

The relationship between the forward- and the realized spot exchange rate in South Africa

Petrus Marthinus Stephanus van Heerden

M.Com Risk Management

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Supervisor: Prof. Dr. Paul Styger

Assistant-supervisor: Dr. André Heymans

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DEDICATION

I would like to dedicate this thesis to my father, Martin van Heerden.

PREFACE

This study represents the original work of the author and has not been submitted in any form to another University. Where use was made of the work of others, this has been duly acknowledged in the text. Unless otherwise stated, all data was obtained from the following sources: Citadel, Department of Labour: Bureau of Labour Statistics' website, Federal Reserve Board of Governors' website, Finance.yahoo.com, McGregor BFA database, MetaStock database, Rand Merchant Bank, and the South African Reserve Bank's website.

The relationship between the ZAR/Dollar forward exchange rate premium and the interest rate differential was presented at the *International Atlantic Economic Society's* conference in Rome, Italy in March 2009. Resolving the difference between the forward exchange rate and the future spot exchange rate was presented at the *South African Finance Association's* conference in Cape Town in January 2010. The methodology to enhance the estimation of the realized spot exchange rate was presented at the *International Atlantic Economic Society's* conference in Prague, Czech Republic in March 2010. Demystifying the South African exchange rate puzzle will be presented at the *South African Finance Association* conference in Cape Town in January 2011 and is also submitted to the *Journal of International Business and Finance*.

The creditability of official inflation targets in terms of inflation expectations based on historical inflation was presented at the *Economic Society of South Africa's* conference in Port Elizabeth in September 2009. Forecasting South African PPI inflation was submitted to the *South African Journal of Economics*. Forecasting the South African PPI inflation, using neural networks, was submitted to *Studies in nonlinear dynamics and econometrics*.

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P.M.S. van Heerden

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ABSTRACT

The inability to effectively hedge against unfavourable exchange rate movements, using the current forward exchange rate as the only guideline, is a key inhibiting factor of international trade. Market participants use the current forward exchange rate quoted in the market to make decisions regarding future exchange rate changes. However, the current forward exchange rate is not solely determined by the interaction of demand and supply, but is also a mechanistic estimation, which is based on the current spot exchange rate and the carry cost of the transaction. Results of various studies, including this study, demonstrated that the current forward exchange rate differs substantially from the realized future spot exchange rate. This phenomenon is known as the exchange rate puzzle.

This study contributes to the dynamics of modelling exchange rate theories by developing an exchange rate model that has the ability to explain the realized future spot exchange rate and the exchange rate puzzle. The exchange rate model is based only on current (time t) economic fundamentals and includes an alternative approach of incorporating the impact of the interaction of two international financial markets into the model. This study derived a unique exchange rate model, which proves that the exchange rate puzzle is a pseudo problem. The pseudo 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. Empirical evidence conclusively shows that using non-stationary, level time series data of current economic fundamentals can statistically significantly explain the realized future spot exchange rate and, therefore, that the exchange rate puzzle can be solved.

This model will give market participants in the foreign exchange market a better indication of expected future exchange rates, which will considerably reduce the dependence on the mechanistically derived forward points. The newly derived exchange rate model will also have

an influence on the demand and supply of forward exchange, resulting in forward points that are a more accurate prediction of the realized future exchange rate.

Keywords: *ARCH model; ARFIMA model; co-integration; Covered Interest Rate Parity; dual-listed stocks; exchange rate puzzle; forward exchange rate; ICAPM; International Equity Parity theory; non-stationary data; PPP; realized future spot exchange rate; stationary data; Uncovered Interest Rate Parity; VEC model.*

OPSOMMING

Die mees belangrike faktor wat internasionale handel inhibeer, is die onvermoë van markdeelnemers om hulle teen ongunstige wisselkoersbewegings te verskans, met die gebruik van slegs die huidige toekomstige wisselkoers as riglyn. Hulle gebruik die huidige vooruitwisselkoers, soos in die mark gekwoteer, om besluite rakende die toekomstige wisselkoersbewegings te maak. Die huidige vooruitwisselkoers word nie slegs deur die interaksie van vraag en aanbod bepaal nie, maar is 'n meganistiese proses wat gebaseer word op die huidige wisselkoers en die drakoste van die transaksie. Die resultate van verskeie studies, insluitende hierdie een, toon dat die huidige vooruitwisselkoers substansieel verskil van die loko-wisselkoers wat op die toekomstige datum gerealiseer het. Die voorval word as wisselkoersvraagstuk geken.

Hierdie studie dra by tot die dinamika van die modellering van die verskillende wisselkoersteorieë deur die ontwikkeling van 'n wisselkoersmodel wat die vermoë het om die gerealiseerde toekomstige loko-wisselkoers, sowel as die sogenaamde wisselkoersvraagstuk te verklaar. Die wisselkoersmodel is slegs op die huidige (tyd t) fundamentele ekonomiese faktore gebaseer en sluit 'n alternatiewe benadering in om die impak van die interaksie tussen twee internasionale finansiële markte in die model te inkorporeer. Die studie het 'n wisselkoersmodel ontwikkel wat bewys het dat die wisselkoersvraagstuk 'n kunsmatige vraagstuk is, wat ontstaan het uit die foutiewe, algemeen aanvaarde beginsel dat huidige, nie-stasionêre tydreeksdata nie gebruik kan word om wisselkoersteorieë te modelleer nie as gevolg van die statisties-onbeduidende resultate van valsregressies. In hierdie studie word dit omvattend aangetoon dat die gebruik van nie-stasionêre, eerstevlak, tydreeksdata, van huidige ekonomiese fundamentele faktore, die gerealiseerde, toekomstige loko-wisselkoers statisties beduidend kan verklaar. So word die wisselkoersvraagstuk dus ook opgelos.

Hierdie model kan markdeelnemers in die wisselkoersmark 'n baie beter indikasie van die verwagte toekomstige wisselkoerse gee, wat die afhanklikheid van die meganisties-afgeleide vooruitwisselkoerspunte aansienlik kan verminder. Die nuut ontwikkelde model kan ook 'n invloed op die vraag en aanbod van vooruitvaluta uitoefen, met die gevolg dat die vooruitwisselkoerspunte 'n baie akkurater aanduiding van die toekomstige gerealiseerde wisselkoers gaan gee.

Sleutelwoorde: *Autoregressiewe-voorwaardelike-heteroskedastiese modelle, Autoregressiewe-gedeeltelike-geïntegreerde-bewegende-gemiddelde modelle; Gedekte-rentekoers-pariteitsteorie; dubbelgenoteerde aandele; wisselkoersvraagstuk; vooruitwisselkoers; Internasionale kapitaalbateprysingsmodel; Internasionale aandeelpariteitsteorie; nie-stasionêre data; Koopkrag pariteit; gerealiseerde toekomstige loko-wisselkoers; stasionêre data; Ongedekte rentekoerspariteitsteorie; Vektor-foutaanpassings-model.*

TABLE OF CONTENTS

LIST OF FIGURES.....	xvi
LIST OF TABLES.....	xviii
CHAPTER 1: INTRODUCTION.....	1
1.1 The South African exchange rate	1
1.2 Estimating future exchange rate movements.....	3
1.3 Problem statement	7
1.4 Research objectives of the thesis	7
1.5 Motivation.....	8
1.6 Contribution.....	9
1.7 Chapter layout.....	10
1.7.1 Chapter 2: Exchange rate puzzle	10
1.7.2 Chapter 3: The Purchase Power Parity and Interest Rate Parity theories.....	10
1.7.3 Chapter 4: Dual-listed stocks and investment theory.....	11
1.7.4 Chapter 5: Methodology	11
1.7.5 Chapter 6: Empirical results	11
1.7.6 Chapter 7: Conclusion.....	12
CHAPTER 2: THE EXCHANGE RATE PUZZLE	13
2.1 Introduction	13
2.2 Exchange rate models.....	15
2.2.1 Introduction	15
2.2.1.1 The monetary approach towards explaining the expected exchange rate.....	15
2.2.1.1.1 The Mundell-Fleming model.....	16
2.2.1.1.2 The sticky-price monetary model.....	16
2.2.1.1.3 The flexible-price monetary model.....	17
2.2.1.1.4 New open-economy macroeconomic models	17
2.2.1.1.5 The portfolio-balance model.....	18

2.3 Exchange rate puzzle.....	19
2.3.1 Introduction	19
2.3.2 The determination puzzle	20
2.3.2.1 Order flow	21
2.3.3 The excess volatility puzzle.....	27
2.3.3.1 Random walk phenomenon.....	29
2.3.3.2 Estimating future exchange rates	31
2.3.4 The forward bias puzzle / forward exchange rate premium puzzle	32
2.3.4.1 Introduction	32
2.3.4.2 Background.....	33
2.3.4.2.1 Factors explaining the forward exchange rate and the risk premium	34
2.3.4.2.2 Interest rates as determinant of the risk premium.....	37
2.3.4.2.3 Introducing the time-varying risk premium	40
2.3.4.2.4 Comparison of the inflation rate differential and the interest rate differential as	
determinants of the forward exchange rate premium.....	41
2.3.4.2.5 Equity premium as determinant of the risk premium.....	43
2.3.4.2.6 Using the forward bias puzzle as a trading indicator.....	45
2.3.5 The home bias puzzle	46
2.3.6 Summary	49
2.4 Exchange rate equilibrium and exchange rate misalignment.....	50
2.4.1 Introduction	50
2.4.2 Two types equilibrium exchange rate models.....	51
2.5 Chapter summary.....	54
CHAPTER 3: THE PURCHASING POWER PARITY AND INTEREST RATE THEORIES	58
3.1 Introduction	58
3.2 Purchasing Power Parity	60
3.2.1 Introduction	60
3.2.2 The law of one price.....	61

3.2.3 The rise of the Purchasing Power Parity theory.....	61
3.2.4 Variations of the Purchasing Power Parity theory.....	63
3.2.4.1 Absolute Purchasing Power Parity	64
3.2.4.2 Relative Purchasing Power Parity	65
3.2.5 Deviations from the Purchasing Power Parity-generated exchange rate	68
3.2.6 Modifications to Purchasing Power Parity	73
3.2.7 Residual validity of Purchasing Power Parity.....	74
3.2.8 Problems in estimating Purchasing Power Parity	75
3.2.9 Summary	78
3.3 Interest Rate Parity.....	79
3.3.1 Introduction	79
3.3.2.1 The rise of the Interest Rate Parity theory: The Fisher effect.....	81
3.3.2.2 The rise of the Interest Rate Parity theory: The International Fisher effect	84
3.3.3 Covered Interest Rate Parity	85
3.3.4 Testing for Covered Interest Rate Parity	89
3.3.5 Covered Interest Rate Arbitrage.....	92
3.3.6 Uncovered Interest Rate Parity	93
3.3.7 Uncovered Interest Rate Arbitrage	96
3.3.8 Real Interest Rate Parity	97
3.3.9 Transaction costs and the risk premium	101
3.3.10 Summary.....	102
3.4 Chapter summary.....	103
CHAPTER 4: DUAL-LISTED STOCKS AND INVESTMENT THEORY.....	105
4.1 Introduction	105
4.2 The development and purpose of dual-listed stocks	108
4.2.1 Introduction	108
4.2.2 Reasons and purpose of dual-listing	108

4.2.3 Dual-listed stocks on the Johannesburg Stock Exchange and the New York Stock Exchange	110
4.2.3.1 AngloGold Ashanti Limited	110
4.2.3.2 Gold Fields Limited	111
4.2.3.3 Harmony Gold Mining Company Limited	111
4.2.3.4 Sappi Limited	111
4.2.3.5 Sasol Limited	112
4.2.3.6 Telkom SA Limited	112
4.2.4 Reasons for listing on the New York Stock Exchange	112
4.2.4.1 The market segmentations hypothesis	113
4.2.4.2 The liquidity hypothesis for cross-listing	113
4.2.4.3 Changes in the information environment	114
4.2.4.4 The corporate governance and “bonding” hypothesis.....	114
4.2.5 The New York Stock Exchange composition	115
4.3 Introduction to the investor’s basic decision-making process.....	117
4.3.1 Introduction	117
4.3.2 Systematic and unsystematic risk	118
4.3.3 The Markowitz efficient frontier	119
4.4 The single factor model: The Capital Asset Pricing Model	124
4.4.1 Introduction	124
4.4.2 Calculating and interpreting beta	126
4.4.3 The Security Market Line	128
4.4.4 The Capital Market Line	132
4.5 The multi-factor model: The Arbitrage Pricing Theory.....	133
4.5.1 Introduction	133
4.6 Comparing the Arbitrage Pricing Theory to the Capital Asset Pricing Model.....	139
4.6.1 Disadvantages of the Capital Asset Pricing Model	139

4.6.2 Comparison of the Arbitrage Pricing Theory model to the Capital Asset Pricing Model	140
4.6.3 The advantages and disadvantages of the Arbitrage Pricing Theory model	141
4.7 The International Capital Asset Pricing Model	142
4.7.1 Introduction	142
4.7.2 Reasons for the development of the International Capital Asset Pricing Model	143
4.7.3 Past empirical studies of the International Capital Asset Pricing Model	145
4.8 Volatility spillover effect	150
4.8.1 Introduction	150
4.8.2 Different models used in past empirical studies	152
4.9 Chapter summary	155
CHAPTER 5: METHODOLOGY	157
5.1 Introduction	157
5.2 The first approach: Using stationary economic time series data to model the realized future spot exchange rate	160
5.2.1 Introduction	160
5.2.2 Literature review	161
5.2.3 Forward points as an explanatory variable	165
5.2.4 The inflation rate and the interest rate as explanatory variables	166
5.2.5 The interaction of the international financial markets as an explanatory variable	168
5.2.6 The multi-variable model	170
5.3 Generating expectations	172
5.3.1 Introduction	172
5.3.2 The procedure of generating expected values	172
5.3.2.1 Testing for long-memory	173
5.3.2.1.1 The Autoregressive Fractionally Integrated Moving Average model	174
5.3.2.1.2 The interpretation of the Autoregressive Fractionally Integrated Moving Average model results	177

5.3.2.1.3 The exponential weighting procedure and the Exponential Weighted Moving Average model	178
5.3.3 The linear interpolation process	182
5.4 Generating a proxy for the interaction of the financial markets	183
5.4.1 Introduction	183
5.4.2 Generating expected stock returns from stock indices and dual-listed stocks.....	183
5.4.3 Generating the International Capital Asset Pricing Model proxy	184
5.4.4 Generating the Vector Error Correction proxy	185
5.4.4.1 The Augmented Dicky-Fuller unit root test.....	186
5.4.4.2 Co-integration	189
5.4.4.3 Interpreting the output of a Vector Error Correction model.....	194
5.5 The second approach: Using non-stationary economic level data to model the realized future spot exchange rate.....	196
5.5.1 Introduction	196
5.5.2 Implementing the second approach	197
5.6 Forecasting accuracy	199
5.7 The data.....	200
5.8 Chapter summary.....	208
CHAPTER 6: EMPIRICAL RESULTS	211
6.1 Introduction	211
6.2 Estimation of the realized future spot exchange rate from stationary economic time series data.....	212
6.2.1 Introduction	212
6.2.2 The presence of long-memory.....	212
6.2.2.1 Long-memory of the ZAR/USD exchange rate	214
6.2.2.2 Long-memory of the South African and U.S.A. PPI	215
6.2.2.3 Long-memory of the resource indices and the individual resource dual-listed stocks.....	215

6.2.3 The presence of the exchange rate puzzle (forward premium hypothesis)	218
6.2.4 Implementing the methodology of Chiang and Yang (2007)	221
6.2.4.1 Introduction	221
6.2.4.2 Generating expected inflation rates and expected stock returns.....	221
6.2.4.3 The Chiang and Yang (2007) methodology as the preliminary model.....	225
6.2.4.3.1 Inflation rates and interest rates as explanatory variables	225
6.2.4.3.2 Stock returns as an explanatory variable.....	229
6.2.4.3.3 The multi-variable model	230
6.2.5 A re-examination of the components of the Chiang and Yang (2007) methodology	232
6.2.5.1 The co-integration estimation approach	233
6.2.5.2 The Ordinary Least Squares estimation approach.....	238
6.2.5.2.1 The Purchasing Power Parity theory	239
6.2.5.2.2 The Fisher effect	240
6.2.5.2.3 The Covered Interest Rate Parity theory	242
6.2.5.2.4 The Uncovered Interest Rate Parity theory.....	244
6.2.5.2.5 The equity premium hypothesis.....	246
6.2.5.2.6 The improved multi-variable model.....	250
6.3 Estimation of the realized future spot exchange rate from non-stationary economic time series data.....	254
6.3.1 Introduction	254
6.3.2 Modelling non-stationary current level economic data	255
6.3.2.1 Estimation of the Chiang and Yang (2007) methodology.....	255
6.3.2.2 Incorporation of individual non-stationary current level economic fundamentals...	256
6.3.2.3 Providing comprehensive validation	264
6.4 Chapter summary.....	272
CHAPTER 7: CONCLUSION	276
7.1 Introduction	276

