsilon = (\varepsilon_E\ \varepsilon_{FR})'$; and $\text{var}(\varepsilon) = \Sigma$. For simplicity of exposition, the constant term is dropped in equation (1). This study uses the log-difference or the difference of each variable (instead of log-level or level) for the following reasons. First, most past studies, such as the studies of Baig (2001), Calvo and Reinhart (2002), Hernandez and Montiel (2003), Levy-Yeyati and Sturzenegger (2005), and Reinhart and Rogoff (2003), have used the percentage changes (or difference) instead of log-level, or level. This helps make the results of this study comparable to past studies. Second, in most countries, the hypothesis of a unit root in log of the exchange rate and the hypothesis of a unit root in the ratio of foreign exchange reserve to monetary base are not rejected at the conventional significance level based on conventional unit-root tests like the augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Third, there are some cases of continuously falling or rising exchange rates such as a crawling peg regime. In such cases, the log-difference of the exchange rate may be more appropriate than log-level.

On the other hand, although some studies, such as Calvo and Reinhart's (2002), used percentage changes in foreign exchange reserves, this study uses the changes in foreign exchange reserves as a percentage of the monetary base in the previous period, as the study of Levy-Yeyati and Sturzenegger (2005) did, for the following reason. The level of foreign exchange reserves may change over time and with countries. For example, Asian countries that had a crisis accumulated a substantial amount of foreign exchange reserves after the crisis. The accumulation of foreign exchange reserves was far faster than development in the countries' general economic activities or monetary environment. In that case, a 1 percent change in foreign exchange reserves may have smaller effects on the exchange rate in the pre-crisis period than in the post-crisis period. To correct this problem, the responses of reserve changes are calculated as a percent of the monetary base of the previous period, since the size of a monetary base may be a reasonable proxy for development in a monetary environment.

As discussed in the Introduction, some policy instrument changes (and the resulting exchange rate changes) are not related to exchange rate stabilizing policy actions. We are interested in only the policy instrument changes that are the results of (exchange rate stabilizing) policy reactions to exchange rate changes. This objective can be achieved in the two-variable model by separately identifying two orthogonal structural shocks: the (structural) shocks to the exchange rate (that foreign exchange reserves react to stabilize the exchange rate), and the (structural) shocks to foreign exchange reserves (that affect the exchange rate). However, popular identification methods that impose zero restrictions on the contemporaneous structural parameters, (developed by Bernanke 1986; Blanchard and Watson 1986; and Sims 1980, 1986;) and that impose zero restrictions on the long-run effects (developed by Blanchard and Quah 1989) are difficult to apply in this case. Both structural shocks are likely to affect both variables contemporaneously, so that imposing zero restrictions on contemporaneous parameters is not feasible.[4] In addition, an imposition of any long-run zero restrictions in the current model does not seem to be firmly supported by theories.

To separately identify the two types of structural shocks, sign restrictions are imposed on impulse responses. First, a positive shock to foreign exchange reserves would lead to exchange rate depreciation (or an increase in the exchange rate); buying foreign currency, selling domestic currency, and building up foreign exchange reserves would lead to a weaker currency value, i.e., exchange rate depreciation. Second, a positive shock to the exchange rate (or exchange rate depreciation) would lead to a decrease in the foreign exchange reserves when the policy authority stabilizes the exchange rate. This is because a decrease in the foreign exchange reserves would appreciate the exchange rate to offset the initial depreciation. That is, shocks to foreign exchange reserves move the exchange rate and the foreign exchange reserves in the same direction, while shocks to the exchange rate move two variables in opposite directions. This study imposes such restrictions only on the impact responses, as it is more difficult to justify the signs of the lagged responses.[5] To implement

[4]In the large-scale model that is estimated over a long sample period, the two types of shocks can be separated with short-run zero restrictions by using other variables as instruments. For example, see Kim (2003, 2005).

[5]For example, a positive foreign exchange reserve shock would depreciate the exchange rate on impact, but the foreign exchange reserve might decrease in the next period if the policy authority tries to offset the initial exchange rate depreciation.

such identification, this study modifies the method developed by Uhlig (2005).[6] See the appendix for details.

The structural-form equations in the VMA (vector moving average) form are

$$\begin{bmatrix} \Delta E_t \\ \Delta FR_t \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) \\ C_{21}(L) & C_{22}(L) \end{bmatrix} \begin{bmatrix} e_{E,t} \\ e_{FR,t} \end{bmatrix}, \tag{2}$$

where $C(L)$s are polynomials in the lag operator $L; e_E$ and $e_{F,R}$ are the structural shock to the exchange rate and the structural shocks to foreign exchange reserves, respectively; e is a two-by-one vector of structural shocks; $e = (e_E \ e_{FR})$'; var$(e) = \Omega$; and Ω is a diagonal matrix. The sign restrictions imposed on this model are $C_{11}(0) \geq 0, C_{12}(0) \geq 0, C_{21}(0) \leq 0$, and $C_{22}(0) \geq 0$.

To infer the degree of exchange rate stabilization, the dynamic policy reaction function is calculated. This function shows the reaction of the foreign exchange reserves to the exchange rate over time in the presence of shocks to the exchange rate. From equation (2), the impulse responses of the exchange rate and foreign exchange reserves to the shocks to the exchange rate are

$$\Delta E_t(e_E) \equiv C_{11}(L)e_{E,t}, \tag{3}$$

$$\Delta FR_t(e_E) \equiv C_{21}(L)e_{E,t}. \tag{4}$$

That is, $\Delta E_t(e_E)$ and $\Delta FR_t(e_E)$ are the exchange rate and foreign exchange reserve changes in the presence of the shocks to the exchange rate only. By combining (3) and (4),

$$\Delta FR_t(e_E) = \frac{C_{21}(L)}{C_{11}(L)}\Delta E_t(e_E). \tag{5}$$

The coefficients on $\Delta E_t(e_E), \Delta E_{t-1}(e_E), \Delta E_{t-2}(e_E), \ldots$ in equation (5) show how much the percentages of the foreign exchange reserves change over time in reaction to a 1 percent depreciation of the exchange rate in the presence of the shocks to the exchange rate.

In the above, the dynamic policy reaction function is constructed by exploiting the impulse responses to the exchange rate shocks. This

[6]Refer to Canova and De Nicolo (2002) for similar types of sign restrictions.

procedure is essentially equivalent to recovering the policy reaction function after controlling the simultaneity between policy instruments and the exchange rate in this two-variable model as shown below.

The structural-form equations in VAR (vector autoregression) form are

$$\begin{bmatrix} B_{0,11} & B_{0,12} \\ B_{0,21} & B_{0,22} \end{bmatrix} \begin{bmatrix} \Delta E_t \\ \Delta FR_t \end{bmatrix} = \begin{bmatrix} B_{11}(L) & B_{12}(L) \\ B_{21}(L) & B_{22}(L) \end{bmatrix} \begin{bmatrix} \Delta E_{t-1} \\ \Delta FR_{t-1} \end{bmatrix} + \begin{bmatrix} e_{E,t} \\ e_{FR,t} \end{bmatrix}, \tag{6}$$

where B_0s are constants and $B(L)$s are polynomials in the lag operator, L. The structural-form coefficients of the VMA from (2) and the VAR from (6) are related by $C(L) = (B0 - B(L)L) - 1$. Note that the first equation in (6) can be interpreted as the foreign exchange market equation and the second equation as the policy reaction function.[7]

From the second equation in (6),

$$\Delta FR_t = (B_{0,22} - B_{22}(L)L)^{-1} \left[(B_{0,21} - B_{21}(L)L)\, \Delta E_t + e_{FR,t} \right]. \tag{7}$$

By tracing coefficients on $\Delta E_t, \Delta E_{t-1}, \Delta E_{t-2}, \ldots$ in (7), we can examine the percentages' change that the foreign exchange reserves exhibit over time in reaction to a 1 percent depreciation in the exchange rate. In this two-variable model, using the relation $C(L) = (B0 - B(L)L) - 1$, it can be shown that the coefficients in equations (5) and (7) are the same, i.e., $\frac{B_{0,21} - B_{21}(L)L}{B_{0,22} - B_{22}(L)L} = \frac{C_{21}(L)}{C_{11}(L)}$. That is, by exploiting the impulse responses to the shocks to the exchange rate that the policy reacts to, the actual policy reaction function can be recovered.

[7]It can be shown that the sign restrictions on impulse responses also imply corresponding sign restrictions on contemporaneous structural parameters, which are $B_{0,11} \geq 0, B_{0,12} \leq 0, B_{0,21} \geq 0$, and $B_{0,22} \geq 0$. The restrictions on the contemporaneous structural parameters, B_0, can be easily interpreted as follows. An increase in the foreign exchange reserves depreciates the exchange rate (in the foreign exchange market), while the policy authority decreases the foreign exchange reserves in reaction to the exchange rate depreciation in order to stabilize the exchange rate (in the policy reaction function).

