Reserve Uncertainty and the Supply of International Credit

This paper shows that uncertainty about an emerging market’s international reserves can affect the willingness of foreign investors to supply international credits. We illustrate the relevance of this concern for South Korea. Uncertainty has asymmetric effects. When the expected reserve position of an emerging market is large relative to the potential bailout in bad states of nature, reserve volatility does not matter. However, the same amount of reserve volatility can cause a large reduction in the supply of international credit if the private sector seriously downgrades its priors about repayment possibilities or becomes more pessimistic about the emerging market’s reserve position.

In October 1997, turbulence in Hong Kong’s foreign exchange and equity markets spread rapidly to other emerging markets, including South Korea. By November, press reports reflected growing uncertainty about the size of Korea’s foreign currency reserve holdings. The Korean Finance ministry would not reveal how much the central bank had sold in dollar forward contracts. Also, there were rumors that the central bank would be unable to use a large share of its reserves because it had previously placed them with foreign branches of domestic banks that might fail if they were withdrawn. Uncertainty about the size of South Korea’s “usable” reserves contributed to the crisis atmosphere in which investors had to operate.

In this paper, we show that increased uncertainty about an emerging market’s foreign reserve position can have a potentially large adverse effect on the willingness of foreign investors to supply international credit. More generally, uncertainty about the ability of an emerging market to bail out foreign creditors, either with foreign reserves, an IMF rescue package, or real resources obtained through structural reforms, can reduce its ability to obtain international credit. As a result, it can contribute to the liquidity shortage often experienced by emerging markets during a crisis.

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We model an emerging-market economy where the private sector believes the domestic authority will use its international reserves to bail out foreign lenders. Reserve uncertainty interacts with uncertainty about the probability of a reserve-financed bailout in an asymmetric manner. When the expected reserve position of an emerging market is large relative to the potential bailout in a bad state of nature, reserve volatility does not matter. However, the same amount of reserve volatility can cause a large reduction in the offered supply of international credit when expected reserves are low. That is because it is more likely the government will be resource constrained in bad states of nature where it needs to finance large bailouts. The anticipated financing gap reduces the expected payoff to creditors and hence their willingness to supply credit.

The intuition for these results can best be understood by considering an options pricing example. From the perspective of bondholders, lending to a firm whose net worth fluctuates randomly is equivalent to purchasing the firm and selling a call option to its shareholders. Higher volatility in the firm’s net worth increases the value of the option and reduces the expected income of the lenders. The same mechanism operates here. Higher volatility in a country’s international reserves reduces the expected pay-out to foreign creditors and consequently their willingness to supply credit. It can magnify the severity of a crisis that has already begun.

Our model provides an analytical framework for interpreting international reserve patterns that might seem counterintuitive in the absence of the above asymmetry. For example, it offers one explanation for The Economist puzzle: “If central bank are so reluctant to intervene in foreign-exchange markets, why do they still hold so many reserves?” In terms of the Far East, the relatively high level of reserve holdings can be interpreted in the context of an implicit contract. For political economy reasons, the monetary authorities use international reserves to finance bailouts. Since reserve volatility can generate large costs in bad states, a government that anticipates turbulent future times will internalize these costs by maintaining a relatively large international reserve position. Our analysis also illustrates that the distinction between the country’s observed gross reserve position and the frequently unobserved net reserve position may help explain the puzzle raised by The Economist.

The South Korean experience during the Asian financial crisis illustrates the issues involved. In the summer of 1997, concern mounted about whether South Korea could withstand the financial crisis engulfing its Asian neighbors. South Korea’s official reserve position appeared strong. After having seen its reserves decline during the first quarter of 1997 following labor unrest and the Hanbo Steel bankruptcy, the

1. The moral hazard problem associated with domestic bailouts has been cited by various observers as a contributing factor in the Asian financial crisis. See Krugman (1998) and Corsetti, Pesenti, and Roubini (1999).

2. The Economist, September 21, 2000. The article also observed “global foreign-exchange reserves are at record levels, equivalent to 15 weeks of imports, more than twice as high as they were in the late 1960s under the Bretton Woods regime. . . Large reserves are not just unnecessary, they are also costly. It is rather as though a household with lots of cash sitting idle in a low-interest bank account was at the same time paying a much higher interest rate on its debts.”

3. Our analysis focuses on the positive aspects of the problem. We do not assert that the reserve patterns we observe are optimal from the overall welfare of the countries involved.
Bank of Korea reported a recovery in its reserve holdings during the second quarter. It announced that its May reserve holdings were almost $32 billion. It put its end-of-June holdings at $33.3 billion.

But over the summer and into the fall, there were rumors that South Korea’s central bank had built up considerable forward dollar liabilities by intervening in the forward market for won. In addition, stories circulated that the Bank of Korea was placing foreign-currency deposits with foreign branches of domestic Korean banks. It was not clear at the time whether this emergency short-term liquidity support for Korean banks was affecting official reserves. As it turned out, the severity of the liquidity pressures facing these banks meant that the central bank deposits could not be withdrawn. Consequently, the international reserves the Bank of Korea could use in a crisis were considerably less than its reported official reserves.

Indeed, the gap between South Korea’s “official” and “usable” reserves turned out to be sizeable. The International Monetary Fund later reported that while official Korean reserves fell from $31 billion to $24 billion between the end of October and early December 1997, usable reserves were only about $6 billion (Adams et al. 1998, p. 20). Figure 1 shows the growing gap between official and usable reserves as the crisis approached.

