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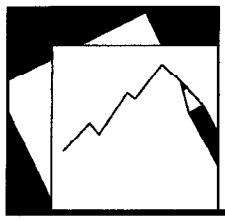

IMF Working Paper

Price Volatility and Financial Instability

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Price Volatility and Financial Instability

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Abstract

Statistical measures of the volatility of exchange rates, interest rates, and stock prices are estimated for a number of countries. Periods of high volatility are identified and compared with periods of financial difficulty. The results indicate that GARCH models of volatility could be potentially useful in assessing financial soundness. Daily data are more revealing, but monthly series allow comparisons among many countries. Country specific models may be needed for more reliable inference.

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I. INTRODUCTION

The development of improved indicators of financial system soundness has been one major response to the immense increase in international financial flows and a series of global financial crises that characterized the second half of the 1990s. These indicators include measures of the volatility of financial prices, a potential source of vulnerability to the financial system (see Davis (1999) and Evans et al. (2000)). At the microeconomic level, price volatility contributes in the short run to interest rate and foreign exchange risk through changes in the balance sheet of corporations; in the long run, volatility also increases the difficulty of evaluating borrowers' credit risk. At the macroeconomic level, stock market, interest rate, and exchange rate volatility may affect economic performance and the smooth functioning of the financial system through changes in consumer and business investment spending. Investors may perceive an increase in stock market volatility as an increase in the risk of equity investments; volatility in interest rates could threaten the viability of financial intermediaries; and exchange rate volatility may alter international capital flows. This study estimates the volatility of three financial prices—interest rates, exchange rates, and stock market indices—for a large number of countries, proposes a criterion for identifying periods of high volatility, and compares such periods with those identified in the literature as periods of financial difficulty.

We examine the estimated patterns of volatility with a view to addressing the following questions: Do periods of high volatility, estimated by simple univariate generalized autoregressive conditional heteroscedasticity (GARCH) models, anticipate or coincide with periods which have been identified elsewhere in the literature as periods of financial difficulty? Given the availability of high frequency financial data, are volatilities of financial prices sufficient as early indicators of financial system soundness?[2] This paper estimates daily price volatility for 14 countries, including a short description of the financial difficulties they faced during the period of analysis, and monthly price volatility for these and a range of other countries.[3] Our results show that (a) standard univariate EGARCH models identify periods of high volatility in many cases, but are less successful in anticipating financial stress; (b) at most two of the three prices were highly volatile at the same time, but that rarely occurred at the onset of financial difficulty. The results suggest that univariate time series models of financial prices are unlikely to be sufficient predictors of financial stress; at a minimum, time series models with richer specifications, including country-specific institutional and market characteristics, will be required.

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[2]Other macroeconomic indicators include growth of credit, changes in real estate prices, trends in the balance of payments, and correlations among financial markets.

[3]Daily data are likely to be more revealing for an analysis of financial sector stability, but only monthly data are available for a large number of countries and a relatively long time period.

Section II describes patterns of volatility in relation to periods of financial difficulty and Section III summarizes the methodology used in the paper. In Section IV, using daily data from 14 countries, we compare periods of high volatility with periods of financial difficulty. Section V does a similar exercise for a broader set of countries using monthly data. Potential extensions of our research are mentioned in Section VI.

II. Data and Stylized Facts

Monthly data for interest rates and exchange rates (end of period, local currency per U.S. dollar) are from the International Monetary Fund's (IMF) *International Financial Statistics* (*IFS*) database. Stock price indices, both monthly and daily, and daily exchange rate changes are from the Wharton Economic Forecasting Associates (WEFA) *Intline* database.[4] The monthly data start in 1970 wherever possible, while the daily data begin in January 1988. For holidays and other days with no quoted data, we use the previous day's quote on occasions when there were no large changes and the average of adjoining dates otherwise.

No attempt was made to improve on previous definitions of periods of financial difficulty. We follow the classifications of Lindgren, Garcia, and Saal (LGS, 1997), Goldstein, Kaminsky and Reinhart (GKR, 2000), and Lindgren et al. (2000). LGS defines periods of crisis by the presence of bank runs and other substantial portfolio shifts; collapses of financial firms; and massive government intervention. We also take account of periods of major financial difficulty that LGS did not rank as full-blown crises. The beginning and end of the crisis periods are loosely defined as the beginning and end of the year, except when specified more accurately in the literature. The results may be sensitive to this choice.

Countries are grouped by categories according to their exchange rate regime[5] and the degree of capital market development. Using the current definitions, countries are classified as pegged if their currencies are linked to the U.S. dollar, the French franc, another reserve currency, the Special Drawing Right (SDR), or another currency basket. Managed exchange regimes include cooperative arrangements and managed floating. The third category is that of independent floaters. With respect to capital market development, mature markets are defined as in the IMF's "Survey of Capital Markets;" emerging markets are those so designated in the International Financial Corporation's (IFC) capital markets database, together with all countries for which *IFS* quotes returns on private securities or money market interest rates. All other markets are classified as underdeveloped.

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[4]The dailies are mid-rate end of day. Bid-ask data would be more appropriate where changes in volatility induce greater changes in the bid-ask spread than in the mid-rate.

[5]The classification of the exchange rate regime is based on *IFS* definitions, which have changed somewhat over time.

Table 1 summarizes the preliminary evidence from charts of monthly financial price changes according to periods of high volatility, exchange rate regime, and capital market development.[6] Of 107 episodes where there appears to have been a sustained increase in volatility of any one of the price indices, about one-third (36 cases) happened before or during periods of financial difficulty. Of these, 12 showed evidence of increased volatility before the onset of difficulty. In six of those dozen cases, price fluctuations subsided to earlier levels at the onset of the problem period; in the remaining six cases, there were wide fluctuations for most of the problem period. In 24 cases where higher volatility coincided with financial difficulty, the change in volatility appeared only after the onset of the period of financial difficulty.

In the 36 cases that preceded or were concurrent with difficulty, volatility in exchange rates increased in 34 cases. In contrast, volatility changes for interest rates and stock price indices were relatively few. There were no cases in which interest rate volatility increased without an accompanying increase in exchange rate volatility. There were only two instances when the volatility of stock market indices increased during a period of financial distress.

When classified by exchange rate regime, the majority of the 36 cases associated with financial distress lies at the extremes of the exchange rate spectrum, 16 with pegged rates and 16 with floating rates. As regards capital market development, higher volatility is associated with financial distress in emerging capital markets in almost one-third of the cases, compared with about one quarter for underdeveloped markets.

III. Methodology

Over the past two decades a voluminous literature has established the presence of non-constant and time dependent volatility in high frequency financial data.[7] The ARCH (Engle (1982)) and its extensions (see Bollerslev (1986), Engle, Lilien and Robins (1987)) model the temporal dependence of the conditional variance as a linear function of past squared errors; these models do not explain the non-linear dependence as a function of other explanatory variables.[8] Generalized

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[6]Copies of the charts are available from the authors. We are indebted to Claudia Echeverría for collecting the data and preparing the charts.

[7]The most popular class of model that has been used to model the volatility of financial time series is the autoregressive conditional heteroscedasticity model (ARCH). Stochastic volatility models are a well-known alternative specification (see Ghysels, Harvey and Renault (1996)).

[8]Applications of ARCH models in the finance literature have focused on equity and foreign exchange markets in developing countries (See Bollerslev et al. (1992, 1994); also, Booth et al. (1992), Diebold and Lopez (1995), Palm (1996), and Stenius (1991)).

autoregressive conditional heteroscedastic (GARCH) models capture the dynamics of the conditional second moment of a series. Let *DLR* be the rate of return on a financial price *R* from time *t-1* to *t* for an information set of past realizations up to *t-1*. In a general model, the rate of return is modeled as a function of a vector of explanatory variables, *X*, and a disturbance term μ. The disturbance term may be assumed to follow a moving average process, and the innovation, conditional on the information set, follows a specified distribution with variance specified as an augmented GARCH process (see Baillie and DeGennaro (1990)).

$$
\begin{aligned}
&DLR_t|\Phi_{t-1} = g(X;\theta) + \mu_t \\
&\mu_t = \varepsilon_t - \textstyle\sum_{j=1}^{q} \gamma_j \varepsilon_{t-j} \\
&\varepsilon_t|\Phi_{t-1} \sim \Omega(0, h_t) \\
&h_t = f(\varepsilon_{t-j}, h_{t-j}) + \xi' Z
\end{aligned}
\qquad (1)
$$

Typically, it is assumed that the mean process is linear and the disturbances are innovations that follow a normal distribution. *Z* is a vector of additional variables explaining the variance of the innovation process. Alternative formulations of *f*, the variance function, exist. Subset restrictions on the parameters of the general structure define special cases and ensure finite variance and stationarity. The above specification shows that important components in the modeling process include the conditioning sets and the functional forms (*f* and *g)* of the variance and mean functions, and the distribution of the innovation process (see Pagan and Schwert (1990)).

The GARCH model hypothesizes that the conditional variance can be modeled as a function of the unexpected returns prior to time *t*. Bollerslev (1986) defines the GARCH (*p, q*) process as:

$$h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} \qquad (2)$$

where $\alpha_1, \cdots \alpha_q$, $\beta_1, \cdots \beta_p$, and α_0 are constant parameters. The model is well defined if the coefficients of the infinite autoregressive representation are all non-negative, and the roots of the moving average polynomial of squared innovations lie outside the unit circle. In the GARCH (1, 1) model, the effect of a shock on volatility declines geometrically over time.

Nelson (1991) argues that returns may exhibit asymmetrical conditional variance behavior in that positive shocks generate an impact on volatility unequal to that caused by negative shocks. He proposed an exponential GARCH or EGARCH (*p, q*) model to capture that asymmetry:

$$\log(h_t) = \alpha_0 + \sum_{j=1}^{p} \beta_j \log(h_{t-j}) + \sum_{j=1}^{q} \omega_j \left(\gamma \frac{\varepsilon_{t-j}}{\sqrt{h_{t-j}}} + \alpha \left[\frac{|\varepsilon_{t-j}|}{\sqrt{h_{t-j}}} - E\left\{ \frac{|\varepsilon_{t-j}|}{\sqrt{h_{t-j}}} \right\} \right] \right) \qquad (3)$$

where $\omega_j, \beta_j, \gamma$, and α are constant parameters. The terms $\varepsilon_{t-1}/\sqrt{h_{t-1}}$ in the equation ensure asymmetry through their coefficients. If a coefficient is negative, the variance increases (decreases)

when the error innovation is negative (positive). Stationarity requires the roots of the autoregressive polynomial to lie outside the unit circle.

