Enhancing the future spot exchange rate estimation

Chris van Heerden[1], & André Heymans[2]

ABSTRACT

When market participants exercise decisions regarding future exchange rate changes they often use the current forward exchange rate as quoted in the market. The current forward exchange rate is however not solely determined by the interaction of demand and supply, but is more of a mechanistic estimation based on the current spot exchange rate and the carry cost of the transaction. Calculating the future spot exchange rate in this manner proves to be ineffective since the current forward rate differs substantially from the realized future spot exchange rate (Chiang & Yang, 2007; Diamandis et al., 2008; Korajczyk, 1985). This phenomenon is known as the exchange rate puzzle, and proves to be a pseudo rather than an econometric problem. The problem is based on the generally excepted fallacy that current non-stationary, level time series data cannot be used to model exchange rate theories, because of the incorrect assumption that all the available econometric methods yield statistically insignificant results due to spurious regressions. However, empirical evidence conclusively shows that using non-stationary, level time series data of current economic fundamentals can statistically significantly explain the realised future spot exchange rate and, therefore, that the exchange rate puzzle can be solved. In order to solve this puzzle we derived an exchange rate model by incorporating the impact of the interaction of two international financial markets into the model.

KEYWORDS: current economic fundamentals; exchange rate puzzle; forward exchange rate; forward points; non-stationary data; realized future spot exchange rate; stationary data.

JEL CLASSIFICATION: B22, B41, C18, E52, F31, G15

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When market participants exercise decisions regarding future exchange rate changes they often use the current forward exchange rate as quoted in the market. The current forward exchange rate is however not solely determined by the interaction of demand and supply, but is more of a mechanistic estimation based on the current spot exchange rate and the carry cost of the transaction. Calculating the future spot exchange rate in this manner proves to be ineffective since the current forward rate differs substantially from the realized future spot exchange rate (Chiang & Yang, 2007; Diamandis et al., 2008; Korajczyk, 1985). This phenomenon is known as the exchange rate puzzle, and proves to be a pseudo rather than an econometric problem. The problem is based on the generally excepted fallacy that current non-stationary, level time series data cannot be used to model exchange rate theories, because of the incorrect assumption that all the available econometric methods yield statistically insignificant results due to spurious regressions. However, empirical evidence conclusively shows that using non-stationary, level time series data of current economic fundamentals can statistically significantly explain the realised future spot exchange rate and, therefore, that the exchange rate puzzle can be solved. In order to solve this puzzle we derived an exchange rate model by incorporating the impact of the interaction of two international financial markets into the model.

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1. INTRODUCTION

The continuous fluctuation of the ZAR/USD exchange rate increases the difficulty to determine future exchange rate movements, which hinder day-to-day decision-making processes of investor, trader, and policy maker. Market participants, therefore, requires an indicator to help estimate the expected future exchange rates, which led to the use of the forward exchange rate. The daily quoted forward points are being used to help determine what the forward exchange rate would be for a certain period, although, evidence was found that there is a large difference between the forward exchange rate and the ZAR/USD

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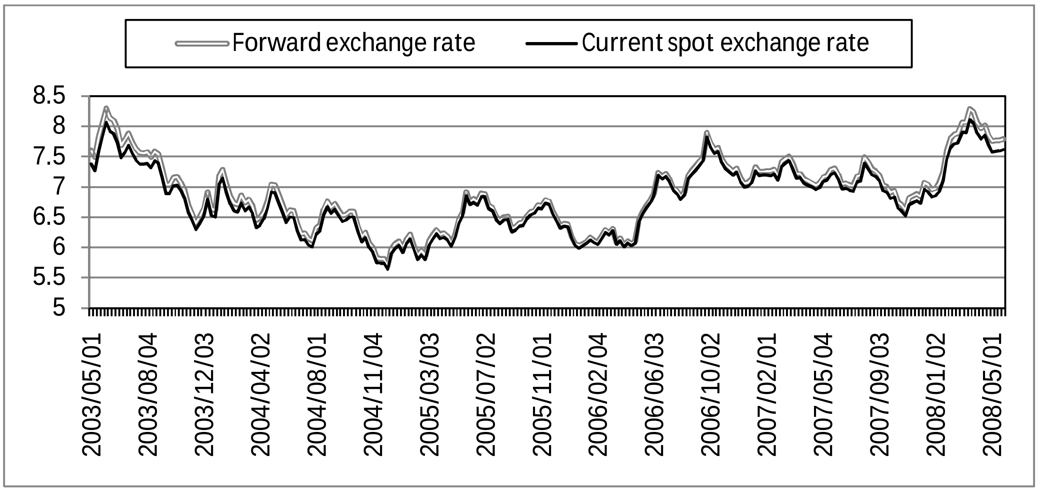
exchange rate. This fact was also emphasized, among others, by Diamandis *et al.* (2008:358) and Albuquerque (2008:461) who stated that the forward exchange rate is a biased estimate of the realized future spot exchange rate. Figure 1 illustrates that the forward exchange rate follows the same trend of the current spot exchange rate, except for the small difference which mainly consists of the carry cost of the transaction. The reason is that the current method, used by South African banks, to quote the forward exchange rate is a mechanical approach. This is a fact that seems not to be widely known or recognized, especially by academics. The importance of this fact will be a focus point of the exposition of this paper.

