Does the Introduction of Futures on Emerging Market Currencies Destabilize the Underlying Currencies?

CHRISTIAN JOCHUM and LAURA KODRES*

Recent interest in futures contracts on emerging market currencies has raised concerns among some central bank authorities about their ability to maintain stable currencies. This paper presents empirical results examining the influence of the Mexican peso, the Brazilian real, and the Hungarian forint futures contracts on the respective spot markets. While measures of linear dependence and feedback indicate strong connections between the respective markets, futures volatility does not significantly explain spot market volatility, nor does it increase after futures introductions. To account for the characteristics of the spot and futures returns, a SWARCH model is employed to estimate volatility. [JEL C22, G15]

INCREASED VOLUME and volatility of capital flows to emerging market countries has sparked interest in derivative contracts on emerging market currencies. High economic growth and capital account liberalization have increased currency exposures of both domestic entities and their foreign counterparts. The demand for instruments to manage the currency risk associated with portfolio investment, as well as foreign direct investment, is also

expanding quickly in these markets as they become more global. Moreover, currency hedging products have emerged as countries have moved from managed float regimes to more fully floating ones. Currency futures, since they are traded on organized exchanges, confer benefits from concentrating order flow and providing a transparent venue for price discovery, while over-the-counter forward contracts rely on bilateral negotiations at often unpublished prices. However, despite the growing demand for such products, currency futures contracts are still in early stages of development.

While futures exchanges, both abroad and domestic, are keen to introduce futures on emerging market currencies, the authorities in many of these countries are wary of their development. A spokesperson from the Monetary Authority of Singapore (MAS) described a commonly held concern: "[The] MAS is concerned about any trading activity in the Singapore dollar, which has the possibility of being destabilizing to the market."[1] A number of speculative attacks have been waged against emerging market currencies of late, making officials more sensitive about their currencies' volatility and their ability to stabilize exchange rates during a currency crisis in the presence of a futures market. The implicit view of many authorities is that futures markets harbor speculators who can employ extensive leverage to move the underlying market in undesired directions.

Although futures on emerging market currencies were introduced relatively recently, the concern that derivative markets destabilize the underlying instrument is a long-standing policy issue. Theoretical work on the impact of futures and options on the underlying instrument has yielded mixed conclusions. Two characteristics of futures contracts—their minimal margin requirements and the low transactions costs relative to over-the-counter markets—drive both the positive and negative results found in the theoretical literature. These two characteristics of futures contracts are inextricably linked to the existence of a clearing house, which takes the other side of every trade, making a credit assessment of one's counterparty unnecessary. Credit risks are further mitigated by daily marking to market of all futures positions with gains and losses paid by each participant to the clearing house by the end of the trading session. Initial margin, typically less than 5 percent of the notional value of a contract, is placed with the clearing house to serve as a buffer or performance bond, while the daily maintenance margin limits the scope of large losses. Moreover, futures contracts are standardized, utilizing the same delivery dates and the same nominal amount of currency units to be traded. Hence, traders need only establish the number of contracts and their price. Contract standardization and clearing house facilities mean that price

[1] International Securities Regulation Report (1997), p. 3.

discovery can proceed rapidly and transaction costs for participants are relatively low.[2]

The two strains of the theoretical literature use these futures market characteristics to argue that, on one hand, since minimal margin requirements and low transaction costs permit investors to hold large, highly leveraged positions and lower the barrier to entry to the market, futures markets attract uninformed, or at least differentially informed, traders who can destabilize the underlying market.[3] As described by Shastri, Sultan, and Tandon (1996), the adverse effects occur when there is a migration of uninformed traders to the futures market from the underlying market. First, market makers in the underlying securities increase their bid/ask spread to insure themselves against the greater probability of trading with an informed investor. Second, trading volume and liquidity in the underlying securities will decrease as activity is drawn to the new market.

On the other hand, it is argued by others that the introduction of additional financial instruments improves the market's overall depth and informativeness by increasing market liquidity and decreasing cash market volatility (e.g., Stoll and Whaley, 1987, and Kyle, 1985). The increased number of futures transactions, owing to their lower transaction costs relative to the underlying instrument, allow prices to adjust more quickly to new information and increase the investment opportunity set available to investors. Moreover, some argue that informed investors, like uninformed investors, find futures to be a superior investment vehicle, given the leverage characteristics and lower transaction costs, implying improved liquidity and reduced volatility accompanying their participation. It is not clear, in advance, which of two theoretical strands is more likely to obtain.

Empirical research examining the effect of the introduction of derivative contracts is more consistent than the theoretical analysis. It points predominantly to a positive influence on the underlying instrument: tighter pricing relations to the underlying, lower cash market volatility, and futures prices or options prices leading cash market prices. Interestingly, the few studies that find a destabilizing effect from the introduction of futures have used the major industrial country currencies as the underlying instrument.

This paper extends the empirical work to examine the introduction of futures on three emerging market currencies: the Mexican peso, the Brazilian real, and the Hungarian forint.[4] While the potentially destabilizing influence

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[2] Other related elements often identified as providing low transaction costs include lower fees and commissions, lower opportunity cost of initial margin, lower opportunity cost of additional liquid assets held to meet variation margin, smaller bid-ask spreads, and fewer regulatory constraints.

[3] See Cox (1976).

[4] While several other emerging market currencies have recently begun trading (or are scheduled to), their price history is still too short to use in any empirical work.

of futures markets has considerable interest in mature markets, the issue of excess fluctuations is even more important for emerging markets where the currencies are more vulnerable to sources of excess volatility and instability and the authorities tend to try to smooth out fluctuations. Because of the managed exchange rate systems that are typical in emerging market countries, we model spot market volatility using a estimation technique for the variance of returns that accounts for the regime shifts evident in the data. The study uses the time-series characteristics of spot and futures market returns to assess the effects of an introduction of futures rather than a cross-sectional approach, in which certain "control" currencies would need to be identified, because identifying currencies whose behavior would be identical except for the introduction of a futures contract is problematic. After appropriately measuring spot market volatility, we find that the introduction of futures contracts lowers spot market volatility for the Mexican peso and has statistically insignificant effects on the spot market volatility of the Brazilian real and Hungarian forint. Additionally, using variance decomposition techniques, we find that spot market volatility is mostly explained by innovations in spot market volatility and not futures market volatility, although there exists a high degree of interdependence between the spot market and futures market. This means that although futures market volatility has some impact on spot market volatility, it is typically short lived.

I. Recent Empirical Studies

Since analysis of the relation of foreign exchange futures contracts and the underlying spot market is relatively sparse, a more extended review of the relation between various derivative markets and their respective underlying instruments can yield useful insights. A summary of the results of various studies is presented in Table 1.

Impact of Options on the Underlying Instrument

The first studies on the effect of the introduction of options concentrated mainly on price effects. Klemkosky and Maness (1980), among others, were unable to find significant changes in the price or the volatility of the underlying stocks after the introduction of options. While the first studies employ only relatively small samples, Conrad (1989) uses a sample of 96 equity options. Using an event study methodology, she shows that the options' introduction causes a statistically significant increase in the price of the underlying equity. A price increase is also reported by Detemple and Jorion (1990), who find that the introduction not only decreases the volatility of the

Table 1. *Studies of the Effects of Derivatives on the Underlying*

Author(s)	Publication date	Underlying	Derivative	Method employed	Effect on underlying
Conrad	1989	equity	options	event study	price increase, decrease in volatility
Stephan & Whaley	1990	equity	options	multiple time-series analysis	cash market leads the option market
Detemple & Jorion	1990	equity	options	event study	confirms Conrad; finds cross effects
Stucki & Wasserfallen	1994	equity	options	event study	confirms Conrad
Shastri, Sultan & Tandon	1996	currency	options	bivariate GARCH	spot volatility decreases
Clifton	1985	currency	futures	correlation	increase in spot volatility
Edwards	1988	stock index	futures	event study	decrease in spot volatility
Ely	1991	interest rate	futures	varying parameter model	spot market not affected
Schwarz & Laatsch	1991	stock index	futures	bivariate random walk	futures reduce mispricing
Bessembinder & Seguin	1992	stock index	futures	2-equation system	decrease in conditional spot volatility
Kawaller, Koch & Koch	1993	stock index	futures	Granger causality	increase in volatility strengthens market relation
Chatrath, Ramchander & Song	1996	currency	futures	GARCH, VAR	increase in spot volatility
Jabbour	1994	currency	futures	CIP, regression and specification tests	futures provide good spot rate predictors
Crain & Lee	1995	currency	futures	Granger causality	transfer of volatility

underlying itself but also has stabilizing and price increasing effects on other stocks, which are correlated with the underlying. The authors attribute these (cross) effects to the expansion of the investment opportunity set achieved through the options' introduction. Stucki and Wasserfallen (1994) use the same approach to study the influence of option introductions on the Swiss stock exchange. They are able to confirm the results presented by Detemple and Jorion and further find that the options market has a considerable lead over the stock market, which they attribute to a lack of liquidity in the stock market.[5]

The effect of the introduction of currency options is investigated by Shastri, Sultan, and Tandon (1996). They estimate a bivariate GARCH (Generalized Autoregressive Conditional Heteroscedasticity) model including an error correction term and find that the conditional mean is not affected by the introduction, but that the conditional variance of the cash market is significantly reduced. In agreement with previous research, the authors conclude that options contracts complete the market and stabilize the behavior of the underlying instrument.

Consequently, the analysis to date suggests that the introduction of option contracts lowers volatility of the underlying instrument, enhancing its stability, regardless of its type.

