Real Exchange Rate Volatility and the Choice of Regimes in Emerging Markets *

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Abstract
Traditional models of the choice of exchange rate regimes ignore the destabilizing effects of sharp and unanticipated exchange rate movements. Recent research, however, has shown that these movements have real costs in emerging markets owing to the dollarization of liabilities. This paper evaluates the performance of an emerging market economy under a credibly fixed-rate, a collapsing fixed-rate, and a flexible-rate regime using a speculative attack model that takes into account the real effects of unanticipated movements in exchange rates. The model is applied to South Korea to determine the dominant exchange rate regime.

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1. Introduction

The choice of an exchange rate regime has been and will continue to be a major, but controversial, area of research in economics. Following Poole (1970) there is some consensus among economists that the optimal exchange rate regime depends on the nature of shocks facing an economy. In particular, it depends on whether shocks are real, nominal, domestic, or foreign. In the standard literature, the comparison of exchange rate regimes is based on the minimization of a loss function that depends exclusively on the variance of real output. The real effects of unanticipated changes in the real exchange rate is left out of the analysis.[1] Some observers have argued that neglecting the destabilizing effects of sharp and unanticipated changes in real and nominal exchange rates is inappropriate because the financial turmoil in Mexico in 1994 and the currency crises in Asia in 1997-98 have shown that these changes have real costs in emerging markets.[2]

These costs can arise through the dollarization of liabilities, as stressed by Calvo (1999).[3] Explanations for the real effects of unanticipated exchange rate changes through this channel can be synthesized as follows. Domestic firms in developing countries have difficulties borrowing or lending in the local currency because of market imperfections or poorly developed financial markets. This encourages foreign currency borrowing and, because domestic firms' assets are predominantly in the local currency, creates a currency mismatch. When liabilities are in foreign

1. See, for example, Flood and Hodrick (1986), Turnovsky (1985), and Flood and Marion (1982). For an interesting analysis of the causes and consequences of exchange market volatility see Rogoff (1998).
2. Velasco (2000) provides an insightful analysis of exchange-rate policies in developing countries. For an overview of the causes of the recent Asian currency and financial crisis, see Corsetti, Pesenti, and Roubini (1998). Kwack (1998, 2000) provides discussion of the factors contributing to the financial crisis in South Korea and six additional countries in Asia.
3. The costs can also result from the use of imported intermediate inputs or the effect of exchange rate uncertainty on trade and investment. When domestic firms use imported intermediate inputs, unanticipated currency depreciations lead to an increase in the cost of production and a decrease in domestic output. One might wonder why domestic firms in emerging markets do not hedge against exchange rate risk. According to Eichengreen and Hausmann (1999), these firms lack the capacity, rather than the incentive, to hedge because foreign investors are willing to lend only in their own currency. Calvo (2002) examines the case for dollarization in emerging markets. Honig(2004) examines the link between exchange rate regimes, dollarization and government quality.

currencies while assets are in the local currency, sharp and unexpected exchange rate depreciations deteriorate bank and corporate balance sheets, threaten the stability of the domestic financial system, and depress economic activity.[4]

The potentially destabilizing effect of sharp and unanticipated exchange rate movements owing to the dollarization of liabilities, has led some economists to take the view that a fixed exchange rate system may be the appropriate regime for emerging markets. Proponents of flexible exchange rate regimes, however, argue that this line of reasoning does not consider the fact that the dollarization of liabilities is, in part, a consequence of the choice of exchange rate regimes. In a fixed exchange rate regime, the government guarantees to buy and sell foreign exchange at a predetermined price. This opens-up a source of moral hazard, promotes unhedged, short-term, foreign-currency borrowing and hence increases firms' vulnerability to exchange rate fluctuations.[5]

Given the policy challenges posed by the dollarization of liabilities, its role in triggering and magnifying the real effects of exchange rate crises, and the costs of these crises in emerging markets, it is necessary to examine the extent to which the incorporation of the real effects of unanticipated exchange rate movements into open-economy rational expectations models affects the choice of regime in emerging markets. We attempt to address this issue using a rational expectations speculative attack model that allows us to evaluate the performance of an economy under three exchange rate regimes: a credibly fixed rate, a collapsing fixed rate, and a flexible rate regime. While a wide spectrum of exchange rate regimes can be incorporated, the three regimes considered are sufficient to capture the main features of observed exchange rate regimes in emerging markets.

Uncertainty enters the model in the form of a foreign interest rate (or capital flow) shock, a domestic monetary shock, and a domestic real demand shock. By introducing a foreign interest rate shock we allow for international capital movements and mirror the observation that the

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4. In theory, an unanticipated real exchange rate depreciation has, simultaneously, a positive and a negative effect on output in an economy. On the one hand, it decreases output owing to the phenomenon of liability dollarization. On the other hand, it stimulates economic activity by increasing the international competitiveness of domestic industries.
5. See Obstfeld (1998) for a link between fixed exchange rate regimes and moral hazard.

volatility of capital flows is a major characteristic of emerging market economies (see Calvo, 1999). The model also incorporates the phenomenon of currency substitution. This is important because it is a feature of emerging markets, especially those in Latin America. In addition, it is a potential source of currency-denomination mismatch and hence has implications for the choice of exchange rate regime. Currency substitution is typically associated with the existence of a large stock of foreign-exchange deposits that may lead to an increase in foreign-currency-denominated loans because banks in emerging markets are often subject to regulations that require them to lend in the same currency in which they are funded (see Calvo, 1999). When these loans are made predominantly to firms in the non-traded goods sector it creates a currency mismatch.