The primary question, posed in this investigation, is: In the light of the possible mechanistic determination of the forward exchange rate, can current (time t) economic fundamentals explain the realized future spot exchange rate (time $t + i$)? To put it differently, can an exchange rate model be developed, from economic fundamentals, that it can estimate/explain the realized future spot exchange rate to such an extent that the market participants will take note of it. The secondary, concomitant, question is whether the exchange rate puzzle is not a pseudo fallacy caused by the rigorous, unyielding practice of exclusively using stationary time series in the investigations into this "puzzle". This paper will start by providing a background (Section 2) on the past literature studies, which will be followed by a discussion on the methodology (Section 3) and the reporting of the results in Section 4.

<u>Figure 1: The current ZAR/USD spot en forward exchange rate</u>



Source: Data from the McGregor BFA database.

2. BACKGROUND

There is a substantial amount of literature regarding the investigation into the difference between the forward exchange rate and the realized future spot exchange rate. The question is, however, how many of these, mainly theoretical studies, actually took cognisance of the fact that in most countries the actual day to day determination of the forward exchange rate is more mechanistic and less based on economic fundamentals. Most academic studies focus on the economic fundamentals that can possibly explain the forward exchange rate or the difference between the forward exchange rate and the realised spot exchange rate on the date that the forward exchange rate contract matures without even mentioning the mechanistic price formulation methodology used in the foreign exchange markets. Examples of these studies include, e.g., the study by Ott and Veugelers (1986:10-14) that stated that the forward exchange rates, that estimate future spot exchange rates, are influenced by changing inflation rate differentials, interest rate differentials and the monetary policy in the two different countries. A study by Korajczyk (1985:357) found that the foreign exchange rate premium[5] can be explained by real interest rates. However, Huang (1990:349) found that the Purchasing Power Parity (PPP) (Section 3.2) approach may yield better results than interest rate differentials to determine the forward exchange rate premium. Thus, the inflation rate and the interest rate have been empirically identified as possible explanatory factors of exchange rate movements and the starting point for formulating an exchange rate model.

Furthermore, Morley and Pentecost (1998:317) and Chiang (1991:360) found that the exchange rate premium is also related to expected equity premiums. The study by Agmon (1972:849) stated that there existed a co-movement between the equity markets of some industrial countries. Evidence was also found that exchange rate excess returns[6] are correlated to the volatility of stock and currency markets (Jiang & Chiang, 2000:102-103), which implies that dual-listed stocks'[7] returns may incorporate the volatility between two stock exchanges and the exchange rates used by them, may enable the estimation of a more accurate realized future spot exchange rate. Dual-listed stocks are stocks that are listed on more than one exchange (Marx et al., 2006:25). According to the single market hypothesis, prices of comparable assets in different countries should be the same (Ip & Brooks, 1996:53). However, the prices of dual-listed stocks still differ on each exchange. This price difference may provide additional information regarding the future movement of the spot exchange rate, and may enhance the ability to incorporate market expectations into an exchange rate model.

Both micro- and macroeconomic-based models, to estimate the realized spot exchange rate or explain the relationship between the forward exchange rate and the actual spot exchange rate on the day that the forward contract matures, have been developed However, their performance was dismal. This is a very serious problem in the foreign exchange market, where market participants are looking for some form of indicator of the future direction of the exchange rate to assist them in this very volatile market. The study by Mussa (1990:2) elaborated even further by stating that 'the most consistently observed fact concerning the behaviour of floating exchange rates is that changes in exchange rates are largely random and

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[5] Foreign exchange rate premium refers to the difference between the forward exchange rate and the realized future exchange rate.
[6] The returns generated over and above market returns.
[7] Note that this study will refer to the word stocks, although in South Africa it is called shares.

unpredictable.' The fact that the realized spot exchange rate differs to such an extent from the forward exchange rate, quoted by the market some weeks or months ago, is called the exchange rate puzzle.

Integral to this whole issue of the exchange rate puzzle is the methodology used in the econometric modelling and data analysis of the exchange rate puzzle. Central is the so called "best practice", drilled into each student and practitioner, that econometric analysis can only be conducted on stationary time series. Failing to comply will result in spurious regression results, statistically insignificant estimations and nonsensical parameter signs. . In this 'best practice' approach time series data must be adjusted for the presence of a unit root, which refers to as generating a weakly stationary series, a second-order stationary series, or a stochastic process (Gujarati, 2003:797). Also, when estimating an Ordinary Least Squares (OLS) model preventative measures should be taken for spurious regressions, which imply OLS models with high R-squares, low Durbin Watson statistic, and highly statistically significant coefficients (Gujarati, 2003:806). Such measures include the rule of thumb that states that there are no spurious results as long as the R-squared is smaller than the Durbin Watson statistic (Granger & Newbold, 1974). However, the study by Ventosa-Santaulària (2009:16) argued that this rule of thumb may be statistically insignificant and by differencing a series may not always prevent spurious estimates. Additional warning signs of spurious regressions in OLS models that incorporated stationary and highly persistent variables, also include inconsistent standard errors that were used in the t-ratios. (Ventosa-Santaulària, 2009:4). However, there exist alternative processes that can be used to prevent these problems, which include the Johansen co-integration model.

Furthermore, unit root processes have limitations when modelling economic theories, because a unit-root model can be rejected 'in favour of a trend "alternative" when in fact that alternative model is nothing other than an alternative representation of the unit process itself' (Phillips, 1998:1317). This also further implies that neither unit root models nor determininstic trends have the ability of modelling economic theory adequately (Ventosa-Santaulària, 2009:2). Least Squares models have also some limitations when investigating non-stationary time series data, which include the potential for interpreting results incorrectly, because results can become misleading if causality and correlation are confused. This contributed to the notion of differentiating non-stationary time series data when estimating regressions or when attempting to 'detrend' time series data by fitting trend lines in the estimation of Least Squares models (Ventosa-Santaulària, 2009:3).

The empirical study will, therefore, consist of two main approaches. The first approach includes the use of stationary economic time series to model the realized future exchange rate, which will be discussed in Sections 3.1. The second approach, using non-stationary economic level data to model the future realized exchange rate, will be discussed in Sections 3.2.

3. METHODOLOGY

Data was collected from a number of data bases, ranging from 2003/05/01 to 2008/05/31. Daily ZAR/USD spot exchange rate data was obtained from the McGregor BFA database. Daily 3-month forward points were supplied by Rand Merchant Bank (RMB). Weakly South African and U.S.A. 91-day Treasury Bills (T-Bills) were obtained from the South African Reserve Bank's (SARB) website and from the Federal Reserve Board of Governors' website, respectively. T-Bills were used as the short-run interest rate, because they are considered to be risk-free. Daily 10-year South African Government yield rates were also supplied by Citadel and daily 10-year U.S.A. Government yield rates were obtained from the U.S. Department of the Treasury's website. The 10-year South African Government yield rates will be used as the long-run interest rates in the empirical study. Monthly South African Producer Price Index (PPI) data was obtained from the SARB's website. Monthly U.S.A. PPI data was also obtained from the U.S. Department of labour: bureau of labour statistics' website. Monthly year-on-year PPI inflation rate series, ranging from 01/05/2002-28/02/2009, was used in an attempt to improve the estimation of more accurate inflation rate expectations. After the monthly inflation expectations have been generated with the use of an exponential weighting procedure and an Exponential Weighted Moving Average (EWMA) model a linear interpolation process was used to convert the year-on-year monthly PPI data into a weekly format. Daily South African Anglogold Ashanti, Sappi Limited, Harmony Gold Mining Company Limited, Sasol Limited, and Gold Fields Limited closing prices, and RESI 20 closing prices were obtained from the McGregor BFA database.

Daily U.S.A. Anglogold Ashanti, Sappi Limited, Harmony Gold Mining Company Limited, Sasol Limited, and Gold Fields Limited closing prices, and NYSE Energy index closing prices were also obtained from finance.yahoo.com. Each stock closing price series also ranged from 01/05/2002-28/02/200, in an attempt to improve the estimation of more accurate stock return expectations[8]. Daily Euro/ZAR exchange rate, Pond/ZAR exchange rate, and daily gold price and brent oil prices were obtained from the MetaStock database. This leads to the following subsections that will discuss the two approaches used to investigate the estimation of the ZAR/USD realized future spot exchange rate.

3.1. <u>The First Approach (stationary)</u>

Before the Chiang and Yang (2007) methodology can be fully examined, the presence of the exchange rate puzzle in the ZAR/USD exchange rate must first be established. In order to determine the presence of an exchange rate puzzle the following adjusted equation was estimated (Chiang & Yang, 2007:184):

$$s_{t+k} - f_t = v_0 + v_1(f_t - s_t) + \varepsilon_{t+k} \quad (1)$$

where:

[8] The same exponential weighting procedure and an Exponential Weighted Moving Average (EWMA) model were used.

- s_{t+k} is the spot ZAR/USD exchange rate at time $t + k$;
- k represents the number of months ahead;
- f_t is the forward ZAR/USD exchange rate at time t;
- v_0 is the constant parameter;
- v_1 is the exchange rate premium coefficient; and
- ε_{t+k} is the random error.