In this paper, we adopt the simple research design of a common model, the EGARCH (1, 1)[9] with a normal distribution,[10] as a tool for uncovering similar volatility patterns across price series and countries and testing for asymmetric effects. The EGARCH is chosen over the simple GARCH model because (a) it does not impose any restrictions on the signs of the parameters in order to guarantee estimated variances are positive; and (b) it can accommodate conditional skewness. The common model is:

Mean Process

$$DLR_t = \theta_0 + \sum_{j=1}^{s} \theta_j DLR_{t-j} + \mu_t$$

EGARCH(1, 1)

$$\log(h_t) = \alpha_0 + \beta \cdot \log(h_{t-1}) + \gamma \cdot \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \alpha \left[\frac{|\varepsilon_{t-1}|}{\sqrt{h_{t-1}}} - \sqrt{2/\pi} \right]$$

For each of the three prices, for each country, an EGARCH (1, 1) model is estimated, with the number of lags *(s)* included in the mean equation determined by the number of significant partial autocorrelations of the series. All models were estimated using the Bollerslev-Wooldridge (1992) heteroscedastic-consistent estimator of the variance-covariance matrix, an estimator that is robust to deviations from normality. The conditional standardized and squared residuals were examined for serial correlation and normality;[11] estimated models were deemed satisfactory if the coefficients satisfied the stationarity condition and if the conditional residuals exhibited both an absence of serial correlation and a reduction in kurtosis.

Periods of high volatility are identified using the following notion of an outlier. A data point is considered to be an outlier if it exceeds the upper quartile by more than an η-multiple of the interquartile range, where $\eta > 1$ (Hoaglin 1983).[12] We then compare the

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[9]If the underlying process driving the financial series changes during a crisis, a switching regime model may be appropriate.

[10]Alternatives to the normal distribution include the student 't' and the general error distribution.

[11]Jarque-Bera tests were conducted on the unconditional as well as the conditional residuals.

[12]Our results are based on $\eta = 1.5$.

periods of high estimated volatility with periods that have been proposed in the literature as periods of financial difficulty. For some series, the equation for the mean was modified to include dummy variables for single episodes of large changes, such as a devaluation of the exchange rate. Such large changes, outliers in the distribution, would otherwise distort the estimated coefficients.

IV. Results with Daily Data

In this section we discuss the results of EGARCH estimates of the daily variance of changes in exchange rates, interest rates, and stock market indices for a selection of countries, as shown in Table 2. Periods of high volatility, derived from the estimates and shown in Charts 1–7,[13] are summarized in Table 3. Most estimated variances are approximately integrated processes with no asymmetric behavior; the EGARCH models reduce but do not eliminate the excess kurtosis in the data. The sample includes three countries—Greece, Peru and South Africa—which escaped major financial difficulties in the estimation period. Periods of high volatility were detected for all countries. On six occasions two indicators appear highly volatile at the same time, and in the cases of Brazil and Korea there were occasions when this occurred at the onset of a financial crisis. There were no instances when all three indicators were highly volatile at the same time.

Brazil

The 1999 financial crisis in Brazil, which raised the spectre of global financial instability, was an outgrowth of the Russian financial crisis, although the mechanisms by which contagion occurred remain contentious. It has been argued that Brazil suffered from efforts of international lenders to rebalance portfolios in light of probable losses in Russia. Bankers claim that attempts to force them to share the burden of resolving bad credit reduced their appetite for lending to emerging markets, including Brazil. Although doubts about the sustainability of the fiscal position in 1998 may have made the economy vulnerable, domestic factors do not appear to have been a trigger for the crisis: productivity was on the increase, foreign reserves were high, and the banking system was in good shape (National Bureau of Economic Research, 2000).

EGARCH estimates for stock market prices and interest rates achieve an improvement in the distribution of the residuals, as may be seen by comparing measures of skewness and kurtosis in the second and third columns of Table 2. No estimate was made for the exchange rate, which was depreciated steadily over time, up until the period of the

[13]There are three panels for each country (one each for the exchange rate, the interest rate, and the stock market index) and two countries per chart. Where no EGARCH estimates were made, the raw series is charted. Those panels are readily distinguished by the absence of a dashed line showing the threshold for high volatility.

financial crisis. Both the stock market variance and the interest rate variance appear to be integrated processes, and the stock market variance shows evidence of significant asymmetry, although the effect is small, judging by the magnitude of the coefficient.

Stock prices experienced periods of high volatility, relative to the series as a whole, in January-April 1995, October-December 1997, and late 1998, the latter just before the 1999 crisis. Interest rates were highly volatile from February-May 1998, a period when the stock market was relatively calm, and from January-March 1999, at the end of a period of high volatility on the stock market.

Chile

Chile suffered a financial crisis during the first half of the 1980s. In 1981, financial institutions accounting for 33 percent of loans were intervened. Associated with the crisis were high domestic and foreign interest rates that weakened corporate balance sheets, a sharp decline in the price of copper, an overvalued real exchange rate coupled with wage rigidity, and the bursting of bubbles in real estate and the stock market. The crisis, which deepened in 1983, was estimated to have cost 10 percent of GDP per year over the period 1982-1985.

The EGARCH estimates for stock prices and interest rates for Chile produce distributions which are significantly closer to the normal than is the variance of the raw data. However, the EGARCH estimate for the exchange rate produces a conditional variance which is more skewed and leptokurtotic than the variance of the unconditional series. Although the estimates are recorded in the table for completeness, no inferences are drawn from these results.

Chile escaped major financial problems in the 1990s. However, periods of high volatility were identified for exchange rates, stock prices and interest rates. The period July-November 1998 was the only occasion on which both interest rates and the stock price index appear to be highly volatile. In addition, stock prices were highly volatile in September-November 1991 and February-April 1994, interest rates were volatile during April-June 1999 and interest rates were highly volatile during January-February 1990 and July-March 1992.

Finland

Finland's financial crisis was related to its 1990-1993 recession, brought on by the collapse of trade with the USSR, the crash of a real estate bubble, the world-wide recessionary effects of the Gulf War, and currency depreciation that led to the failure of some firms with large foreign exposure. A liquidity crisis emerged in September 1991 and financial difficulty lasted until 1994. At the peak of the crisis, nonperforming loans were 13 percent of the total loans.[14]

[14]The Finnish experience is described in Drees and Pazarbasioglü (1998). See also Caprio and Klingebiel (1996).

We did not obtain a well defined estimate of the conditional variance of exchange rate changes, using the standard specification employed for all countries in this paper. In the case of the Finnish stock price index, the volatility persistence factor is close to unity, suggesting an integrated variance process. The volatility persistence for interest rates is not as strong; and the leverage term is significant, suggesting asymmetry. Periods when the daily change in the stock market index exhibited high volatility were identified in December 1995 and October to November 1997. Interest rates were highly volatile August-November 1991 and May-August 1994.

Greece

Greece escaped financial crisis in the 1990s, although between 1991 and 1995 there were a number of localized banking problems which required injections of public funds for their resolution. The EGARCH estimates for Greece are rather weak: leptokurtosis of the conditional variance is lower than that for the unconditional variance only for stock prices. For both the exchange rate and the stock price index, the variance appears to be integrated; the conditional variance of interest rates is not determined by the EGARCH specification.

The exchange rate was highly volatile on several occasions during the first half of the decade, in January-February 1990, March-May 1991, September-November 1992 and March-April 1995. Although there were many short periods of high stock price volatility, the only extended period of high volatility was November-December 1990.

Indonesia

Considerable efforts were devoted to improving the regulatory framework for banks in Indonesia in the 1990s, after the closure of a large private bank in 1992. The worst of the East Asian financial crises emerged in October 1997, as a result of contagion from Thailand. At that time, Indonesian growth and fiscal position were strong. The crisis exposed remaining supervisory weaknesses, such as poor loan classification, the lack of an exit strategy for failing banks and weak enforcement. The problems were rendered almost intractable by an unexpectedly steep currency depreciation, political instability, and the collapse of major enterprises. In addition to the closure of many private banks, all seven state banks needed restructuring; by mid-1999, the total cost to government was estimated at 50 percent of gross domestic product (GDP) (See Lindgren et al., 1999, Appendix I).

The Indonesian exchange rate remained unchanged up to the time of the crisis, and deposit interest rates changed discretely and infrequently. We therefore have volatility estimates only for stock market prices. The distribution of the conditional residuals is closer to the normal than that for the unconditional residuals, and the variance is an integrated process with no significant asymmetry. By the criteria defined in this study, the stock market index displayed sustained high volatility from August 1997 to end-1998, with only a few periods of relative calm, and again during September-November 1999 and May-July 2000.

Korea

Although the standard macroeconomic variables suggested a strong economy, Korean *chaebol* encountered problems in rolling over short-term loans, especially after the Hong Kong stock market crash of October 1997. The ensuing devaluation of the won exposed weaknesses in the financial system, including lending based on collateral rather than the prospective viability of the borrower and excessive leverage in the financing of *chaebol.* Financial reforms and financial restructuring in 1997 and 1998 included government support for banks equivalent to 7 percent of GDP.

The distribution of the EGARCH residuals for interest rates exhibits reduced skewness and kurtosis. The conditional variance for stock prices is less skewed, but more leptokurtotic. There is no estimate for the exchange rate, which demonstrated no noticeable volatility before the crisis. The variance for stock prices and interest rates both appear to be integrated processes, with no significant asymmetrical effects. At the height of the crisis from October 1997–March 1998 both prices were highly volatile, but neither showed volatility that might have anticipated the crisis.

Malaysia

Between 1985 and 1988 a sharp decline in commodity prices led to an economic recession. As a result, corporate debt-service capacity was impaired, and asset prices fell rapidly, contributing to crisis in the financial sector, including a sharp increase in nonperforming loans. The authorities intervened 61 financial institutions, and financial sector losses amounted to 5 percent of GDP.[15] Malaysia was one of the countries at the center of the Asian financial crisis of 1997. A rapid expansion of credit and a rise in nonperforming loans in 1997 left the financial sector vulnerable to the adverse effects of a decline in asset prices, a slowdown in output growth, rising interest rates and a depreciating exchange rate. The cost of financial sector restructuring, up to March 1999, was estimated at 5 percent of GDP (see Lindgren et al., 1999).

Except for devaluations in 1992, Malaysia's exchange rate remained unchanged until it was displaced by the impact of the crisis in September 1997. Interest rates moved in discrete steps, with no day to day volatility. For the stock market price index, the EGARCH estimates offer no evidence of an asymmetrical response to shocks; the persistence coefficient is almost unity. There were significant increases in volatility for the period January to April 1994 and most of the period after August 1997. The first of these periods is not associated with any financial system instability.

[15]See Sheng (1996) and Caprio and Klingebiel (1996).

Mexico

Mexico has suffered two financial crises since 1980, both associated with macroeconomic contraction. The first followed the fall in oil prices at the beginning of the 1980s; in 1982 government nationalized major financial institutions that were in difficulty. The 1994 financial crisis was the result of the sudden outflow of capital and the large currency depreciation in December, accompanied by a sharp increase in interest rates and a severe economic downturn. Banks were unable to roll over foreign currency deposits and short term credit denominated in U.S. dollars, while high interest rates undermined the credit-worthiness of borrowers. The cost of programs to support the banking sector is estimated at 19.3 percent of GDP.

Estimates of volatility in exchange rates were undertaken for Mexico beginning in January 1990; before that date the exchange rate remained unchanged. There is a high degree of volatility persistence and no evidence of significant asymmetry. Significant sustained increases in exchange rate volatility were estimated for the periods December 1994 to May 1995, October to November 1995, October to November 1997, and January to February 1998. The first of these coincides with the financial crisis. For stock market prices a significant increase in volatility is estimated for the period January to March 1995, as the financial crisis unfolded. The stock market volatility estimates satisfy the stationarity condition and show evidence of asymmetric behavior. Interest rate changes occurred regularly, interspersed with periods of unchanged rates. Because of the large number of observations clustered at the value of zero, we do not report EGARCH estimates of interest rate volatility.