The Bank of Korea’s practice of placing deposits with foreign branches of domestic banks actually began in the late 1980s, but the discrepancy between official and usable reserves stayed relatively small through 1996. At the end of 1996, only 10 percent of official reserves were placed in such deposits, making the gap between official and usable reserves $3.8 billion. The discrepancy increased during 1997 as the Bank of Korea extended additional liquidity support to troubled off-shore branches of Korean banks. By the end of June 1997, the gap between official and usable reserves had grown to $8 billion. By the end of November, the gap had risen to $17 billion (BOK news releases 1998).

The size of the gap was unknown to investors when Thailand floated its currency on July 2, 1997, triggering the start of the Asian crisis. All investors had to go on were the reported official reserve figures and rumors that some of those reserves could not be accessed in case of an emergency. By early November, press speculation was rampant about whether Korea was in danger of depleting its foreign currency reserves.

Then on December 2, the Korean Finance Ministry reported to the IMF that the country had only $6 billion in usable foreign exchange reserves. On December 8, a leading Korean newspaper (the Chosun Ilbo) quoted a leaked IMF report as saying that South Korea’s usable reserves were just $6 billion. With financial markets in tur-

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4. The November 7, 1997, London edition of the Financial Times reported that Korea had $30.5 billion in foreign currency reserves at the end of October. This figure was the official number announced by the Bank of Korea. The newspaper went on to write: “The central bank has committed an unknown portion of its reserves to defend the won by selling dollar forward contracts . . . The finance ministry would not reveal how much the central bank has sold in dollar forward contracts . . . Estimates of Korea’s cost of defending the won range from $3bn to $15 bn. In spite of foreign investor demands that Korea give a clear picture of its foreign reserve commitments, [the director of international finance at the finance ministry] said it was under no obligation to do so.”

moil, the Korean Finance Ministry responded on December 10 to the leaks by distributing copies of its agreement with the IMF. It confirmed that usable reserves had fallen to $6 billion and revealed that usable reserves could fall to $3.2 billion by the end of the month. Only the day before, the Finance Ministry had said usable reserves would be $10 billion at month’s end. Adding to the confusion and alarm was the revelation that the IMF’s estimate of Korea’s short-term debts was $100 billion, not the $65 billion previously thought.6 The OECD later reported that “the lack of timely, reliable information on the state of (Korean) banks’ nonperforming loans, official foreign exchange reserves and foreign debt added to uncertainty” during this period (OECD 1998, p. 31).

Figure 2 shows data ultimately reported for official and usable reserves.7 In addition, it gives a forecast of Korean reserves assuming investors had used the Bank of Korea’s end-of-the-month announcement of official reserve holdings to construct their prediction of next month’s reserves.8 It also provides the 95 percent confidence

6. The December 10 Daily Telegraph reflected the market’s reaction to the revelations. It quoted one Citibank dealer as saying, “This is crazy. We are about to face an unprecedented crisis.” Another trader said, “There is a real danger the IMF package may not, after all, be enough and the presidential candidates’ contributions are not good.” The latter remark referred to the news that two of the three presidential candidates had indicated over the previous weekend they would renegotiate the IMF package, which could jeopardize the payments.

7. Some of the monthly observations in 1996 for usable reserves are unavailable, so missing data are obtained by extrapolation.

8. The forecast is based on the regression

\[ R_t^* = 0.4909 + 0.601 R_{t-1}^* - 0.0550 D_t \]

where \( R_t^* \) is the log of (US$ billion) officially reported reserves and \( D_t \) is a dummy variable that takes on the value one starting in August 1997. The standard errors on the intercept, slope coefficient and dummy variable are 0.2351, 0.0681, and 0.0255 respectively. The adjusted \( R^2 \) is 0.84 and Durbin’s \( h \)-statistic suggests that serial correlation is not a serious problem. The sample period is 95:2–97:9. The regression results indicate that investors originally forecast reserves to be somewhat less than 90 percent of the previous month’s announced reserves. The negative and significant coefficient on the dummy variable suggests that investors adjusted downward their estimate of Korea’s reserve position even before the Korean crisis became full-blown and the discrepancy between official and usable reserves was reported. As we shall see below, reserve volatility has a bigger effect on the supply of credit when reserves are low.
band surrounding that forecast. The September 1997 official reserve holdings represent the last available data for use in prediction prior to the start of the Korean financial crisis. For the period after September 1997, the forecast assumes investors continued to use the official September figure to predict reserves.

Note that the level of usable reserves, revealed publicly on December 8, 1997, was multiple standard deviations below the lower confidence band. For the next few months, usable reserves stayed much lower than any reasonable forecast. We thus have some suggestive evidence that reinforces the impression from press reports that the large drop in Korea’s available reserves came as a surprise to investors in December. Moreover, investors attached a higher variance to reserve announcements as the crisis engulfed Korea that December.

We now turn to a model to investigate the impact of this reserve uncertainty. Section 1 describes the model. Section 2 analyzes the effects of lower expected reserve levels and increased volatility of reserves on the supply of international credit extended to emerging markets. Section 3 concludes.

1. THE MODEL

Consider a global economy composed of high-income countries and emerging-market economies. Agents in the high-income countries are risk neutral, so their preferences over a two-period planning horizon are characterized by

\[ V \equiv C_1 + \frac{C_2}{1 + \rho} \]  

Fig. 2. Forecast of Korean Reserves. Source: Bank of Korea
where \( \rho \) is the rate of time preference and coincides with the risk-free interest rate. Agents in the emerging-market economies have preferences represented by

\[
V^* = u(C_1^*) + \frac{u(C_2^*)}{1 + \rho}; \quad u' > 0; \quad u'' \leq 0.
\]  

(2)

We assume that \( \rho^* > \rho \) because the real interest rate in the emerging-market economies is substantially above the rate in the high-income group.