Only with the presence of the exchange rate puzzle will justify the use of additional variables (a multi-variable model) in an attempt to increase the explanatory ability of the future spot exchange rate. The Chiang and Yang (2007) methodology was used as a preliminary model, which is a formulation of a linear combination of the International Equity Parity, the Purchasing Power Parity theory, the Uncovered Interest Rate Parity theory, and the expected hypothesis of the domestic term structure of interest rates. This multi-variable model can be illustrated in the following equation (Chiang & Yang, 2007:185):

$$s_{t+3} - f_t = \propto + \rho[(\Delta p^{e}_{t+k} - r_t) - (\Delta p^{*e}_{t+k} - r^{*}_t)] + \delta[(R^{e}_{t+k} - r_t)(R^{*e}_{t+k} - r^{*}_t)] + \gamma[(r^{L}_t - r_t)(r^{*L}_t - r^{*}_t)] + \varepsilon_t \quad \text{.......... (2)}$$

where:

- t is the number of months;
- k is the number of months forecasted ahead;
- s_{t+3} is the spot ZAR/USD exchange rate at time t + 3;
- f_t is the forward ZAR/USD exchange rate at time t;
- α is the constant parameter;
- ρ is the real risk-free interest rate differential coefficient;
- δ is the risk-free stock return differential coefficient;
- γ is the risk-free long-run yield differential (spread) coefficient;
- Δp^{e}_{t+k} and Δp^{*e}_{t+k} are the expected inflation rates of South Africa and the U.S.A., respectively;
- r_t and r^{*}_t are the South African 91-day T-Bill rates and the 91-day T-Bill rates of the U.S.A., respectively;
- R^{e}_{t+k} and R^{*e}_{t+k} are the expected returns generated from dual-listed stocks of South Africa and the U.S.A., respectively;
- r^{L}_t and r^{*L}_t are the South African long-run 10-year government bond yield rates of South Africa and of the U.S.A., respectively; and

- ε_t is the random error.

The $[(R^e_{t+k} - r_t)(R^{*e}_{t+k} - r^*_t)]$ bracket will be referred to as the stock return differential. This bracket was also substituted with other proxies in an attempt to improve the incorporation of the interaction between the Johannesburg Stock Exchange (JSE) and the New York Stock Exchange (NYSE). These alternative dual-stock proxies included the following:

- The difference in the prices quoted on the JSE and the NYSE.
- Substituting expected stock returns with an International Capital Asset Pricing Model (ICAPM)[9] series.
- Substituting expected stock returns with a 'speed of adjustment' series that was generated with a Vector Error Correction (VEC) model[10].

3.2. <u>The Second Approach (non-stationary)</u>

This approach will continue from the best model derived from the first approach, however, non-stationary level data will be applied. This study will incorporate the following procedure to prevent the possibility of spurious results when using non-stationary current level economic time series data. Firstly, non-stationary level data will be incorporated into a standard OLS model to acquire preliminary results. Secondly, a Breusch-Godfrey serial correlation LM test will be applied to determine the presence of serial correlation among the explanatory variables. This will be followed by testing for the presence of heteroskedasticity[11] with a White heteroskedasticity test. Thirdly, if serial correlation and heteroskedasticity are present an Autoregressive Conditional Heteroskedasticity (ARCH) model or a Generalized ARCH (GARCH) model will be applied, using the model with the lowest SIC and AIC estimate. Fourthly, the ARCH/GARCH model will be checked for any remaining ARCH effects. Fifthly, the best ARCH/GARCH model's residuals will be tested for the presence of a unit root, with no unit root confirming that no spurious results are present. This was followed by testing if the residuals are normally distributed, to ensure that the variance of the residuals is identical and uncorrelated (white noise).

4. RESULTS

The first approach commenced by adjusting all the time series to be stationary, which were also integrated to the same order *I(1)*. Different formats were examined in order to make the data stationary, which include the log-format, the first differencing format, and the fractional differencing format. The first differencing format entails the use of the change in the variables from period t to period t + 1. The first

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[9] See Wu (2008:177) for future references.
[10] See Johansen (1991) for future references.
[11] Heteroskedasticity implies that, in a two-variable regression, the conditional variance of one variable (Y) increases as the conditional variance of the other variable (X) increase (Gujarati, 2003:388). Heteroskedasticity, therefore, implies the presence of correlation among the two variables.

differencing and fractional differencing formats provided the best results and will be used for the stationary approach.

The results reported in Table 1 were obtained by estimating Equation 1 in an Ordinary Least Squares (OLS) model. The present premium $(f_t - s_t)$ could only explain 16% of the future premium $(s_{t+3} - f_t)$ thus indicating the presence of an exchange rate puzzle the ZAR/USD exchange rate. Although the second differencing format (fractionally differenced data) rendered improved results (see Table 2), the present premium $(f_t - s_t)$ still only explains 26% of the future premium $(s_{t+3} - f_t)$. The Durbin Watson statistic and the Ramsey Reset test also indicate that the model is mis-specified.

Table 1: The forward premium hypothesis – first differenced approach

Dependent: Difference of $(s_{t+3} - f_t)$				Coefficient	Std. error	t-prob.
Difference of $(f_t - s_t)$				-17.545	2.641	0.000*
Constant parameter (v_0)				-0.003	0.011	0.796
R-squared	0.155	Prob. (F-statistic)	0.000			
Adjusted R-squared	0.151	AIC	-0.726	Durbin Watson		1.612

** Statistically significant at the 5% level.*
Source: Compiled by authors.

Table 2: The forward premium hypothesis – fractionally differenced approach (OLS)

Dependent: Fractionally differenced $(s_{t+3} - f_t)$				Coefficient	Std. error	t-prob.
Fractionally differenced $(f_t - s_t)$				-4.377	0.477	0.000*
Constant parameter (v_0)				0.354	0.068	0.000*
R-squared	0.259	Prob. (F-statistic)	0.000			
Adjusted R-squared	0.256	AIC	0.190	Durbin Watson		0.458

** Statistically significant at the 5% level.*
Source: Compiled by authors.

These results justify the need to use additional variables to enhance the estimation of the future spot exchange rate. The Chiang and Yang (2007) methodology was therefore applied and the results, as reported in Table 3, were found by estimation Equation 2.

By examining all the dual-listed stocks and the stock indices, as mentioned in Section 3, evidence was found of statistically insignificance for all of dual-listed stocks and stock indices except for the Anglogold Ashanti dual-listed stock and for the Sappi Limited dual-listed stock. The results from Table 3 reported that the $[(\Delta p^e_{t+k} - r_t) - (\Delta p^{*e}_{t+k} - r^*_t)]$ variable was not statistically significant and was substituted by the inverse of the variable. All the dual-listed stock proxies were also found statistically insignificant, except the Anglogold Ashanti stock return differential. Due to a low Durbin Watson statistic an AR(1)-variable was included to eliminate the presence of serial correlation. The chow breakpoint and Cusum test indicated that there were two dummies required. Dummy 1 ranged from 2006/07/02 to 2008/05/04, whereas Dummy 2 ranged from 2007/08/04 to 2008/05/04. All the variables except the long-short spread variable, Dummy 1, and Dummy 2 were statistically significant at a 5% level. However, all these variables were only able to explain 12% of the foreign exchange rate premium $(s_{t+3} - f_t)$. These results implied that the current economic variables proposed by the Chiang and Yang (2007) methodology failed estimate the ZAR/USD realized future spot exchange rate.

Table 3: The multi-variable model – first differenced approach

Dependant: Difference of $(S_{t+3} - F_t)$				Coefficient	Std. Error	t-prob.
Inverse of the real-interest rate differential				-35.487	-2.545	0.012*
Difference of the Anglogold Ashanti stock return differential				3.770	0.009	0.000*
Difference of the long-short spread				-0.466	0.041	0.450
Dummy 1				0.042	0.026	0.104
Dummy 2				-0.036	0.020	0.073**
AR (1)				0.276	0.065	0.000*
R-squared	0.120	Prob(F-statistic)	0.000			
Adjusted R-squared	0.097	Akaike info criterion	-6.631	Durbin Watson		1.965

*Statistically significant at a 5% level.
**Statistically significant at a 10% level.
Source: Compiled by author.

These findings were also justified by the results found by applying fractional differencing to make the data stationary. The results reported in Table 4 illustrate that the Chiang and Yang (2007) methodology is inefficient in explaining the future spot exchange rate (14%).

Table 4: The ARCH(1,0) multi-variable model – fractionally differenced approach

Dependent: Fractionally differenced $(S_{t+3} - f_t)$				Coefficient	Std. error	t-prob.
Fractionally differenced real-interest rate differential				-0.026	0.012	0.033*
Fractionally differenced Sappi Limited stock return differential				-0.030	0.002	0.000*
Fractionally differenced long-short spread				0.084	0.032	0.008*
Intercept (α)				-0.417	0.046	0.000*
Variance equation						
Intercept				0.019	0.003	0.000*
Residual(-1)^2				0.733	0.194	0.000*
R-squared	0.139	AIC	-0.126	Log likelihood		21.303
Adjusted R-squared	0.128	SIC	-0.040	Sum squared residuals		19.650

* Statistically significant at the 5% level.
The AR(1) variable was unable to provide a statistically significant contribution in eliminating serial correlation which led to the use of an ARCH model to eliminate the presence of serial correlation and heteroskedasticity.
Source: Compiled by authors

To determine how to improve the multi-variable model this study re-examined each of the underlying economic theories on which the Chiang and Yang (2007) methodology was build. From the PPP theory, the Fisher effect, the Covered, and Uncovered Interest Rate Parity theory results reported that actual inflation rates and the short-run interest rates provided the most significant results. However, further evidence also implied that by including these variables individually may enhance the estimation of the realized future spot exchange rate. Also, the equity premium hypothesis indicated that the Sappi Limited stock return differential, the Anglogold Ashanti speed series, and the Sappi Limited ICAPM provided the best results for explaining the realized spot exchange rate. By applying these adjustments and by incorporating the fact that the forward exchange rate is a mechanistic estimation, the following results were found, as reported in Table 5.

With the ZAR/USD spot exchange rate that realized over 3-monhts as the dependant variable, results illustrated that the inverse of the real interest rate differential was statistically significant, although the Sappi Limited proxies provided insignificant results, which implied that only Anglogold Ashanti proxies were to be included in the improved multi-variable model. A low Durbin Watson statistic led to the use of an AR(1)-variable to eliminate the presence of serial correlation. Also, although the long-run interest rate differential was insignificant in Table 3 it was still included in an attempt to include both long- and short-run interest rates. However, the long-run interest rate differential still provided insignificant results and was eliminated from this model. The Chow breakpoint test and the Cusum test indicated that there may be structural breaks, which required dummies. Dummy 1 ranged from 2006/07/01-2008/05/04, Dummy 2 ranged from 2006/07/02-2008/05/04, and Dummy 3 ranged from 2006/02/01-2006/04/03 was included in the model. The current spot exchange rate was also included as an explanatory variable, because it provided significant results. The actual inflation rate differential, the inverse of the real interest rate differential, and the Anglogold Ashanti stock return differential was lagged with one period. The Anglogold Ashanti ICAPM was also lagged with 2 periods, while the Anglogold Ashanti Speed variable was lagged with 6 periods. However, this model was only able to explain 19% of the ZAR/USD realized future spot exchange rate.

Table 5: Improved multi-variable model – first differenced approach

Dependant: Difference of S_{t3}				Coefficient	Std. Error	t-prob.
Difference of S_t				0.228	0.093	0.015*
Difference of the actual inflation rate differential (-1)				-0.035	0.022	0.115
Inverse of the real interest rate differential (-1)				5.190	2.094	0.014*
Difference of the Anglogold Ashanti stock return differential (-1)				51.723	0.245	0.036*
Dummy 1				3.625	1.304	0.006*
Dummy 2				-3.505	1.331	0.009*
Dummy 3				0.960	0.443	0.032*
Anglo ICAPM (-2)				-5.430	0.353	0.126
Anglo Speed (-6)				0.175	0.039	0.025*
AR(1)				0.154	0.072	0.034*
R-squared	0.194	Prob(F-statistic)	0.000			
Adjusted R-squared	0.153	Akaike info criterion	-1.370	Durbin Watson		1.984

*Statistically significant at a 5% level.
The fractionally differenced approach did not provide any improved statistically significant results and was, therefore, not reported.
Source: Compiled by author.

This led to the investigation on the impact that the use of non-stationary level data will have on exchange rate modelling. The second approach will, therefore, determine if making time series data stationary prevent current economic fundamentals from providing their true explanatory abilities. During the modelling of non-stationary level data the current spot exchange rate provided insignificant results, which implied that it should be eliminated from further exchange rate modelling. Also, the ARCH model provided more statistically significant results, compared to the results found for the GARCH model, and thus eliminating serial correlation among the variables. Further evidence indicated that the U.S.A. expected inflation rate, the South African actual inflation rate, the South African and U.S.A. 91-day Treasury Bill rates, and the U.S.A. 10 year Government Bond yield rates provided the best statistically significant results from all the individual variables. By re-examining the impact of financial proxies on the model, the Sappi Limited ICAPM proxy was also selected. However, regarding the proxy based on the Anglogold Ashanti dual-listed stock, all the proxies provided statistically insignificant results except the difference in the prices quoted on the JSE and the NYSE.

In addition to the above variables, some cross-exchange rates were also included; these include the Euro/USD, the Pound/USD, the ZAR/Euro, and the ZAR/Pound exchange rates. Cross-exchange rates are useful in modelling exchange rates for two reasons: firstly, both the Euro and the Pound have a significant spill-over influence on the ZAR; and secondly, exchange rates amongst different currencies can be inconsistent, which may lead to arbitrage and thus an additional supply/demand force that can influence the current position of the ZAR. Since the inclusion of these variables led to the presence of serial correlation and heteroskedasticity, an ARCH model was fitted. The results reported in Table 6 demonstrate that all the variables, including the variance residual, were statistically significant at the 5% level and explain 66% of the realised future spot exchange rate. The AIC and SIC were relatively low whilst the log likelihood statistic was relatively high, implying a good fit. The presence of a unit root amongst the residuals was also rejected, thus indicating that this is not a spurious model. Furthermore, there were no remaining ARCH effects in the model and the Jarque-Bera probability statistic indicated that the hypothesis of normally distributed residuals could not be rejected.

Table 6: ARCH(1,0) estimation in level format

Dependent: S_{t+3}				Coefficient	Std. error	t-prob.
U.S.A. expected inflation rate				-0.031	0.006	0.000*
U.S.A. 91-day T-Bill rate				0.241	0.017	0.000*
U.S.A. 10-year government bond yield rate				0.137	0.041	0.008*
South African 91-day T-Bill rate				0.148	0.012	0.000*
South African actual inflation rate				-0.061	0.008	0.000*
AngloGold Ashanti price difference in USD terms				-0.072	0.023	0.002*
Sappi Limited ICAPM				-0.122	0.025	0.000*
Euro/USD exchange rate in ZAR terms				0.944	0.048	0.000*
Pound/USD exchange rate in ZAR terms				-0.532	0.037	0.000*
Constant parameter (v_0)				3.207	0.398	0.000*
Variance equation						
Intercept				0.007	0.002	0.003*
Residual(-1)^2				1.132	0.234	0.000*
R-squared	0.657	AIC	-0.014	Log likelihood		13.651
Adjusted R-squared	0.644	SIC	0.158	Sum squared residuals		26.195

** Statistically significant at the 5% level.*
Source: Compiled by authors.
Although the variance residuals in the ARCH models are just over 1, indicating the possibility of instability, it is still more significant to 1, thus the model is still providing statistically significant results.

However, the Chow breakpoint test and the Cusum test indicated that this model exhibited structural breaks, which implied that the following three dummies had to be incorporated in the model. Dummy 1 was included for the effects of the preliminary shocks of the financial crisis; spanning from the third week in July 2007 to the fourth week in May 2008. Dummies 2 and 3 were included, for the Russian gas crisis, that span from the first week in February 2006 to the fourth week in May 2008 and the first week in February 2006 to the third week in April 2006, respectively. Dummy 4 span from the first week in March 2005 to the fourth week in May 2008 and covers the announcement of the U.S.A. president's second term (January 2005), the announcement of North Korea's nuclear intensions (October 2006) and the commodity crisis from 2007 to 2008.

Although these above mentioned dummies were required to compensate for the above mentioned structural breaks, an alternative approach was followed. As most of these events causing the structural breaks had an influence on the world's gold price and Brent oil price, an attempt was made to improve the accuracy of the explanation of the realised spot exchange rate by including the gold price and Brent oil price as additional explanatory variables. These variables can also decrease the number of intercept dummies required in the exchange rate model. The results reported in Table 7 demonstrate that including the gold and Brent oil price increased the explanatory power of the realised spot exchange rate from 66% to 71%. The results reported in Table 7 illustrate that all the variables were statistically significant at the 5% level, with a relatively low AIC statistic and SIC statistic. Also, a relatively high log likelihood estimate emphasised the goodness-of-fit of the model. No unit root was found amongst the residuals, which implied that this was not a spurious model.

Table 7: Adjusted ARCH(1,0) estimation in level format

Dependent: S_{t+3}				Coefficient	Std. error	t-prob.
U.S.A. expected inflation rate				-0.077	0.010	0.000*
U.S.A. 91-day T-Bill rate				0.108	0.021	0.000*
U.S.A. 10-year government bond yield rate				0.098	0.046	0.033*
South African 91-day T-Bill rate				0.165	0.014	0.000*
South African actual inflation rate				-0.066	0.010	0.000*
AngloGold Ashanti price difference in USD terms				-0.053	0.025	0.036*
Sappi Limited ICAPM				-0.109	0.032	0.000*
Euro/USD exchange rate in ZAR terms				0.534	0.079	0.000*
Pound/USD exchange rate in ZAR terms				-0.311	0.052	0.000*
Brent oil price				0.006	0.002	0.013*
Gold price				0.001	0.000	0.000*
Constant parameter (v_0)				3.532	0.449	0.000*
Variance equation						
Intercept				0.009	0.003	0.001*
Residual(-1)^2				1.045	0.243	0.000*
R-squared	0.714	AIC	-0.028	Log likelihood		17.416
Adjusted R-squared	0.701	SIC	0.173	Sum squared residuals		21.823

** Statistically significant at the 5% level.*
Source: Compiled by authors.

All the variables in the ARCH(1,0) model (see Table 7) were statistically significant at the 5% level, including the residual variance coefficient. Negative coefficients were reported for both the South African actual inflation rate and the U.S.A. expected inflation rate. This is an indication of the price competiveness of these countries, where higher product prices may lead to a decrease in the demand for South African goods, thus leading to a decrease in the demand for ZAR. The AngloGold Ashanti price difference, in USD terms, and the Sappi ICAPM were also negatively related to the ZAR/USD realised spot exchange rate. This may be due to the negative relationship between stock prices and returns, where a depreciation of the ZAR may lead to an increase in the prices of U.S.A. stocks for South African investors, thus causing the relative return on the U.S.A. stock to decrease.

Furthermore, the Euro/USD exchange rate expressed in ZAR has a positive relationship with the ZAR/USD realised spot exchange rate, the gold price and the Brent oil price (see Table 7). However, it was found that the ZAR/USD realised spot exchange rate was negatively related to the Pound/USD exchange rate expressed in ZAR. Table 7 also reports a relatively low AIC and SIC statistic and a relative high log likelihood estimate, implying a good fit. There was no unit root found amongst the residuals, which implies that this is not a spurious model. Further evidence also indicates that there were no remaining ARCH effects in the model. These results confirm that non-stationary, level time series data provides a better explanation of the realised future spot exchange rate. These results also confirm that if the necessary precautions are in place, analysts should not fear the use of non-stationary data when investigating exchange rate theories. However, in order to confirm that the better result was as a consequence of using non-stationary data, and not as a result of a possible improvement in the model, a fractionally differenced data format was used in the final successful model. The results reported in

Table 8 illustrate that all the variables in the ARCH(1,0) model provided a statistically significant contribution to the model, explaining 67% of the realised future spot exchange rate.

Table 8: The ARCH (1,0) comparison with a dummy – fractionally differenced approach

<table>
<tr><th colspan="4">Dependent: Fractionally differenced S_{t+3}</th><th colspan="2">Coefficient</th><th>Std. error</th><th>t-prob.</th></tr>
<tr><td colspan="4">U.S.A. 91-day T-Bill rate</td><td colspan="2">0.195</td><td>0.045</td><td>0.000*</td></tr>
<tr><td colspan="4">U.S.A. expected inflation rate(-1)</td><td colspan="2">-0.046</td><td>0.023</td><td>0.048*</td></tr>
<tr><td colspan="4">U.S.A. 10-year government bond yield rate</td><td colspan="2">0.135</td><td>0.065</td><td>0.038*</td></tr>
<tr><td colspan="4">South African actual inflation rate</td><td colspan="2">-0.067</td><td>0.020</td><td>0.001*</td></tr>
<tr><td colspan="4">South African 91-day T-Bill rate(-4)</td><td colspan="2">0.083</td><td>0.026</td><td>0.001*</td></tr>
<tr><td colspan="4">South African 10-year government bond yield rate</td><td colspan="2">0.252</td><td>0.042</td><td>0.000*</td></tr>
<tr><td colspan="4">AngloGold Ashanti price difference in USD terms(-1)</td><td colspan="2">0.034</td><td>0.014</td><td>0.014*</td></tr>
<tr><td colspan="4">Sappi Limited ICAPM</td><td colspan="2">-0.051</td><td>0.024</td><td>0.038*</td></tr>
<tr><td colspan="4">Euro/USD exchange rate in ZAR terms</td><td colspan="2">0.784</td><td>0.083</td><td>0.000*</td></tr>
<tr><td colspan="4">Pound/USD exchange rate in ZAR terms</td><td colspan="2">-0.440</td><td>0.057</td><td>0.000*</td></tr>
<tr><td colspan="4">Brent oil price(-1)</td><td colspan="2">-0.010</td><td>0.002</td><td>0.000*</td></tr>
<tr><td colspan="4">Gold price</td><td colspan="2">0.002</td><td>0.001</td><td>0.003*</td></tr>
<tr><td colspan="4">Intercept</td><td colspan="2">-0.006</td><td>0.152</td><td>0.968</td></tr>
<tr><th colspan="4">Variance equation</th><td colspan="4"></td></tr>
<tr><td colspan="4">Intercept</td><td colspan="2">0.008</td><td>0.002</td><td>0.000*</td></tr>
<tr><td colspan="4">Residual(-1)^2</td><td colspan="2">1.025</td><td>0.223</td><td>0.000*</td></tr>
<tr><td>R-squared</td><td>0.671</td><td>AIC</td><td>-0.562</td><td colspan="3">Log likelihood</td><td>82.181</td></tr>
<tr><td>Adjusted R-squared</td><td>0.654</td><td>SIC</td><td>-0.344</td><td colspan="3">Sum squared residuals</td><td>11.473</td></tr>
</table>

** Statistically significant at the 5% level.*
**** Statistically significant at the 15% level.*
Source: Compiled by authors.

The sign of each of the variables' coefficients supports the underlying economic theory. By lagging the South African T-Bill rate variable with 4 periods and the AngloGold Ashanti price difference variable with 1 period, the explanation of the realised future spot exchange rate was enhanced. Although Table 8 provides a weaker explanation of the realised future spot exchange rate compared to the 71% found in Table 7, the fractionally differenced approach provides superior results in comparison with the first differenced approach. These results, therefore, confirms that non-stationary, level time series data provides the best results when investigating exchange rate theories. These results also confirm that the exchange rate puzzle is a pseudo problem and that economic fundamentals do have the ability to explain the exchange rate puzzle.

5. CONCLUSION

This study investigated two approaches in an attempt to explain the ZAR/USD realized future spot exchange rate and the exchange rate puzzle. The first approach used the Chiang and Yang (2007) methodology as the preliminary model and results indicated that it was insufficient in explaining the exchange rate puzzle and the ZAR/USD realized future spot exchange rate, which was partly due to the mechanistic estimated forward exchange rate and the use of composite variables suggested by the Chiang and Yang (2007) methodology. However, by incorporating non-stationary level time series data in the second approach results illustrated that economic fundamentals were able to enhance the explanation of the ZAR/USD realized future spot exchange rate and of the exchange rate puzzle, which implied that the rigorous approach of using stationary data to model the exchange rate puzzle led to a pseudo problem. These results implied that investigating non-stationary level data was not to be feared by academicians if the necessary precautionary measures were in place.

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