Norway

Severe financial difficulty emerged in Norway in 1987 after an oil price decline coincided with a fall in the effective nominal exchange rate in 1986. This proved burdensome for firms that had undertaken foreign currency loans but lacked a sufficient flow of foreign exchange earnings. Losses first appeared in financial companies in 1986-87, and the ratio of bank loans to GDP declined after 1990. Heavy losses and insolvencies degenerated into a full banking crisis in 1991. Government took over three of the four largest banks, which together accounted for about half banks' total assets.[16]

The exchange rate equation gives evidence of a statistically significant increase in volatility in the periods March to June 1991 and September to November 1992. The estimates of stock market price volatility show statistically significant higher volatility for the periods November to December 1991 and August to December 1992. The interest rate estimates reveal no extended periods of high volatility. Volatility persistence is highest for the exchange rate, approximating an integrated process; the persistence coefficient for

[16]Drees and Pazarbasioglü (1998).

interest rates is significantly less than unity; and there is no evidence of asymmetric response to shocks.

Peru

Peru experienced a period of financial difficulty during 1983–1990, when two large banks failed after bank nationalizations in 1987. However, there were no further periods of instability in the 1990s, the period for which we have daily data. The volatility persistence coefficient is significantly less than unity for the stock price index and the interest rate; the coefficients of the exchange rate equation are not significant. No series shows evidence of asymmetrical volatility behavior. Although there are marginal decreases in estimated kurtosis for the stock index and the exchange rate, estimated skewness increased in all cases. Both stock prices and interest rates are highly volatile in the first quarter of 1995, the one occasion on which periods of high volatility coincide. Other periods of high volatility for interest rates are August–October 1991, January–April 1992 and February–June 1999. Apart from 1995, stock prices are highly volatile during January–April 1994 and August–October 1998.

South Africa

In 1985, South Africa experienced the most serious financial difficulty seen in that country during the period of our review, the so-called "debt standstill." In 1989-1990, a major bank was reorganized and recapitalized because of large loan losses and management problems. Subsequent liquidation and reorganization of several small banks has had no systematically significant effects.[17]

The estimates of exchange rate volatility indicate that a simple ARCH model could suffice. The estimates of stock market price volatility show significantly higher volatility for the periods October to November 1997 and May to June 1998. The persistence coefficient is high but significantly less than unity; the coefficient indicating asymmetric behavior is insignificant. No interest rate estimates are presented because they changed in discrete jumps, with little day-to-day volatility.

Sweden

Financial liberalization in Sweden in 1985 was followed by a large expansion in credit and a real estate boom. After the 1992 ERM crisis, inflation moderated, from the middle of 1993. Loan losses, which increased during 1990 and 1991, intensified when very high interest rates were used to arrest exchange rate depreciation during the ERM crisis. The cost of support to the banking system is estimated at 4 percent of GDP, but much of this was subsequently recovered.[18]

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[17]See Lindgren, Garcia, and Saal (1996).

[18]See Drees and Pazarbasioglü (1998).

The estimated volatility equations for exchange rate changes, interest rates, and stock market price changes satisfy stationarity conditions, have significant coefficients, and reduce nonnormality; interest rates and stock prices indicate asymmetric behavior. Exchange rates were highly volatile in August to September 1991 and on three occasions in 1993 and in July 1994. There were short episodes of high volatility of interest rates, but no instances of sustained high volatility. For the stock market index periods of volatility were August to October 1990 and October to November 1997.

Thailand

In Thailand there was a banking crisis during 1983-1987, characterized by bank runs, affecting 25 percent of financial assets, and high nonperforming loans (15 percent of total loans). Twenty five institutions were closed and another 27 were merged or given liquidity support, at interest costs estimated at 0.2 percent per year. The roots of the 1997 crisis were an unsustainable balance of payments current account, a substantial appreciation of the real exchange rate, rising short term foreign debt, a deteriorating fiscal balance, and an increasingly vulnerable financial sector. The quality of banks' portfolios deteriorated rapidly. Restructuring programs introduced in October 1997 and March 1998 cost the government about 25 percent of GDP.

The exchange rate of the Thai baht remained unchanged before the crisis, and interest rates changed in discrete steps. EGARCH estimates for stock prices show an integrated variance process with no asymmetrical behavior. The distributions of the residuals are both less skewed and leptokurtotic. Stock prices became highly volatile in late June 1997, just before the crisis broke, and the high volatility lasted until the end of 1998.

Turkey

Turkey's banking problems were ongoing, as of the last quarter of 2000. In the 1990s there were several bank failures, resulting in the liquidation of three small banks in 1994 and the transfer of ownership of three others to the deposit insurance fund in 1997/98. In December 1999, another five banks were intervened, followed by four more in late 2000 and early 2001. In the first quarter of 2001, 12 banks were under receivership by the regulatory authority, affecting about 10 percent of the assets of the banking system.

The Turkish exchange rate depreciated systematically through the 1990s, and we have no daily data on interest rates. The EGARCH estimate for the Turkish stock price index shows an integrated process with no significant asymmetry. There is a single period of sustained instability, August–December 1998.

The signaling effect of high volatility

The literature suggests that high volatility of several indicators, all at once, indicates the potential for severe financial difficulty. The volatility of just three indicators is not

sufficient evidence of financial difficulty, but it suggests a need for monitoring the sector closely.[19] In Table 3 there is no instance in which all three indicators are highly volatile at the same time; periods when two indicators were signaling instability are shown in italics. They occur for Brazil (January 1999), Chile (August–October 1998), Korea (November 1997–March 1998), Mexico (January–March 1995 and October–November 1997), Norway (September–November 1992), and Peru (January–February 1995). In Brazil and Korea the instability of financial prices begins just as the financial crisis becomes evident. In Mexico, 1995 was a year of financial and economic crisis, but 1997 was relatively tranquil in financial markets. As in the case of Korea, financial price instability did not anticipate the crisis that broke in December 1994. Similarly, Norway's financial problems, which dated back to 1987–88, were being resolved in 1992; 1998 was not a crisis year for Chile; and 1995 was not a period of financial difficulty for Peru.[20]

V. Results with Monthly Data

Treasury bill rates

The interest rate volatility estimates for 24 countries[21] (see Table 4) show high volatility persistence coefficients for 20 countries, with significant asymmetry in 14 countries.[22] For some countries, the specification can be improved. For example, the estimates for Australia, Israel, and Sri Lanka do not result in lower skewness and kurtosis in the conditional residuals; estimates for Iceland, Kenya, and Swaziland result in higher skewness; and the estimate for the United Kingdom has higher kurtosis.

Prolonged periods of high volatility of treasury bill rates were identified for 12 of the 20 countries for which we have plausible estimates. The period of interest rate volatility (1992–93) immediately preceded the period of financial difficulty, which began in 1994, only

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[19]Other factors include the structure of financial markets, accounting standards and disclosure requirements, prudential regulations, and quality of supervision of financial institutions.

[20]Statistical tests of the signal-to-noise ratio are made difficult by the fact that, in the available literature, the timing of the onset of financial difficulty is rather imprecise, for example "during the first quarter" or "early in the year." However, it should be possible to make more precise statements about the onset of financial difficulty, and to conduct statistical tests, on a case-by-case basis.

[21]The countries are Australia, Bahamas, Canada, Fiji, France, Germany, Guyana, Iceland, Ireland, Israel, Italy, Jamaica, Kenya, Lebanon, Malaysia, Mexico, New Zealand, Papua New Guinea, South Africa, Sri Lanka, Swaziland, Sweden, United Kingdom, and United States.

[22]The average persistence coefficient for these 20 countries is 0.89.

for Jamaica. In Mexico, Sweden, and the USA, periods of prolonged high interest rate volatility overlap with periods of financial difficulty. For Mexico the period of high interest rate volatility matches the period of financial crisis (1994–95); in Sweden the financial problems appear earlier (1990) than the period of interest rate volatility (1992) and they both last until 1993; in the U.S. the beginning of the high interest volatility period coincides with the start of financial problems in 1980, but interest rates settled down long before the financial difficulties were resolved. In seven of the remaining eight countries where there were periods of high volatility there were also periods of financial difficulty, but they did not coincide with the periods of high volatility. In the eighth country, the UK, no period of financial difficulty is identified in the literature.

Exchange rates

The EGARCH estimates for exchange rate changes for 51 countries are shown in Table 5.[23] The persistence coefficient was significant, positive, and less than unity for 40 countries, significant and negative for two, and insignificant for nine. Of these nine countries, the results suggest five countries may have simple ARCH representations. For the 40 countries with positive significant persistence coefficients, the average persistence coefficient was 0.77; six countries had coefficients less than 0.65 and 12 had significant asymmetrical terms. The standard specification used did not result in any significant terms for Chile, Ireland, Italy, and Spain. The distribution of the conditional residuals had lower skewness and kurtosis than that of the unconditional distribution in all but four cases (Brunei, the Netherlands, New Zealand, and Japan). For France, Germany, Jordan, Pakistan, and Papua New Guinea, the conditional variance was higher.

More than half (26) of the countries with plausible results showed no period of persistent high exchange rate volatility. This group is a mixture of industrial countries such as Australia, Canada, France, Germany, and Japan, and developing countries such as Algeria, India, Mauritius and Tanzania.[24] Of the 21 countries for which periods of high volatility are identified, there are eight for which those periods of high volatility overlap with periods of financial difficulty, and in all cases the financial difficulties persist for much longer than does the high exchange rate volatility. There are three countries where high exchange rate volatility preceded a period identified in the literature as one of financial

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[23]The countries are Algeria, Angola, Australia, Bangladesh, Benin, Bhutan, Botswana, Brunei, Burma, Burundi, Canada, Chile, Fiji, Finland, France, Gambia, Germany, Greece, Iceland, India, Ireland, Israel, Italy, Japan, Jordan, Kenya, Korea, Lesotho, Malaysia, Mauritius, Mexico, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Papua New Guinea, Philippines, South Africa, Sierra Leone, Singapore, Spain, Sri Lanka, Swaziland, Sweden, Tanzania, Thailand, Togo, Tunisia, Turkey, and United Kingdom.

[24]For many developing countries, high exchange rate volatility appears in the parallel exchange markets, not in the organized markets rates that are used for this study.

difficulty— Bangladesh (1979-80), Jordan (1988-89), and New Zealand (1985-89). In Singapore the exchange rate was highly volatile in 1997–98, but there was no major financial difficulty. For nine countries where there was evidence of high volatility of exchange rates, the periods of high volatility did not coincide with, or precede, periods of financial difficulty.

Stock market indices

Of 18 countries for which we have monthly stock market price data,[25] only Singapore failed to produce any significant terms in the volatility equation. The average volatility persistence coefficient was 0.77, of which five were less than 0.65, and six countries had significant asymmetrical terms. Only Canada had a conditional residual distribution with higher skewness and kurtosis.

Except for Denmark and France, all countries showed periods of high stock price volatility, even where, in the cases of the Netherlands and the UK, there were no episodes of financial difficulty during the period of analysis. Both Denmark and France, on the other hand, did experience financial difficulty during the period. Only in the case of Canada (1981–82) does stock market instability appear to have preceded the period of financial difficulty. In Malaysia (1997), Norway (1987–88), Sweden (1990), and Thailand (1997), high stock price volatility overlapped with a period of financial difficulty, though typically the stock market instability was of much shorter duration than the financial difficulty. In all other cases stock price instability was not associated with any financial disturbance.