To infer the interest rate reactions to the exchange rate, a two-variable model is constructed that includes the log of exchange rate changes and the interest rate changes. For the interest rate, a difference form is used following past studies, although mixed evidence is found on the hypothesis of a unit root in the interest rate. In this model, the restriction is imposed such that a positive shock to the interest rate decreases the exchange rate (since an increase in the interest rate makes the domestic currency asset more attractive) while a positive shock to the exchange rate increases the interest rate (since the policy authority tries to stabilize the exchange rate by increasing the interest rate). That is, in the structural VMA form,

$$\begin{bmatrix} \Delta E_t \\ \Delta R_t \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) \\ C_{21}(L) & C_{22}(L) \end{bmatrix} \begin{bmatrix} e_{E,t} \\ e_{R,t} \end{bmatrix}, \tag{8}$$

where R is the interest rate; e_E and e_R are the structural shock to the exchange rate and the structural shocks to interest rate, respectively; and the sign restrictions imposed on this model are $C_{11}(0) \geq 0, C_{12}(0) \leq 0, C_{21}(0) \geq 0$, and $C_{22}(0) \geq 0$.

3. Exchange Rate Arrangements

3.1 De Jure Exchange Rate Arrangements

A number of countries have experienced a severe currency crisis in the 1990s and the 2000s. Among these, eleven countries are considered: five Asian crisis countries (Korea, Indonesia, Philippines, Malaysia, and Thailand), Mexico, Brazil, Russia, Ecuador, Bulgaria, and Turkey. Most of these countries announced changes in the exchange rate regime after the crisis. Table 1 reports roughly the date of the currency crisis and de jure exchange rate regime that each country reported to the International Monetary Fund (IMF), found in the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER).*

Eight countries announced a free float (independently floating) within one and a half years of the onset of the crisis. Among these countries, five countries (Korea, Indonesia, Mexico, Brazil, and Russia) changed from a managed float, Thailand changed from a fixed exchange rate regime, Turkey changed from a crawling peg, and

Table 1. De Jure Exchange Rate Regime Classification

Country	Crisis Date	De Jure Exchange Rate Regime Classification
Korea	1997:M9	Mar. 1980–Dec. 15, 1997: Managed Floating Dec. 16, 1997–: Independently Floating
Indonesia	1997:M6	Nov. 1978–Aug. 13, 1997: Managed Floating Aug. 14, 1997–June 29, 2001: Independently Floating June 30, 2001–: Managed Floating
The Philippines	1997:M6	Jan. 1988–: Independently Floating
Malaysia	1997:M6	Mar. 1990–Nov. 1992: Fixed Dec. 1992–Sep. 1, 1998: Managed Floating Sep. 2, 1998–: Fixed
Thailand	1997:M7	Jan. 1970–July 1, 1997: Fixed July 2, 1997–June 29, 2001: Independently Floating June 30, 2001: Managed Floating
Mexico	1994:M11	1982–Dec. 21, 1994: Managed Floating Dec. 22, 1994–: Independently Floating
Brazil	1998:M12	July 1, 1994–Jan. 17, 1999: Managed Floating Jan. 18, 1999: Independently Floating
Russia	1998:M7	July 6, 1995–Sep. 1, 1998: Managed Floating (Band) Sep. 2, 1998–Sep. 29, 1999: Managed Floating Sep. 30, 1999–Nov. 30, 2000: Independently Floating Dec. 1, 2000–: Managed Floating
Ecuador	1999:M12	Oct. 27, 1995–Feb. 11, 1999: Managed Floating (Band) Feb. 12, 1999–Mar. 12, 2000: Independently Floating Mar. 13, 2000–: Dollarization
Bulgaria	1996:M12	Feb. 8, 1991–June 30, 1997: Independently Floating July 1, 1997–Dec. 31, 1998: Fixed (Pegged to DM) Jan. 1, 1999–: Currency Board
Turkey	2001:M1	1975–June 29, 1998: Managed Floating June 30, 1998–Feb. 21, 2001: Crawling Peg Feb. 22, 2001–: Independently Floating

the Philippines continued a free float. In one or two years, Indonesia, Thailand, and Russia made another transition to a managed float. On the other hand, three countries adopted a fixed exchange rate regime within one and a half years after the onset of the crisis. Malaysia changed from a managed float to a peg (with capital account restrictions). Bulgaria changed from a free float to a soft peg, and then announced a hard peg (currency board). Ecuador changed from a managed float/free float to a hard peg (dollarization).

Pre-crisis regimes may be described as intermediate regimes such as a managed float and soft peg. There are eight or nine such cases.[8] On the other hand, post-crisis regimes are directed more toward polar regimes such as a currency board, dollarization, and free float. There are ten such cases, although three of them made another transition from a free float to a managed float within a few years after the crisis. Overall, based on de jure regime classification, the bipolar view has some support.

3.2 Data and Benchmarks

Although some support for the bipolar view was found based on de jure classification, as suggested by Calvo and Reinhart (2002), each country may act differently from what they say. In order to infer de facto exchange rate arrangements in each country, the methodology developed in section 2 is applied in this section.

During the periods around the crisis date, abnormal behaviors of the exchange rate and the policy instruments are often observed. Therefore, some months before and after the crisis dates are excluded for the estimation.[9] Also, in each country, the sample size of the pre-crisis period has been adjusted to be roughly equal to the sample size of the post-crisis period, in order to make a better comparison between the pre- and post-crisis periods. The estimation periods are reported in table 2.

[8] The case of Ecuador may not be clearly categorized. Ecuador announced a managed float from 1995, but then announced a free float from early 1999. The crisis occurred in late 1999.

[9] In this regard, there are some claims that the effects of monetary policy on the exchange rate are dramatically different during a crisis period. For example, Radelet and Sachs (1998), Stiglitz (1999), and Wade (1998) suggest that a high interest rate policy further depreciated the currency during a currency crisis.

Table 2. Standard Deviations and Correlations of Innovations in Exchange Rate and Policy Instruments

Country vs. Crisis Date	Estimation Period	Model with Reserves			Model with Interest Rate		
		$\sigma(\varepsilon_E)$	$\sigma(\varepsilon_{FR})$	$\rho(\varepsilon_E, \varepsilon_{FR})$	$\sigma(\varepsilon_E)$	$\sigma(\varepsilon_R)$	$\rho(\varepsilon_E, \varepsilon_R)$
Japan ($)	1983:M1–2003:M12	2.70	1.11	−0.35	2.70	0.23	0.10
Australia ($)	1984:M1–2003:M12	2.34	5.40	−0.31	2.34	0.48	0.11
Denmark (DM)	1979:M3–1998:M12	0.66	15.42	−0.17	0.66	1.50	0.10
	1999:M1–2003:M12	0.10	12.21	−0.10	0.10	0.21	0.37
Korea ($)	1992:M1–1996:M12	0.68	2.76	−0.26	0.67	1.22	0.12
1997:M9	1999:M1–2003:M12	1.85	5.72	−0.24	1.86	0.09	−0.17
Indonesia ($)	1992:M1–1996:M12	0.23	3.76	0.16	0.22	1.02	0.13
1997:M6	1999:M1–2001:M6	5.62	6.22	−0.53	5.64	3.49	0.25
	2001:M7–2003:M12	2.82	2.88	−0.25	2.87	1.75	0.14
Philippines ($)	1992:M1–1996:M12	1.33	4.98	−0.12	1.33	3.88	0.09
1997:M6	1999:M1–2003:M12	1.67	5.39	−0.22	1.60	0.55	0.32
Malaysia ($)	1992:M12–1996:M12	1.12	16.24	0.50	1.20	0.28	−0.17
1997:M6	1999:M1–2003:M12	—	—	—	—	—	—
Thailand ($)	1992:M12–1996:M12	0.37	4.13	−0.07	0.36	1.89	−0.14
1997:M7	1999:M1–2001:M6	1.69	4.11	−0.17	1.72	0.37	0.14
	2001:M7–2003:M12	1.11	4.57	−0.36	1.16	0.15	−0.11

(*continued*)

Table 2. (Continued)

Country vs. Crisis Date	Estimation Period	Model with Reserves			Model with Interest Rate		
		$\sigma(\varepsilon_E)$	$\sigma(\varepsilon_{FR})$	$\rho(\varepsilon_E, \varepsilon_{FR})$	$\sigma(\varepsilon_E)$	$\sigma(\varepsilon_R)$	$\rho(\varepsilon_E, \varepsilon_R)$
Mexico ($)	1989:M1–1993:M12	0.52	12.38	−0.33	0.54	2.67	0.07
1994:M11	1997:M1–2003:M12	2.14	4.60	−0.30	2.14	2.40	0.74
Brazil ($)	1994:M7–1997:M12	1.13	5.72	−0.27	1.04	5.23	0.43
1998:M12	2000:M1–2003:M12	4.34	8.13	0.05	4.32	0.49	0.17
Russia ($)	1995:M8–1997:M12	0.33	6.58	−0.00	0.34	24.47	0.18
1998:M7	1999:M10–2000:M11	1.46	3.43	−0.59	1.38	2.46	0.34
	2000:M12–2003:M12	0.47	4.25	−0.32	0.47	4.19	0.23
Ecuador ($)	1995:M11–1998:M12	2.20	11.11	−0.26	2.39	2.33	−0.02
1999:M12	2001:M1–2003:M12	—	—	—	—	—	—
Bulgaria (DM)	1993:M12–1995:M12	5.90	11.66	0.03	5.88	3.41	0.54
1996:M12	1997:M7–1998:M12	0.14	9.27	−0.04	0.14	0.34	0.32
	1999:M1–2003:M12	—	—	—	—	—	—
Turkey (DM)	1993:M7–1998:M6	5.64	10.51	−0.12	4.72	40.37	0.13
2001:M1	1999:M1–2000:M6	1.24	6.34	−0.08	1.43	8.15	−0.03
	2002:M1–2003:M12	4.51	9.98	−0.29	4.43	1.21	0.23

Note: The numbers show the standard deviations (σ's) of and the correlations (ρ's) between the reduced-form residuals.