This paper is organized as follows. Section 2 describes the basic structure of the model. Section 3 solves the model for credibly fixed and flexible rate regimes. Section 4 presents the calibration and simulation of the model using parameters of the South Korean economy, and section 5 focuses on the case of collapsing fixed-rate regimes. We consider an alternative method of incorporating the real effects of unanticipated exchange rate changes in section 6 and conclude the paper in section 7.

2. The model

There are at least two ways to incorporate the real effects of unanticipated changes in real or nominal exchange rates, owing to liability dollarization, into traditional models of exchange rate regimes. One is to have a loss function that depends explicitly on the variance of real output and the variance of the real exchange rate. The other is to have a loss function that depends on the variance of real output but in which real output depends, among other factors, on the deviation of actual from expected changes in the real exchange rate. In this section, we focus on the latter; we explore the implications of the former approach in section 6.

It is well known in the literature that nominal price stickiness is needed in an economy for the choice of an exchange rate regime to matter. To capture this feature, we adopt an exchange rate model in which nominal prices of domestic goods are predetermined and output is demand determined. Our framework draws on the illuminating work of Flood and Hodrick (1986).[6]

However, it differs from the Flood and Hodrick paper in five respects that have important implications for the choice of an exchange rate regime: first, we take seriously the issue of real exchange rate volatility by incorporating a channel through which unanticipated exchange rate movements could have real effects in emerging markets; second, we allow for currency substitution which, as indicated earlier, is a potential source of currency denomination mismatch and has implications for the choice of exchange rate regime; third, we allow the real interest rate to affect aggregate demand, thereby creating a channel through which international capital movements can have real effects; fourth, the demand for money has a positive income elasticity and hence opens the standard channel through which exchange rate movements can stabilize output in response to real shocks; and, finally, our choice of calibration parameters is based on empirical evidence.[7]

The principal equations of our model are described below. All parameters are positive and all variables (except interest rates) are in logarithms. Let s_t denote the nominal exchange rate, p_t the price of the domestic good, p_t^* the price of the foreign good, i_t the domestic nominal interest rate, Π_t the rate of inflation, E_{t-1} the expectation operator conditional on information available in period $t-1$, and Δ the first difference operator.[8]

Our description of the structure of the economy begins with the market for domestic output. In equation (1), aggregate demand or output y_t depends on the level of the real exchange rate $(q_t = p_t^* + s_t - p_t)$, through standard trade channels;[9] the deviation of actual from expected

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6. Osakwe and Schembri (2002) used a similar model to examine the choice of regimes in Mexico. Their framework however does not incorporate the effect of exchange rate volatility on real output and hence the choice of regimes. Furthermore, they did not allow for the effects of currency substitution.
7. There are other differences between our model and that of Flood and Hodrick. For example, in computing the probability of a regime collapse, we assume that the weighted sum of the shocks follow a normal, as opposed to a uniform, distribution.
8. To simplify the analysis, we assume that the price of the foreign good is constant.
9. By allowing aggregate demand and output to depend on q_t, we implicitly assume, as in the standard literature, that real exchange rate depreciations have a positive effect on output through trade channels. This is consistent with the traditional view that an unanticipated real exchange rate depreciation increases demand for domestic goods, and hence domestic output, by making exports less expensive and imports more expensive. More information on the expenditure-switching effects of exchange rate depreciations can be found in Guitian (1976). Dungey (2004) provides empirical evidence on the relationship between real exchange rates and terms of trade for six Asian economies.

changes in the real exchange rate $(q_t - E_{t-1}q_t)$, through liability dollarization;[10] the real interest rate $(i_t - E_t\Pi_{t+1})$, through investment channels; and a real demand shock, u_t.

$$y_t = \beta q_t - \theta(q_t - E_{t-1}q_t) - \lambda(i_t - E_t\Pi_{t+1}) + u_t \tag{1}$$

The process of price determination is represented in equation (2). It states that prices are predetermined such that expected demand or output $E_{t-1}y_t$ is equal to full employment output, $\bar{y}$.

$$E_{t-1}y_t = \bar{y} \tag{2}$$

Without loss of generality, we normalize the level of full employment output to 1 so that its logarithm $\bar{y} = 0$. Equation (3) is the world capital market equilibrium condition. It states that the domestic interest rate is equal to the foreign interest rate, i^*_t, plus the expected rate of currency depreciation $(E_t s_{t+1} - s_t)$. To introduce international capital flows into the model, we assume, in equation (4), that the foreign interest rate is made up of a constant and a foreign interest rate (or capital flow) shock, x^*_t.[11]

$$i_t = i_t^* + E_t s_{t+1} - s_t \tag{3}$$

$$i_t^* = i^* + x_t^* \tag{4}$$

In equation (5), real money demand, m_t^d, depends on the domestic nominal interest rate, through the portfolio motives; aggregate output, through transaction demands; the expected rate of depreciation of the domestic currency, through currency substitution motives; and a money demand shock, v_t. The money-supply definition is represented by equation (6). Domestic money supply consists of a domestic credit component, d_t, and an international reserves component, r_t.

10.Note that $\Delta q_t - E_{t-1}\Delta q_t = q_t - E_{t-1}q_t$. This method of introducing the real effects of unanticipated exchange rate changes implies that depreciations and appreciations have symmetric effects on output.

11. In this model the foreign interest rate is exogenous. Consequently, there is no difference between a foreign interest rate (or capital flow) shock and a risk premium shock.