Impact of Futures on the Underlying Instrument

Early results are presented for cattle futures by Oellerman and Ferris (1985), who use Granger causality tests and find that the futures market leads the cash cattle market. Edwards (1988) points out that this result most likely is due to the faster adjustment of prices in the futures market and cannot, by itself, be seen as proof that futures markets destabilize the underlying. Using event studies to test whether the introduction of a futures market changes the volatility of the underlying (where volatility is defined as the unconditional variance of the percentage price change in daily spot prices as well as a variance estimator using intraday high and low prices), he is unable to reject the null hypothesis of no change. The same result is reported by Ely (1991), who employs a varying parameter technique to detect changes in the underlying demand and supply of the cash market instruments when futures contracts are introduced.

Other studies focus on the incidence of mispricing of the underlying relative to the futures contract. MacKinlay and Ramaswamy (1988) show that

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[5] For the U.S. market conflicting evidence is presented on the question of whether the options market leads the stock market. Stephan and Whaley (1990) present results favoring this conclusion, while Finucane (1991) reaches the opposite conclusion.

the cost-of-carry pricing relation is violated 14.4 percent of the time even after taking account of transaction costs in the stock index futures market. Schwarz and Laatsch (1991) extend this analysis and find that the extent of mispricing is considerably influenced by the futures market volume. As the futures market activity increases, the duration of mispricings decreases and futures market prices lead cash market prices. Finally, the authors conclude that market restrictions, imposed on the futures market after the stock market crash of 1987, seriously impede the usefulness of futures contracts.

Clifton (1985), Bessembinder and Seguin (1992), and Chatrath, Ramchander, and Song (1996) explicitly test the role of futures markets in the volatility process of the underlying instrument. Clifton finds a strong positive correlation between futures trading volume and the daily exchange rate volatility for the major currencies, but does not test for causality. Bessembinder and Seguin find that the conditional standard deviation of equity returns is reduced by a high level of activity in the futures market and reject the argument that derivative markets tend to destabilize the underlying. Contrary to the results presented so far, Chatrath, Ramachander, and Song report a short-lived but significant increase in the currency volatility after a rise in the trading activity on the futures market.[6] Their study involves futures and spot market data on the British pound, Canadian dollar, Japanese yen, Swiss franc, and deutsche mark. They use a VAR system including a futures trading activity variable and volatility, measured as conditional variance of returns using a GARCH(1,1) model, to estimate their results. The finding that volatility is transmitted from the futures to the spot market is also confirmed by Crain and Lee (1995). By explicitly testing the market behavior around announcement dates for macroeconomic news, they show that the leadership effect and the following transmission of volatility measured as the standard deviation of hourly log returns across daily observations, pre- and postannouncement dates, is due to the faster transmission of information into futures contract prices.[7] The futures market shows a sharper jump in the volatility but also a faster decline during the trading hours immediately following the announcement than occurs in the cash market. Consequently, Crain and Lee attribute the transmission of volatility between the markets to the higher efficiency of the futures market.[8]

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[6] McCarthy and Najand (1993) find a positive relation between futures trading volume and futures volatility.

[7] Kawaller, Koch, and Koch (1993) also report a strengthened relation between cash and futures markets as the futures market volatility rises. They attribute this behavior to the speed of information processing.

[8] Jabbour (1994) states that the implied spot rates derived from futures prices are good predictors of future spot rates. This result can be regarded as circumstantial evidence that the derivative market is not excessively volatile.

The evidence on the introduction of futures contracts suggests that giving investors the opportunity to trade futures brings stability to the market of the underlying security. Only foreign exchange futures contracts do not conform to this rule as increased futures activity was found to be positively related to conditional volatility in the spot market in Chatrath, Ramchander, and Song for the five major currencies. Whether or not this is the result of slower information processing in the spot market,[9] as suggested by Crain and Lee, remains to be investigated.

II. Methodological Issues

Before determining the impact of the introduction of futures contracts on the volatility of currencies of emerging market countries, we need a precise measure of volatility. This study uses estimates of the conditional return variance as the proxy for volatility, as did a number of the previous studies mentioned above. After determining this "base case" volatility, we use three methods to examine the relationships between the spot and futures markets. First, we use vector autoregressions (VARs) to examine causal relationships between the two markets. Second, using the VARs, we undertake a variance decomposition of the vector containing spot market volatility, futures market volatility, and futures market trading volume to assess the relative influence of each of the factors. Finally, we undertake a direct test of the directional effect on spot market volatility of the introduction of future markets.

Volatility Estimation and Regime Shifts

Time-series patterns of foreign exchange returns, like many other economic and financial time series, exhibit periods of high volatility followed by periods of low volatility. This is particularly true for emerging market exchange rate series. When the exchange rate fluctuates within a narrow band, as is the case in a managed float exchange rate system, only low levels of volatility manifest themselves. This can conceal increasing pressures, which then may erupt in the form of currency crises or speculative attacks. Rigorous time-series analysis of the experience of emerging market exchange rates reveals patterns of moderate volatility levels interrupted by periods of large fluctuations when the exchange rate bands are violated. The Autoregressive

[9] The crash of the European Monetary System (EMS) in 1992 is a much-cited example for the destructive destabilization emanating from derivative markets. Nevertheless, it could be argued that futures and options markets were anticipating and thus accelerating realignments, which had been postponed for too long.

Conditional Heteroscedasticity (ARCH) methodology takes account of this phenomenon by explicitly modeling the tendency for large (small) changes in the underlying time series to be followed by more large (small) changes, thus permitting estimation of the observed volatility clustering.[10]

One shortcoming of this approach is that the autoregressive structure of the ARCH model produces a high degree of persistence in the volatility series. This persistence is not consistent with the distinct changes in the mean level of volatility associated with a regime shift, as might occur during a speculative attack or a widening or narrowing of the exchange rate bands. In this case, the ARCH model overestimates the true variance of the process.[11] What is needed, therefore, is a methodology that also allows for the sudden and explosive shifts found in the mean of the variance processes of emerging market exchange rates. Regime-switching models, such as those proposed by Hamilton (1989), are able to account for this type of behavior, by allowing for the sudden changes in volatility levels at certain points of time.

Traditionally, regime shifts are described by changes in the constant of the process:

$$y_t = \alpha_1 + (\alpha_2 - \alpha_1)D_t + \phi y_{t-1} + u_t, \tag{1}$$

where y_t is the return series, D_t is a dummy variable that takes the value zero before the shift and one thereafter, and u_t is an error term. The parameters α_1 and α_2 describe the mean of the return series prior to and after the regime shift. The main problem in specification (1) is the implicit assumption that the shift is caused by a single event, which is not going to repeat itself, and can be exogenously determined. This leaves out the possibility that a similar event might repeat itself in the future. Consequently, Hamilton suggests making the change in the regime itself a random variable, implying that the complete time-series model must now include a description of the process governing the transition between different regimes. The behavior of the observable variable y is thus influenced by the unobservable realization of the regime variable S. Equation (1) now becomes

$$y_t = \alpha_{St} + \phi y_{t-1} + u_t, \tag{2}$$

where α_{St} indicates α_1 when $S_t = 1$, and $[\alpha_1 + (\alpha_2 - \alpha_1)]$ when $S_t = 2$. To estimate equation (2), a description of the process that determines S_t is needed. As S_t only takes on integer values $\{1,2,3, \ldots ,N\}$ a Markov chain can be

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[10] For a survey of the vast literature on this subject, see Bollerslev, Chou, and Kroner (1992).

[11] The tendency of ARCH models to imply too much volatility persistence was demonstrated in the analysis of the October 1987 stock market crash, for example, Engle and Mustafa (1992).

used to describe the S_t process. A Markov chain models the behavior of the random variable, S_t, as one whose probability of realizing a certain value $S_t = j$ is fully determined by the past value, $S_{t-1} = i$. The resulting transition probability $P\{S_t = j | S_{t-1} = i\} = p_{ij}$ presents the probability that regime i will be followed by regime j. The set of endogenously determined transition probabilities is collected in an (N x N) matrix $\mathbf{P}$:[12]

$$\mathbf{P} = \begin{bmatrix} P_{11} & P_{21} & \cdot & P_{N1} \\ P_{12} & P_{22} & \cdot & P_{N2} \\ \cdot & \cdot & \cdot & \cdot \\ P_{1N} & P_{2N} & \cdot & P_{NN} \end{bmatrix}.$$

The row j, column i element of $\mathbf{P}$ is the transition probability p_{ij} and all columns i satisfy

$$p_{i1} + p_{i2} + \ldots + p_{iN} = 1. \tag{3}$$

The SWARCH (Markov Switching Autogressive Conditional Heteroscedasticity) specification, introduced by Hamilton and Susmel (1994), is an application of the Markov methodology to modeling a volatility process subject to regime shifts. An ARCH specification is used to model the behavior of the residuals u_t of an autoregressive representation for the variable y_t, thereby proxying volatility as the conditional variance of the return series. For example, with a simple first-order autoregression for y_t,

$$y_t = \alpha + \phi y_{t-1} + u_t, \tag{4}$$

the application of Hamilton's approach to (conditional) variance estimation describes regime dependent changes in the residuals u_t from regression (4) as

$$a_t = u_t / \sqrt{g_{St}} \tag{5}$$
$$a_t = h_t v_t, \text{ where } v_t \sim N(0,1) \text{ i.i.d.}$$
$$h_t^2 = \beta_0 + \beta_1 a_{t-1}^2 + \beta_2 a_{t-2}^2 + \ . \ + \ . \ + \ . \ + \beta_q a_{t-q}^2 + l d_{t-1} a_{t-1}^2.$$

Here a_t is assumed to follow a standard ARCH(q) model, including a leverage term (l), as specified by Glosten, Jagannathan, and Runkle (1993), which sets $d_{t-1} = 1$ if $a_t \leq 0$, and sets $d_{t-1} = 0$ if $a_t > 0$. Regime dependent shifts in the volatility process are modeled by dividing u_t by the constant $(g_1)^{0.5}$ when the regime is represented by $S_t = 1$, by dividing by $(g_2)^{0.5}$ when

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[12] It may be possible to make these transition probabilities a function of macroeconomic variables associated with regime shifts, thereby linking this purely time-series model of volatility to economic fundamentals. However, since our intention is simply to obtain a base case against which to measure the effect of a futures introduction, this extension is left for future research.