The benchmarks of free floaters are Japan and Australia. Both countries are generally regarded as free floaters.[10] The other two G3 countries, Germany and the United States, are also regarded as free floaters. However, Germany has not been used as the benchmark since Germany went through important structural changes such as German unification and European monetary unification. On the other hand, it is less clear that the U.S. results are comparable to other countries since official foreign exchange intervention data shows that transactions of both the German mark (or euro) and the Japanese yen are significant portions of total interventions and the U.S. dollar is the foremost reserve currency of the world. In contrast, Japanese foreign exchange intervention data shows that most portions are transactions of U.S. dollars. Therefore, Japan seems to be a better benchmark than the United States and Germany. Estimation periods are from January 1983 to December 2003 for Japan and from January 1984 to December 2003 for Australia, which has been a free floater.[11]

On the other hand, verifying a fixed exchange rate regime from actual data is relatively easy since the exchange rate is mostly fixed in a fixed exchange rate regime. It is, nevertheless, still worthwhile to have the benchmark case of a tightly managed exchange rate (although not literally fixed) in order to have some idea of the reaction size of a tightly managed exchange rate regime, and also in order to check the validity of the current methodology. Denmark is used as the benchmark. Since 1979, Denmark participated in the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS). Since 1998, the Danish krone has been pegged to the euro within an official band of +/–2.25 percentage points. The ERM period can

[10] The exchange rate stabilizing actions of Japan might not be directly comparable to those of the countries in the sample. Japan's currency is a reserve currency of some countries. Japan is difficult to regard as a small, open economy that characterizes the countries in the sample. Therefore, another benchmark country, Australia, is considered.

[11] The estimation dates are chosen based on the IMF's *AREAEAR*. To be more consistent with the estimation periods of the sample countries, the benchmark cases were also estimated over the periods 1992–96 and 1999–2003. The main conclusions do not change when the estimates for those periods are used. In addition, the same estimation period is used for both the benchmark case and the crisis country for the probability measure reported in table 3. This measure will be explained later.

be regarded as the case in which the exchange rate arrangement is somewhat less flexible than the usual managed float (with discretion) while the latter period acts as the case for fixed exchange rate arrangements within a narrow band. An ERM country has been chosen, since the ERM is a good example of tightly managed exchange rate arrangements. Among ERM countries, Denmark is chosen, as it is one of very few countries that have been within the ERM without much trouble.[12] Estimation periods for Denmark are from March 1979 to December 1998 and from January 1999 to December 2003.

Monthly data have been used for the estimation. All data series are collected from the IMF's International Financial Statistics. For European countries, the exchange rate against the Deutsch mark (DM), before 1999, or the euro, from 1999, has been used. For all other countries, the exchange rate against the U.S. dollar is used.[13] The foreign exchange reserves, in terms of foreign currency, have been used (that is, the foreign exchange reserves in terms of the DM or the euro for European countries and the foreign exchange reserves in terms of U.S. dollars for other countries) because the exchange rate movements would change foreign exchange reserves in terms of the domestic currency without any foreign exchange policy actions.[14] The original monetary base data is in terms of domestic currency, so it is converted to foreign currency terms.[15] For the interest rate, money-market rates have been used.[16] In all estimations, one lag has been chosen based on the Schwarz criterion and a constant term has been included.

3.3 Volatility and Co-movements of Policy Instruments and Exchange Rate

I present the information from the variance-covariance matrix of reduced-form residuals (Σ), to infer whether the overall behaviors of policy instruments and the exchange rate in the post-crisis period differ from those in the pre-crisis period. Table 2 reports the standard

[12] See Eichengreen and Wyplosz (1993).

[13] Monthly end-of-period bilateral exchange rates (IFS line ..AE.) are used.

[14] For reserves, total reserves minus gold (IFS line .1L.D) are used.

[15] For monetary base, IFS line 14... is used.

[16] IFS line 60B.. is used, except for Ecuador. For Ecuador, discount rate (IFS line 60...) is used.

deviations of the innovations in policy instruments' changes and the exchange rate changes (ε_{FR} and ε_E in the first model and ε_R and ε_E in the second model) and the correlation between those two variables for each country during the pre-crisis and the post-crisis periods. The first column shows the country name, the base foreign currency (in parentheses, "DM" indicates German mark or euro), and the crisis date (below the country name). The second column shows the estimation period; the third, fourth, and fifth columns represent, respectively, the standard deviations of ε_E and ε_{FR}, and the correlation between ε_E and ε_{FR}, in the model with foreign exchange reserves; the sixth, seventh, and eighth columns show the standard deviations of ε_E and ε_R, and the correlation between ε_E and ε_R, respectively, in the model with the interest rate.

The standard deviation of innovations in exchange rate changes is higher but the standard deviations of innovations in the two policy instruments are lower in Japan and Australia than in Denmark. This result is in fact not surprising. In a tightly managed exchange rate regime, the policy authority adjusts its policy instruments to a great extent to stabilize the exchange rate, leading to a high level of volatilities in the changes of the policy instruments but a low level of volatility in exchange rate changes.

In most crisis countries, the volatilities of policy instruments' changes and the exchange rate changes in the pre-crisis period are substantially different from those in the post-crisis period. The observation indicates that the exchange rate regime is likely to have changed after the crisis. For many countries, the standard deviation of the innovations in exchange rate changes is higher but the standard deviations of the innovations in two policy instruments' changes are lower in the post-crisis period compared with the pre-crisis period. The difference in the level of standard deviations may imply a transition toward a more flexible exchange rate regime. On the other hand, there are some cases in which the standard deviations of both the exchange rate changes and policy instruments' changes rise (or fall), based on which it is not so easy to draw a clear conclusion on how the exchange rate regime has changed. A more clear inference can be made based on the estimated policy reaction function from the structural VAR model in the next section.

In most cases, the correlation between the exchange rate changes and foreign exchange reserve changes is relatively small in its absolute value; there are only five cases (out of fifty-six) in which the correlation is larger than 0.37. Because exchange rate shocks and policy instrument shocks result in the opposite signs for the correlation between the changes in the exchange rate and policy instruments, a weak overall or unconditional correlation may suggest that neither exchange rate shocks nor policy instrument shocks are dominant. This, in turn, may suggest that the structural VAR modeling (identifying two shocks separately) is a worthwhile attempt. Albeit small, the correlation between the exchange rate changes and foreign exchange changes is often negative and the correlation between the exchange rate changes and the interest rate changes is often positive. This may suggest that the stabilizing actions of policy instruments (in response to exchange rate shocks) are stronger than policy instrument shocks (that affect exchange rate). In the next section, I present the results from the structural VAR model that separates the two types of shocks.

3.4 Estimated Reaction Functions, Probability Measures, and Impulse Responses

The estimated reaction function from the structural VAR model is reported in table 3. The first column shows the country name and the base foreign currency. The second column shows the estimation period; the third, the de jure classification reported to the IMF; the fourth and fifth, the reaction function of the foreign exchange reserves to the exchange rate (the first month and the sixth month); and the sixth and seventh, the reaction function of the interest rate. Note that all the numbers of the reaction functions are cumulative numbers over time. The numbers in parentheses are 68 percent probability bands. There are three cases in which the numbers are not reported because the exchange rate is literally fixed and the reaction functions cannot be calculated.