In equation (7), domestic credit is assumed to grow at a constant (exogenous) rate. This is the main reason for the collapse of a fixed exchange rate regime in the model. The final equation of the model is the money market equilibrium condition in equation (8):

$$m_t^d - p_t = \gamma y_t - \alpha i_t - \varphi(E_t s_{t+1} - s_t) + v_t \quad (5)$$

$$m_t^s = \psi d_t + (1-\psi) r_t \quad (6)$$

$$\Delta d_t = \mu \quad (7)$$

$$m_t^d = m_t^s . \quad (8)$$

The shocks x_t^*, u_t, and v_t are assumed independent and serially uncorrelated, with means zero and variances $\sigma_{x^*}^2$, σ_u^2, and σ_v^2 respectively.[12] Following the literature, we define the optimal exchange rate system as the exchange rate regime that minimizes the variance of real output conditional on information available in period $t-1$. Using equations (1) - (4) we can show that the general expression for the conditional variance of output in the model is

$$V(y_t) = (\beta+\lambda-\theta)^2 V(s_t) + 2(\beta+\lambda-\theta)[CV(s_t, u_t) - \lambda CV(s_t, x_t^*)] + \lambda^2 V(x_t^*) + V(u_t) \quad (9)$$

where V and CV are, respectively, the variance and covariance operator conditional on information available in period $t-1$. In equation (9), the first term, $(\beta+\lambda-\theta)^2 V(s_t)$, is the direct effect of exchange rate fluctuation on the variance of output. The second term, $2(\beta+\lambda-\theta)[CV(s_t, u_t) - \lambda CV(s_t, x_t^*)]$, is the indirect effect of exchange rate fluctuation on the variance of output owing to the covariance between the exchange rate and the shocks. The third term, $\lambda^2 V(x_t^*)$, is the contribution of the foreign interest rate shock to the variance of output, and the last term, $V(u_t)$, is the contribution of the real demand shock to the variance of output.

12. Introducing correlations between shocks will make the model less tractable without adding any significant insights.

3. Credible regimes

The solution of the model depends on the prevailing exchange rate regime. In this section we focus on credibly fixed and flexible exchange rate regimes. In a flexible exchange rate regime, the nominal exchange rate is endogenous and the level of international reserves is constant, $(r_t = \bar{r})$. Equations (1) - (8) can be solved for the nominal exchange rate using the method of undetermined coefficients.[13] The solution is

$$s_t = b_0 + b_1 d_{t-1} + b_2 x^*_t + b_3 u_t + b_4 v_t \tag{10}$$

$$b_0 = \left(\frac{\lambda(\psi - 1) + \beta\psi(1 + \alpha + \varphi)}{\beta}\right)\mu + (1 - \psi)\bar{r} - p^* + (\alpha + \lambda/\beta)i^* \tag{11}$$

$$b_1 = \psi \tag{12}$$

$$b_2 = \frac{\alpha + \gamma\lambda}{\gamma(\beta + \lambda - \theta) + \alpha + \varphi} \tag{13}$$

$$b_3 = -\left(\frac{\gamma}{\gamma(\beta + \lambda - \theta) + \alpha + \varphi}\right) \tag{14}$$

$$b_4 = -\left(\frac{1}{\gamma(\beta + \lambda - \theta) + \alpha + \varphi}\right) \tag{15}$$

Lemma 1. If $\theta < (\beta + \lambda + (\alpha + \varphi)/\gamma)$, then $b_2 > 0$; $b_3 < 0$; and $b_4 < 0$.

Lemma 1 follows from equations (13) - (15). It establishes a necessary condition for the correlations between the nominal exchange rate and each shock in the model to have the expected signs. Economic theory predicts that a positive foreign interest rate shock depreciates the domestic currency while either a positive real demand or domestic money demand shock results

13. To obtain a solution for the nominal exchange rate, note that expected inflation is equal to the constant rate of monetary growth.

in a currency appreciation. For the rest of the analysis, we assume that the condition in Lemma 1 is satisfied.

Letting $\varepsilon_t = b_2 x^*_t + b_3 u_t + b_4 v_t$, we can show, using equations (9) and (10), that the specific expression for the conditional variance of output in a flexible exchange rate regime is

$$V(y_t)\big|_{FLEX} = (\beta + \lambda - \theta)^2 \sigma_\varepsilon^2 + 2(\beta + \lambda - \theta)[b_3 \sigma_u^2 - \lambda b_2 \sigma_{x^*}^2] + \lambda^2 \sigma_{x^*}^2 + \sigma_u^2 \tag{16}$$

Under a credibly fixed exchange rate regime, the nominal exchange rate is fixed $(s_t = \bar{s})$ and the level of international reserves is endogenous. In this case, the variance of output is independent of the exchange rate. Furthermore, a fixed exchange rate regime completely eliminates the real effects of shocks to the demand for money, so that the variance of output is also independent of such shocks. This result can be ascribed to the fact that under a fixed exchange rate regime the monetary authority is required to satisfy all money demand shifts through non-sterilized foreign exchange interventions. Therefore, the conditional variance of output under a credibly fixed-rate regime is simply

$$V(y_t)\big|_{FIX} = \lambda^2 \sigma_{x^*}^2 + \sigma_u^2 \tag{17}$$

Proposition 1. *If unanticipated exchange rate movements have real effects in an economy owing to the dollarization of liabilities, a necessary condition for a flexible-rate regime to dominate a fixed-rate regime is that* $\theta < \beta + \lambda$. *When* $\theta = \beta + \lambda$ *there is regime indifference and when* $\theta > \beta + \lambda$ *a fixed rate regime dominates a flexible-rate regime.*