Comparison of daily and monthly results

Of the 71 episodes of high volatility identified from the daily data, only five— Malaysia (October–December 1999), Mexico (February 1995–February 1996), Norway (April–June 1991), Sweden (September–October 1990), and Thailand (August–September 1997)—were identified as periods of high volatility from the monthly data. In many instances, high volatility measured from daily data lasts two months or less, which would have been considered a spike rather than a period of sustained high volatility on the basis of the monthly estimates. There is clearly a considerable loss of precision in using monthly estimates, and dailies should be used whenever possible. The unavailability of daily data spanning the full period for which monthlies are available also limits the comparisons.

Monthly indicators and crisis periods

Overall, estimates of periods of high volatility for exchange rates, interest rates, or stock prices, based on monthly data, coincide with periods of financial difficulty in about one

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[25]The countries are Australia, Canada, Denmark, France, Germany, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, Norway, Singapore, Spain, Sweden, Thailand, United Kingdom, and United States.

quarter of cases (see Table 7). In about seven percent of all cases the indicators show high volatility in advance of the period of financial difficulty, and in two percent of cases that level of volatility persists during the crisis. In another 16 percent of cases high volatility occurs during the period of financial instability. Estimated periods of high volatility overlap periods of financial difficulty more often for countries with floating exchange rates that are not actively managed, than for other types of exchange regime. In 23 percent of these cases there was some overlap. For managed rates the overlap occurred in about 17 percent of cases, while with pegged exchange rates the figure was seven percent. For countries with developed capital markets, an overlap of periods of financial difficulty and high volatility of one or other of the price indicators occurs in one quarter of the cases. For emerging markets the proportion is 27 percent, while for countries with underdeveloped capital markets the proportion is 10 percent.

VI. Summary and Conclusions

For both monthly and daily estimates, we find, for a majority of cases, no overlap between periods of high price volatility and financial difficulty; further, there are even fewer cases for which high price volatility precedes financial difficulty. The daily data allow for more precise determination of the onset of periods of high volatility, and are therefore potentially more useful as early indicators of the possibility of financial instability. However, in cases where two indicators were volatile at the same time (Brazil, Korea, Mexico and Norway), the volatility did not emerge early enough to have presaged the financial crisis. The results using monthly data reveal only a few cases (Canada, Jamaica, Bangladesh, Jordan, and New Zealand) where signs of high volatility in one indicator preceded a period of financial difficulty. The results suggest that univariate time series EGARCH models of financial prices are unlikely to be sufficient predictors of financial stress. For prediction, we suggest augmenting the mean and variance relationships to include country-specific institutional and market characteristics.[26] The modeling of multivariate relationships among real and financial variables could also be explored.

This research can be extended to (a) examining other closely watched variables such as foreign exchange reserves; (b) testing the predictive ability of country-specific "triggers" in both the variance equations. For example, if high frequency data are available, correlations between volatility and financial instability may be estimated directly by including specific characteristics of financial distress (e.g., level of nonperforming loans in bank portfolios; indicator of disclosure requirements) in the variance equation. Also, panel data studies may distinguish among volatility patterns by including indicators of country size, financial market development, and exchange rate regime.

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[26]See, for example, results for the Trinidad and Tobago stock market in Leon, Nicholls and Sergeant (2000); see also Lamoureux and Lastrapes (1990), Mills (1991), and Karpoff (1987).

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Table 1. Analysis of Charts
(Number of Occurrences)

1. Periods of High Volatility: 107

1.1. No Overlap with Financial Problems: 71
1.2. Coincide/Overlap Financial Problems: 36
1.2.1. Timing: Volatility Before/During Financial Problems
Before: 6
Before and During: 6
During: 25
1.2.2. Variables Exhibiting High Volatility
Exchange Rates: 27 (2 MDCs)
Interest Rates: 0
Stock Prices: 2 (1 MDC)
Exchange Rates, Stock Prices: 4 (1MDC)
Exchange Rates, Interest Rates: 2
Exchange Rates, Interest Rates, Stock Prices: 1

2. The Exchange Rate Regime

2.1 Pegged: 40
2.1.1. No Overlap of High Volatility and Financial Difficulty: 24
2.1.1. Overlap/Coincidence: 16
Volatility of:
Exchange Rates: 12
Stock Prices: 1
Interest Rates: 0
Exchange Rates, Stock Prices: 2
Exchange Rates, Interest Rates: 1
2.2. Managed: 37
2.2.1. No Overlap: 33
2.2.2. Overlap/Coincidence: 4
Volatility of:
Exchange Rates: 3
Exchange Rates, Interest Rates, Stock Prices: 1
2.3. Floating: 30
2.3.1. No Overlap: 14
2.3.2. Overlap/Coincidence: 16
Volatility of:
Exchange Rates: 13
Stock Prices: 1
Exchange Rates, Interest Rates: 1
Exchange Rates, Stock Prices: 1

Table 1. Analysis of Charts (concluded)
(Number of Occurrences)

3. Capital Market Development

- 3.1. Mature Capital Markets: 4
  - 3.1.1. No Overlap of Volatility and Financial Problems: 2
  - 3.1.2. Overlap/Coincidence: 2
    - Volatility of:
      - Exchange Rate: 1
      - Stock Prices: 1
- 3.2. Emerging Markets: 33
  - 3.2.1. No Overlap: 23
  - 3.2.2. Overlap/Coincidence:10
    - Volatility of:
      - Exchange Rates: 7
      - Exchange Rates, Stock Prices: 2
      - Exchange Rates, Interest Rates: 1
- 3.3. Underdeveloped Markets: 70
  - 3.3.1. No Overlap: 52
  - 3.3.2. Overlap/Coincidence: 18
    - Volatility of:
      - Exchange Rates: 7
      - Exchange Rates, Inflation: 11

Table 2. Estimated Daily Volatility of Exchange Rates, Stock Price Indices and Interest Rates[27]

Country	Unconditional SD	Conditional SD	α	γ	β
Brazil					
Stock	0.27	-0.22	0.22*	-0.08*	0.97*
Index	13.08	5.10	(5.18)	(-2.91)	(83.46)
Interest	0.66	0.47	0.38*	0.01	0.95*
Rate	8.88	7.52	(6.07)	(0.04)	(63.91)
Chile					
Exchange	0.06	0.14	0.08	0.001	0.92*
Rate	53.15	60.17	(0.43)	(0.07)	(5.22)
Stock	0.18	0.09	0.31*	-0.01	0.95*
Index	6.05	3.98	(10.18)	(-0.60)	(80.32)
Interest	-0.70	-0.79	0.39*	0.12*	0.78*
Rate	32.68	12.45	(4.73)	(1.92)	(13.08)
Finland					
Stock	-0.34	-0.16	0.10*	-0.02	0.99*
Index	7.87	5.56	(3.66)	(-1.62)	(257.8)
Interest	-3.15	0.94	0.38*	0.12*	0.78*
Rate	103.1	53.60	(6.63)	(1.92)	(13.08)
Greece					
Exchange	0.37	0.34	0.11*	0.001	0.98*
Rate	10.26	10.86	(2.44)	(0.07)	(110.3)
Stock	0.28	0.17	0.24*	0.01	0.98*
Index	8.75	8.74	(7.05)	(0.25)	(118.9)
Interest	0.96	1.45	0.04	-0.01	0.33
Rate	128.8	155.0	(0.06)	(-0.004)	(0.19)
Indonesia					
Stock	0.33	0.06	0.18*	-0.01	0.99*
Index	12.39	7.85	(7.12)	(-0.76)	(203.4)
Korea					
Stock	0.98	0.22	0.17*	-0.02	0.99*
Index	3.40	4.28	(7.66)	(-0.91)	(262.0)
Interest	1.82	-0.80	0.22*	0.04	0.98*
Rate	411.70	19.98	(4.48)	(1.17)	(102.8)
Malaysia					
Stock	0.98	-0.81	0.18*	-0.05	0.97*
Index	25.68	27.99	(4.03)	(-1.50)	(35.94)

[27]Columns 2 and 3 record the skewness and kurtosis of the unconditional and conditional standard deviations of the residuals. The next three columns show the coefficients of the EGARCH equation $\log(h_t) = \alpha_0 + \beta \cdot \log(h_{t-1}) + \gamma\, \varepsilon_{t-1}/\sqrt{h_{t-1}} + \alpha\left(|\varepsilon_{t-1}|/\sqrt{h_{t-1}} - \sqrt{2/\pi}\right)$, with associated t-statistics. Those coefficients significantly different from zero (with 90% probability, minimum) are marked with an asterisk.

Table 2. Estimated Daily Volatility of Exchange Rates, Stock Price Indices and Interest Rates (continued)

Country	Unconditional SD	Conditional SD	α	γ	β
Mexico					
Exchange	2.42	2.63	0.40*	0.05	0.96*
Rate	65.53	25.93	(5.80)	(0.73)	(65.40)
Stock	-0.09	0.05	0.23*	-0.11*	0.91*
Index	8.17	5.14	(4.20)	(-3.16)	(35.01)
Norway					
Exchange	0.53	0.10	0.14*	-0.01	0.98*
Rate	29.85	5.39	(5.66)	(-0.75)	(167.8)
Stock	-0.30	-0.44	0.25*	-0.02	0.93*
Index	14.39	14.74	(3.12)	(-0.75)	(28.51)
Interest	2.25	-1.24	0.55*	0.03	0.71*
Rate	65.37	21.24	(6.89)	(0.54)	(6.38)
Peru					
Exchange	-0.35	1.80	0.11	-0.08	0.84
Rate	90.21	87.68	(0.13)	(-0.32)	(0.99)
Stock	0.51	0.78	0.30*	-0.07	0.92*
Index	11.96	11.38	(6.69)	(-1.40)	(29.31)
Interest	-0.18	5.35	0.27*	-0.04	0.89*
Rate	76.60	134.5	(3.35)	(-0.49)	(16.39)
South Africa					
Exchange	0.42	0.94	0.25*	0.04	-0.16
Rate	21.84	14.94	(2.54)	(0.59)	(-0.13)
Stock	-1.27	-0.58	0.23*	-0.08	0.95*
Index	19.04	8.96	(4.47)	(-1.60)	(63.32)
Sweden					
Exchange	5.27	0.15	0.33*	-0.06	0.95*
Rate	137.0	8.73	(1.68)	(-0.77)	(36.11)
Stock	0.09	-0.37	0.15*	-0.07*	0.96*
Index	9.12	8.98	(3.87)	(-3.17)	(83.44)
Interest	0.65	1.47	0.20*	0.17*	0.89*
Rate	56.43	41.43	(4.01)	(2.54)	(22.52)
Thailand					
Stock	0.49	0.33	0.20*	0.01	0.97*
Index	7.92	5.47	(6.98)	(0.38)	(56.52)
Turkey					
Stock	-0.05	-0.16	0.15*	0.01	0.97*
Index	5.64	4.88	(3.04)	(0.38)	(56.52)

Table 3. Comparison of High Volatility of Exchange Rates, Stock Indices and Interest Rates

