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Do "Flexible" Exchange Rates of Developing Countries Behave Like the Floating Exchange Rates of Industrialized Countries?

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Do "Flexible" Exchange Rates of Developing Countries Behave Like the Floating Exchange Rates of Industrialized Countries?

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Abstract

The paper examines the behavior of daily spot exchange rates for a sample of industrialized countries which are generally considered to be floating with only occasional official foreign exchange market intervention. This behavior is then compared to the behavior of the exchange rates of a sample of sixteen developing countries whose regimes are often classified as being "flexible". Considerable differences in the way these developing countries' exchange rate regimes operate is apparent from the daily data, with some sharing similarities with the regimes of the industrialized countries and with others demonstrating regime shifts and other marked discontinuities.

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Keywords: Flexible and floating exchange rates

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[1] I am grateful for comments from Paul Cashin and Sam Ouliaris. Neither is in any way responsible for any errors in the paper.

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I. Introduction

Over the past two decades or so, the mix of exchange rate arrangements in developing countries has shifted considerably. While in the 1970s the shift was mainly away from "adjustable" pegs vis-à-vis a single currency towards "adjustable" pegs vis-à-vis baskets of currencies, the changes since the early 1980s have marked a shift towards "more flexible" exchange arrangements.[2] More recently, however, currency board arrangements or "hard" currency pegs have been implemented in a number of member countries of the IMF, while in other countries *de facto* currency pegs have been attacked and the monetary authorities have been obliged to give up such pegs (so-called forced 'exits') and adopt "more flexible" exchange arrangements, including in some cases "floats" with only occasional or limited official intervention in foreign exchange markets. While some observers (e.g., Frankel (1999), Williamson (2000)) continue to consider that a spectrum of regimes remains feasible, others have appeared to argue (e.g., Eichengreen (1994), Obstfeld and Rogoff (1995), Krueger (2000)) that in a world of increasing capital mobility characterized by rapid international financial asset arbitrage "free" or at least "fairly clean" floating is really the only practical alternative to "hard" currency pegs or full dollarization.

A number of developing countries claim that their exchange rates are "market determined" and that their official exchange market intervention is being conducted in order to avoid "excessive" volatility or disruptive or discrete jumps in the exchange rate. In some cases it appears that the same words mean different things to different people. Under the Bretton Woods system, for example, the industrial countries undertook to peg their currencies under narrow margins around a central parity. Using foreign exchange reserves (often under the aegis of an exchange equalization or stabilization fund, e.g., the United Kingdom, the United States) the monetary authorities bought and sold foreign exchange in interbank markets to achieve their declared *de jure* exchange rate objectives. It should be noted that while current account convertibility was generally achieved by these countries by the late 1950s, the use of capital controls remained in place for most of the Bretton Woods period and indeed in many for sometime after that system's demise. Many developing countries operated under the Bretton Woods system by declaring central parities to the U.S. dollar or other major currency with the monetary authorities deciding on the margins and for what purposes (enforced by capital controls and exchange restrictions) they would buy and sell foreign exchange to eligible financial intermediaries. These financial intermediaries functioned as fairly tightly controlled agents and conditions were not in place which favored the emergence of an active interbank market. Foreign exchange trading outside this system took place in "curb" or "black" markets. This state of affairs persisted for many developing countries post-1973.

Over time, current account liberalization and reductions in financial repression made it possible for some developing countries to move towards interbank foreign exchange systems. It then became possible for the monetary authorities to attempt to achieve their exchange rate

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[2] See, for example, the *World Economic Outlook* (International Monetary Fund (1997)).

objectives (if any) by official intervention in the interbank market. The exchange rates that emerged were considered by the monetary authorities of some developing countries to be "market determined" whatever the extent of official intervention. This appears to have been the case in certain emerging markets in Asia prior to the crises which operated *de facto* currency pegs until such pegs were undermined by speculative attack (e.g., the Philippines).

It is often quite difficult to determine just what the monetary authorities of a developing country mean by a "market-determined" exchange rate. They may be unwilling to provide data on official intervention on a regular basis or data on foreign exchange reserves may be provided on, say, a monthly basis which reflect not only official intervention in the interbank market but also other transactions undertaken on behalf on the government such as debt service payments and purchases of foreign goods and services. Such relatively low-frequency exchange rate monitoring (e.g., monthly) may also serve to obscure movements in exchange rates by acting as a smoothing filter. The monetary authorities may argue that such official intervention as does take place reflects indeed the desire to "smooth" the path of the exchange rate and avoid disruptive and abrupt changes in the exchange rate. There seems to be a general reluctance in developing countries to adopt "pure floats" or take a position of "benign" neglect towards the exchange rate. Some observers have argued that this fear of floating may be misplaced and, if only the "fundamentals" were right, floating exchange rates would be more stable. However, while the "fundamentals" have explanatory power at low frequencies over lengthy time spans, Frankel and Rose (1994) and Flood and Rose (1999) argue that such is not the case for high frequency exchange rate data for the major industrial countries. As the foreign exchange markets for these countries are well-developed and official intervention is infrequent, the behavior of daily exchange rates for major currencies forms a natural "benchmark" against which to examine the "market-determined" or "flexible" exchange rates of the currencies of developing countries.[3]

Apart from the intrinsic interest arising directly from the envisaged comparison, an important reason for examining daily exchange rate data for developing countries is that within an overall monetary policy framework the monetary authorities have to decide on how they are going to conduct day-to-day operations including whether to intervene in the foreign exchange market. If in the circumstances the authorities decide to eschew intervention and float more or less "cleanly", then their high frequency focus will be on the domestic money market and on the provision of liquidity to the financial system by way of open market operations. In practice this may take the form of targeting a short-term interest rate (often the case in industrialized countries, e.g., the Federal Reserve targets the Federal Funds rate). The high frequency interest rate target is in turn a reflection of decisions usually made at lower frequencies at meetings of policy committees (e.g., the Fed's FOMC, the Bank of England's MPC) which decide on changes in the target interest rate in light of the cyclical state of the economy and in the context of the objective of attaining or maintaining price stability (often a low rate of underlying or

[3] Intraday behavior of exchange rates has also been examined in the literature (e.g., Andersen and Bollerslev (1998)), but tick-by-tick data is not readily available for developing countries.

trend inflation), the latter objective embodying a still lower frequency approach in terms of monetary policy horizon.

The industrialized countries do not completely eschew foreign exchange market intervention, particularly in response to perceived market turbulence or when the authorities believe that the exchange rate is not reflecting the "fundamentals". Australia, for example, is reported to have intervened quite heavily in late 2000 and in the first part of 2001 in the wake of a depreciating currency and in the face of continuing exchange market pressure, possibly because of the impact of rising import prices in domestic currency terms on the rate of inflation in a period of slowing overall economic activity. Developing countries with "flexible" rates face similar if not more difficult challenges in framing monetary policy and exchange market intervention viewed in the frequency domain. There are fears of excessive exchange rate volatility and possibly less than transitory misalignments. And, choices that need to be made may involve assessing trade-offs or facing constraints "imposed" by other policy choices, namely those emanating from the fiscal-monetary policy nexus.[4]

Recent research into exchange rate regimes in developing countries has been attempting to move beyond formally-declared classifications and to examine more thoroughly the behavior over time of "flexible" exchange rates and other key variables (e.g., interest rates, international reserve movements, etc.).[5] The focus has typically been on monthly and/or quarterly data, frequencies at which data on exchange rates, international reserves, monetary aggregates, prices, etc. are readily available. The present paper, in contrast, focuses on daily exchange rate data. Section II presents information on the behavior of daily exchange rates for a sample of industrialized countries with currencies that "float" which will serve as benchmarks for a comparison of behavior. Section III presents the daily exchange rate data for a sample of developing countries with "flexible" exchange rates and examines similarities and differences in behavior in comparison to the industrialized countries and within the developing country group itself. Section IV then offers some concluding remarks on the usefulness of examining daily data in trying to understand what the monetary authorities in developing countries may be attempting to achieve in their exchange rate policy.[6]

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[4] Hence, for example, the literature on inflation targeting in developing countries makes much of the issues of instrument independence for the monetary authorities and of the absence of fiscal dominance, see Masson, Savastano, and Sharma (1997).

[5] Recent papers include Levy Yeyati and Sturznegger (1999) and Calvo and Reinhart (2000).

[6] Edwards and Savastano (1998) argued, for example, that relatively little is known empirically in the case of developing countries.

II. The Industrialized Countries As Benchmarks

In this section of the paper exchange rate data (in terms of domestic currency per U.S. dollar) are examined at the daily frequency for the currencies of eight industrial countries, all of which are considered to be floating with little or only occasional foreign exchange market intervention. The currencies are: the Australian dollar, the Canadian dollar, the German deutsche mark, the Japanese yen, the New Zealand dollar, the Swedish kronor, the Swiss franc, and the U.K. pound. The data covers the period January 2, 1996, to December 29, 2000, a total of 1304 daily observations.[7] The l.h.s of Figure 1 shows the raw exchange rate data in log levels and, in order to give an impression of the "underlying" movements in exchange rates, smoothed versions of the exchange rate series are also shown.[8] The r.h.s of Figure 1 shows the exchange rate 'returns', i.e., the mean-adjusted first differences of the logarithms of the exchange rate levels multiplied by 100. By inspection of the graphs on the l.h.s. of Figure 1, it is obvious the exchange rates in log levels are heavily serially correlated and non-stationary.

Statistical information on the exchange rate returns data are given in Table 1, while Figure 2 shows plots of the estimated spectral density function (SDF), the probability density function (compared to the normal distribution of equal sample standard deviation), and the cumulative distribution function (CDF).[9] Six of the eight exchange rate returns series are significantly skewed, the exceptions being the Canadian dollar (at the 95 and 99 percent levels) and, more strongly, the pound sterling. As is typical of high-frequency financial time series of returns, all the exchange rate returns data are 'fat-tailed and peaked' and the kurtosis test results are highly significant for all eight currencies vis-à-vis the U.S. dollar. Normality is rejected convincingly using both the Bowman-Shenton test (although large samples are required for robust results) and the Doornik-Hansen test.

To test for randomness, use was made of spectral shape tests pioneered by Durlauf (1991) and developed further by Fong and Ouliaris (1995). In essence these tests amount to examining the sample autocorrelations in the frequency domain. Serial correlation in the time domain is transformed into heteroskedasticity in the frequency domain via the Fourier transform. A white noise process in the frequency domain would have a horizontal spectral density function, so that the tests are designed to measure the extent of deviation of the sample spectral density function from a horizontal spectral density function. Asymptotic critical values are available for the test statistics and finite sample critical values are available based on Monte Carlo simulations. The test statistics are the Anderson-Darling (A-D), the Cramer-von Mises

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[7] The data and sources are described in the Appendix.

[8] The nonparametric smoother applied is that of Friedman (1984) and is known as a variable span smoother (*supersmoother*) or a k-nearest neighbor estimator. The algorithm is highly computationally efficient and can easily be updated.

[9] The distributional graphics use the program *GiveWin,* Doornik and Hendry (2000).

Figure 1: Industrialized Countries: Log Levels (Actual and Smoothed) and Returns

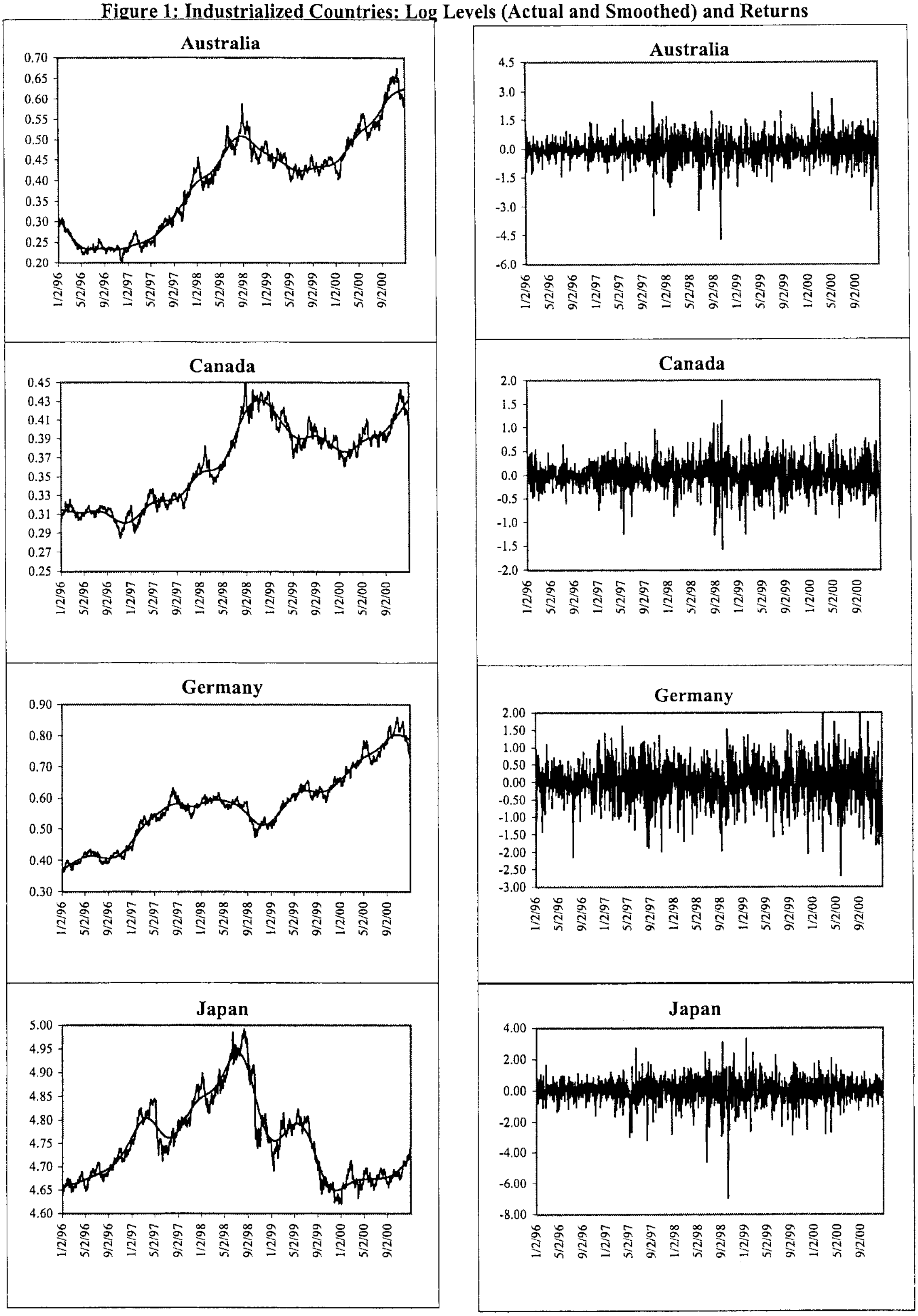


Figure 1 (Contd.): Industrialized Countries: Log Levels (Actual and Smoothed) and Returns

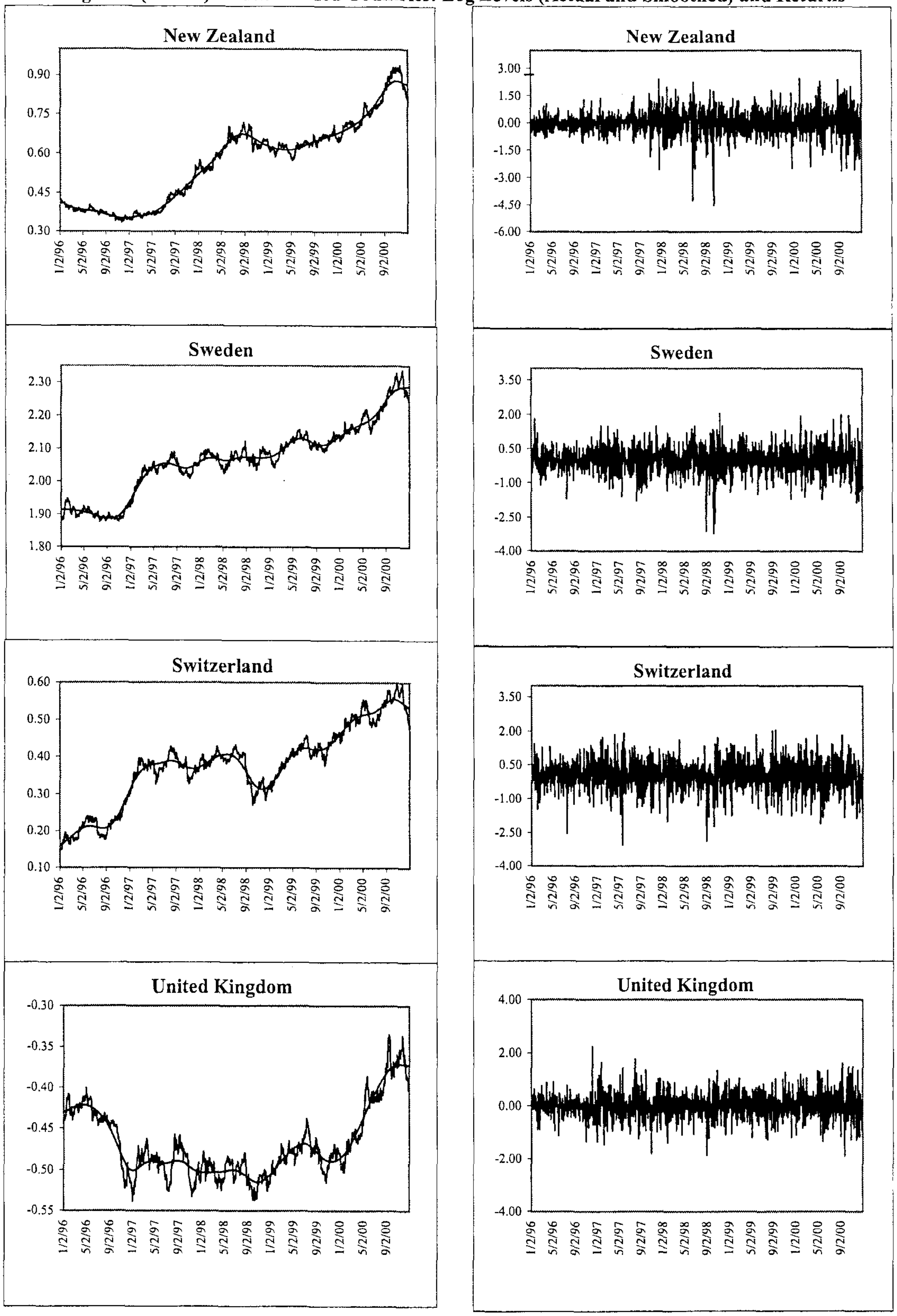
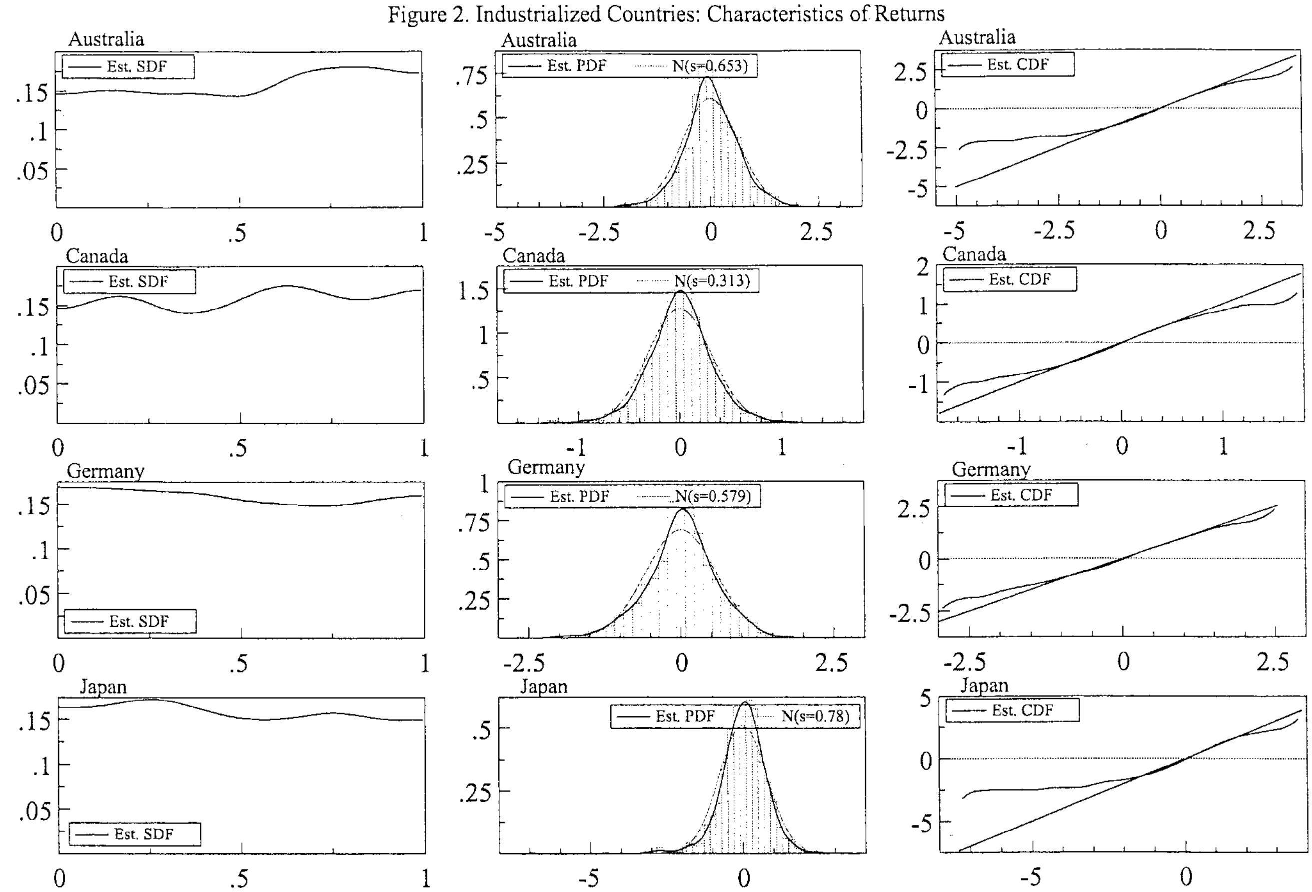


Figure 2. Industrialized Countries: Characteristics of Returns



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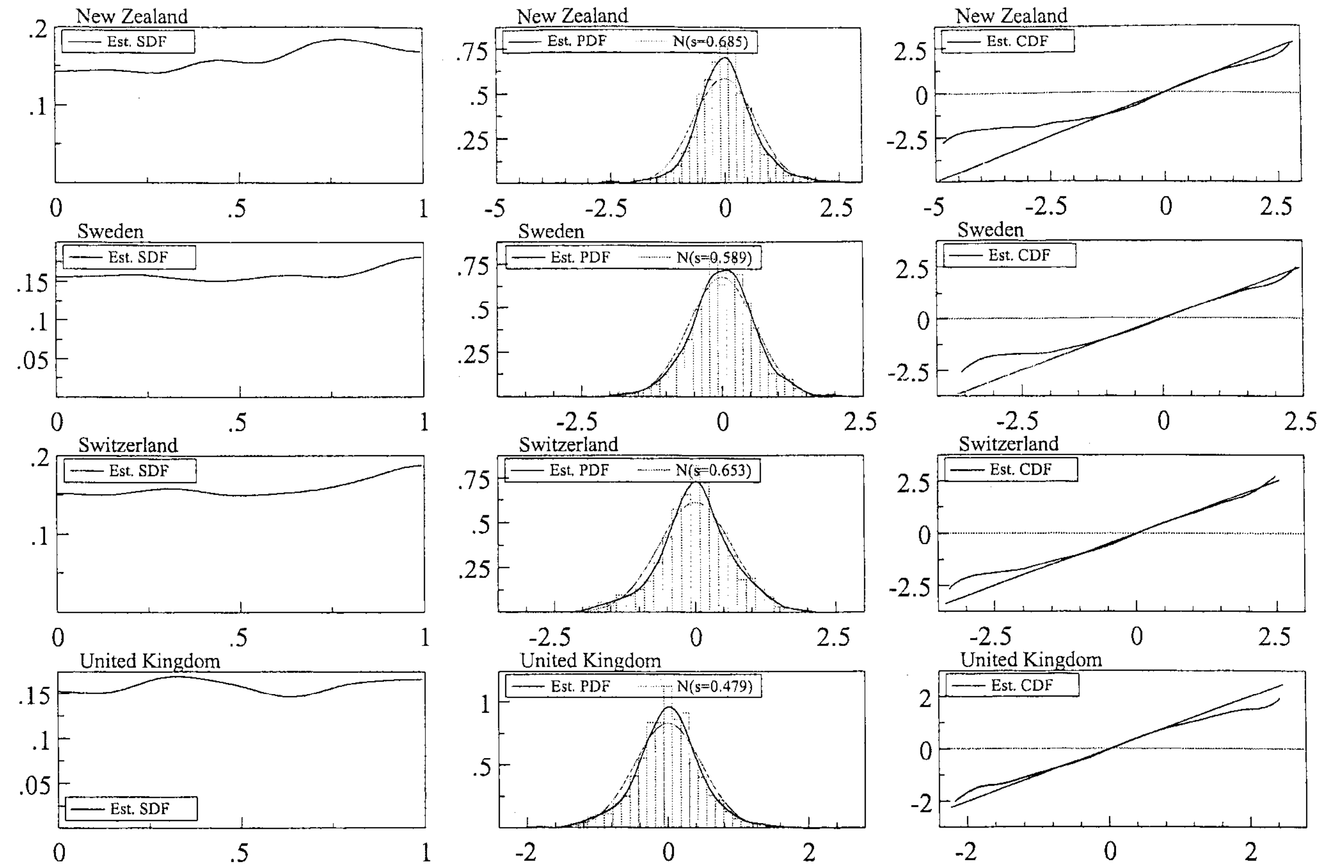

(C-VM), the Kolmogorov-Smirnov (K-S), and the Kuiper (K).[10] The test statistics for the returns of the eight currencies are given in Table 2, along with critical values at the 99 percent level for a finite sample size of 1000 yielded by Monte Carlo simulations; the actual sample size is 1303. The null hypothesis is that the exchange rate returns are white noise and it is accepted for all of the eight exchange rates for the sample period as a whole. The test statistics for the whole sample period were supplemented with rolling window tests based on 500, 250, and 100 observations for which critical values from Monte Carlo simulations are available.[11] As is to be expected the test statistics showed intertemporal variation, but in six of the eight countries critical values were not exceeded in the rolling window tests. For Australia and New Zealand certain relatively narrow windows did give indications of non-randomness, usually associated with periods of higher turbulence and outlying values; but these limited episodes were insufficient to overcome the finding of white noise for the sample period as a whole.

Other time series characteristics of the exchange rate returns data that should be mentioned are that higher level transforms (e.g., $\Delta e(exp2)$, $\log\Delta e(exp2)$ *where "e" is the log of the exchange rate*)[12] often present evidence of serial correlation and clustering (i.e., periods of high volatility followed by periods of lower volatility). Apart from the pound sterling, the Swiss franc, and the deutsche mark, the statistics provide strong evidence of non-linearities in the data.[13] The finding that the returns data are (or are approximately) white noise but not *i.i.d* (an independently and identically distributed sequence) has led investigators towards modeling the changing conditional variance of exchange rate returns. Both ARCH (or in its generalized form GARCH) and stochastic volatility (SV) models (where the variance follows a latent stochastic process, such as an auto regression), have been used to model the serial correlation in the variance and indicate that part of the volatility of exchange rate returns is predictable. However, it is beyond the scope of this paper to pursue such modeling here, as the focus is on setting up a benchmark of time series characteristics for the exchange rates of the industrialized countries to be used in a comparison with the exchange rates of developing countries.

[10] See Fong and Ouliaris (1995) for further details and for information on the robustness of the tests. They find that that the Kuiper (K) statistic is relatively inferior in size and power to the other three statistics.

[11] The rolling window tests are based on rolling *Short-Time Fourier Transforms* (STFT). Recent developments in time-series analysis suggest that "wavelet" analysis, which combines frequency and time-scale analysis, may well be a more precise and useful way of decomposing daily exchange rate data.

[12] Since the first transform can take on zero values, the second transform is based on a Taylor series.

[13] The spectral shape test statistics for these transformations are available upon request.

III. "FLEXIBLE" EXCHANGE RATES IN DEVELOPING COUNTRIES

The daily exchange rate data for the industrialized countries considered above provide a benchmark or metric against which to consider the behavior of "flexible" exchange rate arrangements for a sample of developing countries. The sample consists of daily exchange rate data for 16 developing countries from various regions of the world, all of which for all *or some part* of the sample period (1996–2000) had declared exchange arrangements which allowed their currencies to be classified as "floating independently", "managed floating with no preannounced path for the exchange rate", or having exchange rates allowed to move within "crawling bands".[14]

A review of data graphics for the countries in the sample revealed considerable heterogeneity in behavior (Figure 3). However, while some countries had major discontinuities and breaks in the data series, there were a group of countries whose exchange rate data suggested that a comparison with the industrialized countries was warranted over the full sample period. The first nine countries to be considered are: Chile, Colombia, the Czech Republic, Mauritius, Mexico, Peru, Poland, South Africa, and Sri Lanka. Of these, Mauritius, Mexico, Peru, and South Africa had declared themselves to be "independent floaters" in the sample period. The others declared themselves as operating sliding or crawling bands for part of the sample period, with changes in band width, rate of slide (crawl), and nature of central parity determination (single currency vs. currency basket, currency weights in the basket). The band widths were generally widened over time. On May 27, 1997, The Czech Republic moved from a declared sliding band with a +/-7.5 percent band width to a "managed float". On September 2, 1999, Chile declared an end to its sliding band system which had been based on a three-currency basket (U.S. dollar [80 percent], DM [15 percent], and Yen [5 percent]) and which had been widened gradually from the +/- 8 percent band width operating as of December 21, 1998. On September 25, 1999, Colombia abandoned its crawling band and Poland announced that it was floating independently as of April 11, 2000. Sri Lanka operated a narrow band system until mid-2000 when the rupee came under severe pressure and the bands were progressively widened until a float was announced on January 23, 2001.

The basic exchange rate data on the log-levels and the returns are contained within Figure 3. The data series for these countries show outbursts of particular volatility at times whose timing can often be associated with events such as the speculative attack on the Hong Kong dollar in October 1977 and the associated widespread declines in equities prices, the Russian default in August 1998, and the Brazilian crisis of January 1999. There are also some observations that are large relative to the standard deviation of the sample and which might be outliers due to measurement or data entry error. Data on the distributional characteristics of the sample data are provided in Table 4 and Figure 4 using the same formats as applied to the data of the industrialized countries.

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[14] See *Exchange Arrangements and Exchange Restrictions* (IMF, various issues).

Figure 3: Developing Countries: Log Levels (Actual and Smoothed) and Returns

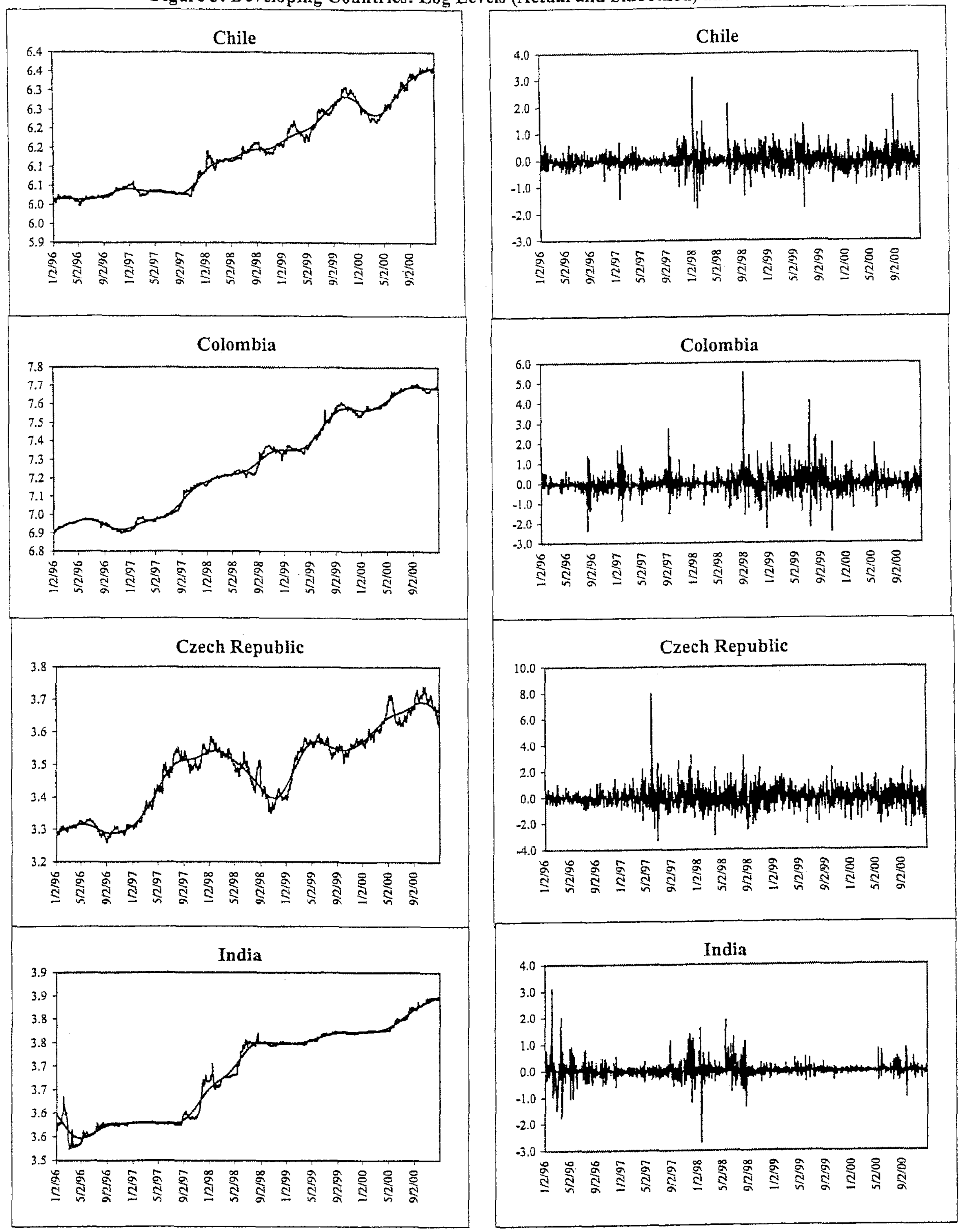


Figure 3 (Contd.): Developing Countries : Log Levels (Actual and Smoothed) and Returns

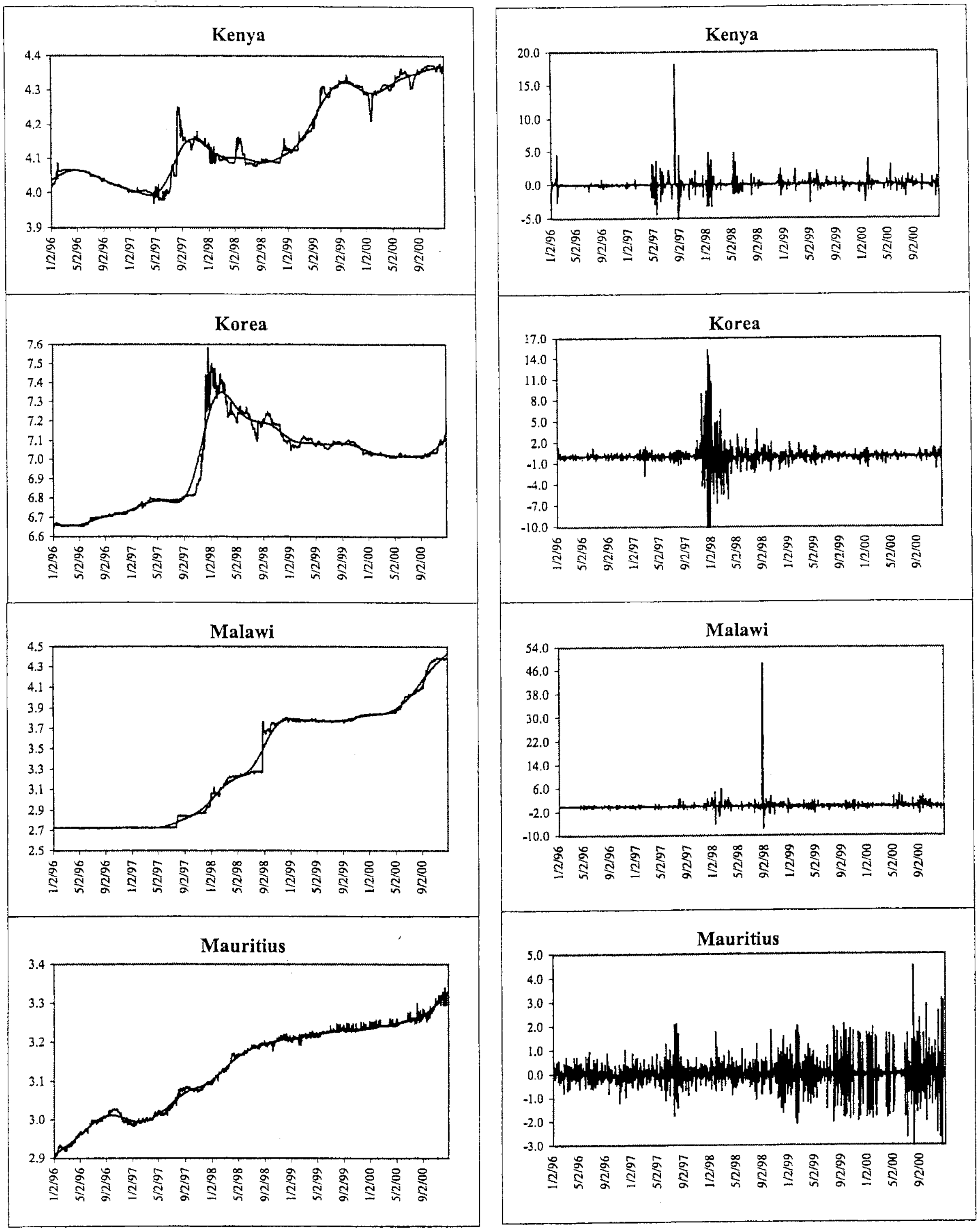


Figure 3 (Contd.): Developing Countries : Log Levels (Actual and Smoothed) and Returns

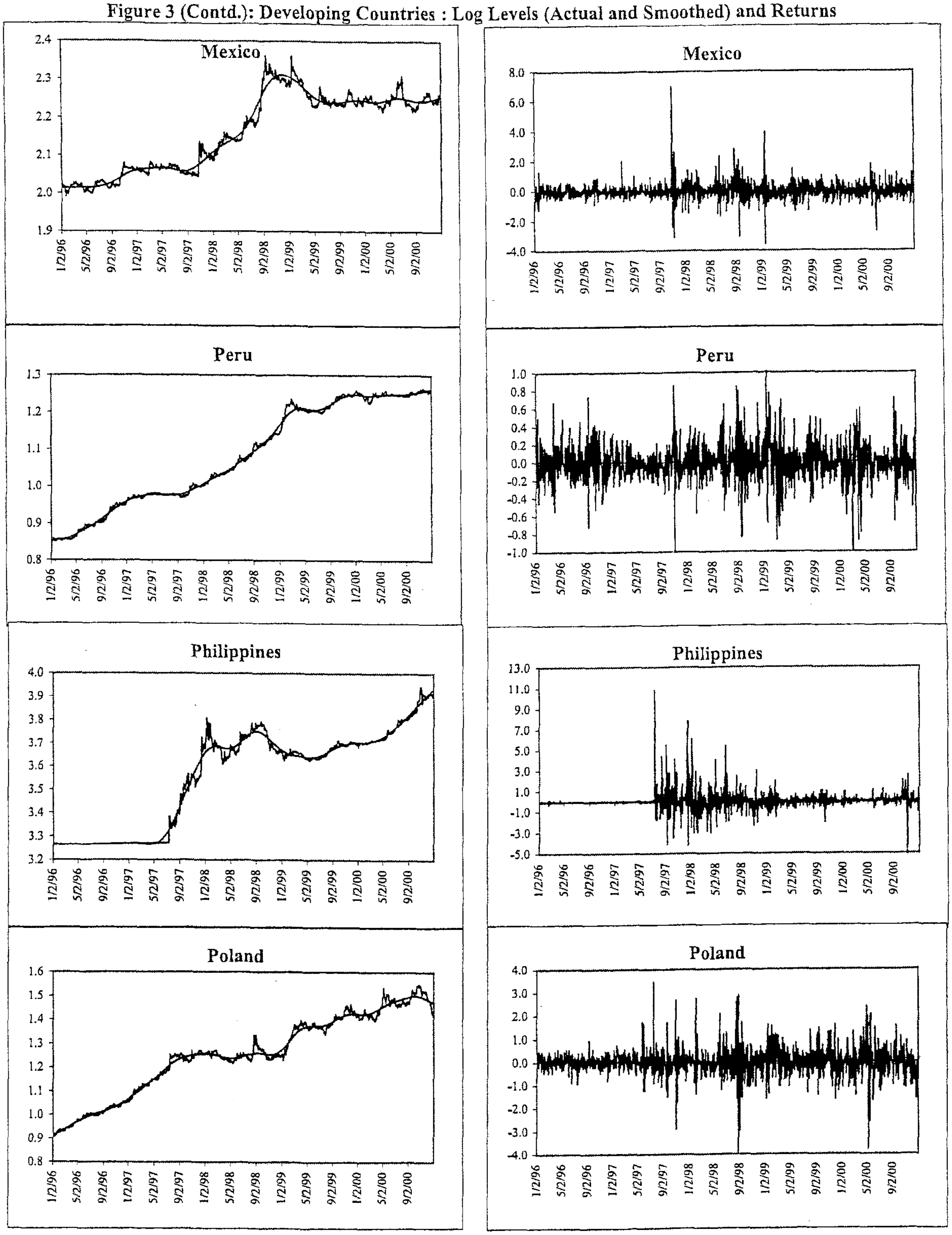


Figure 3 (Contd.): Developing Countries : Log Levels (Actual and Smoothed) and Returns

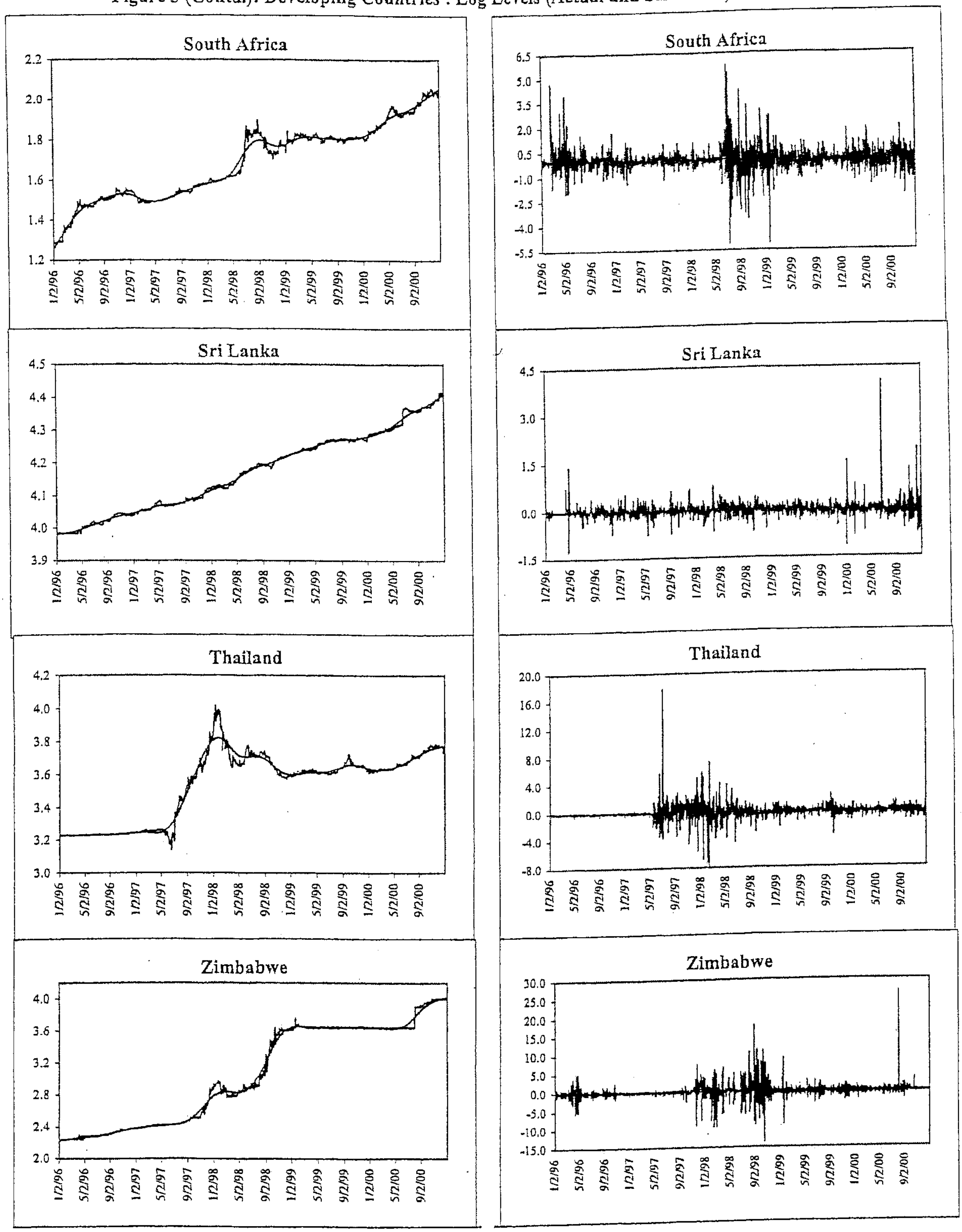


Figure 4. Developing Countries: Characteristics of Returns

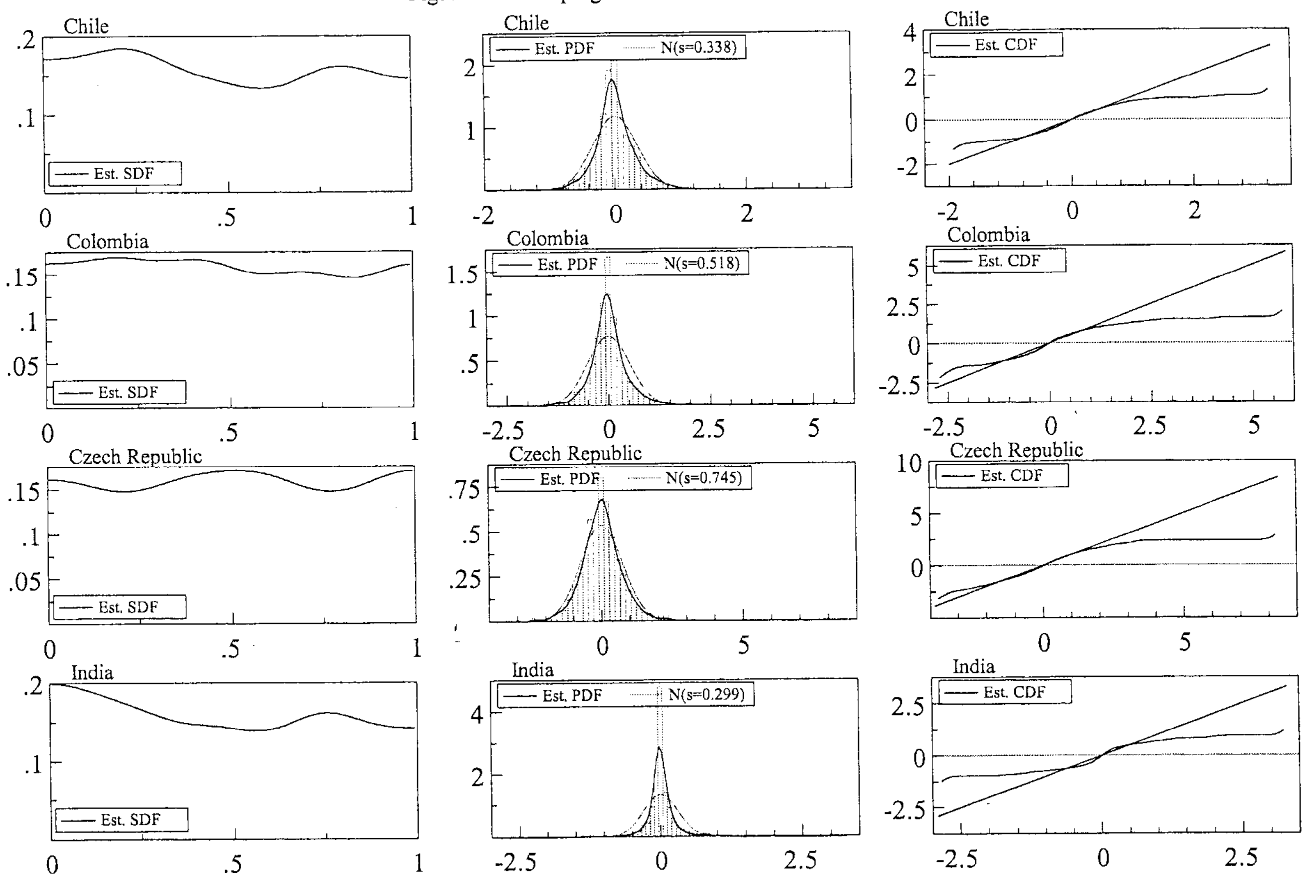


Figure 4 (contd.). Developing Countries: Characteristics of Returns

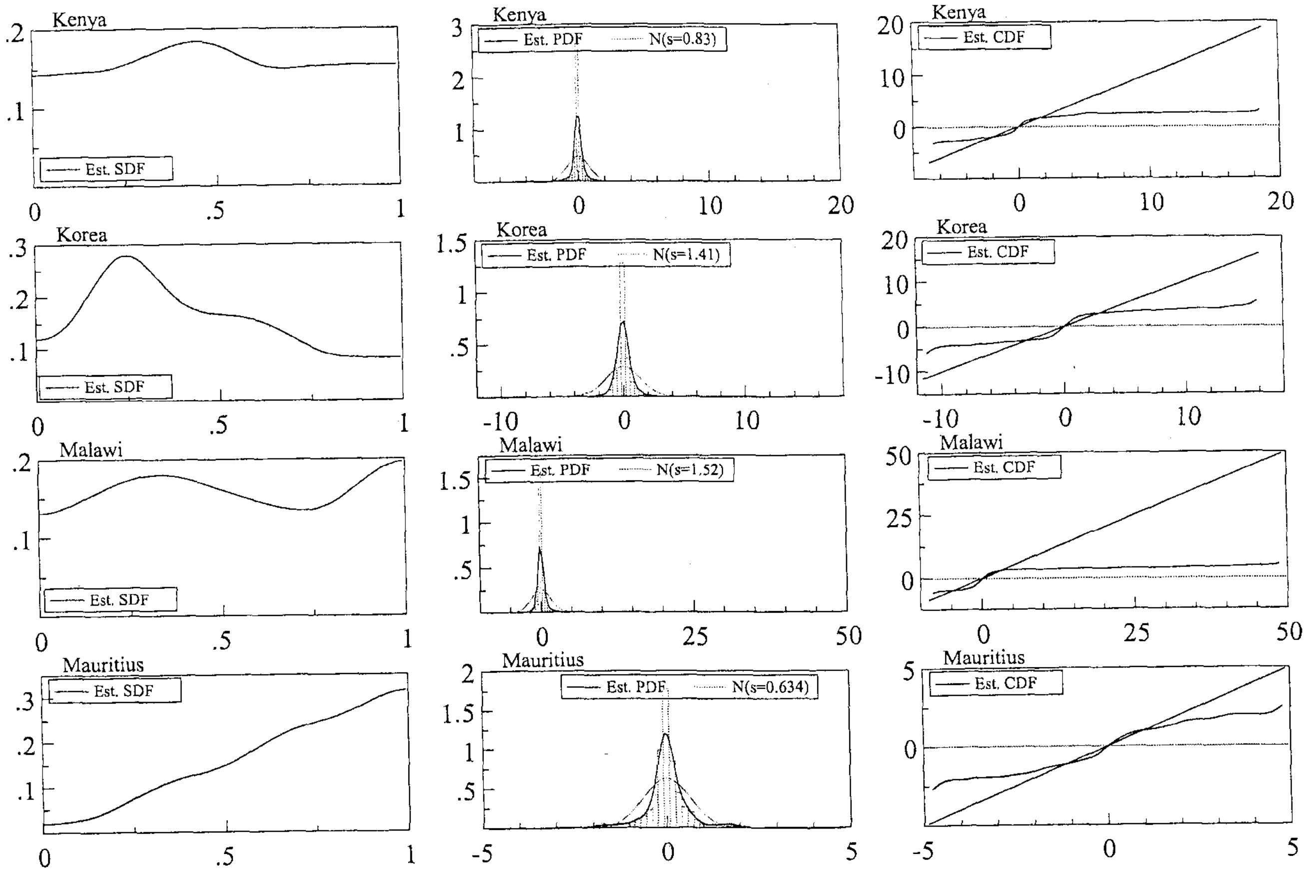


Figure 4 (contd.). Developing Countries: Characteristics of Returns

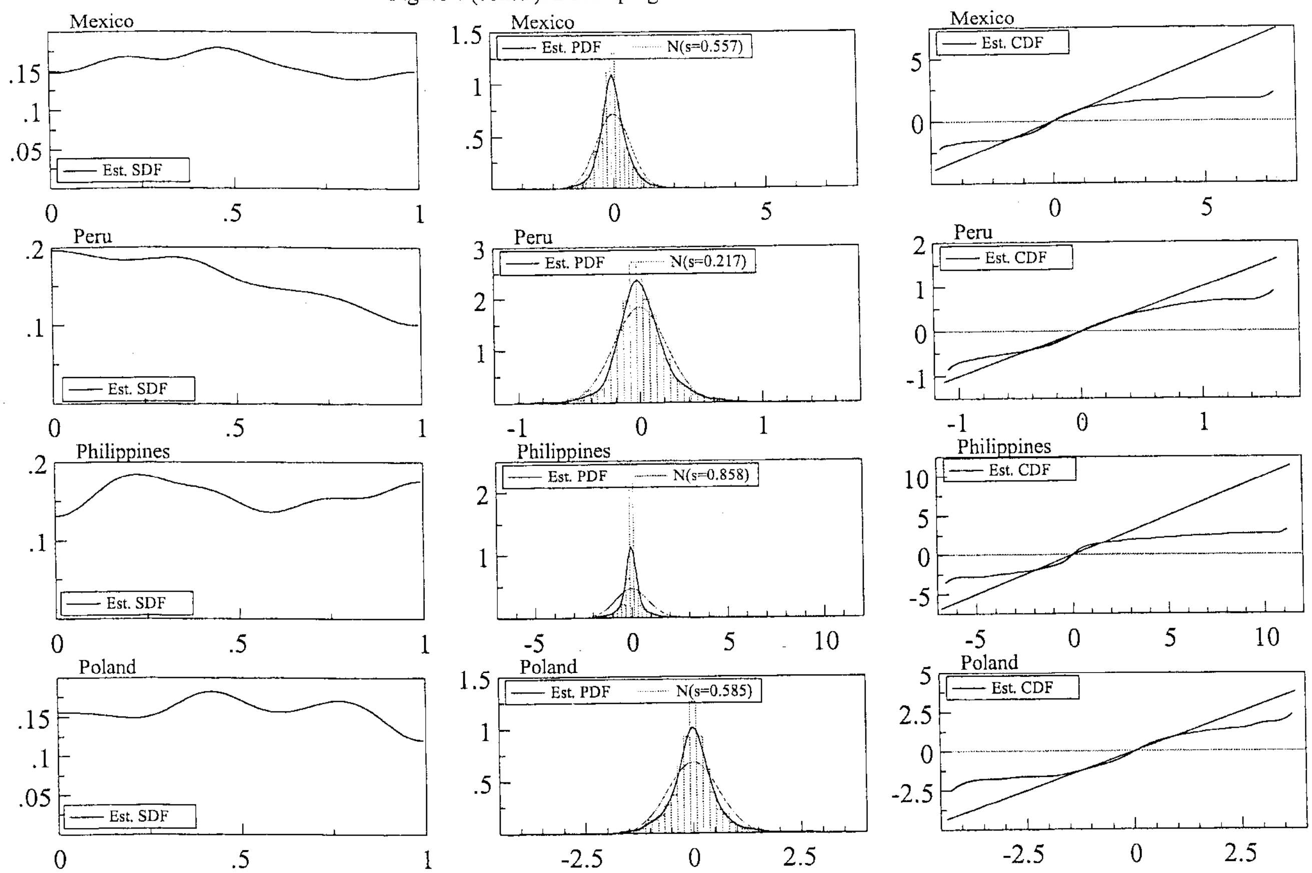
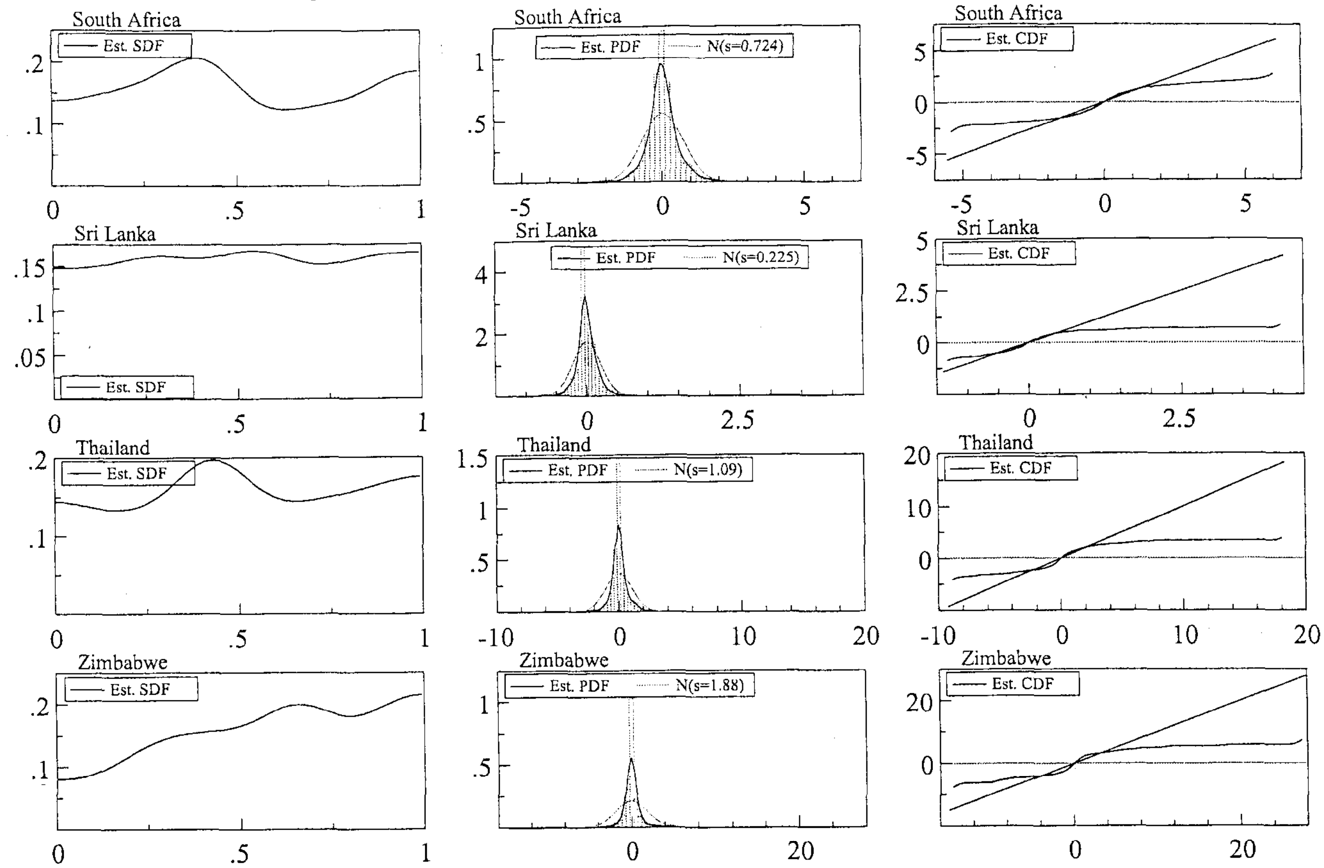


Figure 4 (contd.) Developing Countries: Characteristics of Returns



As a first step in testing the null hypothesis of randomness, the returns data for these particular countries were subjected to the four spectral shape tests for white noise over the whole sample period (Table 4). The null of white noise is accepted for Chile, Colombia, the Czech Republic, Mexico, Poland, and Sri Lanka. The null is rejected for Mauritius and Peru, while the results are ambiguous in the case of South Africa. The test statistics for the whole sample period were supplemented with rolling window tests with windows of 500, 250, and 100 for which critical values from Monte Carlo simulations are available. No evidence emerged that would challenge accepting the null for the Czech Republic, and Poland. In the case of Mexico, the variable window tests showed more temporal variation particularly for the windows which included data covering the wave of depreciations in Asia that started in mid-1997 and the speculative attack on the Hong Kong dollar in October 1997, the Russian crisis in August 1998 and the tightening of Mexican monetary policy in September 1998, and the Brazilian crisis of early 1999.[15] The tests also rise in value in mid-2000 when Mexico significantly tightened monetary policy and there was a sharp appreciation of the peso over several days in response. These results suggest that periods of high turbulence reflected in the exchange rate returns data can push the rolling window tests up and may provide some indications of resistance to exchange market pressure even if the null of white noise is accepted for the whole sample period. The same is true in the cases of Chile and Colombia.

In the case of Sri Lanka, the announced exchange rate regime for the sample period was a crawling band system with the central bank announcing each day buying and selling rates for the U.S. dollar at which it was prepared to trade with market participants. While the null of white noise is accepted for the whole sample period on the basis of all four test statistics, the rolling window tests reject the null of white noise for certain sub-periods in 1996 and 1998, and in 2000 as the rupee came under pressure.

Like the industrialized countries, there is evidence of clustering in the returns data for the developing countries where the null of white noise is not rejected for the whole sample period; there is also evidence that the conditional variance of returns varies over time. But while for the industrialized countries, the conditional variance tends to change relatively smoothly over time, for the developing countries considered here quite sharp changes take place from time to time, reflecting such shocks as the speculative attack on the Hong Kong dollar (October 1997) and to changes in the way the exchange rate regimes chosen by these countries operated. For example, rolling variance statistics for Mexico suggest that volatility in the exchange rate returns was higher in the period October 1997 onwards than it was in the period preceding the speculative attack on the Hong Kong dollar. The variance ratio reaches a maximum on October 22, 1997, and an F test is highly significant at the 99 percent level;

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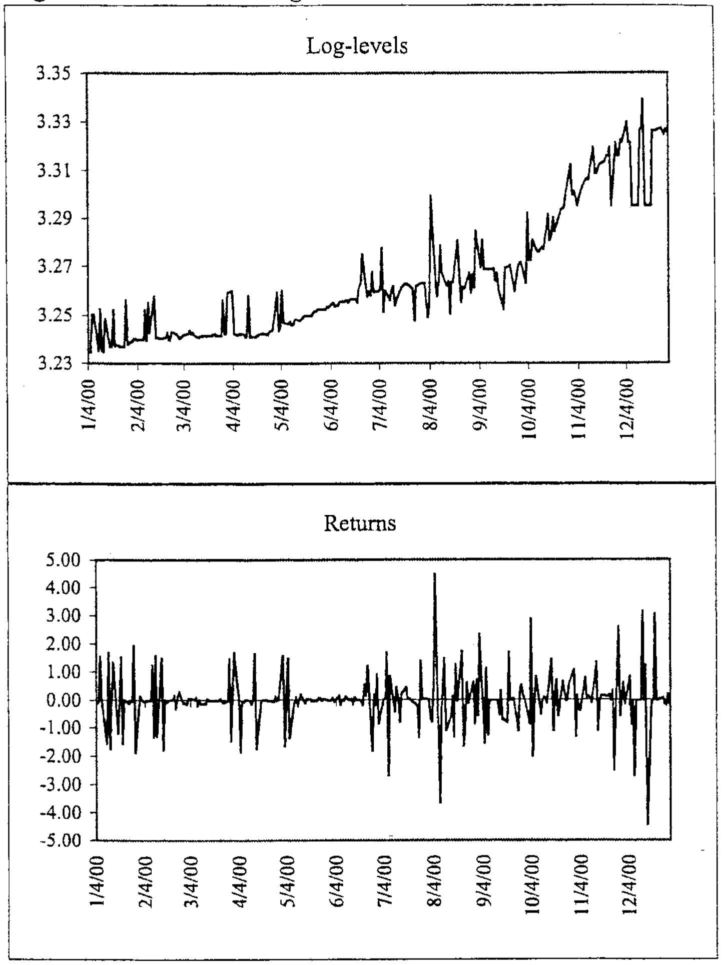
[15] For example, as the rolling window tests using 100 observations start to include the exchange rate crises in Asia, the A-D statistics for Mexico start to rise and for a number of windows the test statistics exceed the 95 percent critical values (although not the 99 percent value) before falling again as more data from 1998 are added to the sample. The test statistics using rolling windows for Mexico and the other countries are available upon request.

i.e., there appears to be a significant increase in the variance of the returns in the period from October 23, 1997 on, compared with the variance in the period prior to this date. Chile also encountered a bout of turbulence around the time of the Hong Kong episode, but the variance of its returns returned in the first part of 1998 to levels comparable to those recorded prior to the Hong Kong episode. The F statistic for a break in variance at this point is not significant. In the second quarter of 1998, however, the peso came under increased exchange market pressure, and the authorities responded by announcing on June 25, 1998, that the band would be *narrowed* from +/-6.25 percent to +/-2.75 percent; subsequently, the band was widened to +/-3.5 percent on September 16; the rate of crawl was increased and the band widened to +/-8 percent on December 20 and 21 respectively, with the idea that the band would gradually widened thereafter. Paradoxically the narrowing of the band announced on June 25 was followed by an increase in the variance of returns. An F test on variances of the returns with June 25, 1998, as the breakpoint yielded a test statistic significant at the 99 percent level. For the Czech Republic the move from a crawling band with margins of +/-7.5 percent to a managed float on May 27, 1997 constituted a breakpoint in the variance of returns with volatility rising in the subsequent part of the sample period; the F test was significant at the 99 percent level. For Poland there is significant breakpoint at February 26, 1998, at which time it was announced that the zloty crawling band would be widened from +/-7 percent to +/-10 percent. For the remaining two countries, Sri Lanka and Colombia, no significant breaks in the variance of the returns could be detected.

It needs to be emphasized that the findings of white noise for the developing countries' exchange rate returns (as is also the case for the industrialized countries) do not imply a totally clean float, the absence of foreign exchange market intervention, no use of monetary policy instruments to influence the exchange rate, or that no stabilizing role can be accorded in those cases where the countries formally declared that the exchange rate regime in operation was that of a sliding/crawling band with particular margins. The results do indicate, however, that it is not possible in general *on a consistent basis* to detect in the data evidence that the authorities were regularly "leaning against the wind", targeting narrowly the level or path of the exchange rate, or attempting to push the exchange rate in particular directions.

The null of white noise for returns is decisively rejected in the case of Mauritius for the whole sample period and using rolling window tests. A feature of the data in the case of Mauritius is the presence of multiple "blips" or "candles" and other seeming idiosyncrasies, particularly in the latter half of the sample period. Figure 5 presents the log-level data and the returns data for Mauritius for the final year of the sample period to better illustrate these kinds of features. These types of "blips" or "candles" are also present in the data for some of other countries in the sample, but generally on a less frequent basis. This feature appears in daily data, but would not be observed in lower frequency data (e.g., monthly). The "blips" or "candles" are consistent with exchange market intervention to immediately reverse daily movements that occur in the foreign exchange market. When occurring frequently, as in the case of Mauritius, they provide an indication that the authorities are attempting not only to limit "large" daily movements but may be trying to prevent more continuous movements in a particular direction and there are also periods when the exchange rate moves very narrowly suggesting more active

Figure 5: Mauritius: Log Levels and Returns (Jan 3 - Dec 29, 2000)



exchange rate management. While the authorities do seem “to burn the candle at both ends”, the log-level data and the sequences in the returns data suggest that there is greater concern about daily depreciations than daily appreciations. The pattern is consistent with a policy of “leaning against the wind” and with data reported by the Bank of Mauritius in its monthly report on sales and purchases of foreign exchange in the market. White noise in the returns for Peru is also firmly rejected for the sample period as a whole and for windows covering all or parts of 1996, 1997, and 1998–1999; for most of the period the New Sol was permitted to trade only within a very narrow range.

The South African rand enjoyed periods of relative quiescence interspersed with periods of considerable turbulence. During the latter periods (notably in February-December 1996 and in the second and third quarters of 1998), the South African Reserve Bank intervened in the forward foreign exchange market on a very large scale and used higher interest rates in defense of the rand. For the whole sample period, the A-D and C-VM statistics accept the null of white noise, but the K-S and K statistics do not. The ambiguity could not be resolved through rolling window tests, although all the test statistics rise when the turbulence of 1996 and then 1998 is included in the window. However, post-turbulence tests using all four statistics accept the null of white noise, suggesting the ambiguity of the full sample period tests may arise from the presence of severe turbulence in the earlier period.

The remaining developing countries in the sample all show considerable intertemporal variation in exchange rate behavior, both in levels and in returns. There is evidence of regime shifts, periods of perturbation and quiescence, and periods where the exchange rate barely moves or shows large discrete jumps. That being the case, it makes even more sense to concentrate on window tests for particular sub-periods as it is much easier to spot regime shifts and other discontinuities (Table 5). Thus, the emphasis here will be on examining exchange rate behavior over time and using window tests where appropriate. First to be considered are two countries, the Philippines and Malawi, which had from the beginning of 1996 until the start of the Asian crisis in July 1997 *de facto* pegs to the U.S. dollar despite declarations that they were “floating independently”. In the case of the Philippines, the *de facto* peg to the U.S. dollar operated from the start of the sample period until July 11, 1997 or very shortly after the start of the Thai crisis on July 2, 1997.[16] Thereafter, the Philippine peso floated, but reportedly with official intervention particularly in 1999 and 2000. Spectral shape tests for the period from July 11, 1997, onward do not reject the null of white noise for the returns data. However, from around the end of February 1999 onwards there is a sharp fall in the variance of the returns data and an F-test for a break in variance is significant at the 99 percent level. This points to an increase in official intervention in this period to reduce high frequency volatility or “smoothing”, although the authorities do not appear to have taken a particular view as to where they wanted the exchange rate to be, based on white noise tests on the sub-sample periods July 11, 1997 to November 23, 1999, and November 24, 1999 to December 29, 2000. However, rolling 100-observation window tests starting around February 2000 rise sharply and the peso

[16] Spectral shape tests for this sub-period clearly reject the null of white noise.

changes little in value suggesting a limited period of official intervention designed to prevent peso depreciation.

Malawi maintained a *de facto* fixed peg to the U.S. dollar from the start of the sample period until July 22, 1997. A number of small discrete adjustment were permitted over the next three days; thereafter the kwacha was permitted to vary narrowly against the U.S. dollar; the permitted adjustments remained small until August 22, 1998, when the kwacha was devalued by 48 percent. In the period from the first series of adjustments until August 22, 1998, there were frequent daily "blips" and "candles", features that continued after the maxi-devaluation of August 1998, and which indicate resistance by the authorities to depreciation until reserve pressures obliged them to allow the currency to depreciate at a faster rate. Spectral shape tests reject white noise for the periods January 3, 1996, to July 22, 1997, July 23, 1997, to August 21, 1998, and the post-devaluation period of August 23, 1998 to December 29, 2000.

At the start of the sample period, Thailand's announced exchange rate regime was a basket peg arrangement with unannounced composition and bandwidth. In fact for the period until the middle of May 1997, the baht was permitted to vary in only a very narrow range against the U.S. dollar. On May 15, 1997, after a week of heavy selling pressure and intervention in forward markets, Thailand imposed capital controls to split onshore and offshore markets for foreign exchange. Subsequently the baht displayed a somewhat higher variance, although exchange market pressure continued to be high until July 2, 1997, when Thailand gave up its defense of the baht and moved to a float. Spectral shape tests reject the null of white noise in the period up to the float. For the period July 2, 1997 onwards the null of white noise is accepted on the basis of all four test statistics using both the sample period July 2, 1997–December 29, 2000, and using rolling window tests covering within sub-sample periods. There is a decline over time in the variance of the returns, but no specific break point appears identifiable.

Until it gave up its defense of the won on November 17, 1997, Korea had maintained a tightly-managed float under which the won fluctuated relatively closely with the U.S. dollar while depreciating gradually over time. As events in Asia (in Thailand, Malaysia, and Indonesia) unfolded in 1997, the Bank of Korea was obliged to use its reserves to defend the won, and the situation worsened in October following the depreciation of the New Taiwan dollar on October 20 and the speculative attack on the Hong Kong dollar and the accompanying stock market crash during October 20–23. It became more difficult and costly to offset the pressure on the won to depreciate. In the period up to November 17, 1997, spectral shape tests clearly reject the null of white noise. Thereafter, the won depreciated rapidly and appeared to overshoot until some semblance of stability emerged by the end of the first quarter of 1998. Tests for the crisis period and afterward reject the null of white noise. In part this reflects the period of extreme turbulence amid considerable uncertainty, particularly as to whether commercial and official foreign debt would be rolled over. But even after the overshooting was corrected and some semblance of stability in the foreign exchange market became evident, tests for white noise using forward-moving windows reject the null. Forward-moving window tests indicate that it is only sometime in the first part of 1999 until the end of the sample period that the null of white noise can be accepted, although the low variance suggests that the authorities could have been smoothing without taking a particular view as to the level and path of the exchange rate. For the earlier period (post-November 17, 1997 until early 1999 (possibly sometime after the Brazilian crisis of January 1999), the rejection of white noise is consistent with the fact that as the won recovered from its nadir the Bank of Korea was frequently intervening in the foreign exchange market to rebuild its foreign exchange reserves and to slow the rate of appreciation.

At the start of the sample period, the Indian rupee showed some volatility against the U.S. dollar, but that was followed by a period of relative quiescence which lasted into late 1997. As events unfolded in Asia and pressure on the Hong Kong dollar and Korean won mounted the rupee was allowed to depreciate and vary more widely. This pattern of exchange rate behavior lasted until late August 1998; thereafter, there was another period of quiescence until mid-2000 when the rupee started to depreciate again and move more widely on a day-to-day basis vis-à-vis the U.S. dollar. A window of about 200 observations covers the initial period of relative volatility, but spectral shape tests reject the null of white noise. A window of approximately 250 observations covers the period of quiescence that ends in November 1997; the spectral shape tests reject the null of white noise at high confidence levels. There follows a period until about August 1998 where the exchange rate moves randomly. Thereafter, the exchange rate reverts to moving narrowly against the U.S. dollar until into the second quarter of 2000 when the rate of depreciation increases. The spectral shape tests reject white noise for the period after August 1998, although rolling window tests do detect some tendency for the test statistics to drop towards the end of the period (May 2000 onwards).

In July 1994, the official rate of the Zimbabwe dollar was unified with the "market-determined" interbank rate and Zimbabwe's exchange arrangement for most of the sample period used in this paper was officially classified as one of "independent floating". However, the levels and returns data indicate few characteristics associated with a floating rate and there is evidence of several regime shifts. For most of 1996, Zimbabwe operated an "adjustable" peg against the U.S. dollar, under which the currency varied narrowly against an exchange rate that was adjusted discretely from Z$ 9.34 per U.S. dollar in stages to Z$ 10.58 per U.S. dollar in late 1996. Thereafter, until the onset of a foreign exchange crisis in late 1997, the Zimbabwe dollar was allowed to depreciate on a more frequent almost daily basis in small increments (1 percent or less). However, on several occasions in the third quarter of 1997 the daily depreciation exceeded one percent and it appears that the authorities intervened strongly to reverse the changes. Apart from possible fallout from the Asian crisis, economic policy developments at home were not supportive of the exchange rate policy the authorities were trying to implement. A large unbudgeted award to civil war veterans amounting to 2 percent of GDP was announced in August 1997 and the currency came under strong pressure late in the year despite increases in the central bank's rediscount rate and the suspension of corporate foreign currency accounts. Pressures continued in 1998 with strikes against administered price adjustments, the emergence of bank fraud cases, a sharp depreciation of the South African rand, and the launch of large-scale military operations in the D.R. of Congo. Despite bouts of resistance by the authorities, the cumulative depreciation over the course of the year had by end-October reached 50 percent. Emergency trade and payments restrictions were then introduced and the exchange rate was permitted to move only narrowly around an exchange rate of Z$ 37 per U.S. dollar. A sharp depreciation occurred in mid-January 1999 which was resisted by the authorities amid warnings to the banks that action would be taken against them for "manipulation" and speculation. The Zimbabwe dollar was pegged thereafter at Z$ 38 per U.S. dollar until there was a discrete devaluation of 27 percent in local currency terms in August 2000 followed by a series of small depreciations. The currency was then repegged at Z$ 55 per U.S. dollar for the balance of the sample period. The economic situation continued to deteriorate and the exchange rate in the black market soared. Not surprisingly, spectral shape tests clearly reject the null of white noise for the various sub-periods using variable window lengths (Table 5).

The final currency in the sample to be analyzed is the Kenyan shilling. At the start of the sample period there was some tendency for the shilling to depreciate and "blips" or "candles" in the log-level data suggest official intervention. There was then a period of relative quiescence during which the shilling appreciated as capital flowed in and the authorities built up reserves under a Fund-supported ESAF program. As the second quarter of 1997 unwound, exchange market pressures grew as the Fund-supported ESAF program was suspended and political tensions mounted as national elections approached. The null of white noise is rejected for the period upto early July 1997 (Table5). Kenya was then obliged to allow the exchange rate to depreciate by 5 percent in mid-July and after some resistance by 20 percent in the second week of August 1997. A sharp hike in Treasury bill rates and the announcement that ESAF negotiations would be resumed helped restore a measure of stability to the market in late September which spread over into the first quarter and part of the second quarter of 1998. The null of white noise is accepted for this period. There followed a period of mounting exchange market pressure which the authorities attempted to resist. There are a number of "blips" or "candles" in the log-level data and there are also flat portions in the graph typical of intervention. This pattern persisted into early 2000 and the null of white noise is clearly rejected. After what seems to be a final bid to have the Kenyan shilling appreciate in late January 2000, the authorities appear to have retreated from the market and over this final section of the sample period, the null of white noise in the returns can be accepted.

IV. Concluding Remarks

The paper sought to examine the behavior of "flexible" exchange rates in a sample of industrialized and developing countries. The daily exchange rates of eight industrialized countries which are classified as "independent floaters" were examined using graphical and statistical techniques. The principal findings were that the exchange rate returns for these countries are not normally distributed with significant skewness in the majority of cases and significant kurtosis in all cases. Using spectral shape tests, the daily exchange rates returns were found to be white noise but generally not i.i.d. The exchange rate data for nine of the developing sixteen countries had no major discontinuities in their data generating processes, while data for the remaining seven show evidence of regime shifts or other significant discontinuities. For six of the first nine developing countries (Chile, Colombia, the Czech Republic, Mexico, Poland, and Sri Lanka) spectral shape tests using the full sample accepted the null of white noise in the returns. Rolling window tests did, however, reveal a somewhat greater intertemporal variation in test statistics than was generally the case of the industrialized countries. There are indications of non-randomness in the data for some windows used in the rolling tests, but these are not prolonged or pronounced enough to affect the full sample findings. Generally these occur in periods where severe turbulence in other emerging countries' exchange or equity markets and/or when there was a significant tightening of monetary policy in domestic financial markets. There is also evidence for some of these countries that the variance of returns increased in the period following the speculative attack on the Hong Kong dollar in October 1997. For two countries, Mauritius and Peru the null of white noise in the returns can be rejected and there is evidence consistent with foreign exchange market intervention. For South Africa the test statistics for the whole sample period are ambiguous, but after a bout of high turbulence in 1998, the test statistics are consistent with white noise.

The remaining developing countries constitute a very mixed bag, but all provide evidence of regime shifts. Korea, the Philippines, and Thailand, for example, had *de facto* pegs or a very close relationship to the U.S. dollar for the earlier part of the sample period only to give up the regime in crisis and abandon currency defenses. There is evidence for Korea that is consistent with exchange rate management and intervention for much of the period after the won collapsed, while both the Philippines and Thailand appear to have engaged in smoothing operations to limit the size of daily movements in their exchange rates. The experience of the other countries is more diverse and is presented in more detail earlier in the paper, but the contrast with the data of the industrialized countries is stark. Not surprisingly the spectral shapes reject the null of white noise and the rolling window tests can help shed light on the exchange rate policy followed in sub-sample periods. An interesting phenomenon that can be observed data for a number of the developing countries where the null of white noise is typically rejected is the presence of often frequent "blips" or "candles" in the log-level data (also reflected in the daily returns data by positive-negative sequences and less commonly by negative-positive sequences).

The paper has sought to show that examining high frequency (daily) exchange rate data for the developing countries in the sample can help towards gaining an understanding of what the objectives of the authorities may be with respect to the exchange rate and how these objectives may change over time. In this respect, such analysis may prove useful for the Fund in providing advice to member countries. This is not to suggest that observing exchange rates, reserve movements, changes in monetary aggregates, etc. on a lower frequency basis (quarterly, monthly) does not supply important information for surveillance and other purposes, but rather it is argued that analysis of higher frequency exchange rate data can provide useful supplementary information. Further progress in this area may well be possible using "wavelet" analysis which combines information on both frequency and time scale, thus addressing some of the shortcomings of time domain analysis and of frequency domain analysis (including windowing).

Table 1. Distributional Characteristics of Exchange Rate Returns (Mean Adjusted) for Industrialized Countries

	Standard Deviation	Skewness	Excess Kurtosis	Minimum	Maximum	Skewness 1/	Kurtosis 1/	Normality Test 2/	
								B-S	D-H
Australian Dollar	0.653385	-0.480649	3.993452	-4.700946	2.941505	50.171**	865.83**	916**	318.07**
Canadian Dollar	0.313297	-0.125455	1.968228	-1.577577	1.58789	3.418	210.32**	213.74**	132.61**
German Deutsche Mark	0.578529	-0.326629	1.175115	-2.697388	2.202632	23.169**	74.971**	98.14**	53.777**
Japanese Yen	0.780176	-1.019606	7.166323	-6.957196	3.325230	225.77**	2788.2**	3014**	447.71**
New Zealand Dollar	0.684702	-0.510621	4.275115	-4.540609	2.459397	56.623**	992.27**	1048.9**	344.41**
Swedish Kronor	0.588732	-0.328715	1.896389	-3.232877	2.046289	23.466**	195.25**	218.71**	111.17*
Swiss Franc	0.652813	-0.272087	1.146312	-3.047299	2.066073	16.077**	71.341**	87.418**	52.418**
U.K. Pound	0.478695	0.009759	1.334989	-1.906312	2.233917	0.020683	96.758**	96.779**	71.786**

Notes: * Denotes exceeding 5 percent critical value
** Denotes exceeding 1 percent critical value

1/ Chi-Square (1)
2/ Bowman-Shenton statistic (B-S) and Doornik-Hansen statistic (D-H) are Chi-Square (2)

Table 2. Exchange Rate Returns for Industrialized Countries:
Spectral Shape Tests for White Noise 1/

	Anderson-Darling Statistic	Cramer-von Mises Statistic	Kolmogorov-Smirnov Statistic	Kuiper Statistic
Critical Value (99 percent) 2/	3.78	0.73	1.54	1.90
Australian Dollar	2.3121	0.47659	1.4550	1.6783
Canadian Dollar	0.9469	0.15241	0.99352	1.3838
German Deutsche Mark	0.61708	0.12414	0.91542	1.1409
Japanese Yen	0.73458	0.13913	0.79638	1.0139
New Zealand Dollar	2.7208	0.58429	1.5134	1.6144
Swedish Kronor	0.60305	0.083211	0.66952	0.82589
Swiss Franc	1.3749	0.20443	0.84541	0.94647
U.K. Pound	0.30783	0.04546	0.52536	0.99224

1/ Rejection of null of white noise marked with an *.
2/ From Monte Carlo simulations with a sample size of 1,000. See Fong and Ouliaris (1995)
Equivalent asymptotic critical values are as follows: AD(3.85); CVM(0.74); KS(1.64); and K(2.01).

Table 3. Distributional Characteristics of Exchange Rate Returns (Mean Adjusted) for Selected Developing Countries
(Daily Observations, Jan. 3, 1996-Dec. 29, 2000)

	Standard Deviation	Skewness	Excess Kurtosis	Minimum	Maximum	Skewness 1/	Kurtosis 1/	Normality Test 2/ B-S	Normality Test 2/ D-H
Chilean Peso	0.337986	0.897206	10.458896	-1.792434	3.096303	174.81**	5938.9**	6113.7**	978.45**
Colombian Peso	0.518485	1.510962	15.694295	-2.433249	5.509067	495.79**	13373**	13868**	1022.8**
Czech Koruna	0.745205	1.014251	11.264047	-3.293762	7.989403	223.4**	6888.5**	7111.9**	986.04**
Indian Rupee	0.299462	0.678923	21.127753	-2.713420	3.086848	100.1**	24235**	24335**	2917.7**
Kenyan Shilling	0.830266	8.210538	183.472201	-6.254406	18.214374	14640**	1.8276e+6**	1.8422e+6**	1527.8**
Korean Won	1.405301	2.014579	38.411378	-10.544618	15.207214	881.38**	80104**	80985**	3339.2**
Malawian Kwacha	1.517760	24.763339	789.652525	-7.637285	48.335293	1.3317e+5**	3.3682e+7**	3.3816e+7**	2.6731e+5**
Mauritian Rupee	0.634077	0.074652	7.809642	-4.455347	4.496341	1.2102*	3311.3**	3312.5**	985.48**
Mexican Peso	0.556915	1.672798	24.862746	-3.572104	6.966399	607.69**	33561**	34168**	2040**
Peruvian New Sol	0.217220	0.264291	4.165112	-1.011490	1.474112	15.169**	941.86**	957.03**	395.37**
Philippine Peso	0.858254	2.791663	34.840552	-6.210110	10.883333	1692.5**	65903**	67595**	1201.3**
Polish Zloty	0.585031	0.132284	7.301333	-3.935269	3.449181	3.8002	2894.3**	2898.1**	897.08**
South African Rand	0.724255	0.555686	14.139672	-5.137549	5.745222	67.058**	10855**	10922**	1849.3**
Sri Lankan Rupee	0.225282	5.178733	88.048483	-1.273281	4.046325	5824.3**	4.209e+5**	4.2672e+5**	1120.1**
Thai Baht	1.091708	2.833346	63.164337	-8.615171	17.745463	1743.4**	2.1661e+5**	2.1835e+5**	4667.4**
Zimbabwe Dollar	1.883389	2.639553	44.267994	-13.691091	26.450288	1513.1**	1.0639e+5**	1.0791e+5**	2590.2**

Notes: * Denotes exceeding 5 percent critical value
** Denotes exceeding 1 percent critical value

1/ Chi-Square (1)
2/ Bowman-Shenton statistic (B-S) and Doornik-Hansen statistic (D-H) are Chi-Square (2)

Table 4. Exchange Rate Returns for Developing Countries (First Group)
Spectral Shape Tests for White Noise 1/

	Anderson-Darling Statistic	Cramer-von Mises Statistic	Kolmogorov-Smirnov Statistic	Kuiper Statistic
Critical Value (99 percent) 2/	3.78	0.73	1.54	1.90
Chilean Peso	2.2208	0.4558	1.4035	1.6821
Colombia Peso	1.2795	0.1778	0.9372	1.4204
Czech Koruna	0.3572	0.0547	0.6827	1.1314
Mauritian Rupee	128.15*	24.4900*	7.0120*	6.9930*
Mexican Peso	1.2887	0.24162	0.9240	1.5658
Peru New sol	12.012*	2.3155*	2.3740*	2.3866*
Polish Zloty	1.5835	0.1807	0.8866	1.7132
South African Rand	2.5777	0.4620	1.8018*	2.6735*
Jan. 2, 1999 - Dec. 29,2000 3/	0.5638	0.0637	0.7539	1.2693
Sri Lankan Rupee	0.3643	0.0492	0.47842	0.6934

1/ Rejection of null of white noise marked with an *.
2/ From Monte Carlo simulations with a sample size of 1,000. See Fong and Ouliaris (1995)
3/ 520 observations. 500 observation critical values (99 percent) at AD (3.68); CVM (0.66) KS (1.52) and K (1.89)
Equivalent asymptotic critical values are as follows: AD(3.85); CVM(0.74); KS(1.64); and K(2.01).

Table 5. Exchange Rate Returns for Developing Countries (Second Group)
Spectral Shape Tests for White Noise 1/

	Anderson-Darling Statistic	Cramer-von Mises Statistic	Kolmogorov-Smirnov Statistic	Kuiper Statistic	Sample Size
Philippine Peso					
01/03/1996-07/10/1997	24.7642*	5.0513*	3.3510*	3.4708*	397
07/14/1997-12/29/2000	1.2404	0.2228	1.1812	2.0431*	905
07/14/1997-07/22/1999	0.9512	0.1881	1.0615	1.6671	422
02/24/1999-12/29/2000	1.6046	0.3340	1.1534	1.6048	483
02/14/2000-06/30/2000	5.4433*	1.1618*	1.9521*	2.0972*	100
Malawian Kwacha					
01/03/1996-07/23/1997	13.8362*	2.6030*	2.9429*	2.9998*	405
07/24/1997-08/21/1998	4.1499*	0.8084*	1.5146	1.5403	283
08/25/1998-12/29/2000	8.5052*	1.7527*	2.2000*	2.8280*	613
Thai Baht					
01/03/1996-07/01/1997	5.7684*	1.1908*	1.9898*	3.7469*	390
07/021997-12/29/2000	0.8933	0.1172	0.7747	1.2843	913
Korean Won					
01/03/1996-11/14/1997	15.1853*	3.3166*	3.4112*	3.4774*	488
11/17/1997-12/29//2000	24.0956*	5.0336*	3.4844*	4.857*	815
03/24/1998-05/03/1999	6.6840*	1.3562*	1.7514*	1.8746*	290
05/04/1999-12/29/2000	0.7092	0.0800	0.6619	1.1585	434
Indian Rupees					
01/03/1996-10/08/1996	7.0321*	1.3910*	1.9836*	2.0607*	200
10/09/1996-11/03/1997	13.6069*	209944*	2.6933*	2.8667*	279
11/04/1997-08/24/1998	0.2750	0.0463	0.5140	0.7992	210
08/25/1998-12/29/1998	9.0547*	1.8884*	2.4596*	2.5558*	614
Zimbabwe Dollar					
01/03/1996-11/11/1997	51.6519*	9.3510*	4.3477*	4.3205*	485
11/12/1997-11/04/1998	4.8893*	0.9329*	1.4788	1.5158*	741
11/05/1998-12/29/2000	10.6982*	2.0690*	1.5019	2.1792*	818

Table 5. Exchange Rate Returns for Developing Countries (Second Group)
Spectral Shape Tests for White Noise 1/

	Anderson-Darling Statistic	Cramer-von Mises Statistic	Kolmogorov-Smirnov Statistic	Kuiper Statistic	Sample Size
Kenyan Shilling					
01/03/1996-07/09/1997	22.5215*	4.7089*	3.6925*	3.6605*	396
07/10/1997-05/08/1998	0.6879	0.1354	0.8487	1.1661	217
05/09/1998-01/31/2000	4.1856*	0.8608*	1.9286*	1.9587*	451
02/01/2000-12/29/2000	0.3376	0.0678	0.5997	0.9068	239

1/ Rejection of the null of white noise marked with an *. Critical values at the 99 percent level taken from Fong and Ouliaris (1995). Nearest sample size used.

Sample Size	A-D	CMV	KS	K
100	4.01	0.78	1.55	1.76
250	3.75	0.73	1.55	1.87
500	3.61	0.66	1.52	1.89
750	3.68	0.71	1.55	1.90
1000	3.78	0.73	1.54	1.90

The Data

Data for the Industrialized Countries

The exchange rate data for the industrialized countries in the sample are from *Bloomberg L.P.* The data are the composite daily exchange rates against the U.S. dollar reported by bank respondents in the New York, London, and Tokyo markets, except for the deutsche mark and the Swedish kronor. For these two currencies (and for reasons that are unclear), the composite exchange rate data for these two currencies displayed serial correlation in the first differences of the log-levels. The data provided by the respondents in the three markets were examined separately and the data were also checked against those of *Datastream International.*[17] These data do not display serial correlation. The exchange rate data used for these two currencies against the U.S. dollar were those reported by bank respondents in the London market. *Bloomberg L.P.* reports as "missing" or "not available" values on holidays. These missing values were replaced by the values yielded by a cubic spline on the log-level data.

Data for the Developing Countries

The exchange rate data for the developing countries in the sample were also taken from *Bloomberg L.P.* The data are typically those reported by respondent banks in the local market in question. The data were checked for broad consistency with those from *Datastream International* and with data reported by central banks on their websites. In the majority of cases data from all three sources were one and the same or very close. However, for Peru and Kenya divergences were larger particularly with respect to the earlier part of the sample period. The Bloomberg data for the currencies of these two countries appear to have a significant number of outliers not present in data from the other two sources. For Peru and Kenya, therefore, the data were taken from the websites of the respective central banks. Missing values for holidays were replaced with values yielded by a cubic spline on the log-level data.

[17] One difficulty with the data provided by *Datastream International* is that missing values for holidays are not indicated and are replaced by entering the previous trading day's value.

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