The intuition behind Proposition 1 is as follows. Under a credibly fixed-rate regime the only sources of output volatility are the foreign interest rate and real demand shocks. Under a flexible rate regime, however, exchange rate fluctuation is an additional source of output volatility. Therefore, the optimal regime depends on whether or not exchange rate fluctuation increases or decreases output volatility. The total effect of exchange rate fluctuations on output volatility has two parts: (i) the direct effect of exchange rate fluctuation on output volatility, which is always positive, and (ii) an indirect covariance effect owing to the fact that the exchange rate responds to shocks. The magnitude and sign of the covariance effect depends on: the covariance between the exchange rate and the foreign interest rate shock $CV(s_t, x_t^*)$; the covariance between the exchange rate and the real demand shock $CV(s_t, u_t)$; and the marginal effect of a change in the nominal exchange rate on the level of output $(\beta + \lambda - \theta)$. From equations (10), (13), (14) and Lemma 1, the covariance between the exchange rate and the real demand shock is negative, while the covariance between the exchange rate and the foreign interest rate shock is positive. Therefore, the ultimate sign of the covariance effect depends on $(\beta + \lambda - \theta)$.

For $\theta < \beta + \lambda$ the marginal effect of a change in the exchange rate on the level of output is positive, implying that the covariance effect is negative. A negative covariance effect opens up the channel through which exchange rate changes could stabilize output because it dampens the direct effect of exchange rate variability on output volatility. However, it does not guarantee that the covariance effect will dominate the direct effect. Therefore, $\theta < \beta + \lambda$ is a necessary, but not a sufficient, condition for a flexible regime to dominate a fixed regime. Whether the covariance effect dominates the direct effect will depend on the relative size as well as the nature of shocks that buffett an economy. In economies in which domestic real shocks are quantitatively more important than nominal shocks, the indirect covariance effect will generally dominate the direct effect, so output will be less volatile in a flexible-rate regime. In contrast, if domestic monetary shocks are quantitatively more important than real shocks, a fixed-rate regime will dominate a flexible-rate regime.

For $\theta = \beta + \lambda$ the marginal effect of exchange rate changes on the level of output is zero. In this case, output volatility is the same under both credibly fixed-rate and flexible-rate regimes, resulting in regime indifference. For $\theta > \beta + \lambda$ the marginal effect of exchange rate changes on the level of output is negative, implying that the indirect covariance effect is positive. This positive covariance effect magnifies and reinforces the direct positive effect of exchange rate variability, thereby shutting off the channel through which the exchange rate insulates an economy. Consequently, a credibly fixed-rate regime unambiguously dominates a flexible-rate regime if the parameter capturing the real effect of unanticipated changes in the exchange rate is greater than the sum of the parameters on the level of the real exchange rate and the real interest rate.

These results are interesting because, on the one hand, they confirm the view in the literature that unanticipated exchange rate changes owing to the dollarization of liabilities, have implications for the choice of exchange rate regimes in emerging markets. On the other hand, they suggest that the parameter capturing the real effect of unanticipated exchange rate changes would have to be quite large for this effect to alter the conventional view that a flexible-rate regime generally dominates a fixed-rate regime. Furthermore, these results link the choice of exchange rate regimes to three parameters that can be directly estimated: the elasticities of output with respect to the level of the real exchange rate, the semi-elasticity of output with respect to the real interest rate and, the elasticity of output with respect to unanticipated exchange rate changes. The first and second parameters are also the weights in monetary conditions indices used by some central banks in small open economies in the design of monetary policy (see Freedman 1995).

4. Calibration and simulation

To shed more light on the implications of liability dollarization for the choice of regimes in emerging markets, we conducted a simulation exercise using parameters of the South Korean economy.[14] Kwack (1998) provides an interesting overview and analysis of the South Korean economy as well as factors that contributed to the exchange rate crisis of 1997. As in any calibration exercise, it is necessary to justify the choice of parameters. Our choice of the money demand parameters is based on Qin's (1998) estimates for South Korea. Accordingly, we set the income elasticity of money demand, γ, to 0.753, the semi-interest elasticity of money demand, α, to 0.016, and the currency substitution parameter, φ, to 0.488. The simulations assumed that the shocks follow a standard normal distribution. Consequently, each shock has unit variance.[15]

14. Although South Korea was chosen owing to data availability, it is also an interesting case because it is one of the emerging-market economies in which domestic firms have high foreign-currency-denominated debt (see Corsetti, Pesenti, and Rubini 1998). Furthermore, of the Asian countries seriously affected by the recent currency crisis, it is the only country that is a member of the Organisation for Economic Co-operation and Development (OECD).