	Exchange Rates	Stock Prices	Interest Rates
Brazil	No Estimate	Jan. 10, 95-Apr. 5, 95 Oct. 31, 97-Dec. 22, 97 Aug. 28, 98-*Jan. 25, 99*	Feb. 26, 98 – May 1, 98 *Jan. 14, 99* – Mar. 30, 99
Chile	Jan. 23, 90 – Feb. 16, 90 Jul. 10, 90 – Mar. 3, 92	Sep. 3, 91-Nov. 14, 91 Feb. 7, 94-Apr. 13, 94 *Aug. 28, 98-Nov 16, 98*	*Jul. 1, 98 – Oct. 22, 98* Apr. 16, 99 – Jun. 23, 99
Finland	May 19, 89-Jun. 12, 89 Jul. 14, 92-Nov. 2, 92	Dec. 18 – 28, 95 Oct. 30 – Nov. 26, 97	Aug. 29, 91–Nov. 25, 91 May 27, 94- Aug. 30, 94
Greece	Jan. 3, 90-Feb. 19, 90 Mar. 22, 91-May 10, 91 Sep. 30, 92-Nov. 4, 92 Mar. 31, 95-Apr. 26, 95	Nov. 9, 90-Dec. 25, 90	May 12, 94-Sep. 6, 94 Oct. 31, 97-Mar. 28, 98
Indonesia	No Estimate	Aug. 29, 97-Mar. 18, 98 May 19, 98-Jun. 25, 98 Aug. 31, 98-Dec. 9, 98 Sep. 9, 99-Nov. 1, 99 May 18, 00-Jul. 10, 00	No Estimate
Korea	No Estimate	*Oct. 29, 97-Mar. 13, 98*	Aug. 3, 94-Sep. 20, 94 Dec. 20, 94-Jan. 31, 95 *Nov. 27, 97-Mar. 4, 98*
Malaysia	No Estimate	Jan. 12 – Apr. 8, 94 Aug. 27 – Sep. 30, 97 Oct. 29, 97– Mar. 13, 98 May 25 – Jun. 26, 98	No Estimate
Mexico	*Dec. 22, 94 – May 9, 95* Oct. 12 – Nov. 24, 95 *Oct. 29 – Nov. 12, 97* Jan. 9 – Feb. 2, 98	*Jan. 10 – Mar. 7, 95* *Oct. 28 – Nov. 14, 97*	No Estimate
Norway	Mar. 26 – Jun. 4, 91 *Sep. 17 – Nov. 9, 92*	Nov. 20 – Dec. 11, 91 *Aug. 21 – Dec. 22, 92*	No Periods of Sustained High Volatility
Peru	Jun. 17, 91-Aug. 5, 92	Jan. 5, 94-Apr. 28, 94 *Jan. 10, 95-Apr. 17, 95* Aug. 24, 98-Oct. 9, 98	Aug. 21, 91-Oct. 14, 91 Jan. 24, 92-Apr. 9, 92 *Jan. 4, 95-Feb. 13, 95* Feb. 9, 99-Jun. 4, 99
S. Africa	May 16, 89-Aug. 8, 89 Feb. 20, 96-Mar. 1, 96 Apr. 1, 96-May 13, 96	Oct. 29 – Nov. 20, 97 May 28 – Jun. 26, 98	No Estimate

Table 3. Comparison of High Volatility of Exchange Rates, Stock Indices and Interest Rates (continued)

	Exchange Rates	Stock Prices	Interest Rates
Sweden	Aug. 20 – Sep. 13, 91 Sep. 15, 92 – Feb. 4, 93 Apr. 5 – 30, 93 Sep. 7 – 22, 93 Jul. 13 – 27, 94	Aug. 7 – Oct. 25, 90 Oct. 28 – Nov. 18, 97	No Periods of Sustained High Volatility
Thailand	No Estimate	Aug. 8, 90 – Oct. 8, 90 Jun. 25, 97 – Dec. 4, 98	Discrete changes
Turkey	No Estimate	Aug. 28, 98 – Dec, 3, 98	N/A

Table 4. Estimated Volatility of Monthly TB Rate[28]

	Skewness, Kurtosis: Unconditional	Skewness, Kurtosis: Conditional	α	γ	β	Period/s High Volatility	Period/s Financial Stress
Australia	0.31	1.66	0.23	0.12	0.83*		89-92
	10.08	14.30	(1.26)	(1.06)	(11.37)		
Bahamas	0.77	0.37	0.28*	0	0.91*		
	4.88	4.11	(2.14)	(-0.03)	(15.39)		
Canada	0.82	0.78	0.45*	-0.04	0.89*	92-93	83-85
	8.38	8.37	(3.95)	(-0.46)	(18.01)	97-98	
Fiji	2.23	-2.13	-0.08	-0.82*	0.95*	86-87	95-
	29.35	12.02	(-0.43)	(-2.71)	(36.92)	88-89	
France	0.74	1.13	0.32	0.05	-0.61	95.04-10	91-95
	11.68	12.23	(1.56)	(0.30)	(-1.51)		
Germany	1.32	1.02	-0.24	0.25*	0.13		90-93
	8.93	8.11	(-1.45)	(2.61)	(0.31)		
Guyana	0.29	0.26	0.47*	-0.12	0.81*		91-
	5.51	4.47	(2.31)	(-0.90)	(5.38)		
Iceland	0.01	-0.52	0.36	0.10	-0.44		85-86
	8.70	8.14	(1.26)	(0.62)	(-0.55)		93
Ireland	1.04	1.52	0.43*	0.34*	0.81*	92-93	85
	32.60	11.12	(3.06)	(2.43)	(10.20)		
Israel	0.04	1.11	0.38*	0.18*	0.78*		83-84
86-98	5.18	7.23	(3.46)	(1.92)	(5.92)		
Italy	0.47	0.42	0.20*	0.16*	0.89*		90-95
	5.52	5.22	(3.76)	(4.82)	(28.53)		
Jamaica	-0.21	0.38	0.32*	-0.18	0.96*	92-93	94-
	9.68	7.14	(3.00)	(-2.83)	(40.36)		
Kenya	1.32	2.63	0.34*	-0.26*	0.92*	77-78	93
	36.67	26.00	(3.93)	(-3.82)	(38.00)	94-95	
Lebanon	-0.55	0.57	0.40*	0.31*	0.83*	92-93	88-90
	16.43	16.14	(5.17)	(4.03)	(33.98)		
Malaysia	-1.41	-1.20	0.23*	-0.34*	0.98*	94-95	85-88, 97-
	15.47	9.46	(2.21)	(-3.72)	(116.7)		99
Mexico	0.94	0.55	0.63*	0.24*	0.90*	94-95	82
	12.32	6.21	(4.10)	(2.32)	(21.78)		94-95
New	0.47	0.22	0.10*	-0.13*	0.95*		89-90
Zealand	4.85	4.43	(1.68)	(-2.03)	(16.70)		

[28]Columns 2 and 3 record the skewness and kurtosis of the unconditional and conditional standard deviations of the residuals. The next three columns show the coefficients of the EGARCH equation $\log(h_t) = \alpha_0 + \beta \cdot \log(h_{t-1}) + \gamma\, \varepsilon_{t-1}/\sqrt{h_{t-1}} + \alpha\left(|\varepsilon_{t-1}|/\sqrt{h_{t-1}} - \sqrt{2/\pi}\right)$, with associated t-statistics. Those coefficients significantly different from zero (with 90% probability, minimum) are marked with an asterisk. Column 7 shows those periods when the conditional standard deviation exceeded its 75th percentile by 150% of the interquartile range. The last column shows periods of financial difficulty for comparison.

Table 4. Estimated Volatility of Monthly TB Rate (continued)

	Skewness, Kurtosis: Unconditional	Skewness, Kurtosis: Conditional	α	γ	β	Period/s High Volatility	Period/s Financial Stress
Papua New	-0.20	0.34	-0.12	0.23*	0.95*		89-
Guinea	9.20	6.41	(-1.57)	(2.98)	(28.46)		
South	1.06	1.14	0.49*	-0.21*	0.97*	73-74	85
Africa	14.47	10.98	(3.54)	(-2.22)	(31.86)	83.03-10	
Sri Lanka	1.41	1.64	0.06	-0.28*	-0.26		Early
	15.18	16.34	(0.23)	(-1.99)	(-0.44)		90s
Swaziland	0.24	0.85	0.50*	-0.25*	0.80*		95
	10.56	8.41	(2.65)	(-1.85)	(7.49)		
Sweden	5.55	1.75	0.65*	-0.16	0.78*	73-74	90-93
	69.34	13.97	(3.45)	(-1.08)	(11.45)	92-93	
UK	0.58	0.48	0.30	-0.02	0.84	77-78	
	6.52	7.11	(2.34)	(-0.29)	(7.20)		
USA	-0.92	-0.21	0.40	-0.02	0.98	80-82	80-92
	8.50	4.23	(2.77)	(-0.33)	(40.73)		

Table 5. Estimated Volatility of Monthly Exchange Rates

Country	Unconditional SD	Conditional SD	α	γ	β	High Volatility Periods	Financial Stress Periods
Algeria	4.64	-0.27	0.99*	0.14*	0.72*	None	90-92
	36.54	4.86	(8.56)	(1.91)	(13.26)		
Angola	-5.58	1.35	2.37*	-0.31	0.15*	None	91-present
	46.39	7.27	(10.05)	(-1.53)	(2.16)		
Australia	1.30	0.19	0.64*	0.25*	0.38*	None	89-92
	8.55	4.85	(5.37)	(2.39)	(2.43)		
Bangla-	11.33	1.18	0.42*	-0.08	0.97*	76.08-	80-present
desh	175.5	11.52	(3.98)	(-0.93)	(37.59)	77.02,	
						79.08-	
						80.07	
Benin	10.46	-0.14	0.27*	-0.02	0.91*	None	88
	160.5	4.24	(2.80)	(-0.54)	(39.99)		
Bhutan	4.55	0.26	0.90*	0.11	0.77*	None	Early 90s –
	44.04	8.13	(6.44)	(1.15)	(13.46)		present
Botswana	1.16	0.19	0.13	0.17*	0.91*	85.09-	94-95
	15.49	7.92	(1.49)	(2.59)	(40.65)	86.07	
Brunei	-0.25	-1.13	0.32	0.04	0.84*	73.03-	Mid-80s
	7.14	9.17	(1.60)	(0.42)	(11.32)	74.03,	
						75.03-	
						75.10	
						97.09-	
						98.07	
Burma	-0.22	2.10	0.37*	0.01	-0.27	None	
	5.99	23.98	(3.52)	(0.10)	(-1.19)		
Burundi	3.12	0.57	-0.28	0.58*	0.20	None	94-present
	21.45	3.90	(-1.53)	(4.45)	(0.65)		
Canada	0.11	0.05	0.21*	0.23*	0.07	None	83-85
	3.58	3.36	(2.03)	(3.11)	(0.31)		
Chile	9.88	1.62	-0.02	-0.06	-0.02	None	81-87
	130.5	12.37	(-0.05)	(-0.30)	(-0.02)		
Fiji	5.09	0.17	0.45*	0.18*	0.75*	72.08-	95-
	45.74	4.02	(4.29)	(2.52)	(16.29)	72.12,	
						73.12-	
						74.04,	
						98.01-	
						98.04	
Finland	0.58	0.01	0.12	0.01	0.93*	93.03-	91-94
	5.63	4.60	(1.05)	(0.16)	(58.76)	93.08	
France	0.19	-0.09	0.11	-0.01	0.92*	None	91-95
	3.76	4.65	(1.46)	(-0.15)	(54.66)		
Gambia	3.83	0.23	0.90*	-0.18*	0.76*	85.05-	85-92
	50.32	5.93	(8.94)	(-1.98)	(18.19)	86.09	
Germany	-0.21	-0.26	0.08	0.002	0.90*	None	90-93
	3.62	4.18	(1.04)	(0.05)	(23.68)		
Greece	1.15	0.21	0.25	0.07	0.89*	None	91-95
	8.22	7.08	(1.62)	(0.99)	(47.62)		