The estimated reaction function with probability bands provides important information on the size of policy reactions, but it is not easy to clearly infer whether the size of the policy reactions of each country is significantly different from the benchmark cases. However, a clear inference on such issues is important. As an example, in order to investigate the case of "fear of floating," it needs to be tested whether the size of the policy reactions of a country that claims a

Table 3. Estimated Policy Reaction Function

Country vs. Crisis Date	Estimation Period	De Jure	Reserve Reactions		Interest Rate Reactions	
			One Month	Six Month	One Month	Six Month
Japan ($)	1983:M1–2003:M12	IF	−0.33 (−0.10,−0.71)	−0.30 (−0.11,−0.63)	0.08 (0.02,0.24)	0.06 (0.02,0.19)
Australia ($)	1984:M1–2003:M12	IF	−1.84 (−0.60,−4.13)	−1.64 (−0.72,−3.17)	0.18 (0.05,0.54)	0.29 (0.10,0.95)
Denmark (DM)	1979:M3–1998:M12	EM	−20.5 (−5.75,−57.3)	−17.6 (−7.48,−51.7)	2.13 (0.59,6.60)	1.32 (0.38,3.79)
	1999:M1–2003:M12	F	−113.4 (−33.3,−356)	−121.0 (−40.1,−274)	1.59 (0.52,3.43)	2.69 (0.70,5.82)
Korea ($)	1992:M1–1996:M12	MF	−3.35 (−0.98,−7.92)	−2.92 (−1.37,−6.62)	1.64 (0.48,4.89)	0.71 (0.05,1.54)
1997:M9	1999:M1–2003:M12	IF	−2.55 (−0.79,−6.27)	−3.33 (−1.83,−6.23)	0.06 (0.01,0.34)	0.09 (0.01,0.56)
Indonesia ($)	1992:M1–1996:M12	MF	−19.6 (−4.54,−104.5)	−23.0 (−5.09,−991)	3.99 (1.14,11.8)	3.61 (1.05,22.5)
1997:M6	1999:M1–2001:M6	IF	−0.80 (−0.29,−1.51)	−0.38 (−0.05,−0.79)	0.52 (0.16,1.31)	0.56 (0.27,1.18)
	2001:M7–2003:M12	MF	−0.84 (−0.25,−2.07)	−0.91 (−0.43,−1.60)	0.55 (0.15,1.63)	0.18 (−0.03,0.55)
Philippines ($)	1992:M1–1996:M12	IF	−3.26 (−0.89,−9.91)	−2.92 (−1.11,−7.46)	2.75 (0.71,8.74)	1.12 (0.38,3.51)
1997:M6	1999:M1–2003:M12	IF	−2.68 (−0.80,−6.79)	−2.34 (−0.81,−5.38)	0.28 (0.09,0.62)	0.35 (0.13,0.58)
Malaysia ($)	1992:M12–1996:M12	MF	−21.39 (−4.98,−93.6)	−74.48 (−9.1,−3140)	0.30 (0.06,1.54)	0.21 (0.04,1.15)
1997:M6	1999:M1–2003:M12	F	—	—	—	—
Thailand ($)	1992:M12–1996:M12	F	−10.23 (−2.79,−34.8)	−10.02 (−4.53,−26.9)	5.98 (1.41,30.17)	7.75 (2.70,273)
1997:M7	1999:M1–2001:M6	IF	−2.10 (−0.60,−5.86)	−0.93 (0.07,−2.15)	0.19 (0.05,0.55)	0.10 (0.00,0.42)
	2001:M7–2003:M12	MF	−3.20 (−1.00,−6.97)	−2.83 (−1.13,−4.58)	0.14 (0.03,0.66)	0.02 (−1.02,0.11)

(*continued*)

Table 3. (Continued)

Country vs. Crisis Date	Estimation Period	De Jure	Reserve Reactions		Interest Rate Reactions	
			One Month	Six Month	One Month	Six Month
Mexico ($)	1989:M1–1993:M12	MF	−19.12 (−6.32,−42.0)	−5.95 (−1.09,−18.46)	4.69 (1.26,15.5)	2.80 (0.25,13.09)
1994:M11	1997:M1–2003:M12	IF	−1.71 (−0.53,−4.01)	−0.96 (−0.09,−2.55)	0.84 (0.42,1.25)	0.84 (0.50,1.18)
Brazil ($)	1994:M7–1997:M12	MF	−4.09 (−1.26,−9.98)	−2.82 (0.26,−12.08)	3.86 (1.35,7.72)	2.23 (0.26,4.32)
1998:M12	2000:M1–2003:M12	IF	−1.95 (−0.49,−7.95)	−0.85 (−0.05,−4.18)	0.10 (0.03,0.27)	0.38 (0.16,1.06)
Russia ($)	1995:M8–1997:M12	MF	−19.1 (−5.16,−72.0)	−1.92 (48.1,−6.09)	60.0 (17.6,165.4)	5.85 (−6.26,25.9)
1998:M7	1999:M10–2000:M11	IF	−1.75 (−0.71,−3.13)	−1.17 (0.23,−2.73)	1.40 (0.46,3.27)	0.32 (−0.28,2.28)
	2000:M12–2003:M12	MF	−7.26 (−2.27,−16.6)	−4.44 (−2.56,−6.84)	7.25 (2.18,18.66)	1.59 (0.36,4.24)
Ecuador ($)	1995:M11–1998:M12	MF	−4.12 (−1.23,−9.78)	−1.43 (0.97,−3.26)	1.03 (0.26,4.15)	1.23 (0.38,3.29)
1999:M12	2001:M1–2003:M12	F(D)	—	—	—	—
Bulgaria (DM)	1993:M12–1995:M12	IF	−2.02 (−0.51,−7.88)	0.21 (1.23,−1.46)	0.43 (0.16,0.81)	0.47 (0.05,0.91)
1996:M12	1997:M7–1998:M12	F	−62.5 (−16.8,−217.2)	−84.3 (−23.5,−299.0)	1.95 (0.63,4.59)	3.32 (1.20,8.85)
	1999:M1–2003:M12	F(C)	—	—	—	—
Turkey (DM)	1993:M7–1998:M6	MF	−1.75 (−0.47,−5.20)	−1.30 (−0.44,−2.48)	7.53 (2.12,22.11)	1.09 (−296.7,2.96)
2001:M1	1999:M1–2000:M6	CD	−4.68 (−1.31,−16.0)	−5.93 (−1.95,−491.7)	5.86 (1.48,23.80)	−1.47 (−504,1.47)
	2002:M1–2003:M12	IF	−1.78 (−0.53,−4.27)	−1.15 (−0.40,−3.05)	0.23 (0.07,0.57)	0.41 (0.19,1.61)

Notes: IF: Independently Floating, MF: Managed Floating, F: Fixed, CP: Crawling Peg, F(D): Dollarization, F(C): Currency Board, EM: Exchange Rate Mechanism. The numbers show the cumulative policy reaction functions, and the numbers in parentheses show 68 percent probability bands.

free float is stronger than those of the benchmark free floaters. In this regard, the probability that the policy reaction of each country is weaker or stronger than the benchmark cases is formally calculated using simulation experiments.[17]

In table 4, each number under the benchmark cases of free floating ("Japan (IF)" and "Australia (IF)") shows the probability that the reaction of each country is not stronger than that of the benchmark case. These numbers can be regarded as the statistics for the test of the null hypothesis that each country actually adopted a free float. A low probability indicates a rejection of the null hypothesis at the probability level. This rejection may suggest that the country is not a free floater and controls the exchange rate more tightly than a free floater. On the other hand, each number under the benchmark cases of the tightly controlled exchange rate arrangements ("Denmark (EM)" and "Denmark (F)") shows the probability that the reactions of each country are not weaker than those of the benchmark cases. These numbers can be regarded as statistics for the test of the null hypothesis that each country adopted a very tightly managed exchange rate policy. Again, a low probability may indicate a rejection of the null hypothesis. This rejection suggests that the exchange rate control is weaker than very tightly managed exchange rate arrangements.

In table 4, the probabilities that are not larger than 0.05 and 0.1 are denoted as underlined bold and bold characters, respectively. To control the time factor that may affect the exchange rate and policy instrument volatility for all countries, the longest sample period that can be applied to both the benchmark case and the country under consideration has been used. For example, to evaluate the post-crisis period of Korea (1999–2003), the benchmark cases are also estimated for the period 1999–2003.[18]

Finally, the estimated impulse responses in percentage terms, with 68 percent probability bands, in the two-variable model with the exchange rate and foreign exchange reserves for the post-crisis

[17]See the appendix for more details.

[18]Since the sample period of the Denmark (EM) case does not have any overlap with the post-crisis period of Korea, the original period of the Denmark (EM) case, March 1979–December 1998, has been used. In general, the original period of the benchmark case is used when there is no overlap between the periods of the benchmark case and each case in question.