For the aggregate demand or output equation, there are no readily accessible parameter estimates for the South Korean economy. Therefore, equation (1) was estimated to obtain values for these parameters. Estimation of this equation raises a statistical question regarding how to deal with the fact that the unanticipated real exchange rate variable $(q_t - E_{t-1}q_t)$ is not observable. To generate series for this variable, the following procedure was adopted. In the model, the expected real exchange rate can be expressed as $E_{t-1}q_t = (p_t^* + E_{t-1}s_t - p_t)$. Furthermore, from the world capital market equilibrium condition in equation (3), the expected nominal exchange rate is $E_{t-1}s_t = (i_{t-1} - i_{t-1}^* + s_{t-1})$. Consequently, the expected nominal exchange rate was computed using data on the nominal exchange rate and the nominal interest rate differential between the domestic and the foreign economy.[16] With data on the expected nominal exchange rate, the expected real exchange rate was computed by adjusting the expected nominal exchange rate using data on foreign and domestic prices. The expected real exchange rate series obtained through this procedure was then used to construct the variable $(q_t - E_{t-1}q_t)$. In the literature, there is emphasis on the fact that real exchange rate depreciations are particularly destabilizing when they are large and unanticipated.[17] To capture this idea, empirically, we used the variable $(q_t - E_{t-1}q_t)$ to generate a dummy variable for large and unanticipated depreciations of the real exchange rate. The dummy takes a value of 1 when the change in $(q_t - E_{t-1}q_t)$ is 0.5 standard deviations above the mean and zero otherwise.[18]

Equation (1) was estimated using annual data for the South Korean economy spanning the period 1966 to 1998. Real output and the real interest rate are in first differences because unit root tests suggest that they are non-stationary. The other variables are stationary and thus are in levels. The estimation uses both contemporaneous and lagged values of the real exchange rate and the real

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15. We used a standard normal distribution because we had no data on the relative variances of the shocks for South Korea. In addition, to compute the probability of a regime collapse, in section 5, we assumed that the shocks follow a normal distribution. Therefore, our use of a standard normal distribution here is also for consistency.
16. The uncovered interest parity condition is widely used in open-economy models.
17. For example, Calvo (1999) argues that "recent financial crisis episodes show that sharp changes in the real exchange rate can cause serious financial damage, especially when those changes reflect a large unanticipated component."
18. A sensitivity analysis was conducted on the threshold used but there was no significant difference in the results. The nominal exchange rate used is the Korean-U.S. bilateral nominal exchange rate defined such that an increase represents a depreciation of the domestic currency. See the Appendix for a description of the sources of data.

interest rate so as to capture lags in, for example, the transmission of monetary policy.[19] The general-to-specific specification strategy was used to determine the number of lags. The final specification, reported in Table 1, includes contemporaneous values of the three explanatory variables as well as one-period lags of the real exchange rate and the real interest rate.

Column two of Table 1 contains results of an ordinary-least-squares (OLS) estimation of equation (1). The estimated coefficients are all of the expected signs and are significant at conventional levels. Because of the potential endogeneity of the explanatory variables, the equation was also estimated using an instrumental variable method.[20] The results are presented in column three of Table 1. Accounting for possible endogeneity of the regressors did not change the results significantly. All explanatory variables remained significant and correctly signed. According to the estimates, the elasticity of output with respect to the level of the real exchange rate, β, is 0.087, the semi-interest elasticity of output, λ, is 0.010, and the elasticity of output with respect to unanticipated exchange rate changes, θ, is 0.029.

Table 2 contains a complete list of all calibration parameters. Results of the simulations are presented in Table 3. Clearly, output volatility is lower under a flexible-rate regime. The results suggest that, for South Korea, the phenomenon of liability dollarization does not invalidate the conventional view that a flexible exchange rate regime dominates a fixed-rate regime.

5. Collapsing regimes

A major disadvantage of fixed exchange rate regimes is that they are subject to speculative attacks. These attacks could occur due to an inconsistency in policy, as in first-generation currency crises models (Krugman, 1979), or self-fulfilling prophecies, as emphasized in second-generation models (Obstfeld, 1996; Velasco, 1996). In this section, we introduce more realism

19. Stiglitz (2000) argues that it takes twelve to eighteen months before the full effects of a change in monetary policy are realized in an economy.
20. The instruments used are a constant term and lagged values of the growth rate of population in Korea, the growth rate of real output in Japan, the growth rate of real output in the U.S., and the U.S. real interest rate.

into the model by assuming that the monetary authority cannot maintain a fixed exchange rate regime indefinitely because it has limited foreign exchange reserves with which to resist a speculative attack on the currency and is unwilling to raise the interest rate sufficiently high to defend against an attack.

To obtain an expression for the conditional variance of output under a collapsing exchange rate regime, we need to know the probability of a regime collapse. Assuming, as in the literature, that the collapse takes the form of a switch to a flexible exchange rate regime, we can solve the model for the shadow exchange rate, $\hat{s}$. This is the rational expectations money-market-clearing rate that would prevail if there were a successful speculative attack on the domestic currency. To find the path of the shadow exchange rate, we assume that the monetary authority abandons the fixed-rate regime when reserves reach a lower bound $(\hat{r})$, and then solve equations (1) through (8) for the shadow exchange rate using the method of undetermined coefficients. The solution is

$$\hat{s}_t = \hat{b}_0 + b_1 d_{t-1} + b_2 x_t^* + b_3 u_t + b_4 v_t \tag{18}$$

$$\hat{b}_0 = \left(\frac{\lambda(\psi-1) + \beta\psi(1+\alpha+\varphi)}{\beta}\right)\mu + (1-\psi)\hat{r} - p^* + (\alpha + \lambda/\beta)i^* \tag{19}$$

where b_1, b_2, b_3 and b_4 are as defined in equations (12) to (15). The introduction of the possibility of a regime collapse implies that the expectation in period $t-1$ of the exchange rate that will prevail in period t is a weighted average of the current fixed exchange rate, $\bar{s}$, and the expected shadow exchange rate conditional on a collapse, $E_{t-1}(\hat{s}_t | Collapse)$. If we let Γ denote the probability of a speculative attack in period t based on information available in period $t-1$, then

$$E_{t-1}s_t = (1-\Gamma_{t-1})\bar{s} + \Gamma_{t-1}E_{t-1}(\hat{s}_t | Collapse) \tag{20}$$

Because the monetary authority's commitment to a fixed rate gives speculators unrestricted access to foreign exchange reserves, speculators can make profits by attacking the currency when $\hat{s} > \bar{s}$. For $\hat{s} < \bar{s}$ speculators would incure losses if they attack the currency. This suggests that an attack will occur only in circumstances in which the shadow exchange rate exceeds the fixed rate.