$S_t = 2$, and so on. Thus, each distinct, endogenously determined regime has its own estimate of volatility relative to the first regime (where g_1 is normalized to 1). By correcting the residuals u_t by the regime specific constant, g_{St}, this approach estimates the ARCH model more accurately, creating more stable standardized residuals for estimating the model's parameters. This model takes account of the nonlinearities reported by Friedman and Laibson (1989), without introducing excessive volatility persistence. Hamilton and Susmel call specification (5) a SWARCH(N,q) model, where N describes the number of possible states and q the number of lags.

Investigating Market Links Using VAR and Variance Decomposition Methods

One method of examining the influence of the futures market on the underlying spot market is to utilize the estimates of volatility developed above to test for the presence of causal relationships. We introduce the following VAR representation for this purpose:

$$z_t = \sum_{i=1}^{m} \beta_i z_{t-i} + v_t \tag{6}$$

$$E(v_t v_s') = \Omega, \text{ if } t = s; \ 0 \text{ otherwise}$$

$$E(v_t) = E(v_t Z_{t-1}) = 0.$$

$z_t = (x_t, y_t)$, is a $g = n + k$ dimensional vector of variables describing the behavior of the futures contract (n variables) and the underlying spot currency (k variables). The vector Z_{t-1} involves all past values of z_t. The error vectors v_t are each serially uncorrelated, but can be contemporaneously correlated as described by the variance covariance matrix Ω. The VAR can be split up, such that

$$x_t = \sum_{i=1}^{m} C_{2i} x_{t-i} + \sum_{i=1}^{m} D_{2i} y_{t-i} + v_{2t} \tag{7}$$

$$y_t = \sum_{i=1}^{m} A_{2i} x_{t-i} + \sum_{i=1}^{m} B_{2i} y_{t-i} + v_{1t}.$$

Taking the second equation from (7), x does not Granger cause y, if $A_{2i} \equiv 0$. Using this approach, we intend to examine whether futures volatility Granger causes spot currency volatility or vice versa. While a time-series link may be present, the results should be interpreted with caution since the existence of a statistical relationship between the markets does not indicate whether the introduction of a futures market contributes to lower (or higher)

volatility in the spot market, but simply that volatility in one market pre-
cedes that of the other.

Using this basic setup, Geweke (1982) defines measures of linear feed-
back, which allow for instantaneous feedback as well. This is achieved by
reestimating the second equation of (7) in the modified form,

$$y_t = \sum_{i=0}^{m} A_{3i}\, x_{t-i} + \sum_{i=1}^{m} B_{3i}\, y_{t-i} + w_{1t}, \tag{8}$$

and comparing v_{1t} with w_{1t}. The null hypothesis is that no significant change
in the error vector takes place.[13] This is formally tested by a likelihood ratio
test of the form $LR = (T{-}m)F_{x,y} \sim \chi^2_{nkm}$, where m is the number of lags, and
n and k are defined as above. $F_{x,y}$ tests the set of linear restrictions that is
implied by the null hypothesis that a (set of) variable(s) can be removed
from the VAR. LR values higher than the χ^2 critical values indicate the pres-
ence of Granger causality.

A useful extension of the analysis based on a VAR and Granger causal-
ity tests can be found in the concept of variance decomposition. Recall that
the VAR representation in equation (6) is analogous to the vector MA
representation

$$z_t = \beta^{-1}(B)v_t = \psi(B)v_t = v_t + \sum_{i=1}^{\infty} \psi_i v_{t-i}. \tag{9}$$

The ψ_i matrices, for $i = 1, 2, \ldots \infty$, can be interpreted as the dynamic mul-
tipliers of the system, as they depict the model's response to a unit shock in
each of the variables.[14] It is important to recall, however, that the VAR
model (6) allows for contemporaneous correlation in the error terms, v_t. To
avoid the contemporaneous correlation problem, a renormalization of the
ψ_i matrices is executed using a specific decomposition of Ω.

The error variance of a H step-ahead forecast of z_i can then be decom-
posed into components that account for the effects one innovation will have
on the other elements of z, where the ordering of the variables in the origi-
nal VAR determines the incremental effect these other elements will have
on the forecasted element of z_i. This procedure is commonly called the vari-
ance decomposition.

III. Empirical Results

The three emerging market currencies investigated below, the Mexican
peso, the Brazilian real, and the Hungarian forint, all follow some form

[13] See Mills (1993) for a description.
[14] The response of an element i in z_t to a shock in another element j in z_t is
described by the sequence $\psi_{ij,1}, \psi_{ij,2}, \psi_{ij,3}, \ldots$: the impulse response function.

of managed exchange rate regime, influencing the characteristics and the form of the resulting time-series model of volatility. Moreover, two of the three currencies experienced major upheavals during the sample period, necessitating a methodology, such as the SWARCH model, to measure volatility appropriately given the distinctive regimes characterizing exchange rate movements. We would like to control for "normal" movements in the volatility using the SWARCH model in order to isolate the effects of the futures market introduction.[15] A short overview of the political and economic developments in each country prior to and during the sample period of January 1, 1995 to February 28, 1997 is presented in Appendix I.

Daily U.S. dollar spot exchange rates on the three emerging market currencies are used in this study.[16] The futures contracts are traded on three different organized exchanges while the spot market is an over-the-counter interbank market. The Mexican peso (MP) futures contract is traded on the Chicago Mercantile Exchange. Futures data on the Brazilian real (BR) are obtained for the contract traded on the Bolsa de Mercadoris & Futuros with the commercial real/U.S. dollar exchange rate as the underlying. The data provided by the Hungarian National Bank describe a Hungarian forint/U.S. dollar (HF) contract. With one exception, volume, open interest and daily settlement prices are available.[17] Unlike forward contracts, futures contracts are standardized to be able to trade on organized exchanges where their liquidity is enhanced by lowering transactions costs: only the quantity of contracts and the price need to be negotiated to culminate a trade. Other characteristics, such as the amount of currency, the date, and procedures for final delivery, are already established. Thus, to produce a time series of prices representing liquid contracts when multiple delivery dates are available, a "nearby series" is typically constructed. Data from each nearby contract are followed for the period in which its delivery date is the closest until the trading volume in the first deferred (next-to-nearby) contract exceeds that of

[15] Many emerging market countries, including those examined here, manage their currencies so as to remain within a band. The use of the SWARCH methodology would, if the band effectively limited ex post volatility to be within a constant range over the sample period, show that only one "regime" would be necessary to accommodate the time-series pattern of volatility. In this case, the SWARCH model is superfluous and the use of an ARCH model would suffice. Thus, since the SWARCH model is purely a statistical model for volatility, the existence or nonexistence of a formal (or informal) exchange rate band does not affect its usefulness. The data determine whether multiple regimes are needed to provide a good statistical fit.

[16] The data were provided by Bloomberg, the Futures Industry Institute, and the Hungarian National Bank.

[17] Daily open interest data are not available on the Hungarian forint/U.S. dollar contract.

the nearby contract, at which point the data switches to the next contract.[18] The observation period[19] for all contracts is January 1, 1995 to February 28, 1997.

Descriptive data statistics presented in Table 2 show characteristics consistent with those assumed in the construction of model (5). All daily return series show a considerable amount of excess kurtosis, which indicates the use of a *t*-distribution in the maximum likelihood function used to estimate the SWARCH model. The ARCH tests reject the null hypothesis of a constant variance at a high level of significance, and the hypothesis that the series contain a unit root is rejected with the exception of the open interest series.[20] All spot return series have a positive mean, with the exception of the Mexican peso futures, which is quoted in dollars per peso instead of the more typical foreign currency per dollar. The sign of the mean results from the continuous devaluations experienced during the observation period. The standard deviations of the return series can be considered high when compared with their respective means.

The results obtained by the estimation of model (5) fail to reject the chosen specification.[21] Most of the coefficients on the (adjusted) lagged squared residuals are statistically significant, confirming the use of the basic ARCH model. Since a managed float exchange rate system can cause unchanged prices for consecutive trading dates, a rather long lag structure of five lags has been chosen to estimate the ARCH process in the spot series.[22] For the futures market, continuous trading usually causes price changes on a daily basis, which is reflected in the shorter lag structure employed.[23] To examine the estimated model for potential misspecification, an ARCH test is conducted for both types of series using the

[18] Because the nearby series will have discrete jumps at transition points between contract months, dummy variables for these dates are introduced in the return equation. The results are not sensitive to this method for estimating the return equation.

[19] Futures data on the Mexican peso are only available after April 1995, since the contract began trading at this time.

[20] The sample lengths are relatively short for unit root tests to have high power. However, despite the added tendency to accept the null hypothesis of a unit root when it is not present, we strongly reject the presence of a unit root.