Table 4. Probability Measures

Country	Estimation Period	Japan (IF)				Australia (IF)				Denmark (EM)				Denmark (F)			
		Reserve		Int Rate		Reserve		Int Rate		Reserve		Int Rate		Reserve		Int Rate	
		1m	6m	1m	6m	1m	6m	1m	6m	1m	6m	1m	6m	1m	6m	1m	6m
Japan	1983:M1–2003:M12	—	—	—	—	—	—	—	—	**.00**	**.00**	**.06**	.13	**.00**	**.06**	**.03**	.12
Australia	1984:M1–2003:M12	.11	**.07**	.30	.15	—	—	—	—	**.05**	**.01**	.15	.37	**.01**	**.06**	**.07**	**.07**
Denmark	1979:M3–1998:M12	**.00**	**.00**	**.06**	.13	**.05**	**.01**	.15	.37	—	—	—	—	.15	.15	.60	.36
	1999:M1–2003:M12	**.00**	**.06**	**.03**	.12	**.01**	**.06**	**.07**	**.07**	—	—	—	—	—	—	—	—
Korea	1992:M1–1996:M12	**.05**	**.02**	**.05**	.20	.46	.46	.15	.39	.18	.12	.56	.50	**.02**	**.07**	.52	.19
1997:M9	1999:M1–2003:M12	.11	**.02**	.30	.34	.45	.21	.50	.30	**.10**	**.06**	**.07**	.15	**.02**	**.07**	**.08**	.15
Indonesia	1992:M1–1996:M12	**.01**	**.03**	**.02**	**.05**	.15	.21	**.08**	.18	.57	.60	.76	.86	.21	.33	.75	.61
1997:M6	1999:M1–2001:M6	.31	.56	**.08**	.15	.81	.66	.13	**.07**	**.03**	**.00**	.19	.29	**.01**	**.04**	.19	.22
	2001:M7–2003:M12	.35	.24	**.01**	.23	.73	.88	.16	.37	**.04**	**.01**	.22	.14	**.01**	.18	.31	.11
Philippines	1992:M1–1996:M12	**.06**	**.05**	**.04**	**.10**	.45	.48	**.10**	.28	.20	.14	.68	.66	**.04**	**.08**	.65	.33
1997:M6	1999:M1–2003:M12	.11	.11	.11	.17	.43	.37	.26	.13	.11	**.05**	**.10**	.15	**.02**	**.07**	.12	.11
Malaysia	1992:M12–1996:M12	**.01**	**.01**	.18	.30	.21	.25	.38	.52	.65	.77	.25	.39	.21	.50	.21	.18
1997:M6	1999:M1–2003:M12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thailand	1992:M12–1996:M12	**.02**	**.03**	**.01**	**.04**	.29	.38	**.06**	**.09**	.48	.48	.82	.97	.11	.12	.80	.80
1997:M7	1999:M1–2001:M6	.14	.36	.18	.37	.55	.52	.28	.32	**.10**	**.01**	**.09**	.13	**.03**	**.05**	**.08**	.18
	2001:M7–2003:M12	**.10**	.11	**.04**	.41	.36	.48	.34	.62	.11	**.02**	.11	**.05**	**.02**	.18	.15	**.06**

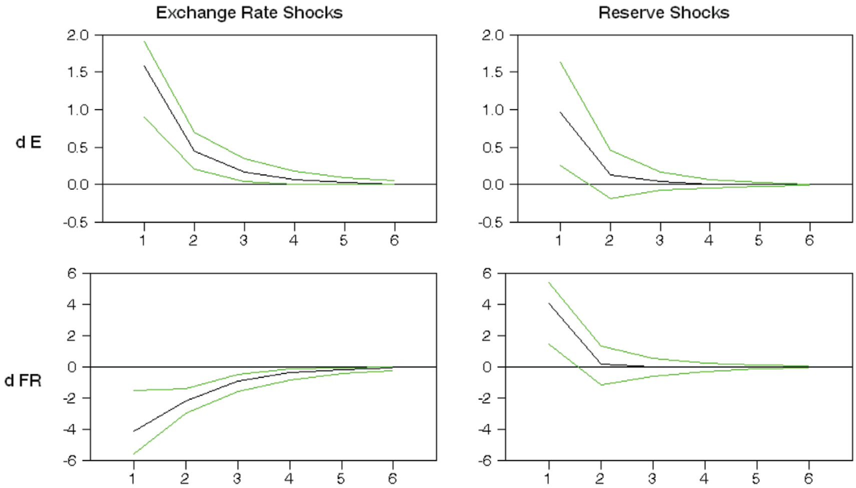
(continued)

Table 4. (Continued)

Country	Estimation Period	Japan (IF)				Australia (IF)				Denmark (EM)				Denmark (F)			
		Reserve		Int Rate		Reserve		Int Rate		Reserve		Int Rate		Reserve		Int Rate	
		1m	6m	1m	6m	1m	6m	1m	6m	1m	6m	1m	6m	1m	6m	1m	6m
Mexico	1989:M1–1993:M12	**.01**	.11	**.02**	.15	**.06**	.29	**.06**	.19	.50	.22	.76	.78	.12	**.09**	.77	.52
1994:M11	1997:M1–2003:M12	.15	.31	**.02**	**.03**	.55	.61	**.08**	**.06**	**.07**	**.01**	.22	.33	**.01**	**.06**	.27	.19
Brazil	1994:M7–1997:M12	**.04**	.21	**.01**	.20	.46	.51	**.08**	.25	.24	.20	.92	.54	**.03**	**.09**	.75	.42
1998:M12	2000:M1–2003:M12	.17	.39	.22	.14	.48	.58	.46	**.09**	.13	**.08**	**.05**	.24	**.04**	.11	**.05**	.17
Russia	1995:M8–1997:M12	**.01**	.35	**.00**	.32	.19	.58	**.00**	.35	.42	**.05**	.99	.65	.18	**.07**	.98	.58
1998:M7	1999:M10–2000:M11	.13	.48	**.03**	.43	.67	.44	**.02**	.33	**.06**	**.02**	.39	.28	**.02**	**.10**	.29	.14
	2000:M12–2003:M12	**.04**	**.04**	**.01**	.17	.15	.13	**.02**	.16	.24	**.07**	.76	.53	**.05**	.12	.83	.51
Ecuador	1995:M11–1998:M12	**.05**	.28	**.01**	**.08**	.39	.55	**.09**	.18	**.07**	**.06**	.51	.49	**.04**	**.06**	.42	.33
1999:M12	2001:M1–2003:M12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bulgaria	1993:M12–1995:M12	**.10**	.62	**.10**	.34	.53	.82	.40	.30	.29	**.08**	.30	.18	**.03**	**.06**	.15	.14
1996:M12	1997:M7–1998:M12	**.01**	**.08**	**.00**	**.02**	**.05**	**.09**	**.01**	**.05**	.76	.79	.47	.72	.35	.61	.42	.32
	1999:M1–2003:M12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Turkey	1993:M7–1998:M6	.12	.13	**.01**	.43	.58	.53	**.03**	.48	.14	**.06**	.96	.58	**.02**	**.06**	.85	.25
2001:M1	1999:M1–2000:M6	**.09**	**.09**	**.01**	.70	.40	.30	**.01**	.68	.22	.34	.72	.17	**.07**	.22	.61	.30
	2002:M1–2003:M12	.21	.27	**.03**	**.09**	.57	.76	.25	**.05**	**.08**	**.04**	**.10**	.28	**.01**	.22	.20	.32

Note: The numbers show the probability that the absolute value of the estimated coefficient is not larger than that of the flexible exchange benchmark cases ("Japan (IF)" and "Australia (IF)") and the probability that the absolute value is not smaller than that of the fixed exchange rate benchmark cases ("Denmark (EM)" and "Denmark (F)").

Figure 1. Impulse Responses, Korea, 1999–2003



period of South Korea, are reported in figure 1. Since the impulse responses themselves do not help much to infer the exact size of policy reaction clearly, only one case is reported. The graphs in the first and the second columns show the responses of percentage changes in the exchange rate and the changes in the foreign exchange reserves (as a percentage of the monetary base in the previous period) to the exchange rate shocks and foreign exchange reserve shocks, respectively. To be consistent with the sign restrictions, the foreign exchange reserves and the exchange rate move in opposite directions in response to exchange rate shocks, while two variables move in the same direction in response to foreign exchange reserve shocks. Note that foreign exchange reserve shocks generate a substantial volatility of exchange rate and foreign exchange reserve movements. Note also that different ratios of exchange rate movements to foreign exchange reserve movements are generated from exchange rate shocks and foreign exchange reserve shocks. These results suggest that the current empirical methodology based on only exchange rate shocks may provide different results than the previous methodology based on unconditional volatility.

3.5 Results for Benchmark Cases

First, the benchmark countries are examined. The point estimates of Japan's foreign exchange reserve reactions show that foreign exchange reserves decreased by 0.33 percent (of the monetary base) in the first month and by 0.30 percent up to the sixth month, as a reaction to a 1 percent exchange rate depreciation. The point estimates of interest rate reactions show that the interest rate increased by 0.06–0.08 percent in reaction to a 1 percent exchange rate depreciation. In Australia, the point estimates of foreign exchange reserve reactions were –1.84 to –1.64 percent while the point estimates of interest rate reactions were 0.18 to 0.29 percent. The point estimates show that exchange rate stabilization was stronger in Australia than in Japan. However, considering wide probability bands, the difference between the two countries does not seem to be statistically significant. To be consistent with this conjecture, the hypothesis that Australian reactions were not stronger than Japanese reactions is not rejected at the 5 percent level in any cases, and is rejected at the 10 percent level in only one out of four cases in table 4.

On the other hand, the estimated reaction function of Denmark implies strong exchange rate stabilization. During the ERM period, foreign exchange reserve reactions were –20.5 to –17.6 percent and interest rate reactions were 2.13 to 1.32 percent. During the post-ERM period, the foreign exchange reserve reactions were even stronger, ranging from –113.4 to –121.0 percent. Interest rate reactions were 1.59 to 2.69 percent. In most cases, the lower band of the Danish reaction (in absolute value) was larger than the upper band of the Australian and Japanese reaction (in absolute value). This implies that the Danish reaction was significantly stronger than the Australian and Japanese reaction. To be consistent, the hypothesis that Japanese and Australian reactions were not weaker than the Danish reactions is frequently rejected at the 5 percent level and mostly rejected at the 10 percent level in table 4. On the other hand, the hypothesis that Danish reactions, during the ERM period, were not weaker than those during the fixed exchange rate period is not rejected at the 10 percent level in any cases.