Therefore, the probability of a speculative attack equals the probability that the shadow exchange rate exceeds the fixed rate. That is $\Gamma_{t-1} = Pr\{\hat{s}_t > \bar{s}\}$, where Pr denotes probability. Using the solution for the shadow exchange rate in equation (18), the probability of a speculative attack can be expressed as

$$\Gamma_{t-1} = Pr\{b_2 x^*_t + b_3 u_t + b_4 v_t > \bar{s} - \hat{b}_0 - b_1 d_{t-1}\} \equiv Pr(\varepsilon_t > a_{t-1}) \tag{21}$$

where $\varepsilon_t = b_2 x^*_t + b_3 u_t + b_4 v_t$ and $a_{t-1} = \bar{s} - \hat{b}_0 - b_1 d_{t-1}$. To provide a more specific solution for the probability expression in equation (21) we need to know the joint distribution of the sum of the random shocks, ε_t. This is a difficult exercise because, in general, each of the three shocks may be characterised by different statistical distributions. Three obvious possibilities are a normal, a uniform, and an exponential distribution. For the rest of the analyses, we assume that the random variables are normally distributed with zero means and variances $\sigma^2_{x^*}$, σ^2_u, and σ^2_v. The normal distribution assumption is appropriate for two reasons: (i) it is analytically tractable and allows us to use the result that the sum of normally distributed random variables is also normally distributed, and (ii) it is likely to be a better proxy for the distribution of the shocks in our model than either the exponential or the uniform distribution.[21] The normality assumption implies that the probability density function for ε_t is

$$f(\varepsilon) = \frac{1}{\sigma_\varepsilon \sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{\varepsilon}{\sigma_\varepsilon}\right)^2\right] \qquad -\infty \le \varepsilon \le \infty \tag{22}$$

In equation (21), a speculative attack occurs when $\varepsilon_t > a_{t-1}$. Therefore, for the normal distribution, the probability of a speculative attack can be obtained by integrating equation (22) over the interval in which $\varepsilon_t > a_{t-1}$. The resulting expression is

$$\Gamma_{t-1} = \frac{1}{\sigma_\varepsilon \sqrt{2\pi}} \int_{a_{t-1}}^{\infty} \exp\left[-\frac{1}{2}\left(\frac{\varepsilon}{\sigma_\varepsilon}\right)^2\right] d\varepsilon \tag{23}$$

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21. For example, using an exponential distribution is tantamount to assuming that the shocks buffetting an economy are positive. This is an unjustifiable assumption, because the type of shocks applied to the model can take either positive or negative values. The two-sided exponential distribution does not suffer from this defect. However, it is less tractable and, for the exercise conducted here, has no obvious advantage over the normal distribution.

where the unconditional mean of the random variable ε is zero and its unconditional variance is $\sigma_{\varepsilon}^2 = b_2^2\sigma_{x*}^2 + b_3^2\sigma_u^2 + b_4^2\sigma_v^2$. Using equations (9), (18), (20), (22) and (23), we obtain a specific expression for the conditional variance of output in a fixed exchange rate regime that is expected to collapse.[22]

$$V(y_t)\big|_{CFIX} = (\beta + \lambda - \theta)^2 H + 2(\beta + \lambda - \theta)K_1 + \lambda^2\sigma_{x*}^2 + \sigma_u^2 \tag{24}$$

$$H \equiv [a_{t-1}\Gamma_{t-1}Z + (\sigma_{\varepsilon}^2 - Z^2)\Gamma_{t-1}^2]$$

$$Z \equiv \left[a_{t-1} - \frac{\sigma_{\varepsilon}}{\sqrt{2\pi}}\exp\left(-\frac{1}{2}\left(\frac{a_{t-1}}{\sigma_{\varepsilon}}\right)^2\right)\right]$$

$$K_1 \equiv \Gamma_{t-1}(b_3\sigma_u^2 - \lambda b_2\sigma_{x*}^2)$$

In principle, equations (16), (17) and (24) could be compared to determine which exchange rate regime has a lower output variance. However, because the expression in equation (24) is complicated, a direct analytical comparison is difficult. To permit a comparison of the conditional variance of output under alternative regimes, we conducted a simulation exercise. The parameter values used in the simulations are the same as in Table 2.

For the simulations, we chose different values for the truncation point a_{t-1} and generated the conditional variance of output under each exchange rate regime. Figure 1 shows the conditional variance of output under the three exchange rate regimes as a function of the truncation point. Output volatility is higher under a credibly fixed exchange rate regime. Furthermore, the volatility of output in a collapsing fixed regime lies between the volatility of output in credibly fixed and flexible regimes.[23] When the truncation point is high, the probability of a regime collapse is low (see equation 21). Consequently, the volatility of output under a collapsing fixed-rate regime is close to that of a credibly fixed-rate regime. In contrast, when the truncation point is low, the

22. Note that this requires calculating the moments of a truncated distribution. For a statistical treatment of this issue, see Greene (2000), page 898.

probability of a regime collapse is high and the volatility of output under a collapsing regime approaches that of a flexible-rate regime.