7.2 Review of the literature and empirical results	277
7.3 Conclusion and recommendations.....	282
APPENDIX	284
REFERENCES.....	295
LIST OF ACRONYMS	341

LIST OF FIGURES

Figure 1.1	The ZAR/USD exchange rate	3
Figure 1.2	The current ZAR/USD spot and forward exchange rate	4
Figure 2.1	Explaining the exchange rate puzzle	14
Figure 2.2	Different information approaches to pricing stock	23
Figure 2.3	Further explanation of the exchange rate puzzle	56
Figure 3.1	The relationship amongst the four parity conditions and the spot exchange rate ...	60
Figure 3.2	The four parity conditions and the spot exchange rate.....	80
Figure 3.3	The Fisher effect.....	82
Figure 3.4	The Covered Interest Rate Parity.....	85
Figure 3.5	U.S.A. and Australia - variability in interest rates and exchange rates	89
Figure 3.6	U.S.A. and Australia – Twelve-month Covered Interest Rate Parity.....	90
Figure 3.7	The Uncovered Interest Rate Parity.....	94
Figure 4.1	The ADR listing composition of the U.S.A. market in 1990.....	115
Figure 4.2	The ADR listing composition of the U.S.A. market in 2003.....	116
Figure 4.3	Systematic and unsystematic risk.....	119
Figure 4.4	The efficient frontier	120
Figure 4.5	The probability distribution of each efficient portfolio.....	121
Figure 4.6	Trade-off between risk and return of various types of investments.....	129
Figure 4.7	The Security Market Line.....	130
Figure 4.8	The Security Market Line and risk indifference curves.....	130
Figure 4.9	Over- and undervaluation of stock	131
Figure 4.10	The CML assuming borrowing and lending at the risk-free rate	132
Figure 5.1	Composition of the literature study.....	158
Figure 6.1	The relationship between the future premium and the real-interest rate differential.....	228
Figure 6.2	Fitted values of MS-VAR model.....	260

Figure 6.3	Cusum test	261
Figure 6.4	Actual/fitted and residual values	263
Figure 6.5	Normal test of the best model	264
Figure 6.6	Comparison of the actual forward with the realized future spot exchange rate	265
Figure 6.7	Comparison of the theoretical forward with the realized future spot exchange rate	265
Figure 6.8	Actual/fitted and residual values of the fractionally differenced approach.....	272

LIST OF TABLES

Table 2.1	Summary of Asian market studies testing for weak-form efficiency.....	30
Table 4.1	Dual-listed stocks that are listed on the JSE and the NYSE.....	110
Table 4.2	Size and volume of the NYSE and the JSE in 2004.....	116
Table 4.3	Interpretation of various beta values	128
Table 4.4	Macroeconomic variables employed in various APT studies.....	139
Table 4.5	Comparing the APT model and the CAPM.....	140
Table 5.1	Interpreting the d -parameter	177
Table 5.2	Weight split combinations tested.....	181
Table 5.3	Variables tested for a unit root	203
Table 5.4	ADF unit root test for the South African PPI and for the U.S.A. PPI	203
Table 5.5	ADF unit root test for RESI 20 and the NYSE Energy Index.....	204
Table 5.6	ADF unit root test for the South African and U.S.A. resource dual-listed stocks...	205
Table 5.7	Summary of the level of stationarity of the resource dual-listed stocks.....	206
Table 5.8	ADF unit root test for the different spot exchange rates	207
Table 5.9	ADF unit root test for additional exchange rates.....	207
Table 6.1	Variables applicable to the EML method.....	213
Table 6.2	Interpreting the d -parameter	214
Table 6.3	EML-estimation for the ZAR/USD exchange rate	214
Table 6.4	EML-estimation for PPI	215
Table 6.5	EML-estimation for RESI 20 and NYSE Energy Index	216
Table 6.6	EML-estimations for South African and U.S.A. dual-listed stocks.....	216
Table 6.7	Combined results from testing for stationarity and long-memory.....	217
Table 6.8	Breusch-Godfrey Serial Correlation LM test between AngloGold Ashanti and Gold Fields Limited	218
Table 6.8	The forward premium hypothesis (OLS).....	219
Table 6.9	The second forward premium hypothesis (OLS)	220

Table 6.10	Generating the best historical $(t + 1)b$ series for the South African PPI and for the U.S.A. PPI	222
Table 6.11	Generating the best 1-month-ahead inflation expectation series $(t + 1)$ for the South African PPI	222
Table 6.12	Generating the best 1-month-ahead inflation expectation series $(t + 1)$ for the U.S.A. PPI	222
Table 6.13	Generating the best historical $(t + 1)b$ series for the South African dual-listed stocks	223
Table 6.14	Generating the best historical $(t + 1)b$ series for the U.S.A. dual-listed stocks.....	224
Table 6.15	Generating the best 1-month-ahead expectation series $(t + 1)$ for individual South African dual-listed stocks and U.S.A. dual-listed stocks	225
Table 6.16	The inflation rate and the interest rate as explanatory variables (OLS)	226
Table 6.17	Long-short spread (OLS)	227
Table 6.18	Improved model on interest rates and inflation rates (OLS)	228
Table 6.19	AngloGold Ashanti stock returns as an explanatory variable (OLS)	229
Table 6.20	Sappi Limited stock returns as an explanatory variable (OLS)	230
Table 6.21	The multi-variable model (OLS)	232
Table 6.22	The <i>ex post</i> PPP theory (Tr statistic).....	235
Table 6.23	The <i>ex post</i> PPP theory (L-max statistic)	236
Table 6.24	The short-run Fisher effect (Tr statistic)	236
Table 6.25	The short-run Fisher effect (L-max statistic).....	236
Table 6.26	The long-run Fisher effect (Tr statistic)	236
Table 6.27	The long-run Fisher effect (L-max statistic).....	236
Table 6.28	The short-run Covered Interest Rate Parity theory (Tr statistic)	236
Table 6.29	The short-run Covered Interest Rate Parity theory (L-max statistic)	236
Table 6.30	The long-run Covered Interest Rate Parity theory (Tr statistic).....	237
Table 6.31	The long-run Covered Interest Rate Parity theory (L-max statistic)	237
Table 6.32	The short-run Uncovered Interest Rate Parity theory (Tr statistic).....	237

Table 6.33 The short-run Uncovered Interest Rate Parity theory (L-max statistic)	237
Table 6.34 The long-run Uncovered Interest Rate Parity theory (Tr statistic)	237
Table 6.35 The long-run Uncovered Interest Rate Parity theory (L-max statistic)	237
Table 6.36 The equity premium hypothesis – AngloGold Ashanti (Tr statistic)	237
Table 6.37 The equity premium hypothesis – AngloGold Ashanti (L-max statistic)	238
Table 6.38 The equity premium hypothesis – Sappi Limited (Tr statistic)	238
Table 6.39 The equity premium hypothesis – Sappi Limited (L-max statistic)	238
Table 6.40 The <i>ex post</i> PPP theory	239
Table 6.41 The PPP theory	239
Table 6.42 The <i>ex ante</i> PPP theory	240
Table 6.43 The short-run Fisher effect (expected inflation)	241
Table 6.44 The short-run Fisher effect (actual inflation)	241
Table 6.45 The long-run Fisher effect (expected inflation)	242
Table 6.46 The long-run Fisher effect (actual inflation)	242
Table 6.47 The short-run Covered Interest Rate Parity theory	243
Table 6.48 The adjusted short-run Covered Interest Rate Parity theory	243
Table 6.49 The long-run Covered Interest Rate Parity theory	244
Table 6.50 The short-run Uncovered Interest Rate Parity theory	244
Table 6.51 The long-run Uncovered Interest Rate Parity theory	245
Table 6.52 The adjusted Uncovered Interest Rate Parity theory	246
Table 6.53 The AngloGold Ashanti stock return differential	248
Table 6.54 The Sappi Limited stock return differential	248
Table 6.55 The AngloGold Ashanti ICAPM	248
Table 6.56 The Sappi Limited ICAPM	249
Table 6.57 The AngloGold Ashanti speed of adjustment series	249
Table 6.58 The Sappi Limited speed of adjustment series	249
Table 6.59 Improved multi-variable model	251
Table 6.60 Improved multi-variable model with AngloGold Ashanti principal component	252

Table 6.61 Improved Chiang and Yang (2007) model.....	253
Table 6.62 Estimation of the Chiang and Yang (2007) methodoogy with level format (OLS).....	256
Table 6.63 ARCH(1,0) estimation in level format.....	258
Table 6.64 Adjusted ARCH(1,0) estimation in level format	259
Table 6.65 Best ARCH(1,0) estimation in level format.....	262
Table 6.66 The forward premium hypothesis – fractionally differenced approach (OLS).....	267
Table 6.67 The ARCH(1,0) multi-variable model – fractionally differenced approach.....	268
Table 6.68 The ARCH(1,0) comparison for level format – fractionally differenced approach..	269
Table 6.69 The ARCH(1,0) comparison with a dummy – fractionally differenced approach ...	271

CHAPTER 1

Introduction

1.1 THE SOUTH AFRICAN EXCHANGE RATE

Each country's exchange rate¹ mirrors the decision-making process of investors, traders, speculators and policy-makers, directed by the economic fundamentals, policy measures, and international economic shocks (Van Bergen, 2004:1). Most countries followed a fixed exchange rate before the First World War, in the form of an international gold standard, where countries tied their currencies to the value of gold and allowed unrestricted exports and imports of gold (Melvin, 2000:43-44). After the Second World War, the Bretton Woods System of fixed exchange rates was used for two decades (Van der Merwe, 2003:1). During the 1960s large deficits in the balance of payments of countries increased the pressure against the Bretton Woods System and it was finally abandoned in 1973. Countries were forced to find an alternative way of restructuring their monetary policies and exchange rate regimes (Van der Merwe, 2003:1-2). South Africa's exchange rate regime and monetary policy measures went through the following phases (Van der Merwe, 2003:2-3):

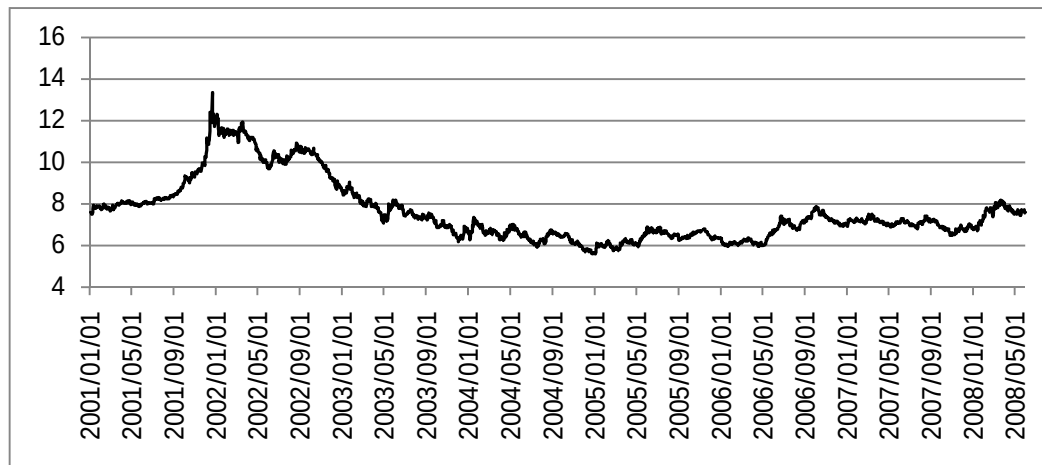
- During the 1970s an attempt was made to maintain a stable exchange rate while following a direct monetary control approach;
- During the 1980s the adoption of money supply targets and changing to more market-orientated measures were pursued;
- During the 1990s informal inflation targeting and a managed floating exchange rate were followed; and
- From the year 2000 a floating exchange rate regime and a formal inflation-targeting monetary policy were implemented.

¹ An exchange rate can be defined as the price of the national currency that is valued against the demand and supply of a foreign currency (King, 2005:4-5).

The value of the South African Rand (ZAR) still experienced extensive swings under the freely floating exchange rate regime. The ZAR experienced significant shocks during 1970-1995 owing to political events and gold price movements, which led to intensified sanctions and capital outflows. The introduction of the Financial Rand System in September 1985 attempted to limit these capital outflows from South Africa. However, the abolishment of the Financial Rand System in 1995 relaxed the exchange control over non-South African residents and on capital outflows, thus escalating the volatility of the South African exchange rate. The ZAR, as an emerging economy currency, was also vulnerable to fluctuations that were caused by the Asian crisis (1997), the Russian crisis (1998), the Brazilian crisis (1999), the Argentinean crisis (2001/2002), and the preliminary shocks of the financial crisis (2007/2008). An example of these large fluctuations is that during 2000 the nominal effective exchange rate decreased by 12.5% and decreased even further in 2001 with 34.5%. However, during 2002 the nominal effective exchange rate increased by 26% and again by 19% in the first quarter of 2003 (Van der Merwe, 2003:35). The recovery of the ZAR in 2002 and the first four months of 2003 was the first in 30 years, where the normal downwards tendency of the ZAR were broken. This recovery could be related to the macroeconomic policies followed at that time (Van der Merwe, 2003:36). The ZAR continued to fluctuate, to a large extent between the R5/USD²1 and the R8/USD1 mark until the end of August 2008. Figure 1.1 illustrates this volatility with the value of the ZAR against the USD, fluctuating between R5 and R13 for one USD.

This continuous fluctuation of the ZAR/USD exchange rate increases the difficulty of the decision-making process of investors, speculators, traders, and policy-makers. However, the estimation of the future direction of the exchange rate movements is still a necessity in daily decision-making processes, but exchange rate modeling still seems to be a taxing cumbersome process with little reward. The following section will briefly elaborate the current method of estimating future exchange rates.

² The notation for the United States Dollar is USD.

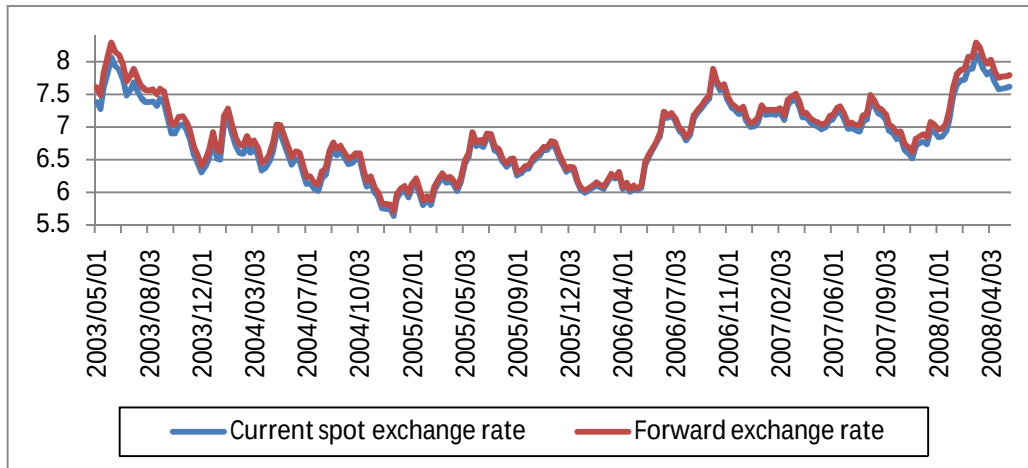
Figure 1.1: The ZAR/USD exchange rate

Source: Data from the McGregor BFA database.

1.2 ESTIMATING FUTURE EXCHANGE RATE MOVEMENTS

Investors make use of the daily quoted forward points in the foreign exchange (FX) market to decide whether they want to hedge either payments to international creditors, or receipts from foreign proceeds against negative fluctuations in the exchange rate. Market participants, needing an indicator to assist with the estimation of the expected future exchange rates, look at the forward exchange rate as an indicator of market expectations. In other words, the forward points are being used to help determine what the future exchange rate would be for a certain period. These forward exchange rates are then used in present transactions and decision-making processes.

Figure 1.2 demonstrates that, although there is a similar trend in the two times series, there is a large difference between the forward ZAR/USD exchange rate, as quoted in the market, and the actual spot exchange rate that **realizes on the date that the forward transaction matures**. This fact was also emphasised, amongst 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 1.2: The current ZAR/USD spot and forward exchange rate

Source: Data from the McGregor BFA database.