Overall, the size of the reactions, based on the current methodology, well describes the relative degree of the exchange rate stabilization between a free float and tight exchange rate arrangements such as the ERM and a peg. In addition, the hypothesis test, based on probability measures, can clearly distinguish between a free float and a very tightly managed exchange rate policy.

3.6 Do Crisis Countries Move to Polar Regimes?

Now the main issue of the paper is discussed: Do crisis countries move to polar regimes? To address this question, it is analyzed whether crisis countries adopted free floats by investigating whether the estimated reactions of crisis countries were stronger than those of benchmark free floaters. To answer this question, it would have been enough to identify the number of countries that adopted polar regimes and intermediate regimes since the case of hard pegs can be easily identified.

First, the pre-crisis period was examined. In six countries (Indonesia, Thailand, Mexico, Brazil, Russia, and Ecuador), both reserve reactions and interest rate reactions were far stronger than those of Australia and Japan. In addition, interest rate reactions of three countries (Korea, Malaysia, and Turkey) and reserve reactions of one country (Malaysia) were far stronger than those of Australia and Japan. The only country that did not have far stronger policy reactions was Bulgaria.

This result can be further confirmed by using the probability measures. When Japan was used as the benchmark case, the hypothesis of free floating was rejected at the 5 percent level frequently in all countries but Bulgaria (out of four cases, three for Korea; two for Ecuador, Mexico, Malaysia, the Philippines, Brazil, and Russia; one for Turkey; and all cases for Indonesia and Thailand). Even when Australia was used as the benchmark case, the hypothesis of free floating was rejected in many countries (at the 10 percent level, one case for Indonesia, the Philippines, Brazil, Russia, Ecuador, and Turkey; two cases for Thailand and Mexico). In Bulgaria, it was not rejected when Australia was used as the benchmark. It was rejected only at the 10 percent level (for two out of four cases) when Japan was used as the benchmark.

Therefore, the exchange rate regime in the pre-crisis period can be characterized as intermediate regimes in most countries (ten out of eleven countries) because a free float was rejected and none of these countries adopted a hard peg.

Next, the post-crisis period was analyzed. The estimated policy reactions of the eight countries that announced a free float tended to be similar to or only slightly stronger than those of Australia, although somewhat stronger than those of Japan in many cases. Exceptions were Mexico and Russia; both interest rate and reserve reactions of Russia and interest rate reactions of Mexico were stronger than those of Australia and Japan.

Based on the probability measures, for five countries (four Asian countries and Brazil) among eight de jure free floaters, it is difficult to reject the null hypothesis of free float. The null hypothesis of free float is not rejected in any cases at the 5 percent level for these countries, except for one case of Korea. Even at the 10 percent level, the null hypothesis of free float was rejected in one out of eight cases for Korea and Brazil, two out of sixteen cases for Thailand, three out of sixteen cases for Indonesia, and none of the eight cases for the Philippines.

On the other hand, more frequent rejections were found in Mexico, Russia, and Turkey. For Mexico, it was rejected in two cases at the 5 percent level and four out of eight cases at the 10 percent level. For the de jure managed floating (2000:M12–2003:M12) period of Russia, it was rejected in four out of eight cases at the 5 percent level. For the de jure free-floating (2002:M1–2003:M12) period of Turkey, it was rejected in two and three out of eight cases at the 5 percent and 10 percent level, respectively.

The remaining three countries (Ecuador, Bulgaria, and Malaysia) clearly adopted the fixed exchange rate regime in the post-crisis period, and among them, two countries (Bulgaria and Ecuador) are clearly hard pegs. Overall, at least five countries adopted free float and two countries adopted hard pegs in the post-crisis period. Therefore, at least seven out of eleven countries adopted polar regimes in the post-crisis period.

To summarize, while about ten countries (out of eleven) adopted intermediate regimes during the pre-crisis period, at least seven countries (out of eleven) adopted polar regimes in the post-crisis period, which is summarized in table 5. This result supports the bipolar view, or “hollow middle” hypothesis.

Table 5. De Facto Exchange Rate Regime Classification

Country	Pre-Crisis	Post-Crisis
Korea	INT	IF
Indonesia	INT	IF
The Philippines	INT	IF
Malaysia	INT	INT
Thailand	INT	IF
Mexico	INT	INT
Brazil	INT	IF
Russia	INT	INT
Ecuador	INT	HP
Bulgaria	IF	HP
Turkey	INT	INT

Note: IF: Independently Floating, INT: Intermediate Regime, HP: Hard Peg.

3.7 Do Countries Overstate Exchange Rate Flexibility?

Next we investigated if countries overstate their exchange rate flexibility or understate their exchange rate controls. In order to identify the case of "fear of floating," the policy reactions of crisis countries were compared with the benchmark cases of free floats. In addition to the case of "fear of floating," we also identified if a country claimed a managed float but actually acted more closely to a peg by comparing the policy reactions of crisis countries with the benchmark cases of very tightly managed exchange rate regimes.

In the pre-crisis period, only two countries claimed a free float and eight countries claimed a managed float. In one of two countries that claimed a free float, the Philippines, the interest rate reactions were too large to be regarded as a free float like Australia. In four out of eight countries that claimed a managed float (Russia, Mexico, Malaysia, and Indonesia), the size of reactions was also as strong as the size of the reactions of Denmark during the ERM period. This suggested that these countries managed the exchange rate very tightly.

A similar conclusion can be derived based on the probability measures. In the case of the Philippines, the null hypothesis of a free float was rejected in three and five cases out of eight cases at the 5 percent and the 10 percent level, respectively. For Malaysia and Indonesia, the null hypothesis of a tightly managed exchange rate regime was not rejected in any cases at the 10 percent level. For Mexico, it was rejected in only one out of eight cases at the 10 percent level and in no cases at the 5 percent level. For Russia, it was rejected in one and two out of eight cases at the 5 percent and the 10 percent level, respectively. Overall, about half of the countries that announced a free float or a managed float tended to overstate their exchange rate flexibility.

In the post-crisis period, there were at best three cases of "fear of floating" (Mexico, Turkey, and Russia) out of eight cases that claimed a free float as discussed in the previous section. Further, among three cases that announced a managed float, at least two countries did not seem to overstate their exchange rate flexibility. The hypothesis of a tightly managed exchange rate regime was rejected in three out of eight cases at the 5 percent level for Indonesia and Thailand. For the remaining one case (Russia), it was more difficult to reject the hypothesis. The hypothesis was rejected in one and two out of eight cases at the 5 percent and the 10 percent level, respectively. Overall, four out of eleven cases tend to understate exchange rate flexibility.

To summarize, the cases in which countries overstate the exchange rate flexibility, including "fear of floating," have frequently been found in the samples under consideration. Such a tendency is weaker in the post-crisis period than in the pre-crisis period.

4. Extended Experiments

4.1 Robustness

First, the baseline models include only two variables and two structural shocks; however, the changes in policy instruments and the exchange rate can be driven by the third variable or the additional shock. In this regard, the baseline model is extended to include an additional variable. For the third variable, I consider the industrial production index that contains the information on the overall production activities. I also consider the world commodity price index that captures the information on inflationary pressure and world economic condition.[19] The same four sign restrictions are imposed, but no additional restriction in relation to the third variable is imposed.

Second, the three-variable model is constructed that includes two policy instruments' changes and the exchange rate changes simultaneously. Seven sign restrictions are imposed. Foreign exchange reserve shocks increase (or decrease) the foreign exchange rate reserve changes and decrease (or increase) the exchange rate. Interest rate shocks increase (or decrease) both the interest rate changes and the exchange rate. Exchange rate shocks increase (or decrease) the exchange rate changes and foreign exchange reserve changes but decrease (or increase) the interest rate changes.

The estimated policy reaction functions for the one-month horizon for these three-variable models are reported in table 6. "Base," "IP," "CMP," and "2P" indicate the baseline two-variable model, the three-variable model with industrial production, the three-variable model with world commodity price, and the three-variable model with the two policy instruments simultaneously. In most cases, the estimated policy reaction for each country is slightly stronger in three-variable models with industrial production or world commodity price than in the baseline model. By including an additional variable or shock, the exchange rate shock that policy reacts to is likely to be identified in a narrower sense. Using such shocks, the estimated policy reaction is likely to be stronger. Further, the estimated policy reaction is even stronger in the model with the two policy instruments than in the models with an additional variable. In this model, the exchange rate shocks are identified in a much narrower sense, since the shock is restricted to the one which both of the policy instruments reacts to.

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[19]The industrial production index and the world commodity price index are obtained from International Financial Statistics. Monthly data on industrial production are not available for some countries. The overall world commodity price index is available only from 1992. When the estimation periods include the periods before 1992, non-fuel world commodity price index that is available for the period before 1992 is used.

See Kim (1999) for documentation that the world commodity price is a useful variable containing inflationary pressure when identifying monetary policy shocks for various countries.