6. An alternative loss function

In the previous sections we incorporated the real effects of unanticipated changes in exchange rates directly in the aggregate demand or output function. This section focuses on an alternative approach based on the specification of the loss function. Here, we recognise the real effects of unanticipated exchange rate changes indirectly by assuming that the monetary authority puts some weight on the variance of output as well as the variance of the real exchange rate.[24] The analysis in this section focuses exclusively on credibly fixed-rate and flexible-rate regimes. We do not analyse the case of a collapsing regime because, as demonstrated in section 5, its conditional variance of output generally lies between the conditional variances of output in a credibly fixed-rate and flexible-rate regimes.

Letting η denote the relative weight on the variance of the real exchange rate, the loss function can be written as[25]

$$L = V(y_t) + \eta V(q_t) \qquad \eta \geq 0 \tag{25}$$

Introducing policy-makers' concern for real exchange rate volatility in the loss function requires modifying the aggregate demand or output function in equation (1) because, in this case,

23. In Flood and Hodrick (1986), a flexible-rate regime has a higher output volatility than a credibly fixed rate regime. Consequently, the volatility of output in a collapsing fixed rate regime lies below that of a flexible rate regime. Our results differ from those of Flood and Hodrick because we allow the real interest rate to affect aggregate demand and the income elasticity of money demand is positive. By setting these key parameters to zero, Flood and Hodrick eliminate important channels through which exchange rate movements could stabilize output.

24. Political factors may motivate inclusion of the variance of the real exchange rate in the loss function.

25. To reduce notations, we use the same symbols as in section 2 except where this could cause confusion.

aggregate demand does not depend on the unanticipated real exchange rate variable. The modified aggregate demand function takes the form:

$$y_t = \beta q_t - \lambda(i_t - E_t\Pi_{t+1}) + u_t \tag{26}$$

Given our assumptions, the general expressions for the variances of output and the real exchange rate are simply

$$V(y_t) = (\beta+\lambda)^2 V(s_t) + 2(\beta+\lambda)[CV(s_t, u_t) - \lambda CV(s_t, x_t^*)] + \lambda^2 V(x_t^*) + V(u_t) \tag{27}$$

$$V(q_t) = V(s_t) \tag{28}$$

In equation (28) the variance of the real exchange rate is equal to the variance of the nominal exchange rate. This follows from the fact that $(q_t = p_t^* + s_t - p_t)$ and the assumption that the price of the domestic good is predetermined while the price of the foreign good is constant. It is consistent with the empirical observation that a large fraction of real exchange rate movements can be explained by nominal exchange rate fluctuations (Obstfeld and Rogoff, 1996). To obtain specific expressions for the variances of output and the real exchange rate under the two exchange rate regimes, we need to solve the model for the nominal exchange rate. Following the same procedure as in section 3, the solution for the nominal exchange rate is

$$s_t = g_0 + g_1 d_{t-1} + g_2 x_t^* + g_3 u_t + g_4 v_t \tag{29}$$

$$g_0 = \left(\frac{\lambda(\psi-1) + \beta\psi(1+\alpha+\varphi)}{\beta}\right)\mu + (1-\psi)\bar{r} - p^* + (\alpha + \lambda/\beta)i^* \tag{30}$$

$$g_1 = \psi \tag{31}$$

$$g_2 = \frac{\alpha + \gamma\lambda}{\gamma(\beta+\lambda) + \alpha + \varphi} \tag{32}$$

$$g_3 = -\left(\frac{\gamma}{\gamma(\beta+\lambda) + \alpha + \varphi}\right) \tag{33}$$

$$g_4 = -\left(\frac{1}{\gamma(\beta+\lambda)+\alpha+\varphi}\right) \tag{34}$$

Using equations (27) to (29) and the definition $\sigma_s^2 = g_2^2\sigma_{x*}^2 + g_3^2\sigma_u^2 + g_4^2\sigma_v^2$, we can show that

$$V(q_t)|_{FLEX} = \sigma_s^2 \tag{35}$$

$$V(y_t)|_{FLEX} = (\beta+\lambda)^2\sigma_s^2 + 2(\beta+\lambda)[g_3\sigma_u^2 - \lambda g_2\sigma_{x*}^2] + \lambda^2\sigma_{x*}^2 + \sigma_u^2 \tag{36}$$

$$V(q_t)|_{FIX} = 0 \tag{37}$$

$$V(y_t)|_{FIX} = \lambda^2\sigma_{x*}^2 + \sigma_u^2 \tag{38}$$

Using equations (35) through (38), in (25), we obtain the welfare loss under a credibly fixed-rate and flexible-rate regimes:

$$L_{FLEX} = V(y_t)|_{FLEX} + \eta V(q_t)|_{FLEX} \tag{39}$$

$$L_{FIX} = V(y_t)|_{FIX} + \eta V(q_t)|_{FIX} \tag{40}$$

To evaluate the performance of the economy under the two exchange rate regimes, we chose values for the money demand and aggregate demand parameters, as well as the variances of the shocks, and then used a grid search procedure to find the critical value of η that would make the monetary authority indifferent between a credibly fixed-rate and a flexible-rate regime. For the money demand parameters as well as the shocks, we used the same values as in section 3. For the aggregate demand or output parameters, we estimated equation (26) using the change in real output as the dependent variable. We chose the contemporaneous and one-period lags of the level of the real exchange rate and the change in the real interest rate as explanatory variables. The regression results are presented in column four of Table 1. All coefficients are of the expected signs and are significant at conventional levels. Based on the regression results, β is set to 0.103 and λ to 0.006.