[21] Only the futures return series for the Hungarian forint does not show the regime switching characteristics initially assumed and thus the SWARCH model is not used in this case. A three-regime model was attempted, but did not converge for any of the series.

[22] Using a shorter lag structure results in very slow convergence and parameter estimates were not robust to alternative starting values. Lag lengths between two and five lags have been investigated.

[23] Note that this feature of the spot and futures prices—that the spot prices remain unchanged for several days at a time while the futures prices are rarely unchanged—by itself suggests that futures markets incorporate information faster than spot markets.

Table 2. *Descriptive Statistics*

	Mean	Standard deviation	Skewness	Excess kurtosis	Unit root[a]	ARCH(5)[b]
Mexican peso[c]						
Spot FX[d]	0.059	0.644	2.359	24.15	–7.77**	158.45**
Futures FX	–0.058	0.875	3.12	33.68	–9.04**	30.25**
Open interest	10331	5383	0.34	–0.69	–1.76	
Volume	1718	1832	2.04	5.43	–3.35*	
Brazilian real[c]						
Spot FX	0.038	0.277	4.057	56.073	–11.19**	29.89**
Futures FX	–0.002	0.321	2.180	27.30	–9.98**	198.18**
Open interest	353,064	106,088	–0.029	–0.431	–1.997	
Volume	104,598	77,934	1.557	2.934	–6.082**	
Hungarian forint[c]						
Spot FX	0.076	0.596	5.828	92.927	–11.78**	40.41**
Futures FX	–0.019	0.476	2.318	46.779	–11.21**	55.45**
Open interest	. . .	. . .	. . .	. . .	. . .	
Volume	1995.96	3165.64	3.44	16.477	–7.635**	

[a] The test for stationarity is an Augmented Dickey-Fuller test with four lags and including a constant (H_0: $\rho = 1$).

[b] The test for the presence of ARCH in the data follows Engle (1982) by testing the joint significance of the regression coefficients of the squared residual on its own past values (H_0: $\beta_1 = \beta_2 = \ldots = \beta_n = 0$). Two asterisks indicate rejection of the null hypothesis on the 1 percent level. The ARCH test for the Hungarian forint includes a one-day impulse dummy for the March 1995 depreciation.

[c] The samples for the Brazilian real and the Hungarian forint range from January 1, 1995 to February 28, 1997, involving 565 observations. The sample for the Mexican peso involves 509 observations between April 25, 1995 and April 4, 1997.

[d] The series spot FX and futures FX describe daily percentage rates of change.

estimated residuals.[24] The results are presented in Table 3. After correcting the residuals u_t for the regime shift, the test results confirm the presence of autoregressive conditional heteroscedasticity in all a_t series with the exception of the Hungarian forint spot series, which highlights the stable volatility behavior of this particular series. The second test uses the corrected residuals, a_t, and further standardizes them by the estimated

[24] Since the appropriate length of time over which agents measure and react to volatility may be different from the daily horizon assumed here, the results for the Mexican peso have been reestimated using returns measured over five trading days. The smaller number of observations typically lowers the significance of the estimated coefficients and the model utilizes a normal distribution, rather than the fat-tailed t distribution, to obtain convergence. However, the results are qualitatively the same: ARCH effects are still present; there are significant regime shifts; and similar probabilities for the transition matrices are obtained. This result accords with other studies—Droste and Nijman (1993) and Diebold (1988)—that show that ARCH effects are relatively stable at multiple sampling frequencies.

Table 3. *ARCH Test for Residuals* $\mathbf{a}_t$, *from Model (5)*

	MP_{spot}	$MP_{futures}$	BR_{spot}	$BR_{futures}$	HF_{spot}	$HF_{futures}$
a_t	247.89**	29.10**	26.82**	165.43**	0.06	55.45**
$a_t/h_t{}^a$	2.85	3.83	1.32	0.072	0.052	3.52

Notes: The test procedure follows Engle (1982), by testing the joint significance of the regression coefficients of the squared residuals on their own past values: (H_0: $\beta_1 = \beta_2 = \ldots = \beta_n = 0$). The test statistic is χ^2 with 5 degrees of freedom. Two asterisks indicate rejection of the null hypothesis on the 1 percent level.

^{a} The expression a_t/h_t describes the standardized residuals from model (5), where h_t is the conditional volatility estimated in model (5).

volatility, h_t, showing that the ARCH model purges the series of heteroscedasticity caused by the serial dependence of the return variance.[25]

Since the leverage term represented by *l* in equation (5) was not found to be statistically significant for any of the series involved, it was removed from the estimated model to facilitate numerical convergence.[26] Economically, this implies that changes in the volatility level due to appreciations and depreciations are the same and that even the massive depreciation found in the case of Mexico does not have an asymmetric effect on the volatility estimates.[27] The results gained from the estimation of model (5) are reported in Table 4, while some graphics describing the return and volatility series and the transition probabilities estimated for the spot market data can be found in Appendix II.

The regime-switching nature of the series is reflected in the significant estimates for g_2 reported in Table 4. The parameter g_1 is normalized to unity and describes the baseline regime of volatility and the variance increases by a factor of g_2 during periods of high volatility. In the spot market, the amount of the increase ranges from 8.60 in the Mexican case to 45.49 in the Brazilian case,

[25] There were a number of large outliers in the data. To gauge their influence on the results, the model is reestimated for the Mexican peso spot rate after removing the four largest outliers (in absolute value) and replacing them with the average value of the previous and following observation. The values of P1 and P2 are virtually unchanged and the correlation coefficient between the estimated volatility of the series with and without the outliers is 0.92. Only the second ARCH coefficient changes appreciably, from 0.203 to 0.112, while the other estimates remain more or less unchanged. From these results, we view the influence of outliers as limited.

[26] The optimization procedure was run in GAUSS 3.0 employing the OPTMUM package. Some of the routines are derived from programs generously provided by J. Hamilton.

[27] Since exchange rates are the price of one currency in terms of the other and can be quoted in dollar terms, or the reciprocal, a leverage effect is thought to be less likely for exchange rate series. However, one could argue that, for emerging market currencies, where the numeraire currency is the dollar, the distinction between a depreciation and an appreciation in local currency may be meaningful. The absence of a leverage term demonstrating this effect may be a reflection of the time period used— all three currencies were depreciating and were expected to maintain this trend.

Table 4. Estimation Results for a SWARCH (N,q) Process with an Underlying t-Distribution with t Degrees of Freedom

	c	y_{t-1}	d	a^2_{t-1}	a^2_{t-2}	a^2_{t-3}	a^2_{t-4}	a^2_{t-5}	g_2	t(d.f.)
Peso	0.001	−0.014	0.041	0.483	0.203	0.274	0.092	0.078	8.597	3.353
	(0.01)	(0.03)	(0.01)	(0.13)	(0.09)	(0.11)	(0.07)	(0.06)	(3.99)	(0.55)
Futures (pesos)	−0.112	0.043	0.100	0.113	0.232	0.394			5.551	3.653
	(0.02)	(0.04)	(0.03)	(0.08)	(0.11)	(0.16)			(2.05)	(0.75)
Real	0.018	−0.011	0.010	0.561	0.015	0.000	0.147	0.061	45.49	2.337
	(0.00)	(0.04)	(0.01)	(0.40)	(0.06)	(0.06)	(0.17)	(0.06)	(12.78)	(0.27)
Futures (reals)	0.024	−0.041	0.001	0.609	0.245	0.178			83.391	2.773
	(0.01)	(0.04)	(0.00)	(0.25)	(0.15)	(0.11)			(27.00)	(0.36)
Forint	0.071	−0.024	0.70	0.000	0.135	0.062			42.02	∞
	(0.01)	(0.02)	(0.01)	(0.07)	(0.06)	(0.05)			(12.59)	
Futures (forints)	−0.034	−0.024	0.102	0.357	0.438					∞
	(0.02)	(0.05)	(0.00)	(0.06)	(0.05)					

Transition Matrix:

Peso:

$$\begin{bmatrix} 0.996 & 0.013 \\ (0.01) & (0.00) \\ 0.004 & 0.986 \\ (0.01) & (0.02) \end{bmatrix}$$

Real:

$$\begin{bmatrix} 0.990 & 0.003 \\ (0.21) & (0.00) \\ 0.010 & 0.997 \\ (0.00) & (0.00) \end{bmatrix}$$

Forint:

$$\begin{bmatrix} 0.966 & 0.501 \\ (0.01) & (0.12) \\ 0.033 & 0.498 \\ (0.01) & (0.13) \end{bmatrix}$$

Futures (peso):

$$\begin{bmatrix} 0.990 & 0.023 \\ (0.01) & (0.02) \\ 0.009 & 0.977 \\ (0.01) & (0.02) \end{bmatrix}$$

Futures (real):

$$\begin{bmatrix} 0.998 & 0.003 \\ (0.00) & (0.00) \\ 0.001 & 0.997 \\ (0.00) & (0.00) \end{bmatrix}$$

Futures (forint):

Notes: The underlying residual u_t is divided by $(g_1)^{0.5}$, with $g_1 = 1$ if the process is in regime 1, and is divided by $(g_2)^{0.5}$ if the process is in regime 2. The constants of the autoregressive process are c and d, respectively. Standard errors in parentheses.

and Hungary between the two with $g_2 = 42.02$. The coefficient on g_2 is significant for all series and indicates that traditional ARCH type models would fail to account for the regime shifts present in the data. The high estimate of g_2 in the case of Brazil can be explained by the strict adherence to an increasingly successful managed floating exchange rate regime after 1995, which constitutes the shift from a high-volatility regime to a low-volatility one.