Figure 1.2 illustrates that the forward exchange rate follows the same trend of the **current spot exchange rate**, except for the small difference that mainly consists of the carry cost of the transaction. The reason is that the current method, used by South African banks, to quote a forward exchange rate, is a mechanistic approach. This is a fact that appears not to be widely known or recognised, especially by academics. The importance of this fact will be a focus point of the exposition of this thesis. The equation used to derive a quote for the forward exchange rate is given as follows (Van Zyl *et al.*, 2009:369-370):

$$\text{Forward exchange rate} = \text{spot exchange rate} \times \frac{1 + \left(\frac{\text{interest rate}_{\text{quoted currency}} \times \text{day count}}{\text{annual basis}_{\text{quoted currency}}} \right)}{1 + \left(\frac{\text{interest rate}_{\text{base currency}} \times \text{day count}}{\text{annual base}_{\text{base currency}}} \right)} \quad (1.1)$$

In the numerator of Equation 1.1, the short-run nominal South African interest rate is used, which is then multiplied with 365 (day count) and divided by 365 (South African annual basis). In the denominator of Equation 1.1 use the short-run nominal United States of America (U.S.A.) interest rate, which is then multiplied with 365 (day count) and divided by 360 (U.S.A. annual basis). Equation 1.1 and banks, therefore, assume that the short-run Fisher effect holds for both developed countries (U.S.A.) and for developing countries (South Africa).

To summarise this opening statement, 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. However, not many of these studies, mainly theoretical, took into consideration 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 explanatory power of the economic fundamentals to explain the forward exchange rate or the foreign exchange rate premium³ on the date that the forward exchange rate contract matured, without mentioning the mechanistic price formulation methodology, used in the FX markets. Examples of these studies include the study of Ott and Veugelers (1986:10-14) who stated that the forward exchange, which 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 of Korajczyk (1985:357) found that the foreign exchange rate premium can be explained by real interest rates.

Huang (1990:349) found that the Purchasing Power Parity (PPP)⁴ (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 became the standard starting point for the formulation of 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 premiums⁵. Agmon (1972:849) stated that there is a co-movement between the stock markets of some industrial countries. Evidence was also found that exchange rate excess returns⁶ are correlated to

³ The foreign exchange rate premium is the difference between the forward exchange rate and the realized future spot exchange rate.

⁴ Any good that is traded on the world market will sell at the same price when the prices are expressed in a common currency (Pakko & Pollard, 2003:9).

⁵ The difference between the stock returns generated from two individual stocks that are listed on two financial markets.

⁶ The returns above the market risk-free rate.

the stock^{7,8} volatility and currency markets (Jiang & Chiang, 2000:102-103), which implies that dual-listed stocks' returns may incorporate the volatility between two exchanges, and 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. These price differences may provide additional information regarding the future movement of the spot exchange rate, and may improve the ability to incorporate market expectations into an exchange rate model.

Both micro-⁹ and macroeconomic-based¹⁰ 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 dismal¹¹. This is a serious problem in the FX market, where the current forward exchange rate is used as the only guideline, which is unsuitable as an indicator of future exchange rate movements. The study of 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 unpredictable”. This weak ability of the forward exchange rate, quoted by the market some weeks or months ago, to explain the realized spot exchange will be termed the exchange rate puzzle¹².

Integral to this issue of the exchange rate puzzle is the methodology used in the econometric modelling and data analysis of the exchange rate puzzle. Current exchange rate modelling is wrongly based on the condition that all data must be stationary. Failing to comply with this

⁷ Note that this study will refer to the word stocks, although in South Africa it is called shares.

⁸ This study will use common stocks, which are also known as equities. Common stocks can be defined as ownership shares in a publicly held corporation (Bodie *et al.*, 2010:36).

⁹ For more on microeconomic-based models see Lyons (2001), Lyons (2002), and Sarno and Taylor (2001).

¹⁰ For more on macroeconomic-based models see Obstfeld and Rogoff (1995), Obstfeld and Rogoff (2000), and Chiang and Yang (2007).

¹¹ For example Korajczyk (1985).

¹² See Obstfeld and Rogoff (2000) and Bacchetta and Van Wincoop (2004) for further research.

condition will result in spurious regression results¹³, statistically insignificant estimations and nonsensical parameter signs. Evidence from the study of Ventosa-Santaulària (2009:16) illustrated that by differencing a series (making it stationary) may not always prevent spurious results. The studies by Phillips (1998) and Ventosa-Santaulària (2009) also argued that non-stationary, level data can be used in exchange rate modelling, without the 'fear' of spurious results, provided that the correct econometric techniques are used.

1.3 PROBLEM STATEMENT

The primary research question, posed in this investigation, is: In light of the possible mechanistic determination of the forward exchange rate, can current (time t) economic fundamentals¹⁴ explain the realized future spot exchange rate (time $t + i$)? To put it differently, can an exchange rate model be developed, from only economic fundamentals, which 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, research question, poised in this study, is whether the exchange rate puzzle is a pseudo¹⁵ fallacy caused by the rigorous, unyielding practice of exclusively using stationary time series in the investigations into this 'puzzle'.

1.4 RESEARCH OBJECTIVES OF THE THESIS

The primary research objective of this thesis is to develop an exchange rate model, using current (time t) time series of economic fundamentals, in an effort to establish a theoretical forward exchange rate that reflects the realized future (time $t + i$) spot exchange to such an extent that market participants will take note of it. The latter resulting in exchange rate expectations that will enter the market as supply and demand forces that will cause the

¹³ Spurious regression results are results that are meaningless, non-sense, and can be misleading (Gujarati, 2003:806).

¹⁴ The economic fundamentals identified in this study entail fundamentals from the goods market and from the financial market, which also form part of the partial equilibrium approach, as mentioned in Section 3.1.

¹⁵ The word pseudo implies that it is an imitation, a fake problem.

mechanistic methodology to be augmented by the significant presence of arbitrage in the formation of the forward exchange rate.

The secondary research objective of this study is to investigate the importance of using (time t) non-stationary, level¹⁶ time series of economic fundamentals to estimate a theoretical value of the forward exchange rate that will reflect the realized future spot exchange rate to such a level of significance that the market participants will use it, resulting in supply and demand to enter the forward exchange market, causing arbitrage to induce a more market related forward exchange rate being quoted. The use of non-stationary, level time series data will, therefore, undermine the rigorous, unyielding practice of exclusively using stationary time series to determine if the exchange rate puzzle is a pseudo fallacy.

This study will also examine the use of alternative approaches^{17,18} of incorporating the interactions of the international financial markets into an exchange rate model as an additional economic fundamental to explain the realized future spot exchange rate. These alternative approaches, which include the use of price differences of dual-listed stocks, entail the ability to incorporate market expectations more effectively. A comprehensive literature review (discussed in Chapter 2) could not locate a published scientific report on the relationship between South-African dual-listed stocks' prices, quoted in USD on the New York Stock Exchange (NYSE) and in ZAR on the Johannesburg Stock Exchange (JSE), and the ZAR/USD exchange rate.

1.5 MOTIVATION

The magnitude of import and export sensitivity to exchange rate movements has an influential effect on policy changes, exogenous shocks, and on the level of national welfare in South Africa (Lawrence & Van der Westhuizen, 1990:318). To be able to estimate the direction of the

¹⁶ This implies that the data is in its original, unadjusted format, before unit root processes are applied.

¹⁷ These alternative approaches will be discussed in Section 5.4.

¹⁸ One of these approaches includes the introduction of an alternative approach for generating stock return and inflation rate expectations. This alternative approach applies the Exponential Weighted Moving Average (EWMA) model to generate expectations and will be discussed in Section 5.3.

realized future spot exchange rate is of paramount importance for importers and exporters alike. It determines their appetite for currency risk and thus for forward exchange rate agreements that will hedge them against unfavorable movements in the exchange rate. The inability to effectively hedge against unfavorable exchange rate movements is one of the key inhibiting factors of international trade. The determination of a theoretical forward exchange rate, determined by market forces, is of paramount importance. This theoretical forward exchange rate will introduce arbitrage to the forward FX market, causing the dissipation of the so-called exchange rate puzzle.

1.6 CONTRIBUTION

This study makes ground-breaking inroads into an acute economic problem that persists for decades, known as the exchange rate puzzle¹⁹. The main contribution of this study resides in the dynamics of exchange rate modeling and addressing the revelation that the exchange rate puzzle may be a pseudo problem. With the focus on the development -of an empirical theoretical forward exchange rate, that statistically significantly estimates the realized futures spot exchange rate to such an extent that market participants are compelled to use it in the process of acquiring forward exchange cover for the proceeds of international trade, which will have a significant impact on market participant's future actions in the FX market.

This study will prove that the rigorous, unyielding practice of exclusively using stationary time series in exchange rate modelling is the reason why the exchange rate puzzle is a pseudo problem. This study will also introduce an alternative approach of incorporating the interaction of the international financial markets into an exchange rate model as an additional economic fundamental to explain the realized future spot exchange rate. One of these approaches also includes the introduction of an alternative approach of generating stock return and inflation expectations. This approach has the ability to incorporate both historical expectations and future (uncertainty) expectations into a 1-month ahead, presently, expected stock

¹⁹ The exchange rate puzzle will be discussed in Section 2.3.

return/inflation rate series.

1.7 CHAPTER LAYOUT

1.7.1 Chapter 2: Exchange rate puzzle

This chapter will commence by elaborating on the past academic perspective of the exchange rate puzzle, which ignored the fact that the forward exchange rate is a mechanistic estimation of the realized future spot exchange rate. The exchange rate puzzle can be divided into four smaller individual puzzles, which included the determination puzzle, the excess volatility puzzle, the forward exchange rate premium puzzle, and the home bias puzzle. These individual puzzles claimed to be only a partial explanation of the foreign exchange rate premium. Also, in an attempt to resolve the foreign exchange rate premium this chapter will briefly discuss the explanatory economic fundamentals that were identified by past literature studies to be eligible in explaining the foreign exchange rate premium. This literature study also leads to the identification of the basic paramount fundamentals needed to develop a theoretical forward exchange rate, which will be able to explain the realized future spot exchange rate with greater significance.

1.7.2 Chapter 3: The Purchase Power Parity and Interest Rate Parity theories

This chapter will focus on the examination of the economic fundamentals that are identified in the previous chapter, which consist of the basic indicators required to determine exchange rate movements. These indicators included the relationship between the inflation rate differential and the exchange rate, which is known as the PPP theory, and the relationship between the interest rate and the exchange rate, which is known as the Interest Rate Parity (IRP) theory. This will consist out of the Fisher effect (Section 3.3.2.1), the International Fisher effect (Section 3.3.2.2), and the Covered-(Section 3.3.3) and Uncovered Interest Rate Parity (Section 3.3.6) theories.

1.7.3 Chapter 4: Dual-listed stocks and investment theory

This chapter will continue to investigate the dominant explanatory economic fundamentals that may solve the exchange rate puzzle. This chapter will introduce the equity premium (Section 2.3.4.2.5) and the purpose of using dual-listed stocks (Section 4.2) to incorporate the interaction of two international financial markets into an exchange rate model. The relationship between the international financial markets and the exchange rate will be discussed in the form of the International Capital Asset Pricing Model (ICAPM; Section 4.7).

1.7.4 Chapter 5: Methodology

This chapter will explain the development of a preliminary exchange rate model, based on past literature studies, that explained the foreign exchange rate premium. The Chiang and Yang (2007) methodology was recognised as the best preliminary exchange rate model, which still ignored the mechanistic estimated forward exchange rate. To improve on this model two approaches are followed, which included the use of current (time t) stationary time series data (Section 5.2) that was compared to the alternative approach that used current (time t) non-stationary, level time series data (Section 5.5). This chapter will also examine alternative approaches of incorporating the interaction of international financial markets into an exchange rate model (Section 5.4) and an alternative approach of estimating expected values, which entails the use of an exponential weighting procedure and an Exponential Weighted Moving Average (EWMA) model (Section 5.3.2.1.3). The EWMA model has the ability to incorporate both historical expectations and future (uncertainty) expectations into a 1-month ahead, presently, expected inflation rate/stock return series.

1.7.5 Chapter 6: Empirical results

Note that detailed interpretations of the coefficients of all the models are not provided until the best exchange rate model is determined. Only with the best exchange rate model can comprehensive interpretations be ensured. This chapter will report that there was an exchange rate puzzle present in the ZAR/USD exchange rate, which implied the need of performing an

empirical investigation into the explanatory capabilities of each of the paramount economic fundamentals identified in the previous literature chapters. The empirical results indicate that the first approach, using first differenced time series data, was unsuccessful in explaining the exchange rate puzzle, which was partly due to the mechanistic quoted forward exchange rate and the use of composite variables. Using fractionally differenced time series data, as an alternative stationary approach, provides an increased explanatory ability of the ZAR/USD realized future spot exchange rate, emphasising the importance of recognising the order of integration when examining exchange rate theories. Evidence indicated the possibility that the order of integration can have an implication on the explanatory abilities of an exchange rate model. However, by estimating an exchange rate model with non-stationary, level time series data it will be demonstrated that the current (time t) economic fundamentals were able to explain up to 80% of the ZAR/USD realized future spot exchange rate (time $t + i$). This is an important discovery that can add a tremendous amount of value to all participants in the FX market. It can cause supply and demand, via arbitrage, to cause the forward exchange rate, quoted by banks, to more accurately predict/reflect the actual exchange rate, which will realize on the date when the forward exchange cover matures. Thus the exchange rate puzzle has in fact been solved and it will be shown that the rigorous approach of using stationary data to model the exchange rate puzzle led to a pseudo problem.

1.7.6 Chapter 7: Conclusion

This chapter will conclude the study by reconciling the problem statement and the final results to form a logical conclusion to this study. Items for further future studies are also identified.

CHAPTER 2

The Exchange Rate Puzzle

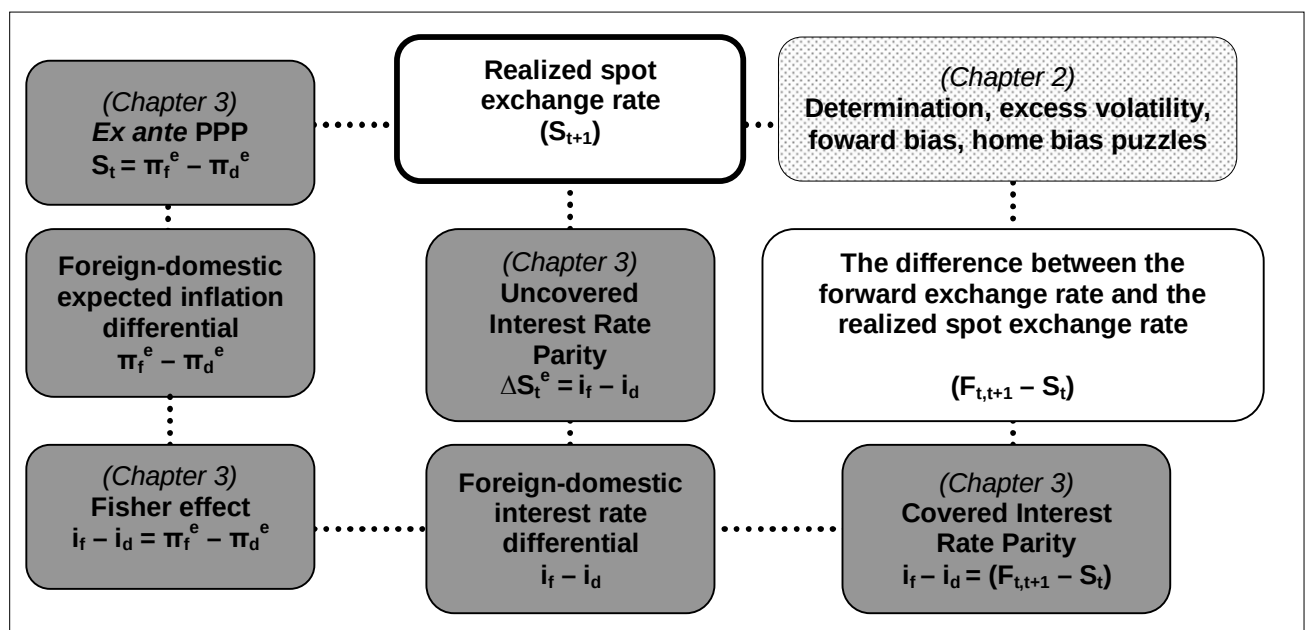
2.1 INTRODUCTION

This study's point of departure is to investigate the core features of exchange rate dynamics. Before an exchange rate model can be constructed, the basis for the construction of such a model must first be established. Exchange rate models are often used to estimate future exchange rate changes. This information is particularly useful for international trade participants (importers and exporters), as well as investors who hold assets in foreign countries. Although these market participants have a variety of tools at their disposal for hedging themselves against exchange rate fluctuations, these hedging activities are usually expensive and sometimes unnecessary. Since exchange rates play an important role in the level of wealth accumulation of the investor's portfolio, it is important to create or select a model that illuminates the workings of exchange rate movements. **This chapter's objectives are to set out the reasons why it is so difficult to predict the future exchange rate accurately and why the current measures used to predict the future exchange rate is inefficient, which also include the solving of the pseudo problem.** The possible factors that prevent these measures of accurately predicting the future exchange rate are covered.

Forward points is currently employed as a measure to estimate the future exchange rate. As stated in the previous chapter (Section 1.2), there is a difference between the forward exchange rate, which is presently estimated using forward points, and the realized future spot exchange rate. Albuquerque (2008:461) emphasises this by stating that the forward exchange rate is a biased estimate of the realized future spot exchange rate. For the remainder of this thesis, this phenomenon will be referred to as the exchange rate puzzle. In order to solve this puzzle, the following questions must be answered: why do the forward exchange rate and the realized future spot exchange rate differ; and what prevents forward points from being an efficient

measure for predicting the future exchange rate? This chapter will discuss the possible causes of the exchange rate puzzle, as evident in the literature. This chapter will commence by briefly describing some of the first exchange rate models that were developed in an attempt to understand the expected exchange rate movements (Section 2.2). Although these models contributed to a better understanding of exchange rate movements, they were unable to explain market expectations. **This chapter's objective is thus to address this deficiency by discussing the exchange rate puzzle as an explanation for market expectations and the starting point to resolve the pseudo problem, as the main contribution of this study.** The exchange rate puzzle can be explained as four different approaches or four individual puzzles (the dotted block in Figure 2.1), which include the determination puzzle (Section 2.3.2), the excess volatility puzzle (Section 2.3.3), the forward bias puzzle (Section 2.3.4), and the home bias puzzle (Section 2.3.5). This chapter will then continue by means of a discussion on the equilibrium exchange rate and exchange rate misalignment (Section 2.4), as an additional problem due to the exchange rate puzzle.

Figure 2.1: Explaining the exchange rate puzzle



Source: Rosenberg (2003:113).

After establishing the reasons for the exchange rate puzzle, in other words the four individual puzzles, this thesis will continue with a discussion of the most basic variables that must be included in an exchange rate model in order to enhance the estimation of forward points and thus predict the future spot exchange rate more accurately (as indicated by the dark coloured blocks in Figure 2.1). Chapter 3 will start with a discussion of inflation (PPP) in Section 3.2 and interest rates (Fisher effect and the Interest Rate Parity theory) in Section 3.3, as the first variables to be included in the exchange rate model. Chapter 4 will then discuss the final variables that must be included in the exchange rate model, which includes the interaction of the international financial markets.

2.2 EXCHANGE RATE MODELS

2.2.1 Introduction

Both micro- and macroeconomic-based exchange rate models have been developed in an attempt to explain the relationship between the current and the expected future exchange rate (Bailliu & King, 2005:3). The following section will briefly describe the development of these models.

2.2.1.1 The monetary approach towards explaining the expected exchange rate

This approach emerged in the 1970s during the period where countries began to follow free floating or managed floating exchange rate regimes. This approach perceives the exchange rate as the relative price of two currencies and models this relative price in terms of the relative demand for and the relative supply of these different currencies (King, 2005:4–5). In other words, it determines a certain exchange rate level at which the demand for and supply of a currency is equal (Hoontrakul, 1999:2). This approach makes the following assumptions (King, 2005:5):

- Domestic and foreign assets are perfect substitutes;
- Prices are perfectly flexible;
- The Uncovered Interest Rate Parity (Section 3.3.6) condition holds at all times; and
- The absolute PPP (Section 3.2.4.1) holds at all times.

The models discussed from Sections 2.2.1.1.1 to 2.2.1.1.5 are all extensions of the monetary approach to explaining expected exchange rates. These models include the Mundell-Fleming model (Section 2.2.1.1.1), the sticky-price monetary model (Section 2.2.1.1.2), the flexible-price monetary model (Section 2.2.1.1.3), the equilibrium models (Section 2.2.1.1.4), and the portfolio-balance models (Section 2.2.1.1.5).

2.2.1.1.1 The Mundell-Fleming model

The original model originated with the assumption of static expectations and fixed prices (Sarno & Taylor, 2002:99). This model considers the money market, the asset market and the goods market under perfect price flexibility over the long-run (Hoontrakul, 1999:2). The Mundell-Fleming model adds a balance of payment equilibrium condition to the Investment Savings/Liquidity preference Money supply (IS-LM) model, thereby extending the closed economy framework (Parke, 2008:1). This model allows the interaction between exchange rate policy and monetary policy, and underlines the differences between floating exchange rates and fixed exchange rates (Parke, 2008:1). The assumption of fixed prices was also replaced by sticky-prices with the sticky-price²⁰ monetary model or the overshooting model (Sarno & Taylor, 2002:104), which will be discussed next.

2.2.1.1.2 The sticky-price monetary model

The sticky-price version of the monetary model, which was developed by Dornbusch (1976:1161–1162), holds a more relaxed assumption of that held by PPP (Section 3.2).

²⁰ Sticky-prices imply prices that adjust slowly.

The sticky-price model allows for the short-term overshooting of the real and nominal exchange rates above the long-term equilibrium levels (Sarno & Taylor, 2002:104). In the sticky-price model, the PPP theory (Section 3.2) holds only in the long-run. Factors such as interest rates and exchange rates, also termed jump variables, compensate for the ability to overshoot the long-run exchange rate equilibrium and for the stickiness in prices (King, 2005:5).

2.2.1.1.3 The flexible-price monetary model

In the flexible-price monetary model, the economic output is at the equilibrium level. However, in this model, in contrast with the sticky-price model, prices are flexible and adjust almost instantly in response to excess demand (Sarno & Taylor, 2002:108). In this model, the domestic interest rate is exogenous over the long-run and is determined by world markets because of the assumption of perfect capital mobility. The PPP theory (Section 3.2) is assumed to hold at all times and increased simplification is achieved by making the assumptions that interest rates are semi-elastic to money and that income elasticity is the same for both foreign and domestic countries (Sarno & Taylor, 2002:109). However, the problem with this model is that it relies on a large number of assumptions. The model also concentrates only on the equilibrium conditions of the money market, thereby making open-economy macroeconomic models more attractive, as the focus of open-economy macroeconomic models is extended to six markets. These six markets are the labour market, FX market, goods market, money market, foreign bonds market and domestic bonds markets (Sarno & Taylor, 2002:110).

2.2.1.1.4 New open-economy macroeconomic models

This exchange rate model emerged in the 1980s and was formalised to determine exchange rates in the context of general equilibrium models with nominal rigidities, microeconomic foundations and imperfect competition (King, 2005:5). These models are also referred to as the equilibrium models and are an extension of the flexible-price model (King, 2005:5). The current new open-economy macroeconomic models are based on the work of Obstfeld and Rogoff (1995). The new open-economy macroeconomic models differ from the Mundell-Fleming model

as follows: firstly, all agents optimise, in other words, firms' value and households' utility are maximised; and secondly, new open-economy macroeconomic models help to advance globalisation of world economies by closing the gap between trade theory and open macroeconomics (Corsetti, 2007:1). A disadvantage of current new open-economy macroeconomic models is that they are sensitive to the particular specification of microeconomic foundation (King, 2005:5). This may be problematic because no consensus has been reached as to which specification of microeconomic foundation is acceptable (Sarno, 2001:33).

Including productivity differentials in an exchange rate model, as an extension of a microeconomic foundation, can help to improve the explanation of real exchange rate movements. Real exchange rates are nominal bilateral exchange rates of two different countries, which are adjusted by relative prices of goods of those countries (King, 2005:5). Exchange rate models derived from this approach are based on work by Samuelson (1964) and Balassa (1964), who derived the Balassa-Samuelson hypothesis. This hypothesis relaxes the assumption that the PPP theory holds at all times. In the use of the Balassa-Samuelson hypothesis the real exchange rate depends on the relative price of non-tradables (King, 2005:5).

2.2.1.1.5 The portfolio-balance model

The portfolio-balance model was developed by Branson and Henderson (1985). According to the portfolio-balance model, foreign and domestic assets are no longer perfect substitutes. This implies that a currency-risk premium is imposed on the Uncovered Interest Rate Parity condition (Section 3.3.6). The exchange rate is, therefore, no longer determined by the supply and demand for money but by all domestic and foreign assets (King, 2005:5). In addition, the assumption that wealth effects on current account imbalances are insignificantly small is also relaxed. Furthermore, the portfolio-balance model is based on the interaction amongst the current account balance, the rate of asset accumulation, and the asset. Thereby enabling it to distinguish amongst flow equilibrium or short-run equilibrium, stock equilibrium, and the active

adjustments to long-run equilibrium (Sarno & Taylor, 2002:115).

In order to solve the shortcomings proposed by the available exchange rate models, Lyons (2001:168) proposed the following microeconomic approaches to be used to determine the exchange rate: the goods market approach, the asset market approach, and the microeconomic structure approach. However, using macroeconomic fundamentals to determine exchange rate movements has been unsuccessful in the past. Obstfeld and Rogoff (2000:40–41) found that there is a weak relationship between macroeconomic variables and the exchange rate, which is termed the exchange rate disconnect puzzle or the determination puzzle. In support of this finding, Meese and Rogoff (1983:12–17) proved that no existing structural model can outperform the random walk model. The traditional models used to explain exchange rate movements are unable to explain the exchange rate puzzle and thus market expectations. This leads to the following section, which will describe the four different approaches/puzzles in order to clarify the reason that the forward exchange rate differs from the realized spot exchange rate.

2.3 EXCHANGE RATE PUZZLE

2.3.1 Introduction

Before the exchange rate can be solved an understanding of what the exchange rate puzzle entails must be understood. The exchange rate puzzle can be divided into four individual exchange rate puzzles: the determination puzzle (Section 2.3.2), the excess volatility puzzle (Section 2.3.3), the forward bias puzzle (Section 2.3.4) and the home bias puzzle (Section 2.3.5). Each individual puzzle will contribute to understanding the exchange rate puzzle, in other words, the reason that the forward exchange rate differs from the realized spot exchange rate. In the determination puzzle, the dispersed information approach that links these four individual puzzles are discussed. The information approach utilises the fundamentals of expectation formation, forecasting and the use of information in the financial markets.

2.3.2 The determination puzzle

Meese and Rogoff (1983:12–17) found that a random walk has the ability to forecast exchange rates better than models that include macroeconomic fundamentals. These poor explanatory powers of macroeconomic fundamentals are termed the exchange rate determination puzzle (Lyons, 2001:171–172). Frankel and Rose (1995:704) state that: “[...] no model based on such standard fundamentals like money supplies, real income, interest rates, inflation rates, and current account balances will ever succeed in explaining or predicting a high percentage of the variation in the exchange rate, at least at short- or medium-term frequencies”. Similarly, Mark (1995:213) found that the explanatory powers of macroeconomic fundamentals are poor over the long-run, but are more suitable over a time horizon of two to four years.

According to Flood and Rose (1995:36), nominal exchange rates are more volatile than macroeconomic fundamentals, which suggest that macroeconomic fundamentals are unlikely to increase the ability to forecast or explain the future nominal exchange rate accurately (King, 2005:8). Despite the inability of macroeconomic variables to forecast nominal exchange rates, speculative bubbles and irrationality may still serve as possible determinants of exchange rate movements (Lyons, 2002:55). A speculative bubble is a non-fundamental component of an asset's price and causes prices to rise rapidly, causing investors to buy even though the bubble may burst at any moment (Lyons, 2002:55).²¹ However, Flood and Hodrick (1990:99) found no evidence to support the notion of speculative bubbles as a determinant of exchange rate movements. Irrationality refers to avoidable expectation errors; thus, it may give a partial explanation of exchange rate fluctuations (Dominguez, 1986:278–281). Another reason for these exchange rate fluctuations is the gap between non-rational behaviour and the determination of exchange rates (Lyons, 2001:173).

Meese (1990:130) elaborates that variables omitted from asset market models offer a possible explanation for exchange rate fluctuations. To this end, “empirical researchers have shown

²¹ For more on speculative bubbles, see Meese (1986).

considerable imagination in their specification searches, so it is not easy to think of variables that have escaped consideration in an exchange rate equation". Evans and Lyons (2002:171) proposed microeconomic theory as a possible solution for omitted macroeconomic variables. They postulate that microeconomic theory may provide better out-of-sample forecasts than a random walk. King (2005:9) agrees and argues that microeconomic models have the potential to explain short-term dynamics in exchange rates and may provide better forecasts of macroeconomic variables and, therefore, better forecasts of overall economic activities. Furthermore, Bacchetta and Van Wincoop (2006:552) state that the microeconomic-structured approach suggests that heterogeneity of investors may explain fluctuations in the exchange rate. To this end, Lyons (2002:55) suggested order flow be included as an additional variable in determining the future exchange rate. Further evidence also suggested that short-run exchange rate volatility is related to order flow, which is associated with investor heterogeneity (Evans & Lyons, 2002:178–179).

Order flow is the transaction volume that is signed by a (+) if bought or by a (-) if sold (Lyons, 2002:52). The exchange rate determination models, which include new open-economy macroeconomic models and portfolio-balance models, accrued from information aggregation (Lyons, 2002:51). The next section will describe order flow as an information aggregator and as a determinant of the exchange rate determination puzzle.

2.3.2.1 Order flow

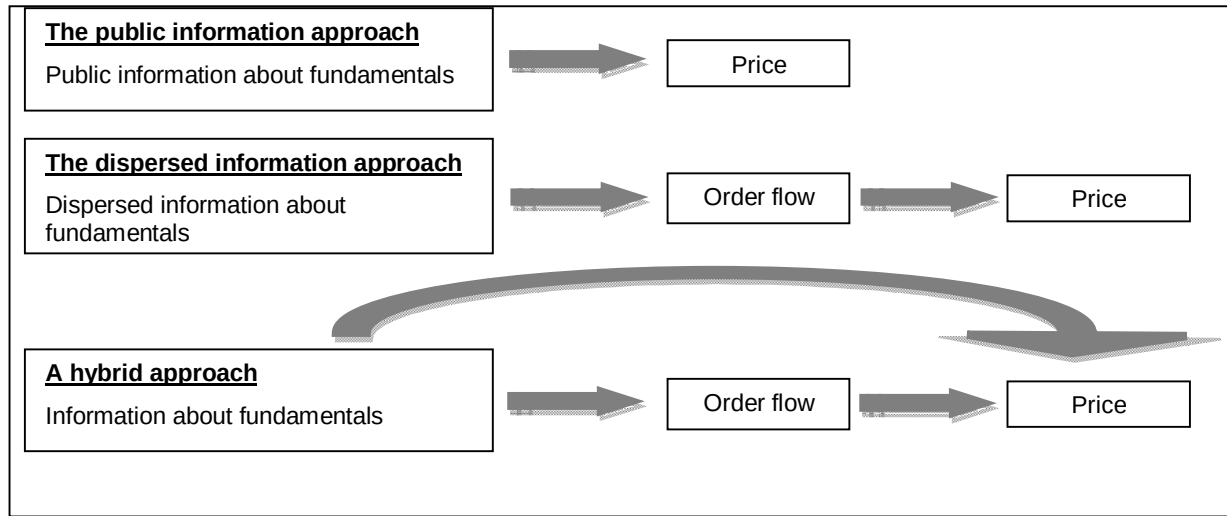
Hayek (1945:519–520) states the following:

"[...] the problem of rational economic order is determined precisely by the fact that knowledge of the circumstances of which we must make use never exists in concentrated or integrated form, but solely as dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess. The economic problem of society is thus a problem of the utilization of knowledge not given to anyone in its totality".

An efficient stock market will process information to help guide market participants to use their capital in the best economic way (Morck *et al.*, 2000:259). Furthermore, within the microeconomic-structured theory the direction of causality holds only one way, in other words, order flow determines prices and not *vice versa* (Lyons, 2002:61–62). Order flow as an information aggregator, based on the information approach (Figure 2.2), can be divided into public information, dispersed information and a combination of the two.

According to Bacchetta and Van Wincoop (2006:567), private information, consisting of future fundamentals and hedge trades, contributes to order flow. Public information, on the other hand, contributes to order flow by providing information about hedge trades only (Bacchetta & Van Wincoop, 2004:24). Investors sometimes find it difficult to determine whether unique information gathered by the individual investor regarding future fundamentals or an increase in unobserved hedge trades will lead to an increase in exchange rates. However, most short-run exchange rate volatility is associated with unobserved hedge trades (Bacchetta & Van Wincoop, 2004:1, 22).

Following public information in the information approach (Figure 2.2) is dispersed information. In dispersed information models, information processing consists of two stages (Lyons, 2002:52). The first stage consists of the observations and analysis by non-dealer market participants, while the second stage consists of the dealers setting prices based on what they have read in the order flow. However, since not all information relevant to FX is publicly known, knowledge gained from order flow can still play a role as a vital fundamental in trading decisions (Lyons, 2002:52). In concurring with this statement, French and Roll (1986:20–23) state that the effect of information on prices is permanent, whereas pricing errors have only a short-lived effect. This means that order flow may have a persisting effect on the exchange rate (Payne, 1999:22). It is thus evident that order flow is an important explanatory variable of the future spot exchange rate.

Figure 2.2: Different information approaches to pricing stock

Source: Lyons (2002:53).

Figure 2.2 illustrates three approaches concerning the process of using information to determine stock prices, namely, the public information approach, the dispersed information approach and the hybrid approach. The public information approach states that the information on fundamentals and the mapping from the information to the price is publicly known; thus, price adjustments are immediate and direct. Under the dispersed information approach, information is not publicly known and only becomes apparent once orders have been placed and order flow established, which signals to the price setters that a price adjustment is required. However, the hybrid approach accommodates both the possibilities of information affecting prices directly and indirectly (Lyons, 2002:52–53). The hybrid model can be given by the following equation (Lyons, 2002:55):

$$\Delta P_t = f(i, m, z) + g(X, I, Z) + \varepsilon_t \quad (2.1)$$

where:

- ΔP_t is the change in the price of FX;
- $f(i, m, z)$ is the macro component;
- $g(X, I, Z)$ is the micro component; and
- ε_t is the random error.

Function $f(i, m, z)$ consists of current and past values of foreign and domestic money supply (m), nominal interest rates (i) and other macro factors (z), whereas, function $g(X, I, Z)$ includes a measure of dealer net position (I), order flow (X) and other micro factors (Z) (Lyons, 2002:55). However, the micro and macro components are dependent not only on past and current values, expectations concerning their determinants' future values are also of the utmost importance in order to provide a forward-looking component for the rational markets (Lyons, 2002:55).

The concept of forecasting will be discussed in Section 2.3.3.2. In order to translate future payoffs into information about the future (i, m, z) for use in macroeconomic models, aggregated information of investors' expectations is required. By giving the price of FX, ΔP_t as a function of current and expected future macro fundamentals, the expectations of traders are fixed as follows (Lyons, 2002:56):

$$P_t = g(f_t, f_{t+1}^e) \quad (2.2)$$

where:

- P_t is the price of FX; and
- $g(f_t, f_{t+1}^e)$ is the current and future macro fundamentals, respectively.

Order flow also provides two addition information types: payoff information and discount rate information. In dispersed information models, price setters use order flow to learn more about changes in (f_{t+1}^e). When order flow provides payoff information, order flow acts as a proximate determinant of prices, and macro fundamentals as an underlying determinant (Lyons, 2002:56).

However, when order flow provides only discount information, functions (i, m, z) and (X, I, Z) are independent. For example, if the discount information flow is based on portfolio-balance effects (such as changing risk preferences, persistent changes in discount rates or changing liquidity demands under imperfect substitutability), and sticky-price and flexible monetary

macroeconomic models are used, these portfolio-balance effects are unrelated to these model specifications (Lyons, 2002:56). The portfolio-balance effects from the order flow are unrelated to $f(i, m, z)$, because the assumptions are made that Uncovered Interest Rate Parity (Section 3.3.6) holds and that different currency assets are perfect substitutes (Lyons, 2001:174). In other words, assets that differ only in currency denomination will have the same expected returns (Lyons, 2002:56). This means that effects from imperfect substitutability are independent of $f(i, m, z)$ and monetary models (Lyons, 2001:174).²²

Bacchetta and Van Wincoop (2004:26) conclude the following regarding the relationship amongst order flow, exchange rates and economic fundamentals:

- Over the short and medium run, fundamentals have little explanatory power regarding exchange rate movements;
- Over the long-run, there is a closer relationship between fundamentals and exchange rate movements;
- The exchange rate movements are a weak estimate of future fundamentals; and
- Order flow and the exchange rate are closely related.

To elaborate on this conclusion, the following paragraphs will briefly discuss additional literature on the strength of economic fundamentals in explaining forward exchange rate dynamics.

Rogoff (1992:31–32) developed a model that indicated that government spending shocks and transitory productivity had a long-run effect on the real exchange rate owing to the traded goods consumption smoothing effect. According to Roll (1988:565), industry influences, systematic influences and events unique to firms ought to explain general stock price changes. However, the following was found by Roll (1988:565–566):

²² See Evans and Lyons (2002) for more information on this topic, in which the Evans-Lyons model is discussed.

- Monthly stock returns were indicated to have explanatory powers;
- Diversification by large firms may not extend a market participant's explanatory powers;
- Firm size does not indicate any contribution to explanatory powers;
- Systematic economic factors do not produce different explanatory powers across different industries; and
- There is little evidence on the impact of public news events; however, private information showed greater promise.

It can be concluded that the movement of stock prices depends mostly on the amount of firm-level and market-level information that is capitalised into stock prices (Morck *et al.*, 2000:216). This was confirmed by Morck *et al.* (2000:216) who reports that stock prices moved in an unsynchronised manner in countries with a high per capita gross domestic product (GDP) and in a more synchronised manner in countries with a lower per capita GDP. This pattern was not due to structural economic characteristics such as market size, country size, co-movement of firm-level fundamentals, fundamentals volatility or economic diversification (Morck *et al.*, 2000:258). In fact, institutional development (which includes property rights) had a greater influence on this correlated pattern. Another factor that has an impact on the synchronicity of stock prices is the level of respect by the government for private property (Morck *et al.*, 2000:258).

Two conclusions can thus be made. As these synchronised stock price movements are not correlated with economic fundamentals, poor property rights protection may deter risk arbitrage (Morck *et al.*, 2000:258) and, therefore, create opportunities for noise traders²³ (De Long *et al.*, 1990:735–736). However, providing stronger legal protection for public stockholders against corporate insiders may lead to greater firm-specific return variation and thus lower synchronicity (Morck *et al.*, 2000:258).

²³ Traders that do not use fundamental data to make buy or sell decisions (Investopedia, 2010c:1).

In summary, there appears to be no convincing evidence that a certain group of economic variables has the ability to explain exchange rate movements completely. However, according to Mussa (1990:2) “the most consistently observed fact concerning the behaviour of floating exchange rates is that changes in exchange rates are largely random and unpredictable”. This leads to the following section, which will discuss the excess volatility puzzle as the second exchange rate puzzle.

2.3.3 The excess volatility puzzle

De Grauwe and Grimaldi (2006:2) state that the exchange rate changes only if unexpected movements in fundamental economic variables occur, which include interest rates, inflation and output growth. Similarly, Faust *et al.* (2002:9) found that exchange rate changes took place after changes in fundamental economic variables, which is emphasised by Obstfeld and Rogoff, (2000:41) who stated that the exchange rate is often disconnected from underlying fundamentals. The volatility of the exchange rate also extends to different forms of itself. Exchange rates will often be more volatile than predictable excess returns and more volatile than the forward premium (Moore & Roche, 2002:401). The exchange rate is not only disconnected from its underlying fundamentals, but is also more volatile than most fundamentals. An exception to this is that central banks can intervene by changing interest rates, which will cause this volatility to decrease (Lyons, 2002:62–63).

The increased volatility, produced by some macroeconomic environments when exchange rates are floating freely, can be explained by two approaches: the theoretical approach and the empirical approach (Lyons, 2002:62). The theoretical approach was developed by Dornbusch (1976:1161–1162) through his sticky-price monetary model, which demonstrated that economic shocks had an overshooting effect on the exchange rate – in other words, a disproportionately large effect on the exchange rate. Contrary to this, Flood and Rose (1995:5) state that the determinants of exchange rate volatility were not due to macroeconomics.

Killeen *et al.* (2001:3) explained the empirical approach by means of an experiment in which they switched from the European Monetary System (EMS) to the European Monetary Union (EMU) in their analysis. They found that exchange rates were more volatile under flexible exchange rates, owing to order flow, because more information was conveyed (Killeen *et al.*, 2001:4–5). This result is supported by the fact that public demand elasticity is lower owing to higher volatility and risk aversion. Under fixed exchange rates, public demand elasticity is infinite if volatility is zero, making FX holdings riskless (Lyons, 2002:63). Killeen *et al.* (2001:23) concluded that the Granger causality²⁴ test indicated that order flow caused the exchange rate to change and not *vice versa*. These results contravened earlier findings by Flood and Rose (1995:3), who found that the volatility of the exchange rate would increase dramatically with a move from a fixed to a flexible exchange rate. Such a dramatic increase in exchange rate volatility will not necessarily be detected by underlying economic variables (Flood & Rose, 1995:36). These findings, therefore, confirm the inability of underlying economic variables to explain future exchange rate movements.

Furthermore, the goal of explaining exchange rate movement is still limited by the possibility of the presence of a random walk. Using standard economic models to explain or forecast exchange rate changes also proved to be inadequate (Kilian & Taylor, 2001:1). According to Leung *et al.* (2000:1094), most econometric models are not able to forecast exchange rates accurately, owing to a random walk (random walk will be discussed in Section 2.3.3.1). Sarno and Taylor (2002:136–137) emphasise these findings, stating that the models developed from empirical work on exchange rates still lack the ability to produce reliable and robust results. The poor explanatory power of exchange rate theories is a significant weakness of international macroeconomics (Bacchetta & Van Wincoop, 2006:552). However, exchange rate forecasting still provides useful information to speculators, international investors and governments (Alvarez-Diaz, 2008:1969). Expectations serve an important role in everyday actions and decision-making (Sill, 2000:4). The following sections will briefly discuss the random walk

²⁴ The Granger causality test determines the direction of causation between two variables (QMS, 2007a:428).

phenomenon (Section 2.3.3.1) and the forecasting of exchange rates (Section 2.3.3.2).

2.3.3.1 Random walk phenomenon

As previously stated, in an efficient stock market, stock prices reflect all available and relevant information. When the current stock price is the best estimate of the future stock price, it is called the Weak-Form Efficient Market Hypothesis (Kim & Shamsuddin, 2008:518–519). According to Hirschey and Nofsinger (2008:163), the Weak-Form Efficient Market Hypothesis holds when the current stock prices reflect all the stock market information. It is thus clear that the Weak-Form Efficient Market Hypothesis will not hold if the stock prices have long-memory behaviour (mean reverting²⁵; Tkacz, 2000:7). A random walk can be described as the inability to predict the direction of future events, for example, the inability to predict the short-run changes in the stock markets (Malkiel, 1996:24). If stock prices are mean-reverting over the long-run and allow for a long-memory process (Styger & Morris, 2008:17; Section 5.3.2.1), they are seen as correlated, thus the Weak-Form Efficient Market Hypothesis does not hold. For a time series to be purely a random or a white noise process, it must have a constant variance, a zero mean and must be serially uncorrelated (Gujarati, 2003:798).

Therefore, as evident in Section 2.3.3, the poor explanatory ability of underlying economic variables can only be justified by the presence of a random walk. However, in the absence of a random walk, the market may show evidence of a certain level of long-memory, which means analysts will turn to economic variables to forecast the future exchange rate. In order to determine the presence of a random walk amongst international markets, several Asian studies and their results on the Random Walk Hypothesis (RWH) are summarised in Table 2.1.

²⁵ Long-memory or mean-reversion implies that the series does not deviate too far from its mean (Gujarati, 2003:798), thus enabling the modelling of long-run effects.

Table 2.1: Summary of Asian market studies testing for weak-form efficiency

Studies	Data and methodology	Markets	RWH hypothesis
Mun & Kee (1994)	D,W, 1982–1991 VR, Spectral shape test	HK, KOR, THA, MAL, TAW	Rejected for all countries with daily data Rejected only MAL & THA with weekly data
Ayadi & Pyun (1994)	D, W, M, 2M, Q, 1984–1998 VR	KOR	Rejected with daily data Not rejected with lower frequency data
Huang (1995)	W, 1988–1992 VR, ADF	HK, IND, KOR, JAP, PHI, SIN, THA, TAW	Rejected for KOR, MAL, HK, SIN, THA
Kawakatsu & Morey (1999)	M, 1976–1997 VR, MVR, ADF	KOR, MAL, PHI, TAW, THA	Find little evidence that financial market liberalisation improves efficiency
Ryoo & Smith (2002)	D, 1988–1998 MVR	KOR	Market approaches RW as price limits are relaxed
Chang & Ting (2000)	W, M, Q, Y, 1971–1996 VR	TAW	Rejected with daily data Not rejected with lower frequency data
Pemg <i>et al.</i> (2004)	W, 1993–2002, chaos theory	TAW	Rejected
Lima & Tabak (2004)	D, 1992–2000 MVR	China, HK, SIN	Rejected for China and SIN
Lee <i>et al.</i> (2001)	D, 1990–1997 VR, ADF	China	Rejected
Hoque <i>et al.</i> (2007)	W, 1990–2004 VR, MVR, W	HK, IND, KOR, MAL, PHI, SIN, THA, TAW	Rejected except for KOR & TAW
D: daily; W: weekly; M: monthly; Q: quarterly; Y: annual; ADF: Augmented Dickey–Fuller Test; MVR: Chow–Denning multiple variance ratio test; VR: Lo–MacKinlay variance ratio test; W: Wright's sign test; HK: Hong Kong; IND: Indonesia; JAP: Japan; KOR: Korea; MAL: Malaysia; PHI: Philippines; TAW: Taiwan; THA: Thailand; SIN: Singapore. All studies listed in this table used aggregate stock market indices to test market efficiency.			

Source: Kim and Shamsuddin (2008:521).

Most of the results, indicated in Table 2.1, rejected the RWH or found little evidence of it. Thus, the overall conclusion of Table 2.1 is that prices adjust slowly in Asian markets. The study by Solnik (1973:1153-1158) estimated the serial correlation coefficients of daily stock prices and dividend data of eight European stock markets and rejected the random walk. Evidence from the study by Smith and Ryoo (2003:298) also rejected the random walk hypothesis for four out of five European emerging stock markets, using multiple variance ratio tests on weekly stock prices. These results, therefore, indicate that the concept of a random walk may play only a small part in determining exchange rate movements. Thus, the concept of a random walk has

no significant influence on the estimation of the future exchange rate. The next section will continue discussing the important considerations in estimating future exchange rates by means of underlying economic variables.

2.3.3.2 Estimating future exchange rates

De Grauwe and Grimaldi (2006:3) state that the exchange rate depends on expectations of other agents, which depends on the expectations of different agents, and so on. This indicates that a heterogeneous agent may play an important role in contributing to the rational expectations model when forecasting the future exchange rate (De Grauwe & Grimaldi, 2006:3). According to Brooks (1996:307), determinants of exchange rates include a non-linear component. By including non-linearity in the forecast model, it might be possible to solve the PPP puzzle (Section 3.2), when taking the adjustment speed of the real exchange rate into account (Kilian & Taylor, 2001:2). Including transaction costs from the goods market as a source of non-linearity is also important for forecasting the exchange rate (Sercu *et al.*, 1995:1309).

In their study, Kilian and Taylor (2001:23) sought to determine whether the non-linearity in the relationship between macroeconomic fundamentals and the nominal exchange rate would aid in the forecasting of the nominal exchange rate. They determined that by using an Exponential Smooth Threshold Autoregressive model, the exchange rate is indeed predictable over a longer time horizon. However, the closer the spot exchange rate was to the equilibrium value, the less predictable and random the exchange rate movements were (Kilian & Taylor, 2001:24).

In summary, several variables have already been used in an attempt to explain future exchange rates. Some of these variables include interest rates, inflation, and output growth. However, the exchange rate appears time disconnected from most fundamental economic variables. Additional anomalies that need to be incorporated into the exchange rate model have also been identified, which include the random walk component and a non-linear agent. However, there is

still no significant evidence that indicates the model and group of variables that best explain future exchange rate movements. As the future forward exchange rate (drawn from the Interest Rate Parity theory (IRP), as discussed in Section 3.3) is deficient in fully explaining the future spot exchange rate, there is a need to identify the most comprehensive explanatory variables. This deficiency is termed the forward exchange rate premium puzzle, which will be discussed in the following section.

2.3.4 The forward bias puzzle / forward exchange rate premium puzzle

2.3.4.1 Introduction

In the past, there has been much interest in the behaviour of the spread (forward exchange rate premium) between the forward FX rate and the spot exchange rate (Roll & Yan, 2000:121). The following example illustrates the concept of the forward exchange rate premium. Suppose that the South African interest rates increase relative to that of the United States and then return to their equilibrium rates. Were investors to know the nature of the interest rate shock, the arbitrage phenomenon would force the domestic currency to appreciate relative to its long-run value. This process of arbitrage would occur until the future expected depreciation was equal to the forward exchange rate premium. The domestic currency would then gradually return to its equilibrium value as the forward exchange rate premium deteriorated; this is termed the forward premium effect (Gourinchas & Tornell, 2004:305).

However, were investors to misperceive the South African interest rate shock as momentary, they would believe that the South African interest rate would return to its equilibrium value rapidly (Gourinchas & Tornell, 2004:305). This will lead to a higher than expected South African interest rate, causing investors to revise their expectations about the continuity of the interest rate shock. This would lead to a persisting appreciation of the domestic currency, which is termed the updating effect. Were the updating effect to be greater than the forward premium effect, there would be a persisting appreciation of the domestic currency (Gourinchas & Tornell, 2004:305).

The following sections will explain the concept of the forward exchange rate premium puzzle further. This discussion will commence with a sketch of the relevant literature (Section 2.3.4.2), which will be followed by a discussion on the findings of using economic fundamentals to explain the forward exchange rate premium puzzle.

2.3.4.2 Background

According to Diamandis *et al.* (2008:358), Dibooglu (1998:427), Nieuwland *et al.* (1998:351), Levine (1989:163) and Albuquerque (2008:461), the forward exchange rate is a biased estimate of the realized spot exchange rate. According to Chiang and Yang (2007:181)²⁶, in past empirical studies where the forward exchange rate has been used to predict the future spot exchange rate, the unbiasedness hypothesis has been generally rejected. The following equation from Chiang and Yang (2007:184) and from Dibooglu (1998:428) can be adjusted to test the state of biased or unbiasedness:

$$s_{t+k} - f_t = v_0 + v_1(f_t - s_t) + \varepsilon_{t+k} \quad (2.3)$$

where:

- 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 intercept;
- v_1 is the exchange rate premium coefficient; and
- ε_{t+k} is the random error.

Equation 2.3 represents the problem of the use of forward points to predict the future exchange rate. Equation 2.3 also represents the first test in the empirical study to determine whether the

²⁶ The Chiang and Yang (2007) approach will be used as a preliminary model in this study to investigate the relationship between the ZAR and the USD.

ZAR/USD forward exchange rate is a biased or unbiased estimate of the future ZAR/USD spot exchange rate (Section 5.2.3 & Section 6.2.3). Only by establishing the presence of biasedness will other variables be required to improve the accuracy of the estimation of the future spot exchange rate.

McCallum (1994:112) was the first to test unbiasedness and found that this unbiasedness was the result of the forward rate and forward premium. McCallum (1994:123) proposed that a monetary rule be used to explain the forward exchange rate premium puzzle in cases in which policymakers may have the tendency to resist changes in exchange rates. However, even when applying the monetary rule in such cases, the forward exchange rate remains a poor estimate of the realized spot exchange rate. Lyons (2001:208) provides two reasons for the forward exchange rate being such a poor estimate of the spot exchange rate: firstly, market systematic errors result in profit opportunities being neglected; and secondly, the risk premium that affects the biasedness of the model used.

In addition to the use of the forward exchange rate, other economic fundamentals have been used in an attempt to enhance the estimation of the realized spot exchange rate. These fundamentals include interest rates (Section 2.3.4.2.2), inflation rates (Section 2.4.4.2.4), the equity premium (Section 2.3.4.2.5), and a time-varying risk premium (Section 2.3.4.2.3). The following section will first discuss the factors explaining the forward exchange rate as an estimate of the realized spot exchange rate.

2.3.4.2.1 Factors explaining the forward exchange rate and the risk premium

According to studies by Ott and Veugelers (1986:10–14), forward exchange rates that forecast future spot exchange rates are influenced by changing inflation rate differentials, interest rate differentials and the monetary policies of the two different countries. These studies imply that

the forecasting error²⁷ can partly be explained by changes in expectations between the time of the spot exchange rate observation and the time of the forward exchange rate prediction (Aggarwal *et al.*, 2008:15). Owing to the poor forecasting abilities of the forward exchange rate to predict the movement of the future spot exchange rate, this puzzle has attracted the most attention of all the puzzles (Lyons, 2001:206–207).

The forward exchange rate premium puzzle contradicts the Efficient Market Hypothesis (EMH), which states that the forward exchange rate should reflect all the available information of investors' expectations concerning the future spot exchange rate, and that the forward exchange rate is an unbiased forecast of the future spot exchange rates (Lin *et al.*, 2002:168). If the EMH holds, no excess returns through speculation must be possible for any market participant (Sarno, 2005:674). In confirming the previous statement, Hansen and Hodrick (1980:846) explain that the expected rate of return in the forward exchange market will be equal to zero, with a risk-neutral economic agent, assuming that EMH holds. This means that if there are no transaction costs and no taxes, the market is competitive and all available information is used rationally.

However, a compensation for risk is needed for the risk-neutral investor, implying that the future spot exchange rate may not differ from expectations (Aggarwal *et al.*, 2008:2). In their studies, Sephton and Larsen (1991:563–568) and Hakkio and Rush (1989:84–85) found no evidence to support the EMH. The EMH did not hold owing to the following factors: the presence of risk premiums in forward exchange rates, irregularities during empirical regressions, the lack of appropriate econometric techniques, the mis-measurement of profit rules, and the negative correlation between the expected future spot exchange rate and the forward risk premiums (Aggarwal *et al.*, 2008:4).

²⁷ The forecasting error refers to the difference between the forward exchange rate and the realized spot exchange rate (see Section 5.2.2).

Bilson (1981:441) was one of the first to observe a negative correlation between the forward exchange rate premium and the future spot exchange rate. A positive forward exchange rate premium is associated with an appreciation of the exchange rate (Gourinchas & Tornell, 2004:304). However, when negatively related to the spot exchange rate, the domestic currency will depreciate when the nominal interest rate is lower (Roll & Yan, 2000:122). The negative correlation was found to be sample-period dependent and the following explanation was given by Roll and Yan (2000:147) as to the reason that the correlation is sometimes negative:

- Unexpected changes in the spot exchange rates dominated the expected changes in the spot exchange rate, making the changes in the spot exchange rate noisy;
- The forward exchange rate, the spot exchange rate and the forward exchange rate premium are nearly non-stationary. Roll and Yan (2000:132) state that an embedded risk premium appears to be the source of the non-stationarity and that inflation risk can be attributed to the embedded risk premium. Furthermore, they concluded that the forward rate was an unbiased estimate of the future spot exchange rate and no time-varying risk premium was detectable over a one-month time horizon (Roll & Yan, 2000:147); and
- Spurious coefficients are generated by the noisy variable regressions, which deliver surprising frequencies.

The possibility of econometric limitations as the probable cause of the forward exchange rate puzzle has also been investigated. Risk premium models have been unable to explain the extent of failure of unbiasedness (Engel, 1996:124). Earlier studies already indicated that the forward exchange rate premium may not be a stationary process. One of these studies is Crowder (1994:562), who was not able to reject the unit root²⁸ in the forward exchange rate premium, implying the existence of rational expectations. Luintel and Paudyal (1998:285) also

²⁸ The term unit root, non-stationarity, and random walk can be seen as synonymous (Gujarati, 2003:802). The presence of a unit root can be tested with the use of the Augmented Dicky-Fuller unit root test (see Section 5.4.1).

found the forward exchange rate premium to be a unit root process²⁹. Furthermore, Baillie and Bollerslev (1994:565) state that the forward exchange rate premium must be characterised as a fractionally integrated process³⁰. In addition to these findings, Maynard and Phillips (2001:696) demonstrate that the forward exchange rate premium may be approximated as a non-stationary, long-memory process, indicating that it may be a form of fractional co-integration³¹. This result indicates that the Uncovered Interest Rate Parity condition (Section 3.3.6) is poorly expressed in Equation 2.5³².

In summary, the forward exchange rate is acknowledged as a biased estimate of the future spot exchange rate. Past findings have indicated that the forward exchange rate premium may be a non-stationary, long-memory process. In addition to these findings, alternative economic fundamentals have been used in an attempt to improve the estimation of the future spot exchange rate, taking into consideration the presence of long-memory (Section 5.3.2.1) in the forward exchange rate premium. This contradicts the findings of a random walk (Section 2.3.3.1), and the poor explanatory ability of economic fundamentals as discussed in Section 2.3.2. The following section will discuss the use of interest rates as an explanatory variable (economic fundamental) of the forward exchange rate premium.

2.3.4.2.2 Interest rates as determinant of the risk premium

Korajczyk (1985:357) states that the FX rate risk premium can be explained by real interest rates. However, according to Roll and Yan (2000:121) this is true on condition that the forward exchange rate premium is equal to the difference between the default-free (risk-free) nominal interest rates of two countries:

²⁹ A unit root process is also known as a random walk model (Gujarati, 2003:801). See Section 2.3.3.1 for the discussion on random walk.

³⁰ A process is fractionally integrated to order d , if its d 'th difference is $I(0)$. Thus a fractionally integrated process can be illustrated as $I(d)$ (Christensen & Nielsen, 2004:2). See also Section 6.3.2.3 for a discussion on the results found by applying the fractionally integrated process in this study.

³¹ See Robinson and Yajima (2002) for a detailed description of fractional co-integration.

³² In order to solve this problem, the test developed by Baillie and Kapetanios (2006a:449–452) must be performed, which includes the use of a non-linear long-memory model based on neural networks and Taylor series approximations.

$$RD,t - RF,t = f_t - s_t = \text{forward exchange rate premium} \quad (2.4)$$

where:

- f_t are the natural logarithms of the forward exchange rates;
- s_t are the natural logarithms of the spot exchange rates;
- R denotes the continuously compounded, nominal zero-coupon interest rate over the same term as the forward contract;
- D denotes domestic; and
- F denotes foreign.

According to the Villanueva (2007:963), the Uncovered Interest Rate Parity theory (Section 3.3.6) implies that the international yield differential reflects expected depreciation of the high yield currency. The Uncovered Interest Rate Parity theory states that the expected future rate of depreciation (appreciation) of a specific currency is equal to the current forward discount (premium), or is equivalent to the interest rate differential (Baillie & Kapetanios, 2006b:12):

$$E_t(\Delta s_{t+1}) = (f_t - s_t) = (i_t - i_t^*) \quad (2.5)$$

where:

- $E_t(\Delta s_{t+1})$ denotes the expectation based on all relevant information at time t ;
- s_t is the logarithm of the spot exchange rate;
- f_t is the logarithm of the forward exchange rate;
- i_t is the maturity nominal interest rate available on domestic assets; and
- i_t^* is the maturity nominal interest rate available foreign assets.

In order to test the Uncovered Interest Rate Parity theory (Section 3.3.6), the following equation can be used (Baillie & Kapetanios, 2006b:12):

$$\Delta s_{t+1} = \alpha + \beta(f_t - s_t) + \varepsilon_{t+1} \quad (2.6)$$

For Equation 2.6, the null hypothesis of the Uncovered Interest Rate Parity theory (Section 3.3.6) is as follows: $\beta = 1$, $\alpha = 0$ and ε_{t+1} is the random error, which should be serially uncorrelated (white noise)³³. The forward premium can obtain a negative slope coefficient in Equation 2.6, indicating that the rate of appreciation of the spot exchange rate is negatively correlated with the lagged forward premium (Baillie & Kapetanios, 2006b:12).

According to Gourinchas and Tornell (2004:304), the forward exchange rate premium puzzle implies that the default-free (risk-free) nominal interest rate differential between the two countries has little predictive power of the forward nominal exchange rate changes. Villanueva (2007:986) emphasised that interest rate differentials do not forecast currency excess returns³⁴ in terms of the Mean Square Forecast Error (MSFE) method³⁵ relative to a constant benchmark. However, interest rate differentials do provide useful information regarding the future direction of currency excess returns (Villanueva, 2007:986). Using a linear Vector Error Correction (VEC) model³⁶ framework for the term structure of interest rate differentials, Diez de los Rios (2006:1) found that the VEC model outperformed the simple random walk (Section 2.3.3.1) forecast. In addition, Bonga-Bonga (2008:1) used the Kalman filter³⁷ and also found that forward exchange rates could predict the future spot exchange rate more reliably than a random walk model.

Apart from interest rates, additional variables (as will be discussed from Section 2.3.4.2.3 to Section 2.3.4.2.5) have also been used in an attempt to improve the accuracy of the estimation of the forward exchange rate premium. One of these variables is a time-varying risk premium, which will be discussed in the following section.

³³ This is a requirement to prevent autocorrelation, see Gujarati (2003:70) for further reference.

³⁴ Currency excess returns are continuously compounded foreign spot returns with interest rate adjustments (Villanueva, 2007:965).

³⁵ MSFE is a criterion for evaluating the performance of macroeconomic models (Ericsson, 1991:1).

³⁶ See Section 5.4.4 for a discussion on the VEC model.

³⁷ The Kalman filter consists of a set of mathematical equations that is able to provide the ability to estimate the state of a process, with the ability to minimize the mean of the squared error (Welch & Bishop, 2006:1).

2.3.4.2.3 Introducing the time-varying risk premium

According to Nieuwland *et al.* (1998:352), forward market efficiency is rejected due to a time-varying risk premium and irrational expectations. In addition, Dibooglu (1998:421) states that the bias may be due to the inefficient use of information by market participants and due to the time-varying exchange rate risk premium. Domowitz and Hakkio (1985:52) used an Autoregressive Conditional Heteroskedasticity (ARCH)³⁸ model into which the time-varying exchange rate risk premium was embedded (this model is applied in Chapter 6). Barkoulas *et al.* (2003:5) state that the forward exchange rate premium can also be expressed by the following equation:

$$f_t - s_t = (s_{t+m} - s_t) + rp_{t,m} - u_{t+m} \quad (2.7)$$

where:

- s_t is the log spot exchange rate at time t ;
- f_t is the log forward exchange rate at time t ;
- s_{t+m} is the log spot rate at time $t + m$;
- $rp_{t,m}$ is the time-varying exchange rate risk premium; and
- u_{t+m} is the rational expectations realized forecast error.

Thus, the forward exchange rate premium can be divided in three components, namely the forward risk premium, the spot return and the rational expectations error, where the spot return ($s_{t+m} - s_t$) and the rational expectations forecast error (u_{t+m}) is a stationary $I(0)$ process (Barkoulas *et al.*, 2003:5). Mayfield and Murphy (1992:321–323) demonstrated that introducing a currency and time-fixed effect (time-varying exchange rate risk premium component) in the equation largely resolves the forward exchange rate premium puzzle. This leads to the following section, which will compare the inflation rate and the interest rate as explanatory variables of the forward exchange rate premium.

³⁸ The ARCH process allows the conditional variance to change over time as a function of past errors and leaves the unconditional variance constant (Bollerslev, 1986:307). See also Section 5.5 for the use of the ARCH model in this study.

2.3.4.2.4 Comparison of the inflation rate differential and the interest rate differential as determinants of the forward exchange rate premium

Huang (1990:349) found that the PPP (Section 3.2) approach may yield better results than interest rate differentials in determining the forward exchange rate premium. Further evidence indicated that there is a co-movement between the forward exchange rate risk premium and the deviations from *ex ante* PPP, which indicates that both interest rate differentials and inflation differentials may determine the forward exchange rate risk premium (Huang, 1990:352–354). The following adjusted equation, which includes the short-run interest rate and the inflation rate, can be used to determine the exchange rate premium (Chiang & Yang, 2007:187):

$$s_{t+k} - f_t = v_0 + v_2[(r_t - \Delta p_{t+k}^e) - (r_t^* - \Delta p_{t+k}^{*e})] + \varepsilon_{t+k} \quad (2.8)$$

where:

- 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 intercept;
- v_2 is the real risk-free interest rate differential coefficient;
- ε_{t+k} is the random error;
- Δp_{t+k}^e and Δp_{t+k}^{*e} are the expected inflation rates of South Africa and the U.S.A., respectively; and
- r_t and r_t^* are the South African 91-day Treasury Bill (T-Bill) rates and the U.S.A. 91-day T-Bill rates, respectively.