The simulation results suggest that a flexible-rate regime dominates a credibly fixed-rate regime if the monetary authority puts a weight less than 0.05 on real exchange rate volatility in the loss function. There are no empirical studies on the weight that the central bank in South Korea puts on real exchange rate volatility. Consequently, it is difficult to make any conclusive statements regarding the optimal regime for South Korea, in this version of the model, because it requires a comparison of the critical value of η with the actual weight, which is not observable.

7. Conclusion

In the standard literature on the choice of exchange rate regimes, it is typically assumed that the objective of the monetary authority is to minimize the variance of real output. This implies that exchange rate volatility is costless. However, recent research has shown that sharp and unanticipated changes in real exchange rates in emerging markets have real costs owing to the dollarization of liabilities. This paper has examined the choice of exchange rate regime using a speculative attack model that took into account the real effects of unanticipated changes in real exchange rates. It also incorporated two features that played prominent roles in recent currency crises in emerging markets: currency substitution and volatile capital flows.

We considered two approaches to incorporating the real effects of unanticipated changes in exchange rates into standard models of the choice of exchange rate regimes are considered. In the first approach, the effects were introduced directly by assuming that the monetary authority's loss function depended exclusively on the variance of real output but that aggregate demand or output depended, among other factors, on the deviation of actual from expected changes in the real exchange rate. In this version of the model, we demonstrated that a necessary, but not a sufficient, condition for a flexible-rate regime to dominate either a collapsing or fixed-rate regime, in an economy buffetted by monetary, real demand and capital flow shocks, is that the parameter capturing the real effects of unanticipated exchange rate changes in the aggregate demand equation is less than the sum of the parameters on the level of the real exchange rate and the interest rate. An evaluation of the model using parameters of the South Korean economy suggested that a flexible-rate regime dominates a fixed-rate regime despite the existence of the phenomenon of liability dollarization.

In the second approach, the real effects of unanticipated exchange rate changes were incorporated indirectly by assuming that the monetary authority's loss function depended on the variance of real output as well as the variance of the real exchange rate. For the South Korean economy, simulations of this version of the model suggested that a flexible-rate regime dominates a fixed-rate regime in an economy buffetted by monetary, real demand, and capital flow shocks if the weight the monetary authority puts on real exchange rate volatility in the loss function is less than 0.05. Since there are no empirical studies on the weigth the central bank of South Korea puts on real exchange rate volatility, we cannot make any conclusive statements on the dominant regime in this version.

The analysis in this paper was conducted on the assumption that the main objective of the monetary authority is to minimize either the variance of real output or the variance of real output and the real exchange rate. We did not consider alternative objectives and other issues. For example, we did not consider the objective of the monetary authority focusing on increasing the short-run growth rate of the economy. Furthermore, we did not examine the relationship between exchange rate regimes and institutional arrangements.The importance of this type of study for emerging markets is noted in Calvo and Mishkin (2003). Hopefully, this and other issues will be the subject of future investigation.

Appendix: Data

The real exchange rate was computed using the Korea-U.S. bilateral nominal exchange rate, and Korean and U.S. Consumer Price Indices (CPI). These series were obtained from the International Financial Statistics (IFS). For the CPI series, 1995=100. The domestic real interest rate was computed using IFS data on Korean CPI and the Bank of Korea discount rate. The nominal interest rate differential was computed as the difference between the Bank of Korea discount rate and the U.S. discount rate. The latter was obtained from the IFS. Data on Real GDP for Korea and Japan were obtained from the World Bank database (CD-Rom). Those for the U.S. were obtained from Data Resources Incorporated (DRI). Data on population for Korea were taken from the IFS.

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Table 1: Real output regression results[a]

Dependent variable: Real output	OLS	Instrumental Variables	Instrumental Variables
Constant	-0.508[b] (0.270)*	-0.512 (0.309)	-0.624 (0.347)*
Real exchange rate[c]	0.087 (0.040)**	0.087 (0.045)*	0.103 (0.051)*
Dummy for large and unanticipated depreciations of the real exchange rate	-0.032 (0.011)***	-0.029 (0.014)**	
Real interest rate	-0.011 (0.003)***	-0.010 (0.004)***	-0.006 (0.003)*
$\bar{R}^2$	0.730	0.706	0.616
DW	2.264	2.273	2.048
Standard error of estimate	0.020	0.022	0.025

a. Real output and the real interest rate were found to be nonstationary and, hence, are in first differences in the estimated equations. Also, note that for the real exchange rate and the real interest rate, the estimates represent the sum of a linear combination of the contemporaneous and one lagged coefficient.
b. Standard errors in parenthesis. ***, **, and * indicate significance at 1, 5, and 10 percent level respectively.
c. An increase represents a depreciation of the domestic currency.

Table 2: Calibration parameters (Benchmark)

	Parameters
Money demand equation	$\gamma = 0.753$ $\varphi = 0.488$ $\alpha = 0.016$
Aggregate demand equation	$\beta = 0.087$ $\lambda = 0.010$ $\theta = 0.029$

Table 3: Simulation results for credible regimes

Variable	Volatility of Output
$V(y_t)\|_{FIX}$	1.00
$V(y_t)\|_{FLEX}$	0.84
Ratio[a]	1.19

a. This is the variance of output under a fixed regime divided by the variance of output under a flexible regime.

Figure 1: Output volatility under collapsing exchange rate regimes