By looking at the matrix of transition probabilities one can gauge the persistence of the regimes. In the Brazilian case, the values of 0.990 and 0.997 on the main diagonal indicate that the high- and the low-volatility regime are highly persistent once a regime shift has taken place. At the same time, the off-diagonal elements show that there is a small, but significant, probability that there eventually will be a switch from one regime to the other. This seems an appropriate description for the exchange rate regimes of most emerging market countries. Brazil, for example, has achieved monetary stability after 1995, but there is, nevertheless, a small but significant probability, reflected in the element p_{12} of the transition matrix, that could indicate a shift back into the high volatility regime. The fact that the estimated probability is only about 1 percent is a tribute to the success of the Brazilian policies.

The transition matrix of the Hungarian forint presents a special case, as the main diagonal element indicating regime 2 has a low value of 0.50. This translates into a persistence of $(1–0.50)^{-1} = 2$ days, meaning that, on average, the exchange rate remains in regime 2, the high volatility state, for only 2 days. A possible interpretation for this result might be found in the willingness of the Hungarian monetary authorities to significantly devalue the currency early, as happened in August 1994 and again in March 1995 when they established a crawling exchange rate peg, rather than support an artificially low exchange rate. This in turn reduces the probability and scope for speculative attacks and the resulting high levels of volatility as experienced by Mexico. Consequently, one might argue that this policy enabled Hungary to better control its currency and avoid persistent high levels of volatility.

Turning to the estimates for the volatility process in the futures markets, one finds that the results presented for the spot markets support the model: there are statistically significant ARCH parameters and regime-switching parameters. The only exception is present in the Hungarian forint futures contract series, which quickly converges to a standard ARCH (2) model with an underlying normal distribution and no regime shifts.

Granger Causality Tests

After establishing the correct specification for the volatility process, we use the resulting estimates to investigate the relationship between the

spot market and the futures market.[28] We begin by testing for the existence of Granger causality and contemporaneous feedback as described in Section II.

The results for the Granger causality tests are presented in Table 5, where arrows indicate the direction of causality investigated and a dot marks the test for instantaneous linear feedback. The most general result is the large number of rejections of the null hypothesis, which indicates strong connections between the futures and the spot market for the three currencies investigated. For the Mexican peso, the null hypothesis of no causality between the spot volatility and the volatility found in the futures market is strongly rejected. Volatility spillovers exist in both directions, although the power of the spillover, described by the reduction in the residual variance, is far weaker for the spillover from futures market volatility to spot volatility, while spot volatility explains futures market volatility to a considerably larger degree. Trading activity in the futures market has some lagged effect on the spot market volatility, but offers no contemporaneous explanatory power. Combining this result with the acceptance of the hypothesis that lagged futures returns do not explain spot returns can be interpreted as evidence that, in the case of the Mexican peso, neither current futures market volumes nor lagged returns influence the current spot rate to a large degree. At the same time, the last set of tests, which include a larger number of variables from the futures market, including estimated volatility, and use spot market volatility as the dependent variable, confirm the existence of a strong connection between the two markets, since both lagged and contemporaneous futures variables are jointly statistically significant.

The tests conducted for the Brazilian real show a slightly different picture than those of the Mexican peso. Generally, the relations between the two markets are stronger in terms of explanatory power and a significant level of mutual influence is indicated for all tests except for the contemporaneous influence of futures trading volume on the spot volatility. A possible reason for the significantly higher level of influence compared to the peso futures market is the tightly managed exchange rate regime underlying the Real Plan. It is also possible that the existence of an active short-term interest rate futures contract means that participants are actively using money market and currency futures and therefore the connections between the currency futures and spot rates are apt to be tighter. Any advantage in the speed of adjustment to news found in the futures market will be reflected

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[28] The use of "generated" variables in subsequent econometric techniques can sometimes be problematic. We believe we have circumvented any biases due to the generated volatility estimates by not using any common variables from the original spot and futures SWARCH specifications in subsequent specifications.

Table 5. *Testing for Granger Causality and Instantaneous Linear Feedback*

	Lags	$[x] \rightarrow [y]$	$[y] \rightarrow [x]$	$[x] \cdot [y]$
Mexican peso				
$[x]$ = [futures market volatility]				
$[y]$ = [spot market volatility]	4	16.50**	307.68**	126.39**
$[x]$ = [futures market trading volume]				
$[y]$ = [spot market volatility]	5	22.58**	30.77 **	3.83
$[x]$ = [futures market daily return]				
$[y]$ = [spot market daily return]	5	3.99	15.06*	189.02**
$[x]$ = [futures market: return, volatility]				
$[y]$ = [spot market: return, volatility]	5	61.41**	314.63**	290.80**
$[x]$ = [futures market: return, volatility, volume, open interest]				
$[y]$ = [spot market volatility]	5	140.83**		111.54**
Brazilian real				
$[x]$ = [futures market volatility]				
$[y]$ = [spot market volatility]	5	228.20**	49.86**	17.77**
$[x]$ = [futures market trading volume]				
$[y]$ = [spot market volatility]	3	16.85**	12.16 **	3.83
$[x]$ = [futures market daily return]				
$[y]$ = [spot market daily return]	5	158.53**	59.38**	291.04**
$[x]$ = [futures market: return, volatility]				
$[y]$ = [spot market: return, volatility]	5	357.87**	160.55**	328.57**
$[x]$ = [futures market: return, volatility volume, open interest]				
$[y]$ = [spot market volatility]	5	339.62**		35.23*
Hungarian forint				
$[x]$ = [futures market volatility]				
$[y]$ = [spot market volatility]	5	99.72**	24.93**	15.51**
$[x]$ = [futures market trading volume]				
$[y]$ = [spot market volatility]	4	4.81	5.54	5.48
$[x]$ = [futures market daily return]				
$[y]$ = [spot market daily return]	5	50.96**	6.64	305.25**
$[x]$ = [futures market: return, volatility]				
$[y]$ = [spot market: return, volatility]	5	204.98**	67.58**	351.79**
$[x]$ = [futures market: return, volatility, volume, open interest]				
$[y]$ = [spot market volatility]	3	105.26**		26.59

Notes: The test statistics reported for Granger Causality and the Geweke measure of instantaneous feedback are calculated for a LR test with a χ^2 distribution with *nkm* degrees of freedom, where k is the number of lags. Two asterisks indicate rejection of the null hypothesis at the 1 percent level.

in the measures for Granger causality connecting the spot market and the futures market.

The Hungarian results also show a strong influence from the futures market on the spot market in terms of volatility changes. However, contemporaneous relations between the spot and futures returns, combined with the volatility estimates, indicate that for the Hungarian forint, the spot also influences the futures market. The trading volume in futures contracts is largely uninfluenced by the volatility in the spot markets, and the hypothesis that the spot volatility is not caused by this variable cannot be rejected.

Variance Decomposition

Although the Granger tests establish the presence of a causal relationship between the variables involved, they do not entirely answer the original question posed: To what extent does the futures market destabilize the underlying spot market? The variance decomposition, presented in Table 6, aims to determine the proportion of the total variance in the spot volatility explained by innovations in the futures volatility, futures trading volume, and spot volatility. But the results of a simple variance decomposition are not unique with respect to the ordering of the variables in the VAR: the choice of a particular recursive ordering of the variables constituting the VAR leads to a unique set of dynamic multipliers, the impulse response function. Cooley and LeRoy (1985), Hamilton (1994), and others point out that the lack of convincing identifying assumptions for the orthogonalization makes necessary a careful interpretation of the economic relationships implied by the ordering of the VAR.

The ordering of the variables in the VAR, which underlies the results presented in Table 6, derives from an assumption about how shocks are transmitted among the original variables, z_t. With this assumption, the associated transformation of the error terms ensures there is no contemporaneous correlation in the corrected error terms, u_t, of the transformed VAR model and that the variance decomposition permits us to examine the impact of volatility on the spot market allowing the other variables to react as well. The economic rationale for the ordering can be found in the managed exchange rate regime of all three countries. We have argued previously, and have seen support in our results as well as others, that the futures market responds more quickly than the spot market to information arrivals. To the extent that a central bank attempts to "lean against the wind" to counteract information influencing spot price movements, the effect of an information arrival is not immediately evident in the spot

Table 6. *Decomposition of Variance*
(In percent)

	Days	Futures volatility	Trading volume	Spot volatility
Mexican peso				
Futures volatility	1	51.77	0.86	47.36
	5	27.19	2.49	70.32
	10	24.60	2.26	73.15
Trading volume	1	0.07	99.81	0.12
	5	0.38	98.96	0.66
	10	0.48	97.50	2.02
Spot volatility	1	0.75	1.01	98.23
	5	2.75	1.56	95.69
	10	4.27	1.42	94.31
Brazilian real				
Futures volatility	1	87.42	6.63	5.95
	5	74.01	7.68	18.31
	10	65.12	7.01	27.87
Trading volume	1	0.06	99.38	0.56
	5	0.71	97.15	2.14
	10	1.72	94.42	3.86
Spot volatility	1	23.01	1.32	75.67
	5	16.37	3.08	80.54
	10	12.20	4.37	83.43
Hungarian forint				
Futures volatility	1	96.55	0.14	3.30
	5	96.29	0.67	3.04
	10	95.20	0.77	4.02
Trading volume	1	0.05	98.63	1.32
	5	0.36	98.47	1.18
	10	0.65	98.20	1.14
Spot volatility	1	13.06	0.54	86.40
	5	17.23	0.80	82.19
	10	17.98	0.80	81.22

Note: The ordering of the underlying VAR model is spot volatility, futures trading volume, and futures volatility.

market, but the futures will have already incorporated the information. This scenario suggests that the ordering of the variables should be spot volatility preceding futures volatility. Placing trading volume before futures market volatility takes account of the strong volume-volatility relationship indicated by previous research. Consequently, the following

ordering is chosen for the estimation of the variance decomposition: spot volatility, futures trading volume, and futures market volatility.[29]

The results presented in Table 6 describe how much of a variable's variance, after an innovation to the system, is explained by each of the variables included in the system. After one day, 51.8 percent of futures volatility in the Mexican peso can be traced back to innovations in futures volatility, while about 0.9 percent is explained by the trading volume and 47.4 percent of the variance is explained by the spot volatility. While innovations in the Mexican peso futures series are to a large degree (47.4 percent) accounted for by changes in the spot volatility, futures volatility explains only a small part (0.8 percent) of the spot volatility after one period. This indicates that the spot market is not significantly influenced by the futures market.

Looking at the Brazilian case, one finds that this conclusion is not supported in the short run: spot volatility explains only a relatively small part (6.0 percent) of the futures volatility, while innovations in the Brazil real spot volatility are 23.0 percent accounted for by innovations in the futures volatility. Thus, over the one-period horizon the Mexican peso and the Brazilian real yield opposing results: peso spot market volatility is not influenced by innovations in futures market volatility while the real spot market volatility is.

Continuing to look at the Brazilian real, the variance decomposition results for 5- and 10-day horizons for futures volatility yield a somewhat stronger result: while the percentage of the variance attributed to innovations in the futures volatility decreases over time, there is an increase in the percentage explained by past spot market innovations.[30] When examining spot market volatility generally, across all three currencies, an important conclusion is that the spot market's innovations dominate its own long-term behavior with always greater than 75 percent of the variance explained by spot volatility.

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[29] While we attempt to use sound economic arguments to appropriately choose the ordering of the variables in the VAR, it is useful to note that the covariance terms in the VAR error variance-covariance matrix are typically quite low, ranging from 0.009 to 0.47 with a mean of 0.12. Since these coefficients are generally low, the orthogonalization and, consequently, the exact methodology used are of somewhat reduced importance. This is borne out by reestimating the variance decomposition using the Bernanke (1986) approach in which the ordering of the variables is replaced by an ordering of the errors, thereby generating an impulse response function that is not influenced by the original ordering of the variables. The results are substantively the same. Further, reestimating the variance decomposition with the positions of spot volatility and futures volatility exchanged does not significantly alter the results in Table 6: for all three currencies and for any ordering chosen over the 10-day horizon, the own-variance of the spot market variable is never lower than 60 percent. Moreover, the futures market variables continue to have strong self-explanatory power as well.

[30] With the minor exception of spot on spot in the Mexican peso case, which most probably is due to the high starting level of 98.23 percent.

The Hungarian forint market displays a slightly different pattern. The degree of influence that can be attributed to the futures market is higher than for the Mexican peso but lower than for the Brazilian real: a change in spot volatility after one day is explained by 0.7 percent, 23.0 percent, and 13.1 percent by the futures market for the Mexican peso, the Brazilian real, and the Hungarian forint, respectively. But unlike the other two currencies, the explanatory power of market innovations on spot and futures volatility appears relatively stable over time, indicating a considerable level of persistence. The proportion of spot volatility explained by futures volatility is the highest of the three currencies—explaining 18.0 percent of the total spot market volatility. It is worth reemphasizing that spot market volatility is overwhelmingly explained by spot market volatility innovations and not futures market innovations.

Another result worth noting is the large degree of independence evident for the trading volume variable, which, for all three currencies, is largely unaffected by the behavior of volatility in the markets and has only limited explanatory power with respect to the other variables. Originally, we were concerned that the inclusion of futures volume might detract from any relation between futures volatility and spot volatility, since futures volume and futures volatility have been found to be highly correlated in previous research. However, it appears the volume-volatility relation is fairly weak in these data. Moreover, we had hoped to examine the potential influence of the futures market on the underlying spot market after correcting for the influence of spot trading on the spot volatility. But since the foreign exchange market is highly decentralized, spot trading volume data are seldom collected and are not available for the three currencies examined here. In these circumstances a significant relationship between spot volatility and the futures market volatility can falsely be established when the spot market volume is absent and the futures market trading activity acts as an instrument for the (missing) spot volume variable.

Three authors offer evidence against the hypothesis that futures volume is very closely related to spot volume, implying this latter issue is moot as well. Wei (1994) argues that the movement of the futures market and the spot market can diverge significantly and he concludes that "the omission of the spot volume variable does not seriously bias the parameter estimation for the market's anticipated volatility." Lyons (1995) reports that much of the currency spot market trading is uninformative as market makers pass through currency positions obtained from their corporate and retail customers. Finally, Poon (1994) shows that regressing the spot volatility on spot volume and derivative volume yields two significant coefficients and that derivative volume tends to lead spot volume, suggesting that both spot and futures volume have their own independent influence on spot volatility.

Direct Tests of Futures Introduction

Following the conclusions indicated by Tables 5 and 6, a direct test of the effect of the futures market on the cash market behavior is suggested below. A simple calculation for a sample period of 809 observations between March 1, 1994 and April 4, 1997[31] shows a variance of daily changes in the Mexican peso/U.S. dollar exchange rate of 7.3622 before the introduction of futures contracts and 0.4179 after the introduction of the contract on April 25, 1995. An *F*-test of the hypothesis that the cash market variance is lower *before* the introduction of the futures market yields a value of 17.62 against a 5 percent critical value of approximately 1.0, which clearly suggests that the cash market volatility is significantly lower for the *post*-introduction period. This result, though, is critically influenced by the fact that the Mexican crises happened before the introduction of futures markets and may have, in fact, been part of the impetus for the introduction of the futures contract. This gives a strong upward bias to the variance of the early sample period. To limit the influence of the Mexican crisis, the SWARCH model is reestimated for the Mexican peso cash market including a step dummy[32] d_t indicating the introduction of futures contracts on April 25, 1995. This implies a change of the conditional variance equation in model (5) to

$$h_t^2 = \beta_0 + \beta_1 a_{t-1}^2 + \beta_2 a_{t-2}^2 + \; \ldots \; + \beta_q a_{t-q}^2 + l d_t. \tag{5a}$$

Estimation of a SWARCH (2,5) model according to specification (5a) yields a coefficient of –0.022 on the dummy variable.[33] The standard error of the coefficient is 0.013, which makes the parameter significant at the 5 percent level. This result can be considered more powerful than the simple *F*-test presented above, since the structure of the SWARCH model accounts for the increased volatility during the Mexican crises and should therefore reduce the sampling bias. The significance of the (negative) dummy coefficient indicates that the existence of a futures market reduces the volatility of the underlying variable in the case of the Mexican peso. A measure of liquidity that is often positively correlated with volatility is the bid-ask spread. While historic bid-ask spread data from the over-the-counter

[31] Our futures data run from January 1, 1995 through February 28, 1997, limiting the sample period for the previous results. However, our spot series is longer, allowing us to expand the sample for this purpose.

[32] The use of dummy variables in (G)ARCH type volatility estimation was first outlined by Baillie and Bollerslev (1989), who use dummies to account for day of the week effects. The dummy d_t takes the value of 1 with the introduction of futures contracts.

[33] Replacing the simple step dummy with a measure of futures market volume decreases the coefficient in absolute size, but does not affect the level of significance or the sign of the coefficient.

peso spot market are unavailable, there were many anecdotal reports that bid-ask spreads in the spot peso decreased substantially after the futures contract introduction.

Trading in futures contracts on the Brazilian Bolsa de Mercadoris & Futuros predates the beginning of our sample period, which suggests a slightly different approach in the investigation: daily trading volume in both the spot and futures market largely reflects speculation and market-making activities, since trade-related uses for currency only involve a minor proportion of the market. Consequently, any independent influence of the existence of a futures market can be proxied by its level of trading activity. To estimate this effect the dummy variable in equation (5a) is replaced by the (stationary) measure of volume V_t,

$$h_t^2 = \beta_0 + \beta_1 a_{t-1}^2 + \beta_2 a_{t-2}^2 + \ . \ + \ . \ + \ . \ + \beta_q a_{t-q}^2 + lV_t. \tag{5b}$$

The coefficient l, estimated for a SWARCH(2,3) model, is –0.000044 with a standard error of 0.000047, indicating that there is no statistically significant influence from futures trading activity on the level of volatility in the market for the underlying spot currency.

Estimation of model (5b) for the Hungarian forint, whose futures market also predates the sample period, produces a statistically insignificant coefficient l of –0.032 with a standard error of 0.332. The evidence gained from including the futures market trading activity as additional explanatory variable into model (5) remains inconclusive. Although the sign of the coefficients points to a reduction in the spot volatility, in two of the three cases the standard errors are too large to assure statistical significance.[34] The lack of statistical significance is also suggested by the previous results in Tables 5 and 6, although no indication of the sign of the relation is forthcoming using the previous techniques. Nevertheless these results are more in agreement with the work presented by Edwards (1988) and by Bessembinder and Seguin (1992), who find a stabilizing effect in the introduction of derivative markets, than the conclusions presented by Chatrath, Ramchander, and Song (1996), who argue that cash market variance increases in response to the introduction of futures markets.

IV. Conclusion

This paper tries to establish the extent to which the behavior of an emerging market currency is influenced by its corresponding futures contract. The

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[34] Replacing the volume variable in models (5a) and (5b) with the SWARCH estimate for futures market volatility again yields negative coefficients on the futures variable, which lack statistical significance in two of the three cases. However, these results were numerically difficult to obtain and appear to lack the robustness of our other results.

theoretical literature on this topic remains divided about the potential consequences of the introduction of derivative contracts, arguing that either the advantages of an increased investment opportunity set or the destabilizing behavior of speculators will dominate the outcome. The vast majority of the empirical evidence on the introduction of other options and futures contracts points to a stabilizing function of the derivative market.

This paper extends this empirical work to emerging market currencies. Since most of these currencies operate in managed exchange rate systems, particular attention has to be paid to the procedure used to calculate the volatility of the exchange rate series, as the volatility process shows discrete shifts in the level of the fluctuations. It is argued that the SWARCH framework developed by Hamilton and Susmel is best able to capture the occasional occurrence of currency crises and other large swings in the exchange rate.

After estimating the volatility, Granger and Geweke measures are used to establish the degree of dependence between the two markets. For all three currencies examined, the Mexican peso, Brazilian real, and Hungarian forint, the hypothesis that the futures and spot markets evolve independently is rejected. A variance decomposition based on a VAR model including spot volatility, futures market turnover, and futures volatility indicates that in the long run, spot market volatility is tied predominately to spot market innovations and not to the futures market. However, for the Brazilian real, at a one-day horizon, 23 percent of the volatility of the spot market is attributable to futures market volatility, suggesting that there is some short-run volatility spillover from the futures to the spot market.

Although the focus of this study is limited to the impact of a futures contract introduction on the underlying spot market, an interesting extension would be to gauge the effectiveness of central bank intervention before and after futures are introduced. This would be especially interesting if central bank authorities intervened in the futures market instead of the spot market, since the results here suggest that the futures market responds faster than the spot market. It does not follow from these results, however, that a change from spot market intervention to futures market intervention would necessarily lower volatility in the spot market. To evaluate such a supposition, one would have to (at least) evaluate the current contribution of spot market invention to spot market volatility and assess whether the existing linkages between the futures market volatility and spot market volatility would be altered if intervention was conducted through the futures market. A previous study in this area, undertaken by Bonser-Neal and Tanner (1996), reported that spot intervention does not reduce the expected volatility in foreign exchange markets. In any event, a longer time series and the exact timing of interventions would be needed to address such issues.

Finally, a reestimation of the SWARCH models for the spot market data, including a variable representing the introduction of the futures market, suggests a stabilizing influence emanating from the futures market. However, for two of the three emerging market currencies the estimated coefficients are not statistically significant, indicating neither a positive nor a negative effect on spot market volatility.

While the results appear reasonably compelling, the absence of a larger sample of emerging market currency futures contracts implies that, at this time, a general conclusion about the benefits of the introduction of futures contracts must await further study. A wider sample of currency futures may be obtained after recently scheduled introductions take place and longer time series become available. Summarizing, the empirical results show a very stable dependence between the markets and to a large degree support the hypothesis that the behavior of the spot market is not destabilized by the futures market.

APPENDIX I

Overview of Political and Economic Developments

The Mexican Peso (1993 and After)

The new Mexican peso was introduced on January 1, 1993, as a signal for monetary and exchange rate stability. During the previous years, Mexico had seen considerable inflows of foreign capital, primarily in the form of portfolio investment, but also as foreign direct investment. These capital flows increased substantially with the ratification of NAFTA, which was widely regarded as a stepping stone for future economic growth.

Following political unrest in southern Mexico and an increase in international interest rates, the Mexican central bank was forced to spend a considerable amount of its reserves defending the exchange rate throughout 1994. In December 1994, the monetary authorities tried to halt the outflow of capital by devaluing the peso by 15 percent. In spite of the devaluation, the peso again came under considerable selling pressure and two days later the Mexican government decided to abandon its implicit support and permit the peso to float. Financial support by the U.S. government, the IMF, the Bank for International Settlements, and other institutions was necessary to stabilize the Mexican economy and the financial markets. Following some initial turbulence in early 1995, and further reinforcement of adjustment policies, by April 1995 most of the measures imposed to halt the continued devaluation of the peso and to curb the high amount of volatility in the markets had successfully taken effect, and the peso stabilized around Mex\$6 to the dollar, only to drop another 20 percent in November 1995.[35] The following period of relative exchange rate stability was interrupted by another market-induced depreciation during October 1996. Market commentary attributed this

[35] Folkerts-Landau and Ito (1995) give an overview of the peso crisis and some of its causes.

devaluation to short sales by local banks and a drop in interest rates during the preceding months.

Mexican authorities granted the Chicago Mercantile Exchange permission to introduce a peso futures contract in April of 1995 and settle the contract through the Mexican clearing system. This was one of several initiatives following the December 1994 peso crisis that signaled to market participants the authorities' ongoing resolve to allow the peso to float. The Mexican authorities have granted some domestic banks the ability to use the contract and, importantly, have permitted the trading to take place on a foreign exchange.

The Brazilian Real (1993 and After)

During the second half of the 1980s and early 1990s, Brazil made several attempts to reduce inflation, which averaged 21 percent a month in the period 1985–93. However, most of these attempts relied heavily on comprehensive price and wage freezes without sufficiently tight fiscal and credit policies. In late 1993, the Brazilian authorities launched the Real Plan aimed at a sharp and lasting reduction in inflation. The program was based on measures to break inflation inertia, a modification of the exchange rate regime that had focused on maintaining a real exchange rate target, and a tightening of fiscal and credit policies.

The authorities introduced the key elements of their program in three phases. First, they set the basis for improving the public finances by targeting an increase in the primary surplus for the federal budget for 1994, and introducing a social emergency fund to allow the federal government more flexibility to allocate and cut expenditures. The second phase prepared the ground for the removal of backward-looking wage and price indexation by introducing a new unit of account that linked price adjustments to the current exchange rate rather than past increases. The third phase of the program was implemented on July 1, 1994, when the government introduced the new currency, the real, with a floating exchange rate against the U.S. dollar, subject to a floor of R$1 to the U.S. dollar. The Real Plan was successful in bringing about a drop in the inflation rate from almost 45 percent a month during the second quarter of 1994 to 3 percent in August of 1994. In March 1995, the central bank introduced a currency band with the exchange rate allowed to depreciate at a rate slightly higher than that necessary to offset the expected inflation differential with the United States.

The Commercial U.S. Dollar futures contract began trading August 1, 1991. It is now one of the two largest contracts on the Bolsa de Mercadoris & Futuros, joined by the One-Day Interbank Deposits futures contract. There were no particular events associated with its introduction.

The Hungarian Forint (1993 and After)

The Hungarian forint, in contrast to the Mexican peso and the Brazilian real, did not experience any extraordinary fluctuations during the period between 1994 and 1997. Between May 16, 1994 and January 1, 1997, the Hungarian forint was linked to a basket composed of the ECU (European Currency Unit) (with a weight of 70 percent) and the U.S. dollar (with a weight of 30 percent). Since January 1, 1997, the National Bank of Hungary has changed the composition of its basket to

a combination of deutsche mark (with a weight of 70 percent) and the U.S. dollar (with a weight of 30 percent). Until March 13, 1995, the value of the peg to the basket was adjusted periodically, mainly based on the difference between domestic and foreign inflation rates. Since then, a crawling peg has been used. The rate of devaluation declined from its initial 1.9 percent a month to 1.1 percent a month by the end of our sample. A particularly large devaluation occurred in March 1995 with the start of the crawling peg. The years 1996 and 1997 saw a continuation in the managed depreciation policy, which as the primary nominal anchor has been associated with a marked decline in inflation. Monetary policy has aimed to keep real interest rates positive after a period in 1992 and 1993 when they were negative. Measures to curb the budget deficit and the current account deficit have shown positive results with substantial improvement in these macro-economic variables.

Trading in currency futures was introduced on the Budapest Commodity Exchange in March 1993, after considerable competition from the Budapest Stock Exchange over the currency market segment. A joint clearing house was then established by the Commodity Exchange and Stock Exchange in December 1993.

## APPENDIX II

Description of Figures

The following figures for the Mexican peso, the Brazilian real, and the Hungarian forint are a representation of the results for model (5) as reported in Table 4. The return series for the Mexican peso and the Brazilian real show very significant clusters of volatility around the time of major disturbances as the peso crisis in December 1994. The return series of the HF indicates little of these characteristics and displays only a number of more or less isolated outliers, such as the March 1995 devaluation. Based on the behavior of the return series, the volatility estimates of the Mexican peso and the Brazilian real show distinct changes in the level of volatility. These observable changes in the level of volatility argue for the introduction of the regime switching ARCH model. The two graphs following the volatility series depict P1 and P2, which are the probabilities that the behavior of the exchange rate fits either the low-volatility profile P1 or the high probability profile P2. The peso crises 1994, for example, is clearly indicated as a regime 2 state. The Mexican peso also shows that the estimates for P1 and P2 pick up changes in the behavior of the return series very fast and that the regimes show a high degree of persistence after the initial shift. The level of persistence is even higher in the case of the Brazilian real, where only one regime shift is indicated in the sample period. Owing to the more stable behavior of the Hungarian forint series, the persistence of the high volatility state P2 is considerably lower than in the other two currencies. This induces frequent switches between the high- and low-volatility regimes and a predominance of the low-volatility state P1.

Figure 1. *Returns and SWARCH Model Results for the Brazilian Real*
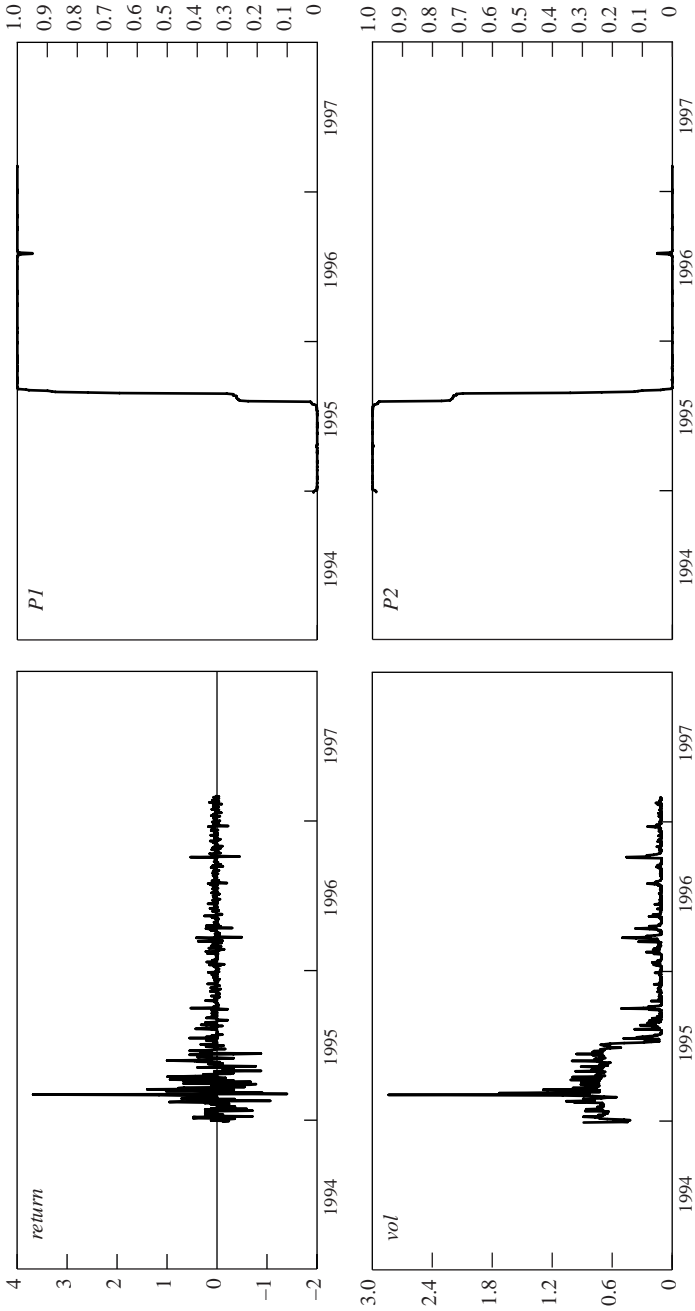
Notes: Return: daily percentage change of the Brazilian real/U.S.$ exchange rate; vol: conditional volatility estimated by SWARCH; P1: probability that volatility process is in regime 1; P2: probability that volatility process is in regime 2.
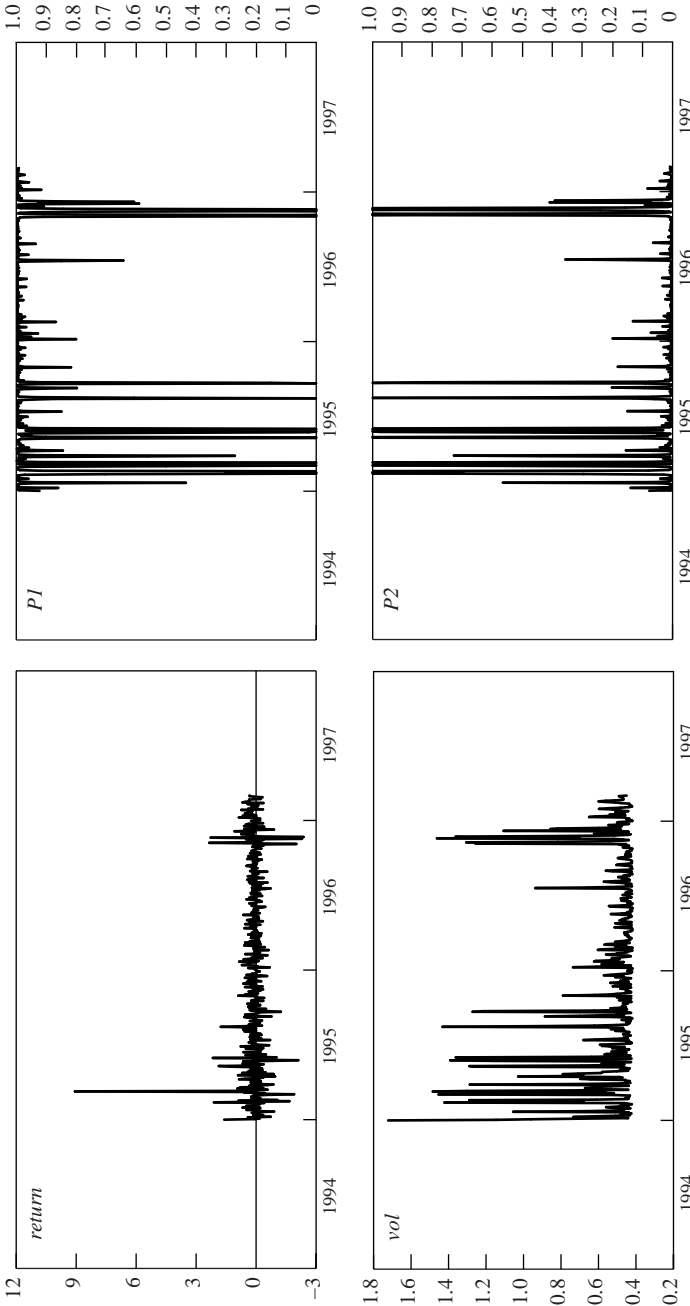
Figure 2. *Returns and SWARCH Model Results for the Mexican Peso*
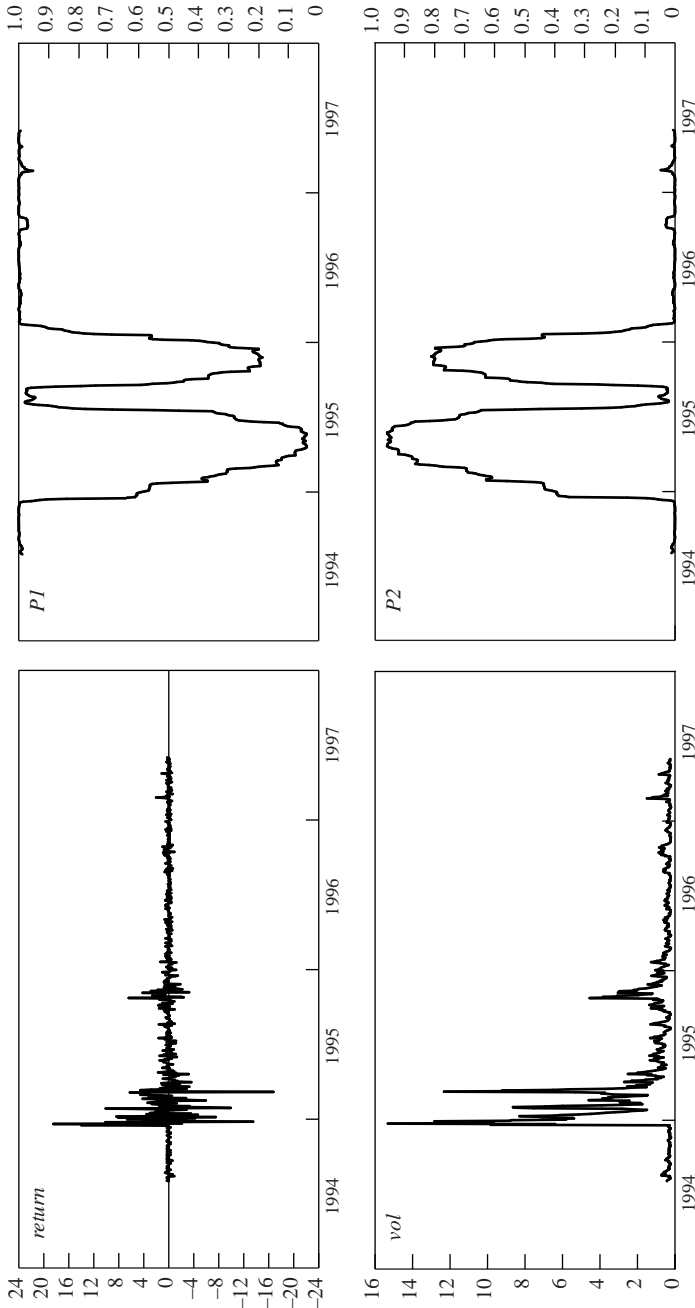
Notes: Return: daily percentage change of the Mexican peso/U.S.$ exchange rate; vol: conditional volatility estimated by SWARCH; P1: probability that volatility process is in regime 1; P2: probability that volatility process is in regime 2.

Figure 3. *Returns and SWARCH Model Results for the Hungarian Forint*

Notes: Return: daily percentage change of the Hungarian forint/U.S.$ exchange rate; vol: conditional volatility estimated by SWARCH; P1: probability that volatility process is in regime 1; P2: probability that volatility process is in regime 2.

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