Table 5. Estimated Volatility of Monthly Exchange Rates (continued)

Country	Unconditional SD	Conditional SD	α	γ	β	High Volatility Periods	Financial Stress Periods
Iceland	2.37	0.64	0.37*	0.22*	0.82*	89.02-	85-86,
	11.44	5.09	(2.74)	(2.83)	(36.48)	89.07	93
India	4.55	0.29	0.88*	0.11	0.78*	None	91-
	44.07	8.18	(6.46)	(1.16)	(13.93)		
Ireland	0.33	0.04	-0.12	0.06	0.001	None	85
	3.89	3.78	(-1.02)	(0.76)	(0.006)		
Israel	2.51	0.55	0.46*	-0.01	-0.88*	86.01-	83-84
	14.78	3.24	(5.69)	(-0.25)	(-105.1)	86.11	
Italy	0.55	0.19	0.15	0.07	0.01	None	90-95
	4.40	4.33	(1.28)	(0.69)	(0.08)		
Japan	-0.57	-0.81	0.007	-0.02	0.91*	None	92-present
	4.09	5.03	(0..13)	(-0.50)	(29.41)		
Jordan	1.44	-1.16	0.14	-0.008	0.91*	88.10-	89-90
	11.29	13.08	(1.60)	(-0.15)	(43.06)	89.10	
Kenya	1.68	0.65	0.58*	0.09	0.64*	81.03-	93
	22.26	9.66	(4.79)	(0.77)	(9.63)	81.12, 94.05- 95.01	
Korea	8.24	0.04	0.99*	0.07	0.77*	95.04-	Mid 80s
	102.0	13.00	(6.43)	(0.41)	(9.76)	98.07	
Lesotho	1.11	0.65	0.36*	0.18*	0.88*	84.11-	88-
	13.05	8.00	(6.48)	(2.21)	(24.63)	85.06	
Malaysia	1.22	-0.48	0.17	0.04	0.87*	73.12-	85-88,
	22.34	12.18	(0.99)	(0.40)	(21.75)	74.05, 97.09- 98.07	97-99
Mauritius	2.21	0.21	0.19*	-0.07	0.92*	None	None
	17.00	6.23	(2.27)	(-1.27)	(31.38)		
Mexico	3.04	0.64	0.87*	-0.15	0.98*	85.07-	81-82,
	17.70	7.57	(3.05)	(-1.30)	(62.61)	85.11, 86.09- 86.11, 95.02- 96.02	94-96
Nether-lands	-0.01	-0.24	0.15	-0.01	0.90*	None	None
	3.17	4.35	(1.19)	(-0.16)	(21.40)		
New Zealand	1.10	-1.87	0.08	-0.01	0.93*	85.09-	89-90
	9.70	18.83	(0.43)	(-0.09)	(22.91)	89.02	
Nigeria	7.81	2.06	0.92*	0.29	0.85*	None	91-95
	78.01	14.80	(5.19)	(1.80)	(25.82)		
Norway	0.08	-0.07	0.33*	0.06	0.66*	91.04-	87-93
	3.21	3.41	(2.92)	(0.91)	(3.12)	91.07, 92.12- 93.01	
Pakistan	2.04	2.09	1.03*	0.28	0.30*	None	80-present
	7.67	10.72	(4.18)	(1.72)	(2.16)		

Table 5. Estimated Volatility of Monthly Exchange Rates (concluded)

Country	Unconditional SD	Conditiona SD	α	γ	β	High Volatility Periods	Financial Stress Periods
Papua	1.25	0.96	0.40*	0.23*	0.06		89-96
New Guinea	9.13	9.39	(2.18)	(1.73)	(0.48)		
Philip-	7.05	2.89	0.66*	0.06	0.69*	70.03-	81-87,
pines	70.57	18.29	(3.93)	(0.35)	(6.01)	70.07, 84.11-85.04, 90.09-91.02, 97.08-98.06	97-99
South	0.79	-0.17	0.09	0.12*	0.95*	None	85,
Africa	10.93	4.94	(1.42)	(2.19)	(24.88)		97-
Sierra	4.44	0.33	1.98*	0.43*	0.04	None	90-present
Leone	33.58	7.39	(9.05)	(2.35)	(0.79)		
Singapore	-0.11	-0.62	0.71*	0.16*	0.82*	97.09-	None
	6.62	5.70	(5.25)	(1.75)	(8.79)	98.07	
Spain	0.87	0.07	0.20	-0.001	0.02	None	77-85
	6.88	4.50	(1.37)	(-0.01)	(0/02)		
Sri	6.99	0.65	1.59*	-0.08	0.88*	77.04-	Early 90s
Lanka	76.03	11.19	(4.29)	(-0.27)	(21.33)	78.05, 80.04-82.02, 83.03-83.10, 93.01-93.10	
Swaziland	0.59	0.37	0.04	0.10*	0.96*	85.04-	95
	10.91	3.43	(0.84)	(2.73)	(34.35)	86.11	
Sweden	1.16	0.20	0.14	0.07	0.78*	None	90-93
	7.23	3.70	(1.52)	(1.24)	(4.80)		
Tanzania	3.76	1.72	0.77*	0.25	0.15*	None	88-present
	22.05	11.54	(3.81)	(1.24)	(14.95)		
Thailand	-0.15	-0.13	-0.01	-0.12	0.93	85.01-	83-87,
	5.38	3.04	(-0.13)	(-0.96)	(23.54)	86.03	97-present
Togo	10.46	-0.14	0.27	-0.02	0.91*	None	89-91
	160.5	4.24	(2.80)	(-0.54)	(39.99)		
Tunisia	0.31	0.19	0.29*	0.07	0.80*	None	91-95
	3.85	3.57	(2.73)	(1.19)	(7.71)		
Turkey	5.51	1.99	1.43*	0.04	0.16*	94.03-	82, 91, 94
	45.42	15.80	(6.94)	(0.25)	(2.44)	94.07	
UK	0.16	-0.13	0.24*	0.02	-0.65*	None	None
	4.19	3.33	(2.06)	(0.30)	(-3.01)		

Table 6. Estimated Volatility of Monthly Stock Market Indices

	Skewness, Kurtosis: Uncond.	Skewness, Kurtosis: Conditional	α	γ	β	Period/s High Volatility	Period/s Financial Stress
Australia	-1.64 12.31	-0.39 4.50	0.39* (1.80)	-0.12 (-0.99)	0.87* (17.73)	74.01- 75.05, 87.11- 88.04	89-92
Canada	-0.69 6.56	-0.85 6.67	0.22 (1.24)	-0.09 (-0.94)	0.79* (3.55)	74.01- 75.02, 81.11- 82.09, 87.11- 88.03	83-85
Denmark	-0.27 6.52	-0.40 6.02	0.29* (2.27)	-0.20* (-2.24)	0.47* (2.02)	None	87-92
France	-0.64 5.61	-0.69 4.84	0.12* (3.01)	-0.01 (-0.33)	0.99* (65.15)	None	91-95
Germany	-1.22 10.04	-0.45 4.55	0.11* (2.11)	0.09* (3.10)	0.99* (66.60)	86.02- 86.12, 88.04- 88.08	90-93
Italy	-0.02 5.82	0.08 4.00	0.43* (2.21)	-0.18 (-1.50)	0.54* (2.38)	77.06- 78.01, 81.08- 81.11	90-95
Japan	-0.42 4.81	-0.20 4.18	0.25* (2.74)	0.004 (0.08)	0.97* (41.57)	90.10- 91.04	92-present
Korea	-0.74 7.15	-0.27 5.50	0.21 (1.52)	-0.02 (-0.32)	0.95* (10.00)	81.04- 81.09, 82.02- 82.08	Mid 80s, 97-present
Malaysia	-1.10 7.39	-0.45 5.47	0.59* (3.43)	-0.31 (-1.62)	0.48* (4.32)	97.09- 97.12	85-88, 97-99
Mexico	-1.18 8.11	-0.42 3.52	0.54* (2.90)	0.09 (0.79)	0.85* (8.56)	86.10- 88.06	81-82, 94-96
Netherlands	-1.29 10.30	-0.11 3.39	0.31 (1.45)	-0.19 (-1.51)	0.54* (2.62)	87.10- 88.01	None
Norway	-1.05 8.10	-0.39 3.21	0.57* (2.84)	-0.30* (-1.71)	0.38* (1.86)	87.11- 88.01	87-93
Singapore	-1.44 11.65	-0.36 5.84	0.35 (1.35)	-0.19 (-1.11)	0.35 (0.75)	87.11- 88.03	None
Spain	-1.07 8.93	0.45 4.29	-0.15* (-2.86)	0.10* (8.68)	0.96* (997.7)	86.01- 86.09	77-85
Sweden	-0.29 4.27	-0.34 4.28	0.23* (1.80)	-0.11 (-1.26)	0.68* (3.01)	97.08- 70.05- 70.07, 87.11- 88.01, 90.09- 90.12	90-93

Table 6. Estimated Volatility of Monthly Stock Market Indices (concluded)

	Skewness, Kurtosis: Uncond.	Skewness, Kurtosis: Conditional	α	γ	β	Period/s High Volatility	Period/s Financial Stress
Thailand	-0.55	-0.10	0.31	0.09	0.74*	97.08-	83-87,
	4.64	3.86	(1.30)	(0.76)	(5.98)	97.09	97-present
UK	-0.44	-0.24	0.30*	-0.14*	0.91*	74.01-	None
	6.99	3.78	(2.50)	(-1.90)	(21.93)	75.05,	
						76.11-	
						77.02,	
						87.12-	
						88.04	
USA	-0.70	-0.46	0.18*	-0.15*	0.90*	70.04-	80-92
	5.12	4.47	(1.68)	(-3.16)	(18.44)	70.10,	
						73.12-	
						75.03,	
						87.11-	
						88.03	

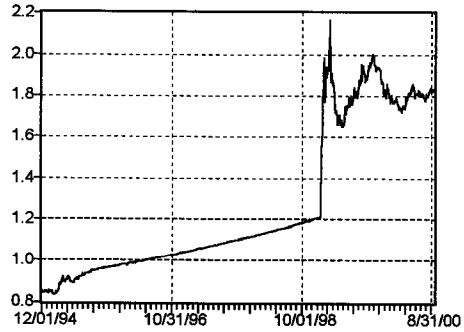
Table 7. Comparison of Periods of High Volatility and Financial Difficulty (Percentages)

	Exchange Rate Regime			Capital Market Development			
	Pegged	Managed	Float	Mature	Emerging	Under-developed	Total[29]
No Overlap	19	25	34	9	25	44	78
Vol. before Stress	2	0	3	0	2	3	5
Before and During	2	0	0	0	0	2	2
Vol. during Stress	0	5	11	3	10	3	16
Total	23	30	48	12	37	52	101

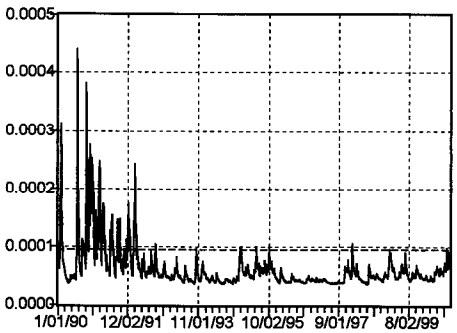
[29]Total percentage does not add to 100 due to rounding.

Chart 1. Brazil and Chile

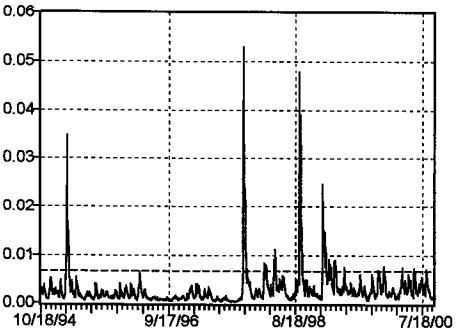
Brazil - Exchange Rate



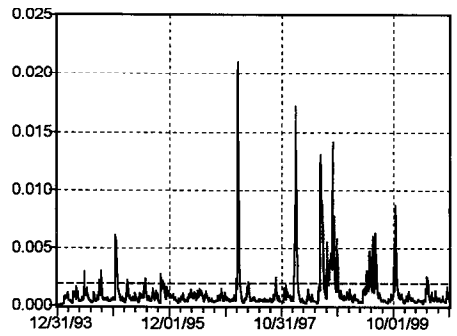
Chile Daily ER Conditional SD
High Vol. 1/23/90-2/16/90,
7/10/90-3/03/92



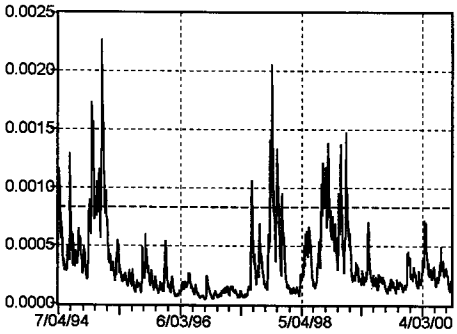
Brazil - Conditional SD of Daily Interest Rates
High vol: 2/26/98 - 5/01/98
1/14/99 - 3/30/99



Chile - Conditional SD of Interest Rates
High Vol.: 7/01/98 - 10/22/98
4/16/99 - 6/23/99



Brazil - Conditional SD Daily Stock Prices
High Vol.: 1/10/95 - 04/05/95
10/31/97 - 12/22/97
8/28/98 - 1/25/99



Chile - conditional SD Daily Stock Prices
High Vol.: 9/03/91 - 11/14/91
2/07/94 - 4/13/94
8/28/98 - 11/16/98

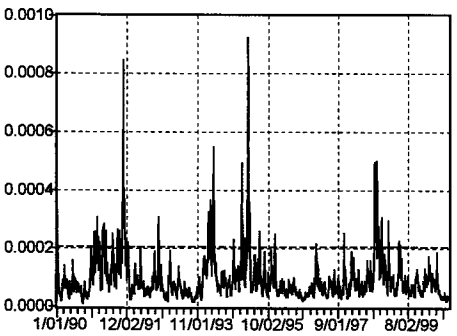
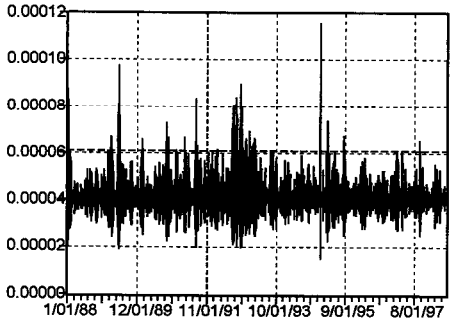
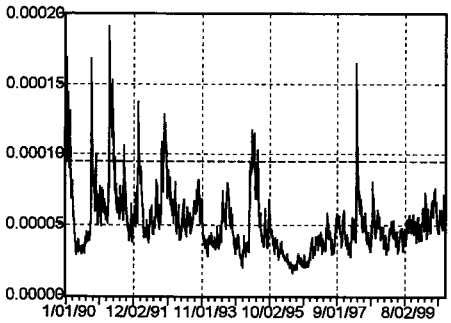


Chart 2. Finland and Greece

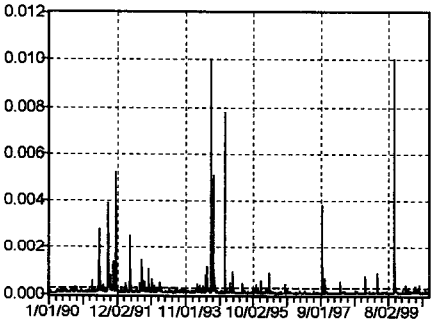
Finland Exchange Rate - Periods of Sustained high Volatility
5/19/89-6/12/89,
7/14/92-11/02/92



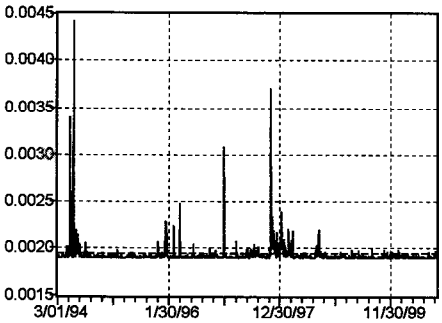
Greece Daily ER Conditional SD
High Vol: 1/03/90 - 2/19/90,
3/22/91 - 5/10/91, 9/30/92 - 11/04/92,
3/31/95 - 4/26/95.



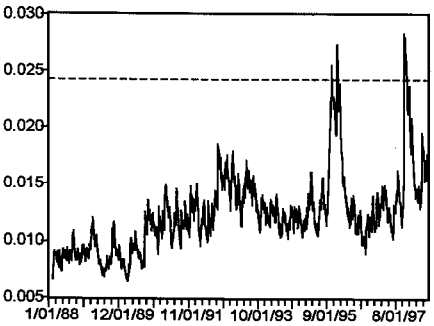
Finland - Conditional SD of Interest Rates
High Vol.: 8/29/91 - 11/25/91
5/27/94 - 8/30/94



Greece - Conditional SD of Interest Rates
High Vol.: 5/12/94 - 9/06/94
10/31/97 - 3/28/98



Finland - Volatility of Stock Market Index
12/18/95 - 12/28/95,
10/30/97 - 12/26/97



Greece - Conditional SD Daily Stock Prices
High Vol.: 11/9/90 - 12/25/90

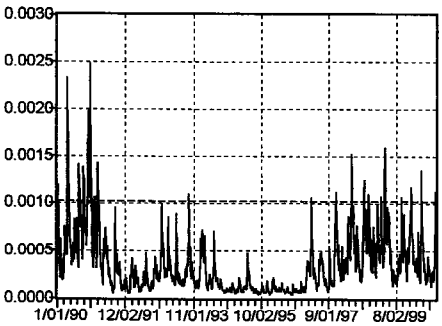
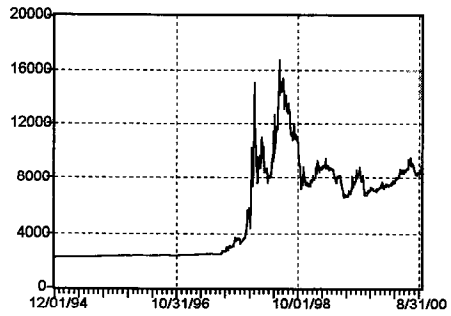
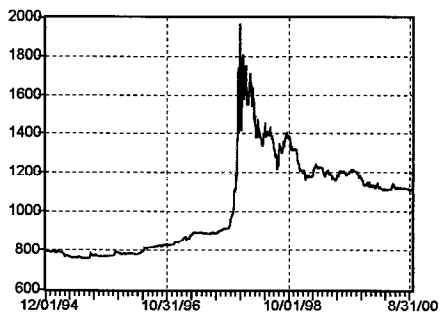


Chart 3. Indonesia and Korea

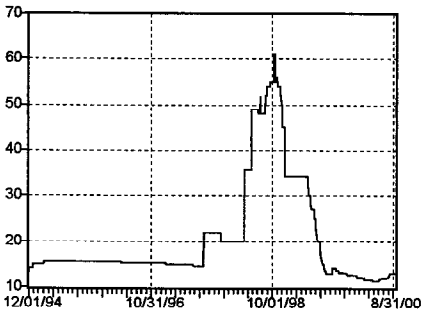
Indonesia - Exchange Rate



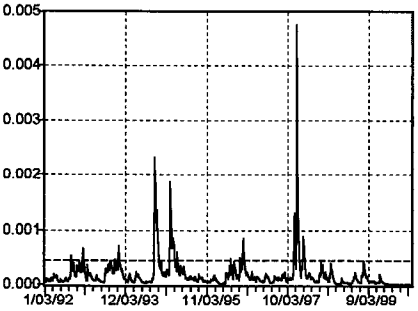
Korea - Exchange Rate



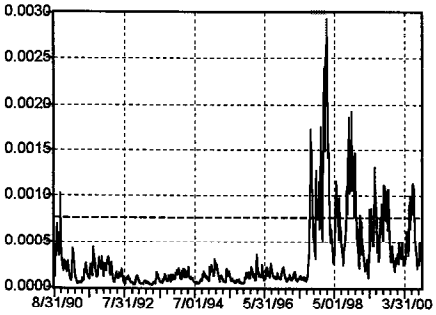
Indonesia - Deposit Interest Rate



Korea - Conditional SD of Daily Interest Rates
High Vol.: 8/03/94 - 9/20/94
12/20/94 - 1/31/95
11/27/97 - 3/04/98



Indonesia - Conditional SD Daily Stock Prices
High Vol.: 8/29/97 - 3/18/98
5/19/98 - 6/25/98
8/31/98 - 12/9/98
9/9/99 - 11/1/99
5/18/00 - 7/10/00



Korea - Conditional SD Daily Stock Prices
High Vol.: 10/29/97 - 3/13/98

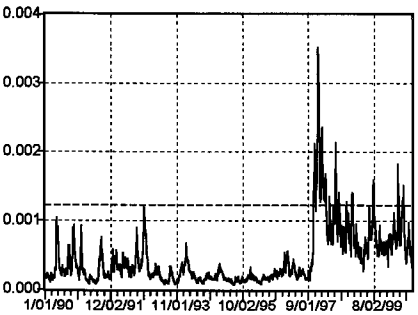


Chart 4. Malaysia and Mexico

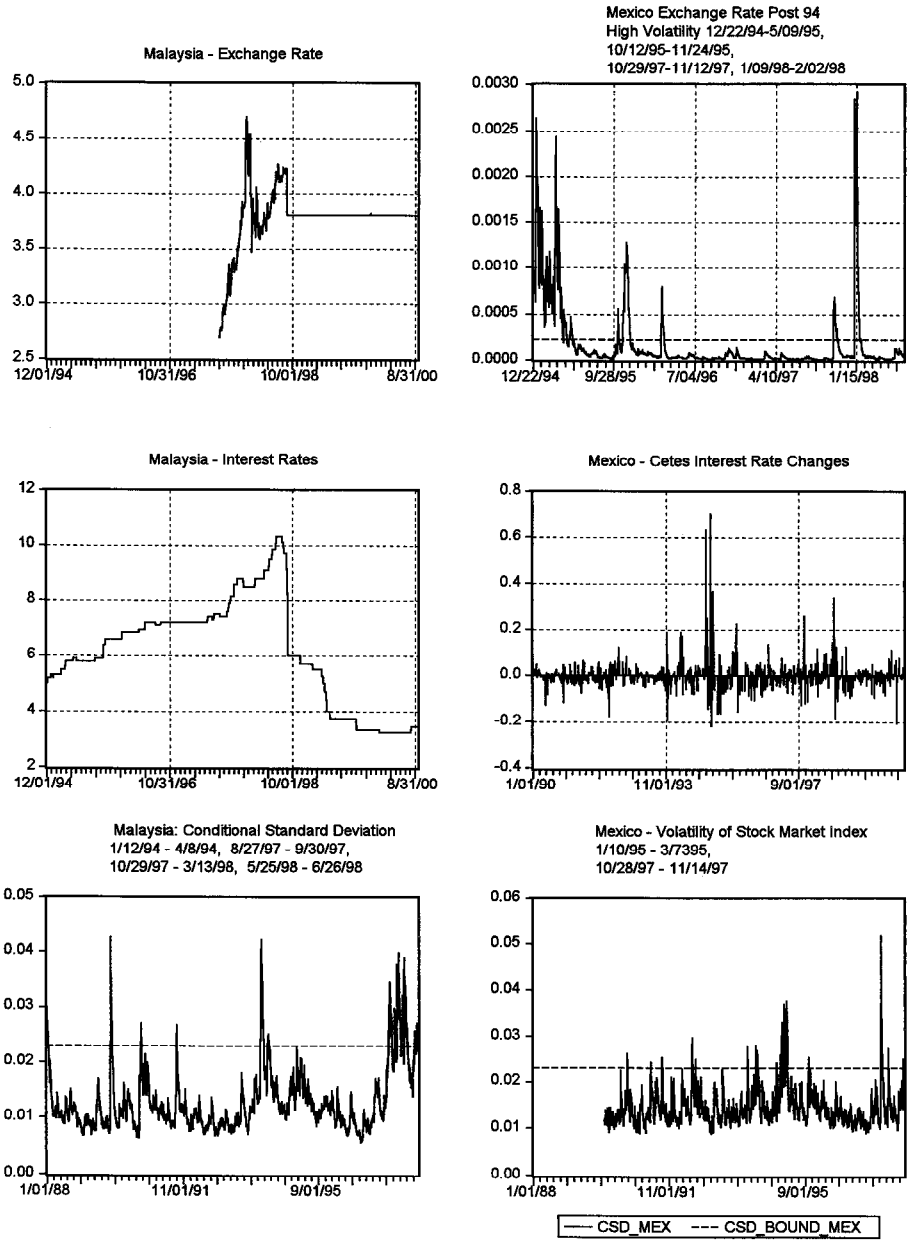
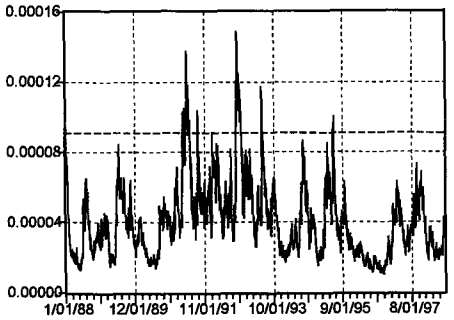
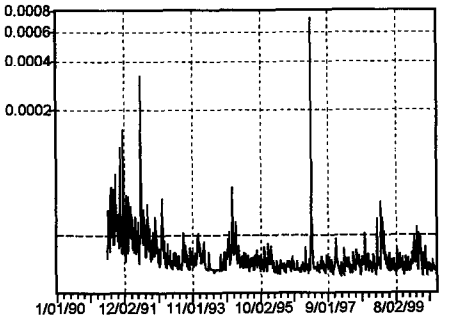


Chart 5. Norway and Peru

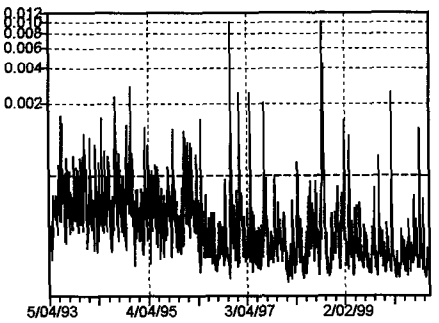
Norway Exchange Rate Daily - Sustained High Volatility
3/26/91-6/04/91, 9/17/92-11/09/92



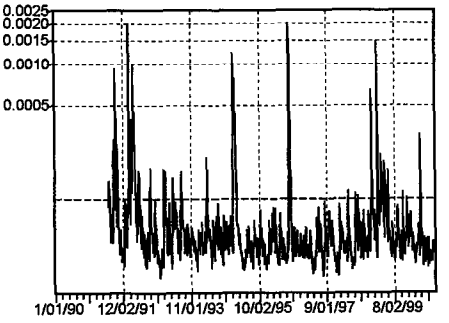
Peru Daily ER Conditional SD
High Vol.: 6/17/91 - 8/05/92



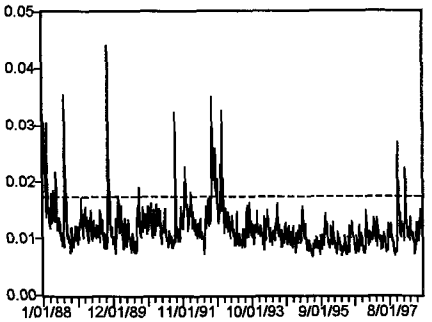
Norway - Conditional SD of Interest Rates
No sustained periods of high volatility



Peru - Conditional SD of Interest Rates
High Vol.: 8/21/91 - 10/14/91
1/24/92 - 4/09/92
1/04/95 - 2/13/95
2/09/99 - 6/04/99



Norway - Volatility of Stock Market Index
11/20/91 - 12/11/91,
7/21/92 - 12/22/92



Peru - Conditional SD Daily Stock Prices
High Vol.: 1/5/94 - 4/28/94
1/10/95 - 4/17/95
8/24/98 - 10/9/98

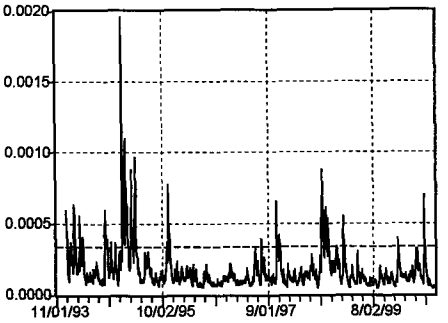
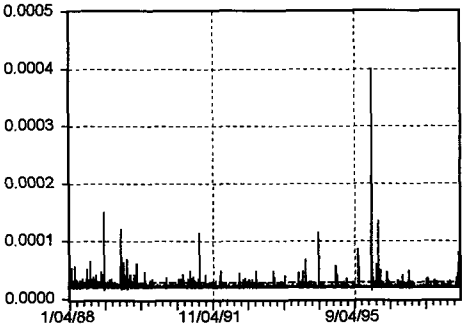
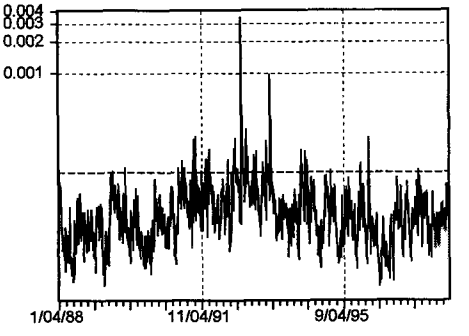


Chart 6. South Africa and Sweden

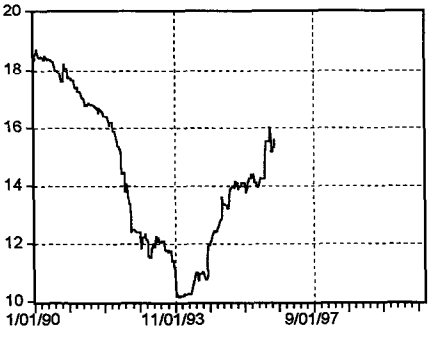
S. Africa - High Volatility Daily ER
5/16/89 - 8/08/89, 2/20/96 - 3/01/96, 4/01/96 - 5/13/96



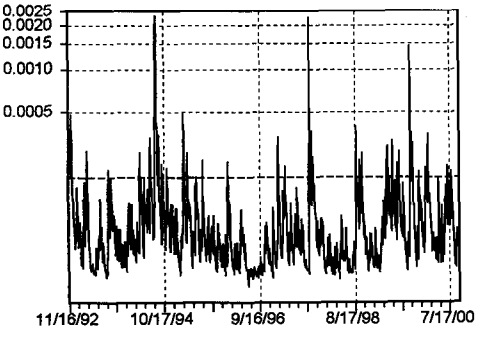
Sweden - Daily ER High Volatility Periods
8/20/91 - 9/13//91, 9/15/92 - 2/04/93,
4/05/93 - 4/30/93, 9/07/93 - 9/22/93,
7/13/94 - 7/27/94



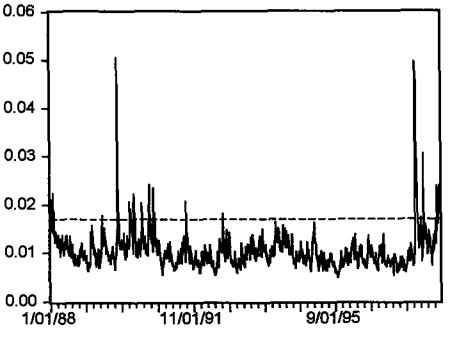
S. Africa - Interest Rates



Sweden _ Conditional SD of Daily Interest Rates
No periods of sustained high volatility



South Africa - Volatility of Stock Market Index
10/29/97 - 11/20/97,
5/28/98 - 6/26/98



Sweden: Conditional Standard Deviation, Stock Market Index
8/7/90 - 10/25/90,
10/28/97 - 11/18/97

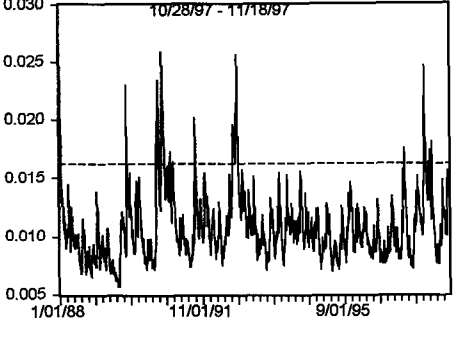


Chart 7. Thailand and Turkey