Furthermore, according to Chiang and Yang (2007:185), long-run interest rates should also be incorporated in the estimation of the exchange rate premium in order to compensate for the

expectations hypothesis of the domestic term structure of interest rates.³⁹ The expectations hypothesis further states that if the different term bonds are viewed as one-period bonds, the yields of each of these bonds must be equal to the expected short-term interest rate for that period (Spaulding, 2008:1). The equation that represents this hypothesis subtracts the short-run, risk-free interest rate from the long-run yield rates to estimate the risk-free, long-short spread, as illustrated in Equation 2.9. The following adjusted equation was used to test this hypothesis (Chiang & Yang, 2007:185; this equation was implemented in the current empirical study):

$$s_{t+k} - f_t = v_0 + v_3[(r_t^L - r_t) - (r_t^{L*} - r_t^*)] + \varepsilon_{t+k} \quad (2.9)$$

where:

- 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 intercept;
- v_3 is the risk-free, long-short interest rate differential coefficient;
- r_t and r_t^* are the South African 91-day T-Bill rates and the U.S.A. 91-day T-Bill rates, respectively;
- r_t^L and r_t^{L*} are the long-run, ten-year government bond yields rates of South Africa and the U.S.A., respectively; and
- ε_{t+k} is the random error.

By including both short-run interest rates and long-run interest rates, it is possible to model both sides of the yield curve. The use of long-run interest rates also makes it possible to capture information regarding relative interest rate risk, which is implied by the expectations hypothesis of the domestic term structure of interest rates (Chiang & Yang, 2007:185). This leads to the

³⁹ The variation of the bond yields with similar risk profiles is called the term structure of interest rates (Spaulding, 2008:1).

final explanatory variable that was used in seeking to improve the estimation of the forward exchange rate premium, which is the stock return differential between countries, also known as the equity premium.

2.3.4.2.5 Equity premium as determinant of the risk premium

According to Moolman (2003:293), stock indices are associated with future economic expectations. Stock price fluctuations are able to reflect recessions and expansions in both domestic and foreign economies (Kaminsky & Schmukler, 2007:20). This makes forecasted stock prices a useful leading indicator of future exchange rate fluctuations. Korajczyk and Viallet (1992:215), Morley and Pentecost (1998:317), and Chiang (1991:360) found that the exchange rate risk premium is related to expected equity premiums. Chiang and Yang (2007:187) undertook a comparative study of sixteen countries in testing whether the stock market excess return differential has significant power in explaining the FX rate risk premium. Their empirical findings suggest that the risk premiums in currency markets are highly correlated with the excess returns in stock markets and goods markets relative to bond markets.

Chiang and Yang (2007:193) concluded that the expected stock market excess return differential (v_4) has significant power in explaining the exchange rate risk premium. Chiang and Yang (2007:188) used the following equation to determine the relationship between the expected equity premium and the exchange rate premium, which can be adjusted for this study as follows:

$$s_{t+k} - f_t = v_0 + v_4[(R_{t+k}^e - r_t) - (R_{t+k}^{*e} - r_t^*)] + \varepsilon_{t+k} \quad (2.10)$$

where:

- 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 intercept;
- v_4 is the risk-free, annualised return differential coefficient;
- r_t and r_t^* are the South African 91-day T-Bill rates and the U.S.A. 91-day T-Bill rates, respectively;
- R_{t+k}^e and R_{t+k}^{*e} are the expected dual-listed stock returns of South Africa and the U.S.A., respectively; and
- ε_{t+k} is the random error.

Studies by Chiang (1991), Morley and Pentecost (1998), and Chiang and Yang (2007) used all-stock indices to generate expected stock returns. **A sub-objective to identifying suitable macroeconomic variables is to incorporate market expectations more effectively by making use of individual dual-listed stocks** (Section 4.2). Furthermore, as it is difficult to generate accurate expected stock returns, this study follows alternative approaches (Section 5.4) in an attempt to enhance the ability to incorporate the interaction of the international financial markets into an exchange rate model. Andersen *et al.* (2001:42, 54) found evidence of the presence of long-memory in a realized volatility series and in absolute returns in stocks and currency markets transformations. The volatility between the stock returns of any two countries may have a significant influence on the prediction of future exchange rates. This volatility component, which is termed the volatility spillover effect in this study, was incorporated into the model developed in this study by means of a Vector Error Correction (VEC) model, which will be discussed in Sections 4.8 and 5.4.4.

As evident from the discussion above, the use of economic fundamentals and the implementation of alternative non-stationary models have not been able to solve the forward exchange rate premium puzzle. While solving the forward exchange rate premium puzzle is a requirement for investing in different exchange markets, it can offer the advantage of serving as a performance measure to help investors in their trading decisions. This will be briefly discussed

in the following section.

2.3.4.2.6 Using the forward bias puzzle as a trading indicator

Financial institutions use the Sharpe ratio to measure the performance of their stock trading. In order to do so, it is necessary to determine the size of the forward bias required in order for the Sharpe ratio to be equal to a buy-and-hold equity strategy⁴⁰ (Lyons, 2001:209–210). The Sharpe ratio can be expressed by the following equation:

$$\text{Sharpe ratio} = \frac{E(R_s) - R_{rf}}{\sigma_s} \quad (2.11)$$

where:

- $E(R_s)$ is the expected return on the strategy;
- R_{rf} is the risk-free interest rate; and
- σ_s is the standard deviation of the returns on the strategy.

The Sharpe ratio of a currency strategy is zero under the null hypothesis of no bias in the forward exchange rate. The denominator, not a function of the bias, is determined by the number of exchange rates included and the exchange rate variances. It is important to note that an increase in the number of currencies provided will increase the diversification provided (Lyons, 2002:210).

In summary, the forward exchange rate premium puzzle explains that the forward exchange rate is a biased estimate of the future spot exchange rate. It was found that the forward exchange rate premium is non-stationary and shows evidence of long-memory. This contradicts the findings of a random walk (Section 2.3.3.1) and justifies the use of economic fundamentals to enhance the estimation of the future spot exchange rate. Some of the economic fundamentals that have been investigated include interest rates (Section 2.3.4.2.2), inflation rates

⁴⁰ It is a passive investment strategy, where investors buy stocks and hold them for a long period, regardless of any market fluctuations (Investopedia, 2010b:1).

(Section 2.3.4.2.4), and an equity premium (Section 2.3.4.2.5). Each of these economic fundamentals will be discussed further in the following chapters. Inflation rates (Purchasing Power Parity) will be discussed in Section 3.2, interest rates (IRP) will be discussed in Section 3.3, and an equity premium will be discussed in Chapter 4. This study will also incorporate different approaches in an attempt to incorporate the interaction of international financial markets (Section 4.2), and to enhance the estimation of the future spot exchange rate.

This leads to the final exchange rate puzzle termed the home bias puzzle. According to the home bias puzzle, investors only invest in their home country and ignore foreign investment opportunities (Coval & Moskowitz, 1999:2045). The home bias puzzle and the excess volatility puzzle (Section 2.3.3) can partially explain the price differences of dual-listed stocks (Section 4.2) on different exchanges.

2.3.5 The home bias puzzle

According to Kang and Stulz (1997:4), the preference for investing domestically rather than internationally can be considered an international phenomenon. French and Poterba (1991:222) found that the U.S.A., Japan and the United Kingdom (U.K.) allocated 94, 98 and 82%, respectively, of their stock investment domestically. By the end of 2003, U.S.A. investors held only approximately 14% of foreign stocks in their stock portfolio (Thomas *et al.*, 2004:40). Cooper and Kaplanis (1994:46) found that a large fraction of total portfolio stocks are invested domestically, ranging from 64.4% in France to 100% in Sweden. The home bias puzzle can exist in any market in which investors invest only in their home country (Coval & Moskowitz, 1999:2045).

According to Campbell and Kräussl (2007:1239), investors are continuing to invest domestically, despite the better integration of international capital markets. Goetzmann and Kumar (2001:2) argue that this may be the case because market participants may have an indistinct view of the benefits of diversifying their portfolio and, therefore, fail to diversify adequately.

Bailey and Stulz (1990:61) state that the importance of a well-diversified international portfolio may be overestimated by market participants and the need to hold foreign assets is therefore not justified.

Another reason for home bias puzzle is that investors may perceive international investments to be more risky than domestic investments (Campbell & Kräußl, 2007:1240). It is confirmed by Solnik (1996:118) that investors unfamiliar with foreign capital markets perceive them as very risky. French and Poterba (1991:224–225) point out that the home bias phenomenon may be due to relative unfamiliarity with foreign institutions and foreign markets. This indicates that risks, like transfer risk or sovereign risk, can be greater than perceived by the investors and the effect of the risk is not fully captured in the estimation of the risk (Campbell & Kräußl, 2007:1240).

Investors may also only invest in familiar stocks because they wish to invest in stocks with which they consider themselves competent and knowledgeable (Campbell & Kräußl, 2007:1243). This is termed the competence hypotheses (Heath & Tversky, 1991:7). People prefer not to risk money in an investment with an uncertain outcome (Barberis & Thaler, 2003:1073). This is termed the aversion to ambiguity (Campbell & Kräußl, 2007:1243).

Stulz (1981:933) explains that barriers to international investment contribute to the home bias phenomenon. Examples of these barriers include foreign taxes, high transaction costs and government restrictions on domestic and foreign capital flows. However, Ahearne *et al.* (2004:314, 329–330) state that measurable transaction costs do not adequately explain the home bias phenomenon. According to Coval and Moskowitz (1999:2045–2046), the cause of home bias can be grouped into two categories: the first category is associated with national boundaries, including variation in regulation, sovereign risk, exchange rate fluctuation, taxation and culture; and the second category is associated with the preference for geographic proximity/distance. It is also argued that the informational difference between the domestic and

foreign investors is the cause of home bias (Coval & Moskowitz, 1999:2046).

Another factor to consider for the existence of the home bias puzzle, is the hedging of output of firms that produce goods not traded internationally (Coval & Moskowitz, 1999:2046). Furthermore, Stockman and Dellas (1989:272–275) suggest that the hedging of non-traded consumption goods may be considered a reason for holding domestic stocks. Coval and Moskowitz (1999:2046) argue that investors may have easier access to information about local firms, or investors may have a psychological desire to invest only in domestic companies. Huberman (2001:660–661) found that investors may prefer local Regional Bell Operating Companies (RBOC) to foreign RBOCs, even though they may be listed on the same stock exchange market, because investors prefer to invest in that with which they are most familiar.

In addition, Coval and Moskowitz (1999:2047) found that local stock preferences are related to leverage, firm size and output tradability, and that firm leverage captured local stock preferences better than the market-to-book ratio (Coval & Moskowitz, 1999:2048). Contrary to these findings, Fama and French (1992:428) found that the market-to-book ratio had a greater explanatory power for expected returns than firm leverage. Furthermore, Coval and Moskowitz (1999:2046) explain that the relationship between these company characteristics and the propensity to invest locally may also have an effect on asset pricing. Fama and French (1992:428) state that firm characteristics may be a proxy for firm risk sensitivity and, therefore, compensate investors with higher average returns.

Karlsson and Norden (2007:322–323) elaborate on the home bias phenomenon, finding that gender, net wealth, occupation, age and the familiarity with risky investment opportunities may influence willingness to allocate assets to foreign equities. According to Campbell and Kräussl (2007:1242), the culture, language and the distance of the company from the investor also play an important role in the decision of investing in that particular company. However, Falkenstein (1996:132) explains that mutual fund managers may only prefer large, liquid stocks.

According to Obstfeld and Rogoff (2000:5), border costs such as exchange rate risk, non-tariffs, transport costs and tariffs largely resolve the home bias puzzle in international trade. Although, Cooper and Kaplanis (1994:45) disagree with this statement, claiming that neither observable international investments costs nor inflation hedging are able to explain the home bias phenomenon. Furthermore, they state that hedging PPP deviations (Section 3.2.5) will cause home bias only if there are low levels of risk aversion and if the domestic inflation is negatively correlated with stock returns (Cooper & Kaplanis, 1994:57).

Uncertainty has failed to explain the home bias phenomenon because it assumes that a strong degree of belief in a market is required (Pastor, 2000:209). The degree of uncertainty can be minimised with the help of backward-looking and forward-looking forecasting models, which can also be used to assist investor's investment decisions. Capital Asset Pricing Models (CAPM) are an example of forward-looking models, which can be of great importance in conveying exchange rate behaviour (Mussa, 1990:4). Coën (2001:497) developed an international counterpart of the CAPM, the International Capital Asset Pricing Model (ICAPM; Section 4.7), which includes human capital. He found that human capital, which is positively correlated with domestic financial assets, can deteriorate the home bias phenomenon (Coën, 2001:497). The CAPM also has the ability to price assets, which may be essential for maximising a portfolio's value, and thus help to determine the most dominant dual-listed stocks to use in this study's exchange rate model. According to Roll (1988:542–543), the most common theories examining the pricing of assets are the CAPM (Section 4.4) and Arbitrage Pricing Theory (APT; Section 4.5), which will be discussed in Chapter 4.

2.3.6 Summary

The exchange rate puzzle was discussed as a partial explanation of market expectations. However, by investigating macroeconomic fundamentals' explanatory power, and by investigating the four individual exchange rate puzzles, it was established that it is still not possible to estimate the realized future spot exchange rate with a reasonable measure of

accuracy. These puzzles are the determination puzzle (Section 2.3.2), the excess volatility puzzle (Section 2.3.3), the forward exchange rate premium puzzle (Section 2.3.4), and the home bias puzzle (Section 2.3.5). In order to overcome the inability to accurately estimate the realized future spot exchange rate, this study make use of the price differences of dual-listed stocks, as an explanatory variable, in an attempt to incorporate market expectations more effectively.

In addition, by studying backward-looking models, it is clear that the exchange rate has a fixed long-run equilibrium (Mussa, 1990:4). If the exchange rate has reached its long-run equilibrium level, no further movements will occur; however, an additional change in exogenous variables (which include market expectations) will cause the exchange rate to adjust its current position (Mussa, 1990:4). This study attempts to include market expectations more effectively by means of incorporating the price differences of dual-listed stocks, in seeking to improve accuracy in estimating the realized future spot exchange rate. Without the ability to estimate the realized future spot exchange rate with accuracy, it is not possible for a country to estimate its long-run equilibrium level or to determine its misalignment level. This leads to the following section, which will discuss the difficulty of estimating the equilibrium exchange rate and exchange rate misalignment, as well as the present conundrum of estimating the realized future spot exchange rate with accuracy.

2.4 EXCHANGE RATE EQUILIBRIUM AND EXCHANGE RATE MISALIGNMENT

2.4.1 Introduction

This section enhances the understanding of accurate future exchange rate estimation. Without a suitable starting point from where exchange rate equilibrium can be estimated, can lead to the undermining of future policy decisions. With the ability to solve the pseudo problem and to develop a more accurate exchange rate model may increase the ability to estimate the exchange rate equilibrium more accurately, which may also resolve the problem of undervaluing

or overvaluing the exchange rate⁴¹. The exchange rate equilibrium can be defined as the level of which the exchange rate is consistent with a set of fundamentals over the long and medium run (Takagi & Hicklin, 2007:53). The Natural Real Exchange Rate (NATREX) is the exchange rate that prevails when cyclical factors and speculation are removed, while a level of natural unemployment holds (Takagi & Hicklin, 2007:55). There are two types of exchange rate models that link economic fundamentals with the equilibrium real exchange rate. These two models will be discussed in the following section and are based on the following (Takagi & Hicklin, 2007:53):

- A reduced-form equilibrium real exchange rate regression; and
- External and internal balances.

2.4.2 Two types of equilibrium exchange rate models

The first type includes the Permanent Equilibrium Exchange Rate (PEER) model and the Behavioural Equilibrium Exchange Rate (BEER) model. The second type includes the Desired Equilibrium Exchange Rate (DEER) model and the Fundamental Equilibrium Exchange Rate (FEER) model (Takagi & Hicklin, 2007:53). The FEER can be defined as the exchange rate that is simultaneously consistent with both the external and internal balance (Takagi & Hicklin, 2007:53).

An internal balance is reached when the full-employment level of output at stable prices is reached by an economy, while an external balance is reached when a sustainable balance of payment is achieved over the medium run by an economy (Takagi & Hicklin, 2007:53). The FEER model can be used to split the current account of an economy into the following two components: net trade balances and returns generated from net foreign assets. Both the returns

⁴¹ The estimation of the exchange rate equilibrium does not fall in the scope of this study, but is recommended for future studies.

to net foreign assets and the net trade balance are influenced by the Real Effective Exchange Rate (REER; Takagi & Hicklin, 2007:54).

By substituting the external balance with a current account target, which is set by policymakers, the FEER becomes the DEER (Takagi & Hicklin, 2007:54). By splitting the variables that determine the real exchange rate into short-run real interest rate differentials and long-run economic fundamentals, the FEER becomes the BEER (Takagi & Hicklin, 2007:54). However, the BEER does not distinguish between short-run and long-run economic variables. By splitting the real exchange rate into permanent and temporary components, therefore considering long-run sustainable economic fundamental levels, the BEER will be changed into the PEER (Takagi & Hicklin, 2007:55).

This section only provides an extension to the Nominal Effective Exchange Rate (NEER) and REER, and will thus not elaborate further on the PEER, BEER, and DEER but will focus only on the effective exchange rate and exchange rate equilibrium misalignment. The reason for focussing only on the effective exchange rate is, because one of this thesis' research objectives is to explain the realized future spot exchange rate, which implies explaining the overall future movement of a country's currency. The effective exchange rate also includes the REER and NEER.

The NEER is the relative value of a country's currency compared to the other currencies being traded. It also indicates the relative price payable for an imported good (Investopedia, 2008a:1). The NEER is the unadjusted weighted average value of a country's currency relative to a currency within the same index (Investopedia, 2008a:1). The importance of a foreign country determines the weights used. A NEER coefficient above 1 indicates that the domestic currency is worth more than the foreign currency. A NEER below 1 indicates that the domestic currency is worth less compared to the foreign currency (Investopedia, 2008a:1). The REER is used to determine a country's currency value relative to other currencies (Investopedia, 2008b:1).

The REER is the weighted average of a country's currency relative to a currency and is also adjusted for inflation. These weights are determined by comparing the relative trade balances of two different countries in terms of one country's currency (Investopedia, 2008b:1).

The REER illustrates the relative price in a country, which can be used as a measure of competitiveness (Hyder & Mahboob, 2006:237–238) and to determine the performance of the export sector (Caballero & Corbo, 1989:20). The deviation of the actual REER from the Equilibrium Real Effective Exchange Rate (EREER) is termed exchange rate misalignment (Hyder & Mahboob, 2006:238). In the case of misalignment, the REER fails to be an appropriate measure of resource allocation (Montiel, 2003:311).

Over the short-run, the market-determined exchange rate can deviate significantly from the equilibrium values owing to the following reasons (Hyder & Mahboob, 2006:238):

- FX market failure that is caused by feedback trading and herding that is based on price movements; and
- Transitory shocks caused by weak FX markets in developing countries.

Various studies have sought to estimate the real equilibrium exchange rate, for example MacDonald (1995) and Rogoff (1996). According to Williamson (1994:187), the competing method for estimating the equilibrium exchange rate, besides FEER, is PPP.⁴² Baffes *et al.* (1999:427–433) used co-integration techniques to estimate the equilibrium exchange rate. Montiel (1997:277) suggests that co-integration may be the more superior method for estimating the real exchange rate. However, estimating exchange rate misalignments poses a problem because there is no agreement regarding the manner in which to estimate the equilibrium

⁴² However, as will be seen in Chapter 3 (Section 3.2), it is found that PPP (thus using the inflation rate as an explanatory variable) has both advantages and disadvantages when used as an individual measure to determine exchange rate movements. Past studies have also found evidence that the PPP was not an appropriate measure to determine the equilibrium exchange rate because of the slow mean-reversion of the real exchange rate (see MacDonald & Ricci, 2003:3, for example).

exchange rate. Owing to the complexity of alternative methodologies, the PPP (Section 3.2) may be the only feasible approach owing to its simplicity (Hinkle & Montiel, 1999:33). The commonly used indicators to calculate the exchange rate equilibrium include the following (Hyder & Mahboob, 2006:239):

- Interest rate differentials;
- Nominal and real effective exchange rates;
- Terms of trade;
- Balance of payment outlook and the current external account; and
- Productivity and other competitiveness measures.

These measures however do not allow policymakers to determine the degree of misalignment sufficiently accurately to identify the degree of intervention required and the precise timing (Hyder & Mahboob, 2006:239).

To recapitulate, there is still no suitable model to determine the exchange rate equilibrium, which makes estimating exchange rate misalignment even more difficult. Past empirical studies have indicated that the overall problem in estimating exchange rate movements is determining the ultimate group of variables that have the ability to fully explain exchange movements. This is still the greatest shortcoming in exchange rate dynamics, and this study will attempt to improve on past empirical findings by formulating a model to determine realized future spot exchange rate movements more accurately.

2.5 CHAPTER SUMMARY

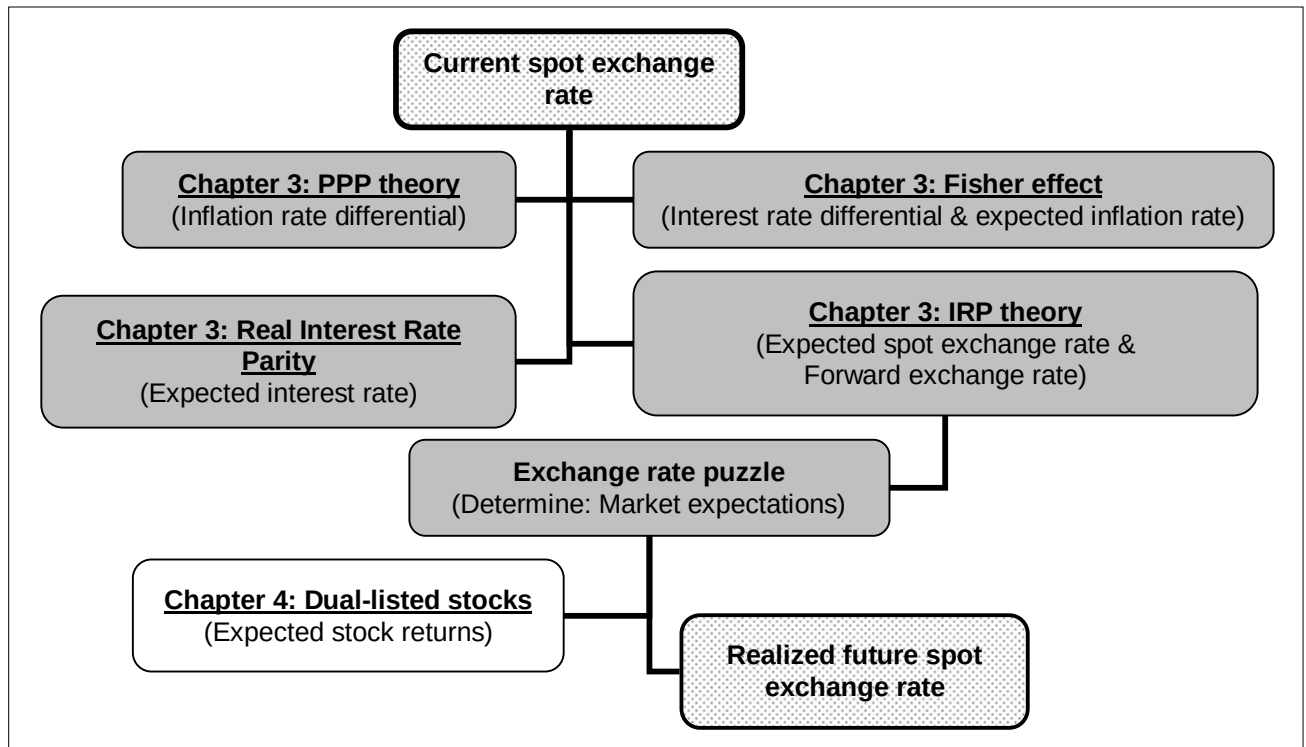
This chapter began by providing an overview of the traditional models developed in an attempt to explain exchange rate movements (Section 2.2). It was established that there is no convincing evidence of a certain group of economic variables that have the ability to explain

exchange rate movements completely. Although, past empirical studies have identified economic variables that were able to provide a partial explanation of exchange rate movements, however, all past models have failed to incorporate market expectations successfully. The exchange rate puzzle was discussed as an explanation of market expectations. The exchange rate puzzle was divided into four smaller puzzles, namely the determination puzzle (Section 2.3.2), the excess volatility puzzle (Section 2.3.3), the forward exchange rate premium puzzle (Section 2.3.4), and the home bias puzzle (Section 2.3.5). The determination puzzle and the excess volatility puzzle emphasise the poor explanatory power of macroeconomic fundamentals and the lack of correlation to exchange rate movements. Furthermore, it was established that the random walk hypothesis (Section 2.3.3.1) has no significant ability to explain exchange rate movements, which contradicts the determination puzzle and the excess volatility puzzle. Furthermore, according to the forward exchange rate premium puzzle, the forward exchange rate is a biased estimate of the realized spot exchange rate. According to the home bias puzzle, investors continue to invest domestically, despite the better integration of international capital markets.

In addition, when analysing the forward exchange rate premium puzzle, it is clear that using forward points only to predict the future exchange rate will lead to biased results. However, by investigating the explanatory power of macroeconomic fundamentals and by investigating the four individual exchange rate puzzles, it was established that the existing models are unable to estimate the realized future spot exchange rate with a reasonable measure of accuracy. Thus, while the explanatory power of macroeconomic variables is under question, **this study's first objective will be to determine the basic macroeconomic explanatory variables required in an exchange rate model.** Chapter 3 will discuss variables that can be used to estimate the current spot exchange rate, which includes the inflation rate differential (the PPP theory in Section 3.2), interest rate differential (the Fisher effect in Section 3.3.2.1), expected inflation rate (the Fisher effect in Section 3.3.2.1), expected interest rate (the Real Interest Rate Parity in Section 3.3.8), current expected spot exchange rate (the IRP theory in Section 3.3),

and the forward exchange rate (the IRP theory in Section 3.3). This is illustrated in Figure 2.3.

Figure 2.3: Further explanation of the exchange rate puzzle



Source: Compiled by author.

Furthermore, in previous studies, it was found that when the exchange rate reached a long-run equilibrium level no further movements occurred, except if exogenous variables had changed (such as market expectations). The inability of existing models to estimate these exogenous variables accurately emphasises their failure to measure the exchange rate equilibrium and the degree of misalignment. Thus, without the ability of estimating the future spot exchange rate accurately, it is not possible to determine the long-run equilibrium level of the exchange rate. Therefore, this study seeks to improve the incorporation of market expectations in exchange rate modelling. This involves including the interaction between two international financial markets (JSE and the NYSE) as different financial market proxies. These financial market proxies will be evaluated to determine which contributes more to exchange rate modelling (Section 5.4). This leads to the following chapter, which will determine the basic macroeconomic explanatory variables required in an exchange rate model. The chapter will begin by examining

the PPP theory (Section 3.2) and the IRP theory (Section 3.3).

CHAPTER 3

The Purchasing Power Parity and Interest Rate Parity Theories

3.1 INTRODUCTION

It is evident from the literature that the use of forward points to estimate the forward exchange rate will provide unsatisfying results. Dibooglu (1998:427) and Nieuwland *et al.* (1998:351), for example, state that the forward exchange rate is a biased estimate of the future spot exchange rate. This means that additional explanatory variables are required (need to be identified) to enhance the estimation from the use of forward points to predict the future exchange rate, which is the primary research objective of this study. In order to identify the required explanatory variables, past exchange rate theories must be examined to identify the most basic variables required for inclusion in a standard exchange rate model. These exchange rate theories can be divided into three main schools of thought, which include the following (Kanamori & Zhao, 2006:30):

- The partial equilibrium approach;
- The general equilibrium approach; and
- The hybrid or disequilibrium approach.

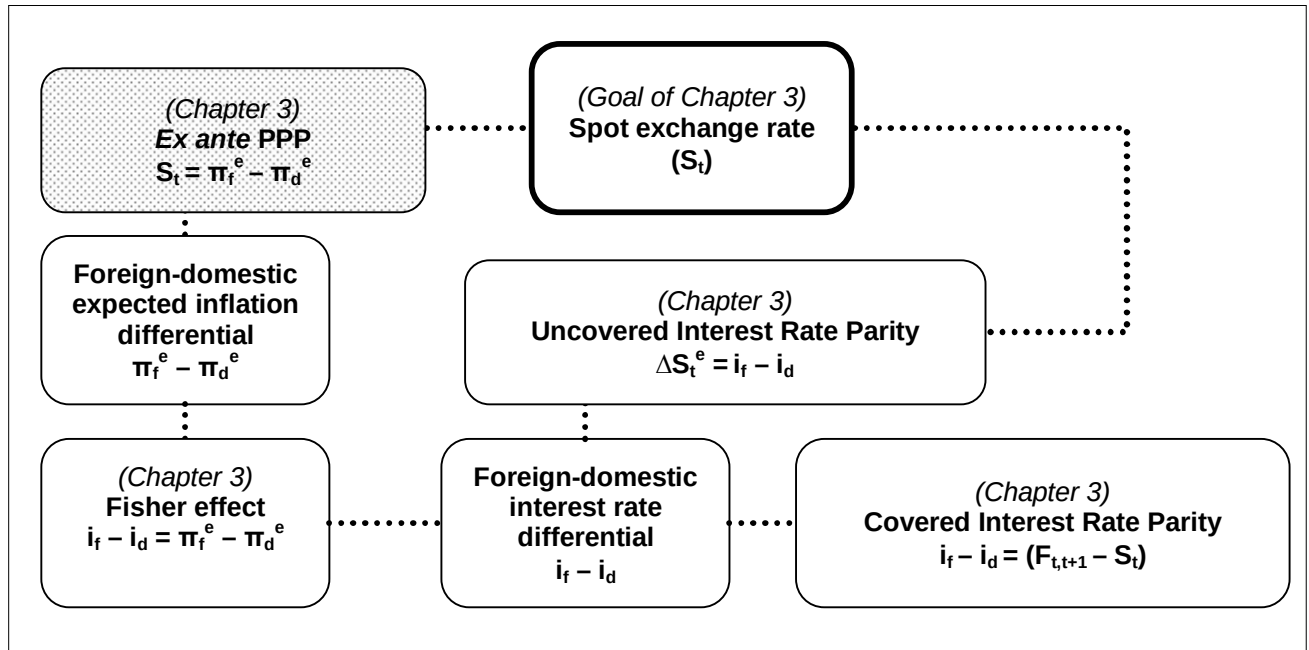
Firstly, the partial equilibrium approach consists of the PPP theory in absolute (Section 3.2.4.1) and relative form (Section 3.2.4.2). Secondly, it consists of the Uncovered Interest Rate Parity theory (Section 3.3.6); and thirdly, of the Covered Interest Rate Parity theory (Section 3.3.3). The first school of thought posits that the absolute PPP and the relative PPP theory consider the factors influencing prices (exchange rates) in the goods market, while the Uncovered Interest Rate Parity and Covered Interest Rate Parity theories consider only the factors

influencing prices (exchange rates) in the financial market (Kanamori & Zhao, 2006:30).

These theories converge to form an integrated whole of the factors driving the spot exchange rates between any two trading countries. The second school of thought consists of the Balassa-Samuelson model, the Mundell-Fleming model, the Pricing-to-market model, and the Redux model, when considering the general equilibrium approach (Kanamori & Zhao, 2006:30). The Balassa-Samuelson model focuses on the role of exchange and the appropriate exchange rate that leads to the maximisation of profit, whereas the Mundell-Fleming model describes the influence of exchange rates on the equilibrium of the money market, the goods market and the balance of payments. Additionally the Redux model explains the influence of exchange rates on the maximisation of a consumer's utility (Kanamori & Zhao, 2006:30). The third school of thought supports the hybrid model and includes the Mundell-Fleming-Dornbusch model, which can be formulated by combining the monetary equilibrium with the adjustment of output and prices towards their long-run equilibrium (Kanamori & Zhao, 2006:30).

Figure 3.1 below illustrates the relationship amongst these four key parity conditions and the current spot exchange rate. Furthermore, Figure 3.1 indicates that this chapter will only discuss the work of the first school of thought, which is the partial equilibrium approach, because this study focuses on the goods market and the financial market. **This chapter's aim is, therefore, to discuss the first two explanatory variables that will be incorporated into this study's exchange rate model, which include the inflation rate and the interest rate.** This chapter will begin by discussing the PPP theory (the dotted block in Figure 3.1), which is also termed the inflation theory of exchange rate (Kanamori & Zhao, 2006:30), as discussed in Section 3.2. The remainder of the chapter will discuss the IRP theory, which consists of the Covered and Uncovered Interest Rate Parity theories with the focus on the factors that influence prices (exchange rate) in the financial market. Regarding the IRP theory, the determination of the forward exchange rate will be discussed as an explanatory variable of the current spