The forward rate as an optimal predictor of the future spot rate in South Africa: An econometric analysis

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Contents

List of figures

List of tables

The forward rate as an optimal predictor of the future spot rate in South Africa : An econometric analysis

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This paper investigates empirically the relationship between spot and forward rates in the South African foreign exchange market for the period 1987 to 1998. There is often the belief that the forward rate must be an unbiased predictor of the future spot rate, otherwise speculators could profit from the bias by taking one position in the spot market and the opposite position in the forward market. Various hypotheses on rational expectations are therefore tested in this regard. Unit-root tests are performed to confirm the validity of the use of the Rand/US$ exchange rate specification in level form. For the entire sample period, the empirical evidence indicates that both current spot rates and current forward rates are significant in the predictions of the future spot rate. However, the current spot rates provide better forecasts of the future spot rates than do the current forward rates. Empirical tests also indicate that estimated coefficients for the forward rates (and the spot rates) fall below one, rejecting the "unbiased predictor" hypothesis. Rolling regression and structural stability tests are used to test for the sensitivity of estimated coefficients to new information. This study suggests that, in addition to a search for explanatory variables such as "news" and risk factors, further research should be done on an analysis of the time-variant coefficients.

Key Words: *Exchange rates; forward rates; spot rates; speculation; prediction; unit-roots; structural stability; rational expectations*

1. Introduction

In deciding on monetary policy, the South African Reserve Bank (SARB) must take into account existing relationships between interest rate margins, spot exchange rates and forward rates. A disruption of these relationships could easily lead to new speculative transactions in the foreign exchange market. The extent to which exchange rate markets can be characterised approximately as efficient markets remains an interesting question that can best be answered through formal econometric analysis.

According to Cornell (1987) there is often the belief that the forward rate must be an unbiased predictor of the spot rate, otherwise speculators could profit from the bias by taking one position in the spot market and the opposite position in the forward market. For example, if the US dollar forward rate systematically under-predicted the future spot rate, speculators could buy US dollars while simultaneously taking a short forward position. On the day when the forward contract falls due, the position could, on average, be closed out at a profit because the spot rate would be above the rate specified by the forward contract. Therefore, the argument runs, the existence of such bias is inconsistent with the concept of an efficient market. The asset approach to exchange rate determination, explored by Fama (1984) and others, emphasises the role of new information on exchange rate movements and poses two alternative hypotheses for the predictions of future spot rates.

One popular hypothesis is the expectations theory of a forward rate model. In the “simple efficiency” specification of forward exchange markets, it is often argued that the forward rate “fully reflects” available information about the exchange rate expectations; consequently the forward rate is usually viewed as an unbiased predictor of the future spot rate. The expectations theory posits that the economic agents are able to process information rapidly. Through the arbitrage activities of the economic agents and market adjustments, the forward rates reflect the information that is expected to determine future exchange rates.

Another hypothesis is the random walk model. This model emphasises the random characteristic of exchange rate behaviour. This hypothesis states that, since current

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spot rates summarise all the relevant information that determines future exchange rates, current spot rates are the best predictors of future spot rates.

Empirical work by Edwards (1983) and Cornell (1987) supports the unbiased forward-rate hypothesis (UFH). By contrast, Meese and Rogoff (1983) and Longworth (1981) have found that current spot rates predict future exchange rates significantly better than the corresponding forward rates. Previous tests conducted by Hakkio (1985) and others show that the evidence supporting this UFH is quite weak. They find that a non-constant risk premium is present in several major foreign exchange markets. The implication of these findings is that one cannot use the forward rate directly as a measure of the future spot rate. Instead, prediction of the exchange rate should be based on the estimated coefficients from an appropriated exchange rate specification.

In many of the above studies, the empirical approach is based on the hypothesis that the spot and forward series are stationary. It is always useful to provide statistical support for this hypothesis as there is increasing evidence that these exchange rates are not stationary (see Meese and Singleton 1982, Goodhart et al. 1993). The frequency of the series as well as the time period plays a major role in the results of these tests and they cannot be generalised from one case to another. Furthermore, if it were the case that the series are non-stationary, cointegration procedures could be used and would provide statistically more reliable results (see for example, Sosvilla-Rivero and Park, 1992 and Ngama, 1994).

This paper investigates empirically the relationship between spot and forward rates on the South African exchange rate market for the period 1987 to 1998. It therefore contributes to the considerable literature on the efficiency and rationality of exchange rate markets. The investigation attempts to identify whether the South African exchange rate market is efficient, i.e. whether agents fully incorporate all available information efficiently in their forecasts of the Rand/US$ exchange rate. Uncovering agents' behaviour and particularly the way they form expectations would be a valuable input for conducting monetary policy. Since the development of the flexible regime, the foreign exchange market has become the most important market for testing the efficiency hypothesis. The finding in this study that the forward rate is not an unbiased predictor of the spot rate is consistent with existing findings for other currencies and other time periods based on a similar empirical methodology.

The paper is divided into six sections. The first section contains the introduction. The basic theoretical framework appears in Section 2. In Section 3, various specifications for the relationship between the spot and forward exchange rates are estimated and alternative hypotheses with regard to the predictive power of the forward rate are tested. In effect, testing for specific parameter values in the different specifications corresponds to testing the way that agents form expectations and their attitude toward risk. Specifically, if the forward rate is an unbiased predictor of the spot rate, agents form rational expectations and are risk-neutral. The findings of the study suggest that, over the full period, the forward rate unbiasedness hypothesis can be rejected. Following that conclusion, further investigations are conducted in an attempt to identify the nature of the bias. Unit-root tests are performed to confirm the validity of the use of the Rand/US$ exchange rate specification in level form. Structural stability tests in Section 4 show that the parameters are not time invariant and that they may be sensitive to new information or to changing risk factors. A discussion of the implications of the findings and suggestions for further research follow in Sections 5 and 6. As regards the effective use of information, the procedures and methodology in this paper are more compatible with the notion of market efficiency than those in some of the previous studies.

2. Models for predicting future spot rates

Empirical models for testing the predictability of future spot rates consist of the following set of equations:

$$S_{t+k} = \alpha + \beta F_t + \epsilon_{t+k} \quad (1)$$

$$S_{t+k} = \alpha + \gamma S_t + \epsilon_{t+k} \quad (2)$$

$$S_{t+k} = \alpha + \beta F_t + \gamma S_t + \epsilon_{t+k} \quad (3)$$

$$S_{t+k} = \alpha + \beta F_t + \psi F_{t-1} + \epsilon_{t+k} \quad (4)$$

where S_t is the natural logarithm of the spot rate at month t and F_t is the natural logarithm of the forward rate at month *t*, with *k* the 3-month settlement period. The exchange rates are defined as rand per unit of the US dollar. The terms α, β, γ, and ψ are, respectively, constant parameters, and ϵ_t is an error term in period *t+k*. Each of these models is discussed in turn.

Equation 1 is designated to test the hypothesis that the forward rate is an unbiased predictor of the future spot rate. This equation expresses the notion of rational expectations with no risk premium. The assumption is, therefore, that market participants are risk neutral and form expectations in a "rational" manner; the expected values of exchange rate determinants are explicitly discounted to the present values. The relevant information for predicting exchange rates is fully reflected in the current forward exchange rate. Therefore, testing the hypothesis of forward market efficiency is equivalent to testing the joint hypothesis $\alpha = 0$ and $\beta = 1$. Failure to reject the joint hypothesis implies that the forward rate determined at time t is an unbiased predictor of the spot rate for time t + k. However, statistical rejection of this joint hypothesis means either that the market is inefficient or that the specification of the model is incorrect, or both.

Equation 2 tests the random walk hypothesis of exchange rate behaviour. Assuming that the disturbance term is serially uncorrelated, the random walk hypothesis states that the current spot rate is the best predictor of the future spot rate. This hypothesis is based on the notion that the foreign exchange market, like other asset markets, is efficient so that all the information pertinent to the determination of the exchange rate is fully summarised in the current spot rate. Market efficiency in this model is tested by the joint hypothesis $\alpha = 0$ and $\gamma = 1$. Failure to reject this joint hypothesis means that the changes in the exchange rate are essentially in response to random disturbances. However, if the changes in the exchange rate exhibit serial dependency, the exchange rate relationship expressed by Equation 2 is usually classified as a martingale model.

Equation 3 , by contrast, states that the future spot rate is specified as a weighted average of the current forward rate and the corresponding spot rate. This means that market participants recognise the importance of information contained in F_t and S_t for predicting the future spot rate. The testable hypotheses are $\alpha = 0$, $\beta + \gamma = 1$. The model presented here is similar to the specifications given by Bilson (1981) and Longworth (1981). According to their classification, if the forward market is efficient, the hypothesis $\beta = 1$ and $\gamma = 0$ should not be rejected.But if expectations are static, $\beta = 0$ and $\gamma = 1$ should not be rejected. The specification involved in Equation 3 is more flexible and is not restricted to the two special cases discussed above.

Equation 4 is a general equation usually added to the model for testing market efficiency. If the market is efficient and there is no risk premium, then F_t contains all the information for the prediction of S_{t+k} as described by Equation 1; the inclusion of F_{t-1} (or other lagged and/or predetermined variables) is to see whether further lags in the forward rate still contain unexploited information and it usually should not significantly increase the explanatory power. Therefore, testing for market efficiency is equivalent to testing the hypothesis that $\psi = 0$. Rejection of the hypothesis would indicate that the market is inefficient since the lagged forward rate contains useful information for the prediction of the future spot rate.

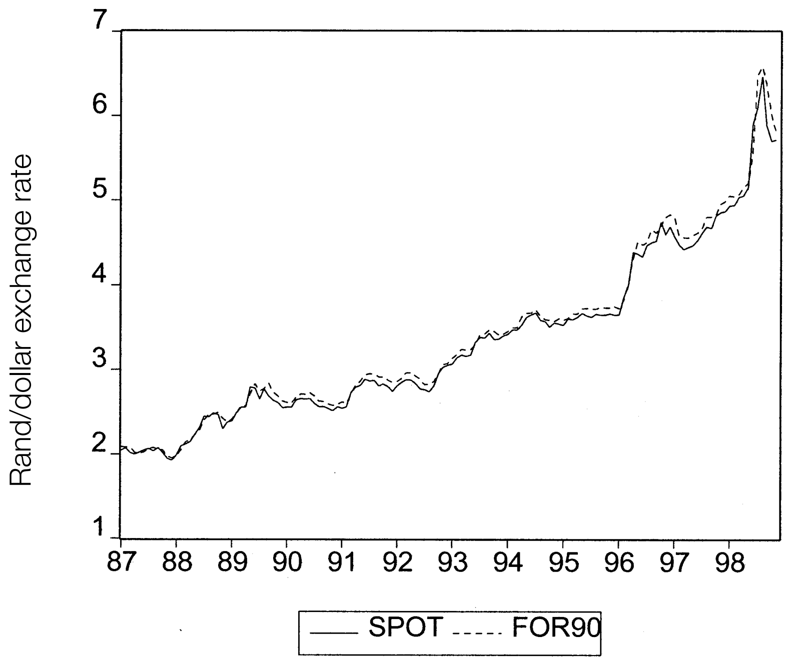
3. Tests

3.1 Unit-roots and cointegration

Nonstationarity of time series is regarded as a problem in econometric analysis. It has been shown in a number of theoretical works (see Phillips, 1986) that, in general, the statistical properties of regression analysis using nonstationary or trending time series are dubious.

In Figure 1 below, the Rand/dollar spot rate (SPOT=S) and ninety-day forward rate (FOR90=F) are clearly nonstationary as they are both subject to positive trends. However, they seem to be floating in time together in the long run. In such a case they are presumably integrated of the same order, and the fact that the differences

Figure 1 Rand/dollar spot rate vs ninety-day forward rate



between S_t and F_t do not have a clear tendency to rise or decline suggests that these differences might be stationary. If this is the case, the variables in question are said to be cointegrated.

The Augmented Dickey-Fuller test (see Dickey and Fuller, 1981) is an appropriate and simple method of testing whether the residuals from the long-run regression are stationary, and if the variables are cointegrated of the same order. In testing the null hypothesis of nonstationary (or a unit root), the MacKinnon (1991) critical values are used to assess the signifcance.

3.2 Structural changes

The debt standstill and the sanctions issue in South Africa have, *inter alia*, emphasised the need for empirical methodology in econometrics to test for structural changes over time.

One of the notable characteristics of the current international monetary system is the variability of exchange rates. In a major review of the performance of the system of generalised managed floating since 1973, Goldstein (1984: 5) from the International Monetary Fund noted that:

By almost any measure, exchange rate variability has been much greater during the period of floating rates (1973 onwards) than it was during the previous decade of the adjustable par value system (1963 - 1972).

The South African currency appears to have exhibited similar behaviour during the period since 1973. Casual inspection of the data reveals a marked increase in the variability of the rand, particularly during 1996 and 1998. The sudden weakness of the rand during 1996 was a combination of several factors, such as large-scale speculation, initially triggered by unfounded rumours about the health of President Mandela, and negative views about the South African socio-political situation. There was also a strong demand for spot dollars from importers who had left a substantial portion of their future foreign-currency commitments uncovered in the period following the initial depreciation. The Asian crisis and the increase in the Reserve Bank’s net open forward position inspired another round of speculation against the rand in 1998. Any one of these factors, on its own, or in conjunction with other changes, may therefore be responsible for structural weaknesses in econometric equations via one or more transfer mechanisms discussed by Wesso (1988: 53).

Since it is widely speculated that the effect of these economic structural changes will be with us for a long time (see Wesso, 1995), it is worthwhile investigating the structural stability condition of the exchange rate equations. These changes may be either gradual or abrupt and structural stability testing procedures can be used to identify structural breaks. Sudden changes are tested by the widely used Chow tests (1960) which reject the null hypothesis of parameter stability whenever the fit of the equation can be greatly increased by splitting the regression into two parts.

Another approach would be to use recursive estimations in which the sample is increased one observation at a time at one end while the starting date is fixed. Many econometric packages provide graphs of the evolution of the coefficients with the standard errors as the sample is progressively increased. This methodology has the advantage of allowing for the precise identification of the parameter shift during the period and then appropriate tests for structural breaks can be conducted. The Brown, Durbin and Evans (1975) CUSUM and CUSUM of squares testing procedures were therefore applied to calculate sums of the recursive residuals, or squares of residuals, and to check whether the resulting sequences have deviated too much from their expected path. The CUSUM of squares is the more powerful of the two tests. A 5 per cent significance level was used in all tests.

4. Empirical results

4.1 Estimation and hypothesis testing

Monthly South African exchange rate data over the period January 1987 to November 1998 (in Appendix 1) are used to estimate the various equations. Both spot rates and ninety-day forward rates are defined as the units of local currency per unit of US dollar and are expressed in terms of natural logarithms. All the data refer to the end of the month and are taken from the data bank of the South African Reserve Bank. The Rand/Dollar exchange rate (SPOT) versus the ninety-day forward rate (FOR90) is depicted in Figure 1. This figure indicates a close relationship between the forward rate and the three-month future spot rate.

Ordinary least squares regressions are used to estimate Equations 1 to 4. Table 1 shows the regression results obtained by using entire sample observations; the corresponding Student's t-statistics, for testing the coefficients for unity, the Wald-F

Table 1 Empirical results of exchange rate estimations

			Independent variables			Summary of statistics			
Dependent variable	Number of equation	Constant	F_t	S_t	F_{t-l}	R^2	Durbin-Watson	ADF test	In-Sample RMSE
S_{t+k}	1	0,008	0,985*			0,986	0,959	-5,12	0,034
		(0,719)	(100,6)					(-2,883)	
	2	0,005		1,002*		0,990	1,750	-5,696	0,029
		(0,55)		(124,1)				(-2,883)	
	3	0,006	-0,188	1,192*		0,991	1,982	-5,774	0,028
		(0,58)	(-1,38)	(8,63)				(-2,883)	
	4	0,012	1,438*		-0,459*	0,988	1,398	-5,252	0,034
		(-1,04)	(12,72)		(-4,02)			(-2,883)	

Notes: a The values in parentheses are *t* statistics in the case of coefficients, and the Mckinnon critical values in the case of the ADF test
b * indicates statistically significant at the 0,05 level

statistics, for testing the joint hypotheses, and the Augmented Dickey-Fuller (ADF) test for unit-roots are presented in Table 2.
In general, all the equations perform reasonably well in terms of explanatory power. This can be seen in the high R^2 for each estimating equation. The Augmented Dickey-Fuller test shows that the residuals from the long-run regressions are all stationary, and that the variables are cointegrated of the same order.

In Table 2 the evidence from Equation 1 indicates further that the joint hypothesis $\alpha = 0$ and $\beta = 1$ is rejected at the five per cent level of significance. A similar con-

Table 2 Tests of individual and joint hypotheses

	Student's t-statistics				Wald-F statistics	
Number of equation	α=0	β=1	α=0	γ=1	α=0 and β=1	α=0 and γ=1
1	2,25*	1,51			5,96* (p=0,003)	
2			0,55	0,21		4,97* (p=0,008)

Notes: a t statistics are calculated for testing the hypotheses $\alpha = 0$, $\beta = 1$, or $\gamma = 1$. F statistics are for testing the joint hypotheses $\alpha = 0$ and $\beta = 1$, or α=0 and $\gamma = 1$
b * indicates statistically significant at the 0,05 level

clusion is reached for the constant term, but not for the slope coefficient (see t statistics in Table 2). However, a careful examination of the Durbin-Watson statistics signifies first-order serial correlation, which casts some doubt on the efficiency of the market. The existence of serial correlation may be due to a mis-specification of the model. Table 2 shows further that none of the t statistics for Equation 2 is statistically significant at the five per cent level. The results do not hold true for the joint tests.

The serial correlation in error terms may result from sampling error or misspecification of the model. Based on the results of the in-sample root mean square error (RMSE), the evidence in Table 1 shows that the current spot rates perform slightly better than the corresponding forward rates for the predictions of the future spot rates. This point will become clear when the results of the F-tests are presented in Table 3 later in this paper.

The evidence on Equation 3 in Table 1 indicates that the constant term is insignificant and the sum of the estimated coefficients ($\beta + \gamma = 1{,}004$) does not differ significantly from one. For each individual coefficient, the coefficients of S_t are statistically significant at the five per cent level. The coefficients of F_t in the case of Equation 3 are not significant, suggesting that in predicting S_{t+k} the information contained in S_t is more relevant than that contained in F_t. The coefficients of F_t and S_t differ significantly from one, indicating that the static expectations hypothesis is rejected by these data.

Finally, the empirical evidence concerning Equation 4 in Table 1 shows that the coefficients on both current and lagged forward rates are statistically significant and their sum is approximately equal to 1. This suggests that the hypothesis that the lagged forward rates contain no explanatory power for predicting the future spot rates and should be rejected. This finding, along with the improved value of Durbin-Watson statistics, would be evidence against the simple efficient market hypothesis with no risk premium.

To provide further evidence on the alternative information relevant to the exchange rate prediction, it is appropriate to perform F tests on pairs of equations to determine the significance of the incremental variables. The F statistics are constructed as follows:

$$F = [(SSE_r - SSE_u)/(df_r - df_u)]/(SSE_u/df_u) \quad (5)$$

where SSE_r and SSE_u denote, respectively, the sums of the squared errors from the estimates of the restricted and unrestricted equations; df_r and df_u are the corresponding degrees of freedom. On the basis of Equations 1 to 4, three pair-wise relationships are examined below.

(i) The F test for Equations 1 and 3 tests the hypothesis (restriction) $\gamma = 0$. Rejection of this hypothesis implies that the inclusion of S_t contains additional explanatory power for the prediction of future spot rates.

(ii) The F test for Equations 2 and 3 tests the hypothesis $\beta = 0$. Failure to reject this hypothesis implies that the F_t contains no additional explanatory power for the prediction of the future spot rates when S_t has been included in the equation.

(iii) The F test for Equations 1 and 4 tests the hypothesis $\psi = 0$. Rejection of this hypothesis implies that the lagged forward rates contain useful information for the prediction of the future spot rates. This would be the evidence against the efficient market hypothesis.

The F statistics for testing the above hypothesis are presented in Table 3. The hypothesis $\psi = 0$ is rejected at the five per cent level, but the hypothesis $\beta = 0$ cannot be rejected at the five per cent level. These results support the proposition that the current spot rate is a better predictor of the future spot rate than is the current forward rate. Moreover, the third set F test in Table 3 indicates that the hypothesis $\psi = 0$ should also be rejected, suggesting that the use of the forward rate alone may not be adequate to convey all the information for the prediction of the future spot rates.

Table 3 Tests of the incremental efficiency for various exchange-rate variables

Number of equation	F statistic	Restriction
1 & 3	74,42*	$\gamma=0$
2 & 3	1,907	$\beta=0$
1 & 4	16,17	$\psi=0$

Notes: a The F statistic is defined by Equation 5
b * indicates statistically significant at the 0,5 level

4.2 Structural change analysis

In the previous section, the empirical estimation used the entire data sample between January 1987 and November 1998. Two characteristics of this approach are noteworthy. First, all the historical observations were included and they were equally weighted. Second, the estimated coefficients were implicitly assumed to be constant throughout the entire sample period. Market participants may astutely assess the information set for their market predictions, and their behaviour may be sensitive to public policy changes or to external disturbances. Accordingly, the estimated coefficients may adapt to changing market conditions or vary with changes in the external environment.

Figure 1, where the forward and spot series are represented, indicates that there are apparantly two major breaks or regime shifts: one in 1996 and the other in 1998. This is confirmed by the recursive residuals outside the standard error bands in Figure 2 (see Appendix 1). No Chow tests were performed in 1998 because of the limited number of observations in the latter time domain of the Chow statistic. Also reported are the results of the CUSUM and CUSUM of squares tests. The CUSUM and CUSUM of squares tests find parameter instability if the cumulative sum of the residuals over time goes outside the area between the critical lines in Figure 2. The recursive coefficient estimates, by contrast, trace the evolution of any coefficient as more and more of the sample data are used for estimation. The test gives a plot of coefficients, with two standard error bands around the estimated coefficients. If such coefficients show dramatic jumps, it will be a sign of structural weakness in the equation.

The results of the tests for structural stability applied to the various spot rate equations are summarised in Table 4. The table contains the name of the dependent variable, the equation number in the text, the timing and the p-value of the associated Chow test. The results of Equation 3 are more stable than the rest in terms of structural stability. This view is also supported by the relatively small in-sample root mean square error of the equation in Table 1. Equation 4 shows structural weaknesses according to all the tests used in the analysis, although no dramatic jumps are observed in any of the recursive estimates of the four equations.

Table 4 Tests for structural change

		Was structural stability test rejected at a 5 per cent level of significance?		
Dependent variable	Number of equation	Chow test at 196.2	CUSUM	CUSUM of squares
S_{t+k}	1	yes (p=0,002)	no	yes
	2	yes (p=0,019)	no	yes
	3	no (p=0,054)	no	yes
	4	yes (p=0,003)	yes	yes

Equations 1 and 2 were furthermore re-estimated by varying the sample periods to include new information in the estimates. Following Chiang (1985), four years of monthly data were used to estimate the parameters of Equations 1 and 2, and the estimations were made by rolling the sample period forward one month at a time. The rationale of this methodology is based on the following: first, choosing 48 monthly observations as a given sample size represents a reasonable information set for the empirical analysis, which covers at least four seasonal observations and also satisfies the large-sample property. Second, estimating the model in a rolling-sample manner – by adding the most recent observation and dropping the oldest observation – is consistent with rational behaviour in the sense of recognising the value of new information and the irrelevance of the most distant observation. Therefore, this procedure could be used to examine the stability of the coefficients as new information is included in the estimation process.

The estimated β_t and γ_t values and the corresponding statistical results of Equations 1 and 2 are summarised in Table 4. Since the constant terms are statistically insignificant, the focus is on the analysis of β_t and γ_t.

Table 5 A summary of the estimated β_t and γ_t using rolling samples

β_t Coefficient: Equation 1					γ_t Coefficient: Equation 2				
Range	Mean	Lower bound	Upper bound	R^2	Range	Mean	Lower bound	Upper bound	R^2
0,827-0,899	0,885	0,844	0,926	0,89-0,92	0,895-0,965	0,948	0,910	0,986	0,92-0,94

Notes: a The entire sample covers the period from 87Q1 to 98 Q2. Since estimates were made with 48 monthly observations in a rolling sample fashion, 84 coefficients were generated in this table
b The upper and lower bounds refer, respectively, to the values of (mean ± 2 standard errors)

2. *Detailed results supporting Table 5 appear in Appendix 1.*

The empirical evidence shown in Table 4 demonstrates consistently that both F_t and S_t have significant explanatory power in predicting S_{t+1}. This is reflected in the high R^2 (ranging from 0,89- 0,94) in most cases. The evidence in Table 1 also indicates that the coefficients of both F_t and S_t are highly significant and the constant terms in most cases are statistically insignificant. In general, these results suggest that both F_t and S_t provide good information for the prediction of the future spot rates[2].

5. Monetary policy implications

Several important empirical conclusions can be drawn from the experiments. First, consider the relative performance of S_t and F_t as predictors. Using the minimum in-sample root mean square error (RMSE) in Table 1 as a criterion, the spot rate is superior to the forward rate in predicting future spot rates. The relative performance of these two rates is closely tied to the nature of exchange rate behaviour and/or the nature of expectations formation. If expectations are formed "rationally" and, correspondingly, the forward rate appropriately reflects the expectations of exchange rate determinants, the forward rate is expected to perform well in predicting the future spot rate. By contrast, if expectations are static or the exchange rate per se follows a random process, then the spot rate will perform better. However, if the expectations are adaptive, a bias may relate to the trend movements of the exchange rates during the entire sample period for regression estimations. In particular, if there is a trend increase in S_t, an adaptive expectation will consistently underestimate its future value and vice versa.

Second, the coefficients on both F_t and S_t are sensitive to the inclusion of the new observation and the exclusion of the old observation. The estimated coefficients vary with the rolling sample periods, suggesting that the assumed constant coefficient will generate biased estimates. In most cases, the estimated coefficients from the rolling regressions fall below one, indicating that using forward rates (or spot rates) as predictors of the future spot rates would on average lead to a downward bias and in turn create forecast errors. The evidence from subsample experiments concludes that the "unbiased predictor" hypothesis should be rejected. One possible explanation for this bias is the existence of risk premiums. Other factors, such as news, macro-innovations, or misspecification of the model may also lead to biased estimates. [See Edwards (1983a), and Fama (1984).]

Third, the empirical experiments also indicate that the estimates (β_t and γ_t) generated from the rolling sample process deviate significantly from the values estimated by using the entire sample period (where β_t = 0,985 and γ_t = 1,002). This means that empirical interpretation based purely on the entire sample estimation could be misleading, especially when coefficients are variable over time. This finding confirms the test results in this study and those provided by Gregory and McCurdy (1984).

Fourth, although the estimated coefficients of β_t and γ_t exhibit stochastic behaviour, it is possible to analyse the underlying patterns of β_t and γ_t to incorporate them into the forecasting process. Chiang (1985b) has shown that the series for β_t and γ_t, respectively, follows an AR (2) of ARIMA (1,1,0) process. One can first predict the value of β_t or γ_t and then use the predicted coefficients to forecast future spot rates. This procedure is likely to capture the information contained in the time-variant coefficient and, hence, possibly improve the predictability of the exchange rate equation.

6. Concluding remarks

This paper investigates the empirical issue of market efficiency for the South African currency from January 1987 to November 1998. The empirical evidence for the entire sample period indicates that both current spot rates and current forward rates are significant in the prediction of the future spot rate. However, the current spot rates provide better forecasts of the future spot rates than do the current forward rates.

With the rolling subsample studies, the evidence shows that the estimated coefficients are sensitive to the inclusion of new observations in the estimates, suggesting that the constant coefficient assumption would create biased estimates. The tests also indicate that the estimated coefficients for the forward rates (and the spot rates) in most cases fall below one, rejecting the "unbiased predictor" hypothesis. This study suggests that, in addition to a search for other explanatory variables such as the "news" and risk factors, further research should be devoted to the analysis of the time-variant coefficients. According to Chiang (1985b) the estimated coefficients of β_t and γ_t might follow a particular pattern, AR(2), or ARIMA (1,1,0) which should be incorporated into the predictions of the future spot rates.

Finally, the empirical experiments using the rolling subsample methodology yield the conclusion that the spot rates for the rand outperform the forward rates in the prediction of future spot rates.

7. References

Bilson, J.F.O. 1981. Rational expectations and the exchange rate. In The *Economics of Exchange Rates,* edited by Jacob A. Frenkel and H.G. Johnson, p. 75-96. Reading, Massachusetts: Addison- Wesley.

Baekart, G. and R.J. Hodrick, 1993. On biases in the measurement of foreign exchange risk premiums. *Journal of International Money and Finance,* vol. 12, pp. 115-138.

Bilson, J.F.O. 1981. *The speculative efficiency hypothesis*. The Journal of Business, vol. 54, p. 435-451.

Brown, R.L., Durbin, J., and Evans, J.M. 1975. Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society B,* vol. 37, pp.149-192.

Chiang, T.C. 1985b. *On the predictors of the future spot rates - a multi-currency analysis.* A paper presented at the Eastern Finance Association Meetings in Williamsburg. Virginia, April 24-27.

Chiang, T.C. 1985a. The impact of unexpected macro-disturbances on exchange rates in monetary models. *Quarterly Review of Economics and Business,* vol. 25, No. 2, p. 49-59.

Chow, G.C. 1960. Tests of equality between sets of coefficients in two linear regressions. *Econometrica*, vol. 28, pp. 591-605.

Cornell, B. 1987. Spot rates. Forward rates and exchange market efficiency. *Journal of Financial Economics*, vol. 5, p. 55-65.

Dickey, D.A. and Fuller, W.A. 1981. Distributions of the estimators for autoregressive time series with a unit root. *Econometrica*, vol. 49, pp. 1057-1072.

Edwards, S. 1983. Floating exchange rates: expectations and new information. Journal of Monetary Economics, vol. 11, p. 321-336.

Fama, E.F., 1984. Forward and spot exchange rates. *Journal of Monetary Economics,* vol. 14, pp. 319-338.

Giddy, I. H. and Dufey, G. 1975. The random behaviour of flexible exchange rates. *Journal of International Business Studies,* vol. 6, p. 1-32.

Goldstein, M. 1984. The exchange rate system: lessons of the past and options for the future. A study by the research department of the IMF, *Occasional Paper no. 30,* Washington D.C.

Goodhart, C.A.E., McMahon, P. C. and Ngama, Y.L. 1993. Testing for unit roots with very high frequency spot exchange rate data. *Journal of Macroeconomics,* vol. 15, no. 3, pp. 423-438.

Gregory, A.W. and McCurdy, T.H. 1984. Testing the unbiasedness hypothesis in the forward foreign exchange market: a specification analysis. *Journal of International Money and Finance.* vol. 3, no. 3, pp. 357-368.

Hakkio, C.S. 1985. Expectations and the forward exchange rate. *International Economic Review* no. 22, p. 663-678.

Hansen, L.P. and Hodrick, R.J. 1980. Forward exchange rates as optimal predictors of future spot rates: an econometric analysis. *Journal of Political Economy*, vol. 88, pp. 829-853.

Kohlhagen, S.W. 1978. *The behaviour of foreign exchange markets: a critical survey of the empirical literature.* New York: New York University Press.

Levich, R.M. 1997. On the efficiency of markets for foreign exchange. In Rudiger Dornbusch and Jacob A. Frenkel (eds). *International economic policy: theory and evidence.* Baltimore, Maryland: The Johns Hopkins University Press.

Longworth, D. 1981. Testing the efficiency of the Canadian - U.S. exchange market under the assumption of no risk premium. *Journal of Finance,* vol. 36, pp. 43-49.

MacKinnon, J.G. 1991. Critical values for cointegration tests In Engle, R.F. and Granger, C.W.J (eds), *Long-run economic relationships,* Oxford: University Press, Oxford.

Meese, R. and Singleton, K. 1982. A note on unit roots and the empirical modelling of exchange rates. *Journal of Finance,* vol. 37, pp. 1029-1035.

Meese, R.A. and Rogoff, K. 1983. Empirical exchange rate models of the seventies: do they fit out of sample? *Journal of International Economics,* vol. 14, pp. 3-24.

Mussa, M.L. 1979. Empirical regularities in the behaviour of exchange rates and theories of the foreign exchange market. In Karl Brunner and Allan H. Meltzer (eds). *Carnegie - Rochester Conference Series on Public Policy,* vol. 11, pp. 9-57.

Ngama, Y. L., 1994. A re-examination of the forward exchange rate unbiasedness hypothesis, *Weltwirtschaftliches Archive.* vol. 130, no. 3, pp. 447-460.

Phillips, P.C.B. 1986. Understanding spurious regressions in econometrics. *Journal of Econometrics,* vol. 33, pp. 311-340.

Sosvilla-Rivero, S. and Park, Y.B. 1992. Further tests on the forward exchange rate unbiasedness hypothesis. *Economics Letters.* vol. 40, pp. 325-331.

Wesso, G.R. 1988. Structural stability in South African econometric models - some empirical results. *Journal for Studies in Economics and Econometrics,* vol. 12, no. 1, pp. 51-71.

Wesso, G.R. 1995. Varying and random coefficient regression models in economics: an overview. *Journal for Studies in Economics and Econometrics,* vol. 19, no. 2, pp. 43-59.

8. Appendix 1

Table 6 Rolling regression results

Equation 1 $$S_{t+k} = \alpha + \beta_t S_t + \epsilon_{t+k}$$

β_t	R^2	Adj. R^2	Sample	β_t	R^2	Adj. R^2	Sample
0.8963323	0.9166800	0.9148698	1	0.8961114	0.9070233	0.9050451	43
0.8955681	0.9173779	0.9156200	2	0.8965965	0.9056202	0.9036121	44
0.8999292	0.9107125	0.9088120	3	0.8828167	0.9016328	0.8995399	45
0.8987391	0.9089800	0.9070400	4	0.8767704	0.8985662	0.8964080	46
0.8919085	0.9101899	0.9082791	5	0.8613585	0.8929312	0.8906532	47
0.8951508	0.9082977	0.9063466	6	0.8274091	0.8904166	0.8880850	48
0.8961114	0.9070233	0.9050451	7	0.8963323	0.9166810	0.9148698	49
0.8965965	0.9056202	0.9036121	8	0.8955681	0.9173779	0.9156200	50
0.8828167	0.9016328	0.8995399	9	0.8999292	0.9107125	0.9088128	51
0.8767704	0.8985662	0.8964080	10	0.8987391	0.9089765	0.9070398	52
0.8613585	0.8929312	0.8906532	11	0.8919085	0.9101899	0.9082791	53
0.8274091	0.8904166	0.8880850	12	0.8951508	0.9082977	0.9063466	54
0.8963323	0.9166810	0.9148698	13	0.8961114	0.9070233	0.9050451	55
0.8955681	0.9173779	0.9156200	14	0.8965965	0.9056202	0.9036121	56
0.8999292	0.9107125	0.9088128	15	0.8828167	0.9016328	0.8995399	57
0.8987391	0.9089765	0.9070398	16	0.8767704	0.8985662	0.8964080	58
0.8919085	0.9101899	0.9082791	17	0.8613585	0.8929312	0.8906532	59
0.8951508	0.9082977	0.9063466	18	0.8274091	0.8904166	0.8880850	60
0.8961114	0.9070233	0.9050451	19	0.8963323	0.9166810	0.9148698	61
0.8965965	0.9056202	0.9036121	20	0.8955681	0.9173779	0.9156200	62
0.8828167	0.9016328	0.8995399	21	0.8999292	0.9107125	0.9088128	63
0.8767704	0.8985662	0.8964080	22	0.8987391	0.9089765	0.9070398	64
0.8613585	0.8929312	0.8906532	23	0.8919085	0.9101899	0.9082791	65
0.8274091	0.8904166	0.8880850	24	0.8951508	0.9082977	0.9063466	66
0.8963323	0.9166810	0.9148698	25	0.8961114	0.9070233	0.9050451	67
0.8955681	0.9173779	0.9156200	26	0.8965965	0.9056202	0.9036121	68
0.8999292	0.9107125	0.9088128	27	0.8828167	0.9016328	0.8995399	69
0.8987391	0.9089765	0.9070398	28	0.8767704	0.8985662	0.8964080	70
0.8919085	0.9101899	0.9082791	29	0.8613585	0.8929312	0.8906532	71
0.8951508	0.9082977	0.9063466	30	0.8274091	0.8904166	0.8880850	72
0.8961114	0.9070233	0.9050451	31	0.8963323	0.9166810	0.9148698	73
0.8965965	0.9056202	0.9036121	32	0.8955681	0.9173779	0.9156200	74
0.8828167	0.9016328	0.8995399	33	0.8999292	0.9107125	0.9088128	75
0.8767704	0.8985662	0.8964080	34	0.8987391	0.9089765	0.9070398	76
0.8613585	0.8929312	0.8906532	35	0.8919085	0.9101899	0.9082791	77
0.8274091	0.8904166	0.8880850	36	0.8951508	0.9082977	0.9063466	78
0.8963323	0.9166810	0.9148698	37	0.8961114	0.9070233	0.9050451	79
0.8955681	0.9173779	0.9156200	38	0.8965965	0.9056202	0.9036121	80
0.8999292	0.9107125	0.9088128	39	0.8828167	0.9016328	0.8995399	81
0.8987391	0.9089765	0.9070398	40	0.8767704	0.8985662	0.8964080	82
0.8919085	0.9101899	0.9082791	41	0.8613585	0.8929312	0.8906532	83
0.8951508	0.9082977	0.9063466	42	0.8274091	0.8904166	0.8880850	84

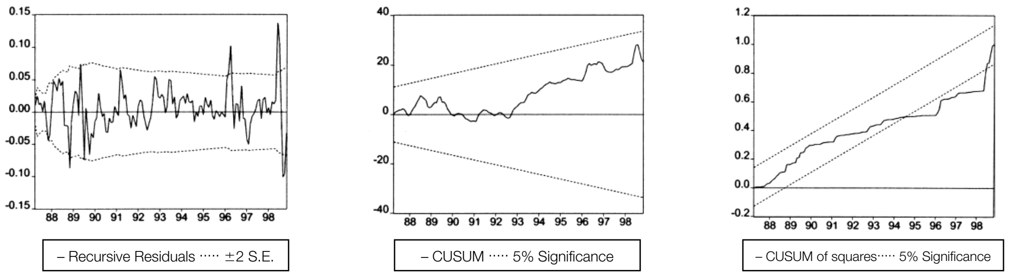
Table 6 continued

Equation 2: $S_{t+k} = \alpha + \gamma_t S_t + \epsilon_{t+k}$

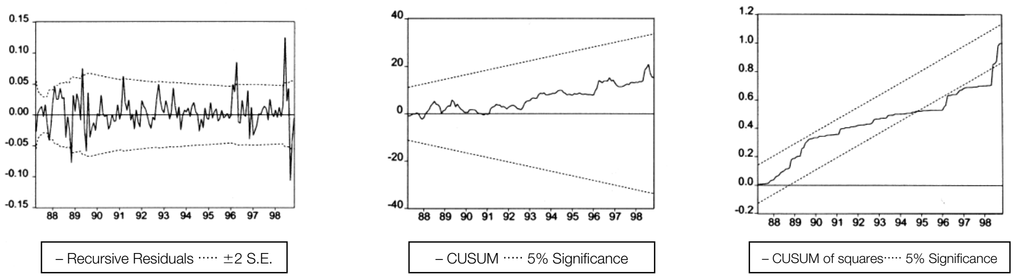
γ_t	R^2	Adj. R^2	Sample	γ_t	R^2	Adj. R^2	Sample
0.9556347	0.9385573	0.9372216	1	0.9578257	0.9304591	0.9289795	43
0.9562378	0.9390691	0.9377727	2	0.9568055	0.9294394	0.9279382	44
0.9648876	0.9326859	0.9312537	3	0.9419918	0.9269987	0.9254455	45
0.9602114	0.9337851	0.9323763	4	0.9439555	0.9241283	0.9225140	46
0.9552615	0.9331466	0.9317242	5	0.9250439	0.9226691	0.9210238	47
0.9611183	0.9315198	0.9300628	6	0.8947054	0.9192720	0.9175543	48
0.9578257	0.9304591	0.9289795	7	0.9556347	0.9385573	0.9372216	49
0.9568055	0.9294394	0.9279382	8	0.9562378	0.9390691	0.9377727	50
0.9419918	0.9269987	0.9254455	9	0.9648876	0.9326859	0.9312537	51
0.9439555	0.9241283	0.9225140	10	0.9602114	0.9337851	0.9323763	52
0.9250439	0.9226691	0.9210238	11	0.9552615	0.9331466	0.9317242	53
0.8947054	0.9192720	0.9175543	12	0.9611183	0.9315198	0.9300628	54
0.9556347	0.9385573	0.9372216	13	0.9578257	0.9304591	0.9289795	55
0.9562378	0.9390691	0.9377727	14	0.9568055	0.9294394	0.9279382	56
0.9648876	0.9326859	0.9312537	15	0.9419918	0.9269987	0.9254455	57
0.9602114	0.9337851	0.9323763	16	0.9439555	0.9241283	0.9225140	58
0.9552615	0.9331466	0.9317242	17	0.9250439	0.9226691	0.9210238	59
0.9611183	0.9315198	0.9300628	18	0.8947054	0.9192720	0.9175543	60
0.9578257	0.9304591	0.9289795	19	0.9556347	0.9385573	0.9372216	61
0.9568055	0.9294394	0.9279382	20	0.9562378	0.9390691	0.9377727	62
0.9419918	0.9269987	0.9254455	21	0.9648876	0.9326859	0.9312537	63
0.9439555	0.9241283	0.9225140	22	0.9602114	0.9337851	0.9323763	64
0.9250439	0.9226691	0.9210238	23	0.9552615	0.9331466	0.9317242	65
0.8947054	0.9192720	0.9175543	24	0.9611183	0.9315198	0.9300628	66
0.9556347	0.9385573	0.9372216	25	0.9578257	0.9304591	0.9289795	67
0.9562378	0.9390691	0.9377727	26	0.9568055	0.9294394	0.9279382	68
0.9648876	0.9326859	0.9312537	27	0.9419918	0.9269987	0.9254455	69
0.9602114	0.9337851	0.9323763	28	0.9439555	0.9241283	0.9225140	70
0.9552615	0.9331466	0.9317242	29	0.9250439	0.9226691	0.9210238	71
0.9611183	0.9315198	0.9300628	30	0.8947054	0.9192720	0.9175543	72
0.9578257	0.9304591	0.9289795	31	0.9556347	0.9385573	0.9372216	73
0.9568055	0.9294394	0.9279382	32	0.9562378	0.9390691	0.9377727	74
0.9419918	0.9269987	0.9254455	33	0.9648876	0.9326859	0.9312537	75
0.9439555	0.9241283	0.9225140	34	0.9602114	0.9337851	0.9323763	76
0.9250439	0.9226691	0.9210238	35	0.9552615	0.9331466	0.9317242	77
0.8947054	0.9192720	0.9175543	36	0.9611183	0.9315198	0.9300628	78
0.9556347	0.9385573	0.9372216	37	0.9578257	0.9304591	0.9289795	79
0.9562378	0.9390691	0.9377727	38	0.9568055	0.9294394	0.9279382	80
0.9648876	0.9326859	0.9312537	39	0.9419918	0.9269987	0.9254455	81
0.9602114	0.9337851	0.9323763	40	0.9439555	0.9241283	0.9225140	82
0.9552615	0.9331466	0.9317242	41	0.9250439	0.9226691	0.9210238	83
0.9611183	0.9315198	0.9300628	42	0.8947054	0.9192720	0.9175543	84

Figure 2 Recursive residuals, coefficient estimates, and CUSUM (of squares) of the four equations

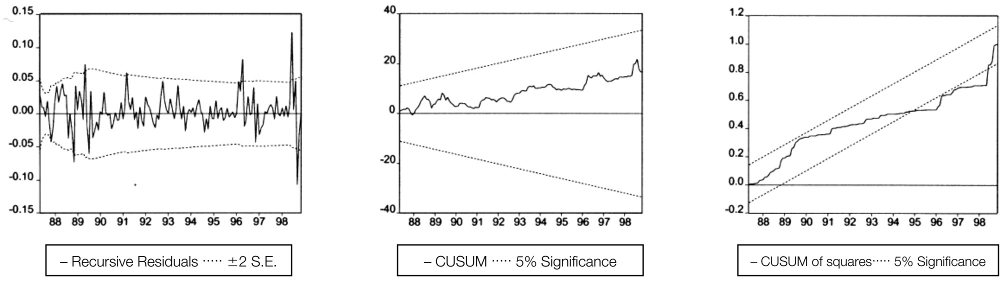
$$S_{t+k} = \alpha + \beta F_t + \epsilon_{t+k}$$



$$S_{t+k} = \alpha + \gamma S_t + \epsilon_{t+k}$$



$$S_{t+k} = \alpha + \beta F_t + \gamma S_t + \epsilon_{t+k}$$



$$S_{t+k} = \alpha + \beta F_t + \psi F_{t-1} + \epsilon_{t+k}$$

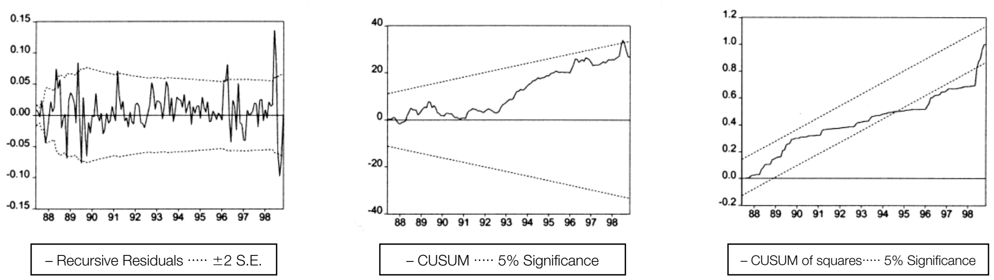
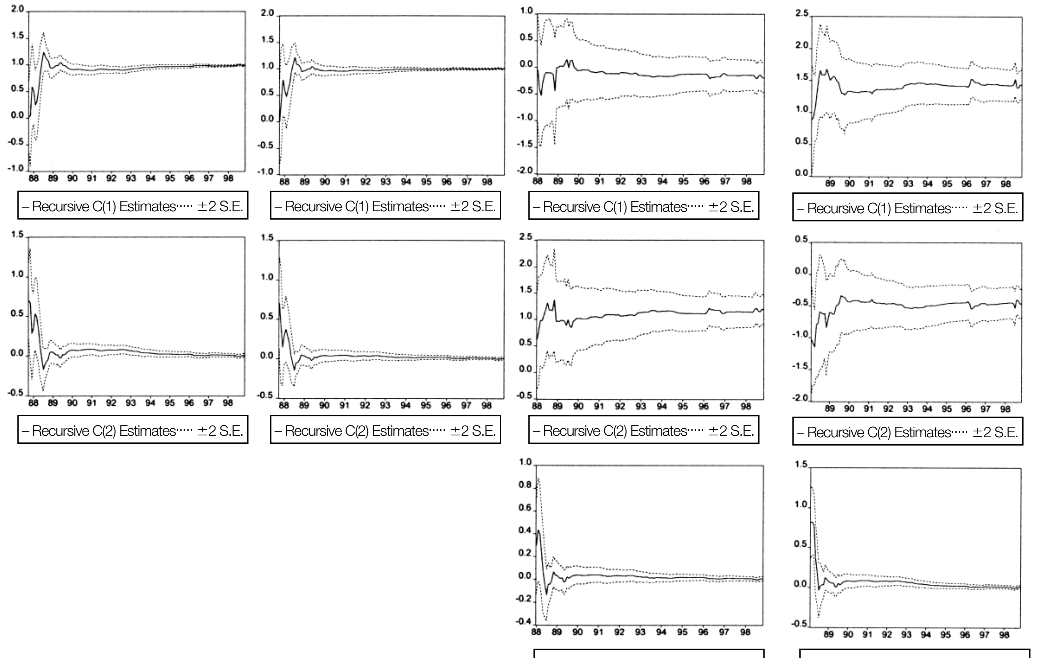


Figure 2 continued

Equation 1	Equation 2	Equation 3	Equation 4
$S_{t+k} = \alpha + \beta F_t + \epsilon_{t+k}$	$S_{t+k} = \alpha + \gamma S_t + \epsilon_{t+k}$	$S_{t+k} = \alpha + \beta F_t + \gamma S_t + \epsilon_{t+k}$	$S_{t+k} = \alpha + \beta F_t + \psi F_{t-1} + \epsilon_{t+k}$



c(#) = coefficient number

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