Table 6. Estimated Policy Reaction Function from Three-Variable Models (one-month horizon)

Country vs. Crisis Date	Estimation Period	Reserve Reactions				Interest Rate Reactions			
		Base	**IP**	**CMP**	**2P**	**Base**	**IP**	**CMP**	**2P**
Japan ($)	1983:M1–2003:M12	−0.33	−0.41	−0.44	−0.66	0.08	0.08	0.09	0.18
Australia ($)	1984:M1–2003:M12	−1.84	—	−2.25	−4.04	0.18	—	0.20	0.42
Denmark (DM)	1979:M3–1998:M12	−20.5	−24.0	−26.0	−38.0	2.13	2.23	2.15	4.39
	1999:M1–2003:M12	−113.4	−127.7	−121.1	−169.1	1.59	2.11	2.02	4.01
Korea ($)	1992:M1–1996:M12	−3.35	−4.17	−4.06	−6.57	1.64	1.84	1.81	3.91
1997:M9	1999:M1–2003:M12	−2.55	−3.13	−2.95	−5.52	0.06	0.05	0.05	0.09
Indonesia ($)	1992:M1–1996:M12	−19.6	—	−17.2	−22.7	3.99	—	4.12	11.2
1997:M6	1999:M1–2001:M6	−0.80	−1.10	−1.12	−1.58	0.52	0.62	0.63	0.97
	2001:M7–2003:M12	−0.84	−1.01	−1.04	−1.79	0.55	0.60	0.62	1.24
Philippines ($)	1992:M1–1996:M12	−3.26	−3.72	−3.80	−6.42	2.75	3.00	2.87	6.33
1997:M6	1999:M1–2003:M12	−2.68	−3.22	−3.18	−4.89	0.28	0.36	0.33	0.64
Malaysia ($)	1992:M12–1996:M12	−21.4	−14.2	−14.7	−11.3	0.30	0.22	0.24	0.63
1997:M6	1999:M1–2003:M12	—	—	—	—	—	—	—	—
Thailand ($)	1992:M12–1996:M12	−10.2	—	−11.5	−21.4	5.98	—	5.28	7.20
1997:M7	1999:M1–2001:M6	−2.10	—	−2.42	−2.76	0.19	—	0.21	0.46
	2001:M7–2003:M12	−3.20	—	−4.14	−7.57	0.14	—	0.14	0.22

(*continued*)

Table 6. (Continued)

Country vs. Crisis Date	Estimation Period	Reserve Reactions				Interest Rate Reactions			
		Base	IP	CMP	2P	Base	IP	CMP	2P
Mexico ($)	1989:M1–1993:M12	−19.1	−24.8	−23.8	−45.2	4.69	4.99	4.85	10.7
1994:M11	1997:M1–2003:M12	−1.71	−2.24	−2.07	−1.49	0.84	1.25	1.11	1.52
Brazil ($)	1994:M7–1997:M12	−4.09	−5.31	−4.84	−9.52	3.86	4.82	4.85	7.12
1998:M12	2000:M1–2003:M12	−1.95	−1.81	−1.87	−2.85	0.10	0.11	0.12	0.24
Russia ($)	1995:M8–1997:M12	−19.1	−18.2	−19.3	−28.2	60.0	67.5	68.1	94.2
1998:M7	1999:M10–2000:M11	−1.75	−3.16	−2.35	−3.10	1.40	2.40	1.61	2.76
	2000:M12–2003:M12	−7.26	−9.37	−8.74	−13.8	7.25	8.96	8.97	18.1
Ecuador ($)	1995:M11–1998:M12	−4.12	—	−5.05	−8.21	1.03	—	0.96	2.19
1999:M12	2001:M1–2003:M12	—	—	—	—	—	—	—	—
Bulgaria (DM)	1993:M12–1995:M12	−2.02	—	−1.92	−2.91	0.43	—	0.61	0.93
1996:M12	1997:M7–1998:M12	−62.5	—	−82.1	−93.7	1.95	—	3.00	4.11
	1999:M1–2003:M12	—	—	—	—	—	—	—	—
Turkey (DM)	1993:M7–1998:M6	−1.75	−1.82	−1.93	−3.87	7.53	8.47	8.37	20.0
2001:M1	1999:M1–2000:M6	−4.68	−5.03	−5.82	−8.77	5.86	5.63	7.75	10.4
	2002:M1–2003:M12	−1.78	−2.52	−2.16	−3.38	0.23	0.28	0.25	0.38

Notes: The numbers show the estimated policy reaction function for the one-month horizon. Base: two-variable baseline model, IP: three-variable model with industrial production, CMP: three-variable model with the world commodity price index, 2P: three-variable model with the two policy instruments.

However, the increases in estimated policy reactions in the three-variable models do not change our main conclusion on the exchange rate policies of crisis countries. The increases are found in almost all countries, not only in benchmark countries but also in crisis countries. Because the inference on the exchange rate policy of crisis countries is conducted in comparison with the benchmark cases, the main conclusion does not change much.

On the other hand, the exchange rate stabilization of the central bank can also help central banks' other objectives such as output and inflation stabilization. Therefore, it is difficult to infer the ultimate policy goals of the central banks from the policy reaction functions (to exchange rate shocks) identified in this study. A future study, possibly estimating the policy reaction functions including more variables to the model, will be conducive to clarify the issue.

Second, other benchmark countries were used to check the robustness of the main results. As the benchmark for a free floater, the most popular free floater, the United States, was considered. Since the United States often intervenes its exchange rate against two currencies—the DM (or euro) and the Japanese yen—two models, one against the DM (or euro) and the other against the Japanese yen, were constructed. The size of policy reactions of the United States has been similar to that of Japan.[20] As the benchmark for a very tightly managed exchange rate regime, Hong Kong, which has adopted the currency board system, was considered. Hong Kong has been keeping its exchange rate against U.S. dollars very tightly, even more tightly than Denmark. The size of reactions has turned out to be even stronger than those of Denmark.[21] When these benchmark countries are also used, the main conclusions do not change.

Third, experiments were performed with various measures of foreign exchange reserve changes such as percentage changes in foreign exchange reserves and foreign exchange reserve changes as a

[20] The reserve and interest rate reactions of the United States against the Japanese yen for the period 1983–2003 are 0.08 to 0.09 and –0.24 to –0.59, respectively. Those against the DM for the period 1983–98 are 0.11 to 0.09 and –0.30 to –1.23, respectively. Those against the euro for the period 1999–2003 are 0.06 to 0.05 and –0.17 to –0.84, respectively.

[21] The reserve and interest rate reactions of Hong Kong are –198.14 to –252.18 and 20.57 to 15.05, respectively, for the period 1996:M12–2003:M12 (the data availability dictates this choice of estimation period).

percentage of the average monetary base during the sample period. The main results do not change.

4.2 Comparison with Methodology of Calvo and Reinhart (2002)

The results using the methodology developed in this paper are now compared with the results based on Calvo and Reinhart's (2002) methodology in order to discuss some shortcomings of Calvo and Reinhart (2002). For this purpose, the two methods of Calvo and Reinhart (2002) are applied to the same samples. First, Calvo and Reinhart (2002) used the probabilities that the absolute value of the percentage changes in the exchange rate, foreign exchange rate reserve, and the interest rate are lower than the threshold values. A lower probability for the exchange rate (that is, more volatile exchange rate changes) and higher probabilities for the policy instruments (that is, less volatile policy instrument changes) are regarded as indicating a more flexible exchange rate arrangement. Second, Calvo and Reinhart (2002) used the exchange rate flexibility index, the ratio of the variance of the percentage changes in the exchange rate to the sum of the variances of the interest rate changes and the variance of the percentage changes in foreign exchange reserves. A larger number suggests a more flexible exchange rate arrangement, since a larger number should be related to a larger variation in the exchange rate and lower variations in the policy instruments.

Table 7 reports the probability that each variable changes less than 1 percent as well as the exchange rate flexibility index (EFI).[22] The index reasonably explains the relative degree of exchange rate flexibility for the benchmark cases; Japan has a higher number than Australia and Australia has a higher number than Denmark. However, the exchange rate flexibility numbers often fail to capture the relative rankings of exchange rate flexibility. The index numbers of the benchmark free floaters seem to be too small compared with the index numbers of crisis countries. There are nine cases in which the index numbers of crisis countries are higher than that of Australia (the post-crisis periods of South Korea, Indonesia, the Philippines,

[22] When different threshold values are used, the main conclusion remains unchanged.

Table 7. Measures of Calvo and Reinhart (2002)

Country vs. Crisis Date	Estimation Period	Probability (< 1%)			EFI
		E	FR	R	
Japan ($)	1983:M1–2003:M12	33.1	55.0	99.2	0.80
Australia ($)	1984:M1–2003:M12	31.0	23.8	93.3	0.14
Denmark (DM)	1979:M3–1998:M12	92.4	13.5	78.5	0.00
	1999:M1–2003:M12	100.0	15.3	100.0	0.00
Korea ($)	1992:M1–1996:M12	88.1	27.1	61.0	0.05
1997:M9	1999:M1–2003:M12	42.2	33.9	100.0	1.37
Indonesia ($)	1992:M1–1996:M12	98.3	40.7	69.5	0.01
1997:M6	1999:M1–2001:M6	13.3	30.0	50.0	1.10
	2001:M7–2003:M12	34.5	48.3	41.4	2.82
Philippines ($)	1992:M1–1996:M12	62.7	11.9	42.4	0.03
1997:M6	1999:M1–2003:M12	57.6	27.1	88.1	0.26
Malaysia ($)	1992:M12–1996:M12	72.9	27.1	100.0	0.03
1997:M6	1999:M1–2003:M12	100.0	32.2	98.3	0.00
Thailand ($)	1992:M12–1996:M12	98.3	30.5	30.5	0.02
1997:M7	1999:M1–2001:M6	37.1	42.9	88.6	0.88
	2001:M7–2003:M12	51.7	20.7	100.0	0.30
Mexico ($)	1989:M1–1993:M12	67.8	18.6	30.5	0.00
1994:M11	1997:M1–2003:M12	50.0	33.3	52.8	0.29
Brazil ($)	1994:M7–1997:M12	75.6	26.8	41.5	0.01
1998:M12	2000:M1–2003:M12	17.0	27.7	76.6	0.42
Russia ($)	1995:M8–1997:M12	53.6	0.0	10.7	0.00
1998:M7	1999:M10–2000:M11	61.5	0.0	15.4	0.09
	2000:M12–2003:M12	80.6	16.7	27.8	0.01
Ecuador ($)	1995:M11–1998:M12	18.9	8.1	32.4	0.13
1999:M12	2001:M1–2003:M12	100.0	39.1	100.0	0.00
Bulgaria (DM)	1993:M12–1995:M12	20.8	4.2	58.3	0.11
1996:M12	1997:M7–1998:M12	100.0	17.6	94.1	0.00
	1999:M1–2003:M12	98.3	11.9	64.4	0.00
Turkey (DM)	1993:M7–1998:M6	6.8	11.9	10.2	0.02
2001:M1	1999:M1–2000:M6	23.5	17.6	35.3	0.02
	2002:M1–2003:M12	17.4	26.1	47.8	0.85

Note: The numbers show the respective probability measures for the exchange rate (E), the foreign exchange reserves (FR), and the interest rate (R), and the exchange rate flexibility index (EFI), developed by Calvo and Reinhart (2002).

Thailand, Mexico, Brazil, and Turkey). In four cases (the post-crisis periods of South Korea, Indonesia, Thailand (1999–2001:M6), and Turkey), the numbers are even higher than that of Japan. It is quite difficult to believe that the degree of exchange rate flexibility of all the aforementioned countries is higher than that of Australia and Japan. This problem also arises for some cases in the pre-crisis period. For example, the number for Ecuador in the pre-crisis period is 0.13, which is similar to that of Australia (0.14), but it may be difficult to believe that the pre-crisis exchange rate arrangement of Ecuador was as flexible as that of Australia.

In addition, there are at least three cases in which the conclusion on the classification of free floating based on Calvo and Reinhart (2002)'s exchange rate flexibility index is different from the one based on the methodology developed in this paper. The exchange rate flexibility index of Turkey for the post-crisis period (0.85) is larger than those of Japan and Australia, the index of Brazil for the post-crisis period (0.29) is larger than that of Australia, and the index of Ecuador for the pre-crisis period (0.13) is similar to that of Australia. Although these countries are classified as intermediate regimes based on the measures developed in this paper, they are likely classified as free floating based on the exchange rate flexibility measure of Calvo and Reinhart (2002).

Next, the probability measures are examined. For benchmark cases, Australia seems to have a less flexible arrangement than Japan; while the probability that the percentage exchange rate changes are lower than 1 percent is similar for both countries, the probability that the percentage changes in foreign exchange reserve are lower than 1 percent is far lower in Australia than that in Japan, and the probability that the changes in the interest rate are lower than 1 percent is also lower in Australia than that in Japan, which implies policy instruments have higher volatilities in Australia than in Japan. Denmark has a higher probability for exchange rate changes (or a lower exchange rate volatility) and lower probabilities for policy instrument changes (or higher volatilities of policy instruments) than Japan and Australia, as expected.

However, it is often difficult to make a clear conclusion on whether one country has a tighter exchange rate arrangement than the benchmark countries based on probability measures because the probabilities for both policy instruments and the exchange rate are larger (or smaller) in one country than those in benchmark countries. For example, in the cases of post-crisis South Korea, Ecuador, and Malaysia and pre-crisis Malaysia, all probabilities are higher in crisis countries than those in Australia. In the case of the pre-crisis periods of Ecuador, Bulgaria, and Turkey, all probabilities are lower in crisis countries than those in Australia. There are many more cases in which the probabilities for at least one policy instrument and the exchange rate are larger (or smaller) in crisis countries than those in Australia. The difficulty in this comparison arises mostly because at least two numbers (one for exchange rate and one for policy instruments) should be compared, and it is not so easy to have a clear conclusion with the two numbers that have possibly different implications on the size of policy actions.[23]

To summarize, although the probability measures developed by Calvo and Reinhart (2002) provide useful information, it is often difficult to use the measures to make a comparison across different sample periods and countries. On the other hand, the exchange rate flexibility measures developed by Calvo and Reinhart (2002) sometimes provide results that seem unreasonable, but they still provide a good summary measure that can be easily adopted to compare across different countries and sample periods. Overall, in addition to the conceptual advantage of the measure developed in this paper over those of Calvo and Reinhart (2002), there seem to be practical advantages as well.[24]

5. Conclusion

This paper first develops a method to identify the de facto exchange rate arrangements using a structural VAR model with sign restrictions on impulse responses. The method improves upon the

[23]For example, suppose that the numbers for policy instrument and exchange rate are 20 percent higher in one case than the other case. Then, it is difficult to interpret the results because a 20 percent higher probability of each variable is not clearly related to policy actions, and it is difficult to judge whether it implies more flexible exchange rate arrangements.

[24]However, the current methodology has two shortcomings compared with Calvo and Reinhart (2002). First, the analysis itself is more complicated. Second, application of the analysis is more suited to a longer sample period because a multi-variable time-series model is estimated.

previous methodologies, as it uses only relevant information for inferring exchange rate stabilization, and it formally derives the policy reaction function.

By applying the method to the countries that have experienced a severe crisis, the exchange rate policy transition around the crisis period is examined. In the post-crisis period, a large fraction of these countries have moved to bipolar regimes—either hard pegs, such as a currency board and dollarization, or more flexible exchange arrangements that are close to a free float. This is consistent with the bipolar view. Countries often overstate their exchange rate flexibility, but such a tendency is a bit weaker in the post-crisis period than in the pre-crisis period. Indeed, these countries seem to have learned from their crises. By moving toward polar regimes, they seem to be trying to lower the possibility of a future crisis in integrated capital markets. They may have also learned that just saying is not enough since they experienced crisis regardless of what they had said.

Appendix

This appendix explains details on the implementation of the sign restrictions discussed in the main text of this paper. The reduced-form VAR equations can be written as $Y_t = A(L)\varepsilon_t$, where Y_t is an n×1 data vector, $A(L)$ is an n×n matrix polynomial in lag operator L, ε_t is a serially uncorrelated n×1 vector of residuals in the reduced-form equation, and $\text{var}(\varepsilon) = \Sigma$. Finding the structural form amounts to finding an n×n matrix, K, such that $\varepsilon_t = Ke_t$, where $\text{var}(e_t) = I_n$. Cholesky factorization of Σ is one example of finding a structural form. That is, a Cholesky factor, P, can be used as K, where $\Sigma = PP$' and P is a Cholesky factor. Also, note that PN, where N is an n×n orthonormal matrix (i.e., $NN' = I_n$) can be regarded as K. As discussed in Uhlig (2005), the space of K is spanned by N given P. $A(L)$ and Σ are drawn from normal Wishart distribution. To draw N, some elements of N are drawn from the standard normal distribution and other elements are recovered by using the restrictions that are implied by $NN' = I_n$.

For the two-variable model, I draw each element in the first row of N from the standard normal distribution and normalize to have the norm of 1 (which is implied by $NN' = I_n$). The second row of N is derived from the restriction $NN' = I_n$ given the drawn two elements of the first row of N. For the three-variable model, I draw each element in the first row of N from the standard normal distribution and normalize to have the norm be 1. In the case of the three-variable model, another element in N is still needed to recover all elements of N. Thus, I draw each element in the second row of N from the standard normal distribution and normalize them to have the norm to be 1. Since only one element is needed, I only use the first element of the second row, and discard other elements. The remaining five elements are drawn from the restriction $NN' = I_n$ given four drawn elements.

I generate 10,000 draws and keep the draws that satisfy the sign restrictions, while discarding the draws that do not, and then calculate the median impulse responses and probability bands. The policy reaction function is calculated for each draw kept, and then the median and the probability bands are calculated. For simulation experiments to compare the size of policy reactions between the two cases, I compare the sizes of policy reactions for each draw kept, and calculate the probability that the size of policy reactions of one case is not larger (or smaller) than that of the other case. For the two-variable model of the exchange rate and the foreign exchange reserve, I discard the draws where both shocks move two variables in the same direction or in opposite directions. I keep the draws where one shock moves two variables in the same direction and the other shock moves two variables in opposite directions, and define the former as the shocks to the foreign exchange reserves and the latter as the shocks to the exchange rate. For other models, a similar procedure is used.

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