The only exogenous source of uncertainty is a productivity shock to second-period output in the emerging markets:

\[
Y_2^* = Y^*(1 + \varepsilon)
\]  

(3)

where \( \varepsilon \) is a stochastic shock with probability density function \( f(\varepsilon) \) over the range \( -\varepsilon_0 \leq \varepsilon \leq \varepsilon_0 < 1 \), with \( \varepsilon_0 > 0 \). All private agents are price takers.

Emerging-market economies may borrow internationally, but their ability to borrow is constrained by the limited enforceability of international contracts. Consider the simple case where emerging markets initially have no outstanding foreign debt. Suppose that the high-income countries lend an aggregate amount \( B_1^* \) in period 1 to private agents in the emerging-market group at a contractual interest rate of \( r \). In period 2, the borrowers must repay the loan, but because their output is uncertain, they may default.

Let \( S_2 \) denote the debt repayment to foreign creditors in period 2. In the event of default, suppose creditors can penalize the borrowing countries by reducing their net output by an amount \( \chi Y_2^* \). The parameter \( \chi \) reflects the bargaining power of foreign lenders, where up to a fraction \( \chi \) of output can be “confiscated” by lenders due to the threat of embargoes, retaliatory trade measures, and other actions. Consequently, the effective ceiling on net resource transfers to creditors is

\[
S_2 = \min[(1 + r)B_1^*, \chi Y_2^*].
\]  

(4)

The size of the productivity shock that makes the emerging-market countries indifferent between repaying the loan or defaulting and facing the output penalty is \( \varepsilon^* \), where \( \varepsilon^* \) is determined by the condition

\[
(1 + r)B_1^* = \chi Y_2^*(1 + \varepsilon^*).
\]  

(5)

Thus,

9. The term \( \chi \) is influenced by a host of factors that relate to the integration of markets.

10. Recall that \( -\varepsilon_0 \leq \varepsilon \leq \varepsilon_0 < 1 \). Hence, if \( \frac{(1 + r)B_1^*}{\chi Y_2^*} - 1 < -\varepsilon_0 \), no default occurs because the default penalty exceeds the contractual debt in the worst state of nature. In these circumstances we define \( \varepsilon^* = -\varepsilon_0 \).
11. To simplify, we lump together the costs of monitoring and enforcement, and we ignore the possibility of randomized monitoring. Boyd and Smith (1994) show that random monitoring makes the financial contract more complex without altering first-order welfare effects. See Townsend (1979) for a model where a debt contract with state verification costs is optimal. See Bernanke and Gertler (1989) for a related analysis.

12. While our focus is on the impact of uncertainty about the international reserves of the emerging markets, we can easily add within our framework uncertainty about the possibility of eventual bailouts financed by the global financial community. For a model of moral hazard generated by the expectation of a bailout by the international community, see Aizenman and Turnovsky (2002).

For realized productivity shocks between $-\varepsilon_0$ and $\varepsilon^*$, default saves the borrowers (at the expense of the lenders) the difference between the contractual repayment and the output penalty. We denote this gap—the potential bailout—by $b$:

$$b \equiv (1 + r)B_1^* - \kappa Y^*(1 + \varepsilon) = \kappa Y^*(\varepsilon^* - \varepsilon).$$

The international credit market is risk neutral and characterized by competition among banks that are fully informed about the debt exposure of the emerging-market group. Default by the emerging markets requires that creditor banks spend real resources $\mu$ in order to verify the productivity shock and to enforce the transfer of resources from emerging markets according to (4). The monitoring/enforcement costs are a reduced-form way of capturing several considerations. First, they provide a rationale for a debt contract (see Townsend 1979). Second, they make partial defaults costly by increasing the expected cost of funds. Finally, they motivate government bailouts, since bailouts mitigate the adverse effects of partial defaults on domestic investment and the expected rents of entrepreneurs (see the Appendix for details).

Since large defaults are potentially destabilizing, agents anticipate there is some probability of a public bailout by the treasury or central bank of the emerging-market block. We summarize the bailout expectations in a reduced-form equation, where the bailout probability $\phi^*$ increases with the default size:

$$\phi^* = \phi^*(b), \text{ where } [\phi^*(b)]' > 0 \text{ for } b > 0; \phi^*(0) = [\phi^*(0)]' = 0.$$ (8)

In the event of a default, emerging-market governments try to compensate lenders for the revenue shortfall using their actual period-2 net international reserves, $F_2^*$. However, their reserve stockpile may not be adequate to accomplish a full bailout. Creditor income earned on the loan in the case of default and a bailout is equal to either the full bailout or the stock of reserves held by emerging markets, whichever is less, plus the output penalty obtained by lenders:

$$\min[b, F_2^*] + \kappa Y^*(1 + \varepsilon).$$ (9)

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Equations (1)–(9) can be viewed as a reduced-form description of an economy where political economy considerations motivate the bailout. In the Appendix, we provide a more detailed description of such an economy and show that anticipated bailouts have two important effects. They subsidize current investment and mitigate the deadweight loss associated with partial default. We do not attempt to explain why an economy such as that of Korea decides to subsidize investment and allow the formation of huge conglomerates (the chaebols).\textsuperscript{13} We treat that policy choice as given and evaluate the effect of uncertainty about the bailout on the supply of credit.

The intertemporal pattern of consumption and lending is determined by agents who maximize their discounted expected utility. The risk neutrality of lenders implies that they offer an elastic supply of credit at an expected yield equal to their rate of time preference. Thus the interest rate on emerging-market debt \( r \) is determined by an arbitrage condition that equates the expected yield on loans to emerging markets to the risk-free return:

\[
(1+r)B_1^* \int_{-\varepsilon_0}^{\varepsilon^*} f(\varepsilon)d\varepsilon + \int_{-\varepsilon_0}^{\varepsilon^*} \{\phi^* \min[F_2^*, b] + \lambda \gamma(1+\varepsilon) - (1-\phi^* \lambda)\mu\} f(\varepsilon)d\varepsilon \\
= (1+p)B_1^*
\]

where \( \lambda = \min[F_2^* - b, 0] / F_2^* - b \) is an indicator function whose value is one whenever reserves are high enough to support a complete bailout and is zero otherwise. The left-hand side of (10) consists of two components: (i) the return on the loan in the absence of default; and (ii) the return on the loan in the presence of default, which equals the possible bailout and the share of foreign output claimed in a default, all minus enforcement costs. Enforcement costs accrue whenever the sum of debt service and the realized bailout falls short of the contractual repayment. Applying (10), it follows that the original borrowers’ expected debt service is

\[
E(S_2) = (1+r)B_1^* \int_{-\varepsilon_0}^{\varepsilon^*} f(\varepsilon)d\varepsilon + \int_{-\varepsilon_0}^{\varepsilon^*} \lambda \gamma(1+\varepsilon)f(\varepsilon)d\varepsilon \\
= (1+p)B_1^* + \int_{-\varepsilon_0}^{\varepsilon^*} \{(1-\phi^* \lambda)\mu - \phi^* \min[F_2^*, b]\} f(\varepsilon)d\varepsilon .
\]

Note that the bailout scheme shifts the burden of servicing the debt and financing the enforcement costs from the original borrowers to the agency financing the bailout. Using (7), we can rewrite the left-hand side of (10) as

\textsuperscript{13} See Krueger and Yoo (2001) for a review of these policies.
14. The specification in (13) is the simplest way to model reserve uncertainty. The key results of the model, summarized below in Proposition 1, hold for other distributions of $l$. (See the discussion following Proposition 1.)

Equations (10) and (11) imply that the financial premium charged to emerging markets takes into account the riskiness of these loans:

$$(1+r)B^* + \int_{-\varepsilon_0}^{\varepsilon_0} \{\phi^* \min [F_2^*, b] - \chi Y^* (\varepsilon - \varepsilon) - (1 - \phi^* \Omega) \mu \} f(\varepsilon) d\varepsilon = (1+r)B_1^* - \int_{-\varepsilon_0}^{\varepsilon_0} \{b + (1 - \phi^* \Omega) \mu - \phi^* \min [F_2^*, b] \} f(\varepsilon) d\varepsilon.$$  

(11)

Note that monitoring and enforcement costs increase borrowing rates, whereas expected bailouts reduce them.

For future reference, we will want to use a rearranged version of (12):

$$r - \rho = \frac{\int_{-\varepsilon_0}^{\varepsilon_0} \{b + (1 - \phi^* \Omega) \mu - \phi^* \min [F_2^*, b] \} f(\varepsilon) d\varepsilon}{B_1^*}.$$  

(12)

2. THE EFFECTS OF RESERVE UNCERTAINTY

We now examine how uncertainty about reserves held by emerging markets affects the supply of international credit they can obtain. Consider the simplest form of international reserve uncertainty that gives rise to a gap between “official reserves” and “actual reserves.” Suppose actual reserves in period two are either low or high with equal probabilities:

$$F_2^* = \begin{cases} F^* (1 - \lambda) & \text{with probability 0.5} \\ F^* (1 + \lambda) & \text{with probability 0.5} \end{cases}$$  

(13)

where $F^*$ is the expected value of (usable) reserves and reserve volatility is given by $\lambda$, with $1 \geq \lambda \geq 0$. Market participants in period 1 have information only about the distribution and expected value of reserves.
The scarcity of reserves does not bind for small bailouts. This would be the case if

\[ b \leq F^* (1 - \lambda) \]  

(14)

or equivalently, if

\[ (1 + r)B_1^* - \chi Y^* (1 + \varepsilon) \leq F^* (1 - \lambda). \]  

(14')

We define \( \bar{\varepsilon} \) as the value of the productivity shock that requires emerging markets to use all their reserves to meet the bailout in the state where reserves are low. This value of \( \bar{\varepsilon} \) makes (14') hold as an equality and is given by

\[ \bar{\varepsilon} = \max \left[ \frac{(1 + r)B_1^* - F^* (1 - \lambda)}{\chi Y^*} - 1, -\varepsilon_0 \right]. \]  

(15)

We define \( \underline{\varepsilon} \) as the value of the productivity shock that equates the needed bailout to total reserves in the state where reserves are high [where \( b = F^* (1 + \lambda) \)]:

\[ \underline{\varepsilon} = \max \left[ \frac{(1 + r)B_1^* - F^* (1 + \lambda)}{\chi Y^*} - 1, -\varepsilon_0 \right]. \]  

(16)

For productivity shocks in the range \( \underline{\varepsilon} \leq \varepsilon \leq \bar{\varepsilon} \), the scarcity of reserves binds with probability one-half in the event of a bailout. If actual reserves are insufficient for a full bailout, the bailout is partial and equals \( F^* (1 - \lambda) \). For productivity shocks \( \varepsilon \leq \underline{\varepsilon} \), all bailouts are constrained by reserves. Assuming that a bailout occurs, the expected bailout is summarized by

\[ E_b \{ \min[F_2^*, b] \} = \begin{cases} b & \text{for } \bar{\varepsilon} < \varepsilon \leq \varepsilon^* \\ 0.5[F^* (1 - \lambda) + b] & \text{for } \underline{\varepsilon} \leq \varepsilon \leq \bar{\varepsilon} \\ 0.5[F^* (1 - \lambda) + F^* (1 + \lambda)] = F^* & \text{for } \varepsilon < \underline{\varepsilon} \end{cases} \]  

(17)

where \( E_b \) is the expected size of the bailout, conditional on having a bailout.

Figure 3a illustrates the expected repayment of the loan for given values of the productivity shock. In the absence of a bailout, the repayment is the minimum of the contractual debt repayment (curve PK) and the output penalty (curve NJ). This repayment is traced out by the thick dashed curve NLK. For shocks in the range \( -\varepsilon_0 \leq \varepsilon \leq \varepsilon^* \), if a bailout occurs, the expected repayment is equal to the return in the absence of a bailout plus either a full bailout or a bailout that just exhausts the reserves held by the emerging markets. This expected repayment \( \chi Y^* + E_b \{ \min[b, F_2^*] \} \) is illustrated by the curve N'M'ML.  

15. The curve N'M'ML is drawn for \( \chi = 0.4; Y^* = 1; F^* = 0.2; r = 0.1; B_1^* = 0.5, \) and \( \lambda = 0.2. \)
itors is constrained by reserve uncertainty when the productivity shock lies in the range \(-\varepsilon_0 \leq \varepsilon \leq \varepsilon_0\).

Figure 3b demonstrates that for productivity shocks in the range \(\varepsilon \leq \varepsilon \leq \varepsilon_0\), greater reserve volatility (\(\lambda\)) also reduces the expected return to creditors. Curve \(N’QK\) represents the expected repayment if the bailout takes place and there is no reserve volatility (\(\lambda = 0\)). A lower curve \(N’M’MK\) corresponds to the expected repayment if there is some reserve volatility (\(\lambda = 0.2\)), while an even lower curve \(N’S’S’K\) illustrates the expected repayment when reserve volatility is still higher (\(\lambda = 0.4\)). Note that the range of shocks for which reserve volatility matters increases as the level of volatility increases.

To calculate the expected repayment on the foreign loan when the shock is in the default range \(-\varepsilon_0 \leq \varepsilon \leq \varepsilon_0\), we substitute (17) into (10) to get

\[
(1 + \varepsilon)\lambda Y^* = (1 + r)B_1^*.
\]
\[
\int_{-\varepsilon_0}^{\varepsilon_0} \{ \phi^* \min [F_2^*, b] \} f(\varepsilon) d\varepsilon = \left[ \int_{-\varepsilon_0}^{\varepsilon_0} \{ b \phi^* \} f(\varepsilon) d\varepsilon + \int_{-\varepsilon_0}^{\varepsilon_0} \{ 0.5 [F^*(1 - \lambda) + b] \phi^* \} f(\varepsilon) d\varepsilon + \int_{-\varepsilon_0}^{\varepsilon_0} \{ F^* \phi^* \} f(\varepsilon) d\varepsilon \right]
\]

Substituting (18) into (12), we note that the interest rate on loans to emerging markets \( r \) is determined by

\[
\int_{-\varepsilon_0}^{\varepsilon_0} \{ b + (1 - \phi^* \Omega) \mu \} f(\varepsilon) d\varepsilon = \left[ \int_{-\varepsilon_0}^{\varepsilon_0} \{ b \phi^* \} f(\varepsilon) d\varepsilon + \int_{-\varepsilon_0}^{\varepsilon_0} \{ 0.5 [F^*(1 - \lambda) + b] \phi^* \} f(\varepsilon) d\varepsilon + \int_{-\varepsilon_0}^{\varepsilon_0} \{ F^* \phi^* \} f(\varepsilon) d\varepsilon \right] - (r - \rho) B_1^* = 0
\] (19)

Equation (19) defines the supply of international credit facing the economy (along with the definitions of \( \varepsilon^*, \varepsilon, \varepsilon \)). We denote the left-hand side of (19) by \( H \). Applying the implicit function theorem to (19) and (12'), the slope of the supply of foreign credit facing the emerging market is

\[
\frac{dB_1^*}{dr} = \frac{-H'}{H B_1^*}
\] (20)

where

\[
-H' = B_1^* \int_{-\varepsilon_0}^{\varepsilon_0} f(\varepsilon) d\varepsilon + \left[ \chi Y^* \int_{-\varepsilon_0}^{\varepsilon_0} \frac{d\phi^*}{db} \Omega f(\varepsilon) d\varepsilon - f(\varepsilon^*) \right] \frac{\mu}{\chi Y^*} B_1^*
\]

\[
+ \frac{\partial}{\partial r} \int_{-\varepsilon_0}^{\varepsilon_0} \min [F_2^*, b] \phi^* f(\varepsilon) d\varepsilon
\]

\[
H' B_1^* = \left[ 1 + \rho - (1 + r) \int_{-\varepsilon_0}^{\varepsilon_0} f(\varepsilon) d\varepsilon \right] + \left[ f(\varepsilon^*) - \chi Y^* \int_{-\varepsilon_0}^{\varepsilon_0} \frac{d\phi^*}{db} \Omega f(\varepsilon) d\varepsilon \right] \frac{\mu}{\chi Y^*} (1 + r)
\]

\[
- \frac{\partial}{\partial B_1^*} \int_{-\varepsilon_0}^{\varepsilon_0} \min [F_2^*, b] \phi^* f(\varepsilon) d\varepsilon
\]
We assume that the emerging-market economies operate along the upward-sloping portion of the supply of international credit.\textsuperscript{16} Such would be the case if $-H'_{r*} > 0$ and $H'_{r*} > 0$. The supply of international credit [defined implicitly by (19)] and the demand for international credit jointly determine the equilibrium interest rate and lending level.\textsuperscript{17}

Applying (19), we find that for a given interest rate, a downward revision in the expected reserve level shifts the supply of credit curve leftward since

$$\frac{d\dot{B}_*}{d\bar{F}} \bigg|_{r} = \left[ \int_{\bar{F}_{0}}^{\bar{F}} \phi \hat{f}(\varepsilon) d\varepsilon + \int_{\bar{F}}^{\bar{F}_{0}} 0.5(1 - \lambda)\phi \hat{f}(\varepsilon) d\varepsilon \right] > 0. \quad (21)$$

This reduction in the supply of international credit occurs whenever the stock of emerging-market reserves is expected to limit the size of the bailout. The reserve constraint is binding when productivity shocks lie in the range $-\varepsilon_0 \leq \varepsilon \leq \bar{\varepsilon}$. Note that the drop in expected reserves has a nonlinear impact since the reduction in the supply of credit is magnified by the expected marginal bailout associated with an extra dollar of reserves. Hence, news about the expected reserve position of a country matters less for countries where the commitment to a “no-bailout” policy is credible or where foreign debt repayments are relatively small.

We also observe that an increase in reserve volatility shifts the supply of credit curve leftward by the amount:

$$\frac{d\dot{B}_*}{d\lambda} \bigg|_{r} = -\frac{0.5\bar{F}_{0}\int_{\bar{F}}^{\bar{F}_{0}} \phi \hat{f}(\varepsilon) d\varepsilon}{H'_{r*}} < 0. \quad (22)$$

An increase in volatility reduces the supply of credit in proportion to the expected probability of a bailout in the range where the scarcity of reserves binds partially, $\varepsilon \leq \varepsilon \leq \bar{\varepsilon}$. This is the range where there is a full bailout if actual reserves turn out to

\textsuperscript{16} For a sufficiently low level of foreign debt, $\varepsilon^* = -\varepsilon_0$. In these circumstances the critical condition for $dB/d\lambda > 0$ reduces to $\mu f(-\varepsilon_0)/\gamma Y < 1$, a condition that is satisfied for a low enough but positive enforcement cost, $\mu$. If $\mu f(-\varepsilon_0)/\gamma Y > 1$, the supply of credit is backward bending at interest rates marginally above the risk-free rate. In these circumstances it would be in the interest of borrowers to prohibit borrowing. Consequently, we assume $\mu f(-\varepsilon_0)/\gamma Y < 1$, so that the supply-of-credit curve is upward sloping at relatively low interest rates. In general, the supply curve may contain a backward-bending section at high interest rates and external debt levels. In these circumstances, it would be in the interest of the borrowers to adopt policies that prevent them from reaching the backward-bending section of the supply curve since such a point entails lower welfare than the point where external borrowing is maximized. See Aizenman (1989) for further discussion.

\textsuperscript{17} The demand for credit reflects the demand for investment in the first period (see the Appendix for further details). We assume an internal equilibrium in the credit market, where the supply of credit is upward sloping, the demand for credit is downward sloping, and the demand for credit is high enough to induce a positive risk premium, $r > \rho$. We focus our attention on the supply side and the supply response to uncertainty. The full impact of uncertainty can be obtained by studying the interaction between demand and supply.
be high but only a partial bailout if actual reserves turn out to be low. Recall that the threshold values defining this range, \( \varepsilon \), depend on both the expected reserve level and the degree of volatility. A fall in the expected reserve level expands the range as does an increase in volatility. [See (15) and (16)]. Hence,

**PROPOSITION 1:** *Greater uncertainty about an emerging market’s reserve position reduces the supply of international credit offered. The reduction in credit is magnified as uncertainty increases.*

Proposition 1 follows from the concavity of the creditors’ payoff with respect to the reserve position, and it applies to any distribution \( f(\varepsilon) \). Specifically, recall that the expected bailout repayment is

\[
\int_{-\varepsilon_0}^{\varepsilon^*} \{ \phi^* \min[F_2^*, b] \} f(\varepsilon) d\varepsilon \quad \text{for} \quad -\varepsilon_0 \leq \varepsilon \leq \varepsilon^* , \quad \text{and that}
\]

the debt is fully repaid for \( \varepsilon^* < \varepsilon \leq \varepsilon_0 \). Recall also that the bailout \( b \) is a function of the productivity shock. Hence it is known following the realization \( \varepsilon \). Thus, conditional on the realized \( \varepsilon \), the bailout transfer to foreigners is \( \min[F_2^*, b] \), which is a concave function of \( F_2^* \). Consequently, the expected repayment falls with increased uncertainty about reserves, leading foreign creditors to reduce their supply of credit.

These results are a direct application of options pricing logic. From the perspective of bondholders, lending to a firm whose net worth fluctuates randomly is equivalent to purchasing the firm and selling a call option to shareholders. Higher volatility in the firm’s net worth increases the value of the call option and reduces the expected income of the lenders.\(^{18}\) In terms of our example, higher reserve volatility increases not only the likelihood that reserves will cover small bailouts but the likelihood that they will not cover large bailouts. The concavity of the payoff function implies that the second effect dominates. Thus more reserve volatility reduces the supply of credit at any given interest rate.

Observe that greater reserve volatility has a nonlinear effect on the supply of international credit. Greater volatility does not affect the supply of credit when the expected reserve position is large enough so there can be a full bailout.\(^ {19}\) But suppose the expected reserve position is low enough so that the size of the bailout might be constrained by the scarcity of reserves. Then the impact of greater reserve volatility is magnified by the expected bailout in the range where the scarcity of reserves binds partially. In terms of Figure 3b, greater reserve volatility shifts down a segment of the expected repayment line and widens the range \([\varepsilon, \varepsilon^-]\) where the scarcity of reserves binds partially. The net effect of higher reserve volatility is minimal around point Q, which corresponds to the case of no volatility (\( \lambda = 0 \)), but it progressively gets larger as volatility increases (as we move to line segment M’M and then down to segment S’S).

\(^{18}\) Note that \( \min[F_2^*, b] = F_2^* - \max[F_2^* - b, 0] \). The expected income to bondholders, \( \min[F_2^*, b] \), is equivalent to the income of an agent owning the entire income stream, \( F_2^* \), who sells a call option on that income stream, \( \max[F_2^* - b, 0] \). Higher volatility of the income stream increases the expected value of the call option and reduces the expected income of the bondholders. We are grateful to an anonymous referee for suggesting this options pricing analogy.

\(^{19}\) This will be the case if \( \varepsilon = \varepsilon = -\varepsilon_0 \). Applying (14) and (15), this is equivalent to \( (1 + r)B_1^* - \chi \gamma (1 - \varepsilon_0) (1 - \lambda) < F^* \).
The above considerations may be illustrated more formally. Let $\phi^*(\hat{\varepsilon})$ be the probability of a bailout defined by $\phi^*(\hat{\varepsilon}) = \frac{\int_{\hat{\varepsilon}}^{\varepsilon^*} \phi^*(\varepsilon) f(\varepsilon) d\varepsilon}{\varepsilon - \hat{\varepsilon}}$. Applying (15) and (16),

$$\phi^*(\hat{\varepsilon}) = \frac{\int_{\hat{\varepsilon}}^{\varepsilon^*} \phi^*(\varepsilon) f(\varepsilon) d\varepsilon}{\varepsilon - \hat{\varepsilon}} = \frac{1}{2F^*\lambda(\chi Y^*)} \int_{\hat{\varepsilon}}^{\varepsilon^*} \phi^*(\varepsilon) \frac{1}{H_{\hat{\varepsilon}'}, \chi Y^*} d\varepsilon.$$  

Substituting this expression into (22) gives:

$$\frac{dB_1^*}{d\varepsilon} = -\lambda(\hat{\varepsilon})^2 \phi^*(\hat{\varepsilon}) \frac{1}{H_{\hat{\varepsilon}'}, \chi Y^*} < 0.$$  

From (23) we observe that the leftward shift in the supply of international credit when there is reserve volatility is larger as reserve volatility increases or as the probability of bailouts rises. The intuition for the latter result is based on a time inconsistency story. A declared “no bailout” policy is not credible in regimes where the “too-big-to-fail” argument or the lobbying of pressure groups forces the government to use international reserves for bailouts. In these circumstances, the lack of transparency of international reserves acts as a tax. The tax is larger in weak regimes where the probability of a bailout is considered high.

The condition under which reserve uncertainty influences the supply of credit can be expressed in still another way. We know that reserve scarcity binds as long as productivity shocks lie in the range $-\varepsilon_0 < \varepsilon < \bar{\varepsilon}$, where we have assumed $-\varepsilon_0 < \bar{\varepsilon}$. Given the definition of $\varepsilon$ in (15), the assumption that $-\varepsilon_0 < \varepsilon$ is equivalent to

$$(1 + r)B_1^* - \chi Y^*(1 - \varepsilon_0) > \bar{\varepsilon}^* (1 - \lambda).$$  

This condition implies that the supply of international credit is reduced by greater reserve volatility when the potential bailout in the worst state of nature (defined by the lowest productivity shock) is greater than the lowest possible reserve level. This condition is more likely to hold the lower is expected international reserves and the greater is the volatility of reserves.

Our analysis has focused on the role of uncertainty when an emerging market’s central bank uses its stock of international reserves to finance a bailout. The outcome would be the same if an external agent like the IMF financed the bailout and there was uncertainty about the amount of funding. Of course, the identity of the financing agent would determine the ultimate income effects of the bailout. But it would

20. Assuming that $\phi^*$ is a continuous function, there exists a unique value of $\hat{\varepsilon}$ such that $\bar{\varepsilon} > \hat{\varepsilon} > \varepsilon$, satisfying this condition.

21. In these circumstances, (13) would reflect the uncertainty about IMF funding to help service the debt and (8) would describe the probability of an IMF bailout.
not affect the equilibrium determination of the supply of credit, since creditors do not care who ultimately finances their repayment.\textsuperscript{22}

3. CONCLUSION

The unwillingness of foreign lenders to extend new credits or to roll over existing credits to emerging markets is thought to have been an important factor in the 1997–98 Asian crisis (Chang and Velasco 1998a, 1998b; Radelet and Sachs 1998). This paper shows that when loan repayments become less certain, foreign lenders are less willing to offer international credit. More importantly, it demonstrates that reserve volatility can, under plausible circumstances, induce large adverse effects for emerging markets. Volatility that is benign when nonlinearities are absent generates large costs when nonlinear restrictions bind. We observe that when the expected reserve position of emerging markets is large relative to the potential bailout in a bad state of nature, reserve volatility is unimportant. The same amount of reserve volatility can cause a large reduction in the offered supply of international credit once investors become more pessimistic about either repayment possibilities or the reserve position of emerging markets.\textsuperscript{23} Such reserve uncertainty characterized the Korean crisis and can help explain the collapse of the international credit market facing that emerging market.

APPENDIX

This appendix provides a more detailed version of the model used in the text. We consider an economy where the capital stock is determined by first-period investment. Anticipated bailouts reduce the risk premium attached to foreign borrowing costs, subsidizing investment and increasing rents. They also reduce the deadweight loss associated with partial defaults. These features are consistent with the Korean experience, where selective investment subsidies were aggressively promoted. Over time, these policies led to the concentration of production under the control of large conglomerates (the \textit{chaebols}) who were able to influence the design of public policies and the allocation of credit.

We do not attempt to investigate the optimality of these policies. Instead, we take it for granted that, in the 1990s, market participants believed these \textit{chaebols} to be big enough and close enough to the government to be bailed out if needed, even though these bailouts were not formally guaranteed. These beliefs were strengthened by the heavy involvement of Korean banks in financing the \textit{chaebols}, since outright defaults

\textsuperscript{22} These considerations also imply that if bailouts were financed out of domestic output obtained through structural reforms, greater uncertainty about these reforms would have similar effects to the ones studied above.

\textsuperscript{23} The interaction between volatility and nonlinearity may help explain the finding that higher macroeconomic volatility in emerging markets is associated with lower private investment and economic growth. See Aizenman and Marion (1999).
would lead to systemic banking risk. Indeed, the events of the late 1990s have validated the correctness of these expectations. The following report summarizes concisely these considerations:

South Korea’s capital markets have been the creatures of big business and government. It is time to set them free . . . From the beginning of the 1960s it (Korean government) used the banks to funnel capital to favored businesses on attractive terms . . . Banks knew that the government would bail out their biggest clients and their depositors, so they never developed adequate credit-risk analysis. The partial liberalization of the economy in the years leading up to 1996–7 made the banks even more vulnerable. The government withdrew its guarantee to support the banks, but introduced no corresponding improvement in supervision. No wonder international investors at first refused to believe that the government would let businesses and banks fail. The financial crisis struck partly because those investors eventually concluded that perhaps it would, after all. At one point in late 1997 South Korea’s foreign-exchange reserves dipped to a microscopic $3.9 billion . . . At the end of 1997 the government launched an emergency rescue. The idea was to prevent panic, and also thoroughly overhaul bank supervision to rebuild confidence. The bail-out funds had a total of 64 trillion won, raised through a government bond issue, with which to buy bad loans and inject new capital into the banking system in the form of equity.

_The Economist_ (Capital Flaws, July 8, 1999)

We now describe a minimal framework consistent with Korean’s experience. We assume that domestic entrepreneurs borrow abroad to finance investment, and they determine the debt service according to equation (4). The central bank controls the use of its international reserves. Large partial defaults induce the central bank to bail out foreign parties in order to subsidize investment and to reduce the deadweight losses associated with defaults. Specifically, recall that the second-period output is

\[ Y_2^* = Y^*(1 + \varepsilon) . \]  

(A3)

Assume a Cobb-Douglas production function,

\[ Y^* = A(K^*)^\alpha \]  

(A1)

where \( K^* \) is the stock of capital. Suppose that entrepreneurs are risk neutral, financing \( K^* \) by borrowing funds and servicing the debt according to (4). The stock of capital is determined in period one by equating the expected marginal product of capital to the expected costs of funds

\[ 1 + E(\rho^*) = A\alpha(K^*)^{-(1-\alpha)} \]  

(A2)

where \( E(\rho^*) \) is entrepreneurs’ expected real cost of funds. Hence, the demand for capital is

\[ K^* = \left( \frac{A\alpha}{1 + E(\rho^*)} \right)^{1/(1-\alpha)} , \]  

(A3)
and the expected rents are

\[
C_0 = \frac{A^{\frac{1}{1-\alpha}} \alpha^{\alpha/(1-\alpha)} \gamma (1 - \alpha)}{[1 + E(\rho^*)]^{\alpha/(1-\alpha)}}; \quad C_0 = A^{\frac{1}{1-\alpha}} \alpha^{\alpha/(1-\alpha)} (1 - \alpha)
\]  

(A4)

Thus, applying (A4) and (10'), the entrepreneurs’ expected cost of funds is

\[
E(\rho^*) = \frac{\int_{0}^{\epsilon^*} \{ (1 - \phi \Omega) \mu - \phi \min[F^{\phi}_{2}, b] \} f(\epsilon) d\epsilon}{B_1^*}.
\]

(A5)

Anticipated bailouts reduce the expected cost of funds for entrepreneurs, thereby subsidizing their investment and increasing expected rents, (A4–5). In addition, anticipated bailouts mitigate the adverse consequences of partial default. They reduce the incidence of default and the expected deadweight loss associated with default.24

In the text, creditors face a deadweight loss ex post due to monitoring and enforcement costs. Ex ante, this loss is passed on to borrowers through higher borrowing rates [see (A5)]. The analysis can readily be extended to the case where borrowers incur some of the deadweight loss ex post because production is disrupted when there is default. In that case, bailouts would reduce the deadweight loss borne ex post by borrowers as well as lenders.25

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24. Applying (10), the anticipated bailout reduces the expected deadweight loss by \( \mu \int_{-\epsilon_0}^{\epsilon^*} \phi \Omega f(\epsilon) d\epsilon \).

25. A more complete treatment would expand the model horizon to three periods. If a partial default in the second period leads to production losses in the third period, a second-period bailout would reduce these production losses [see Hart and Moore (1998) for an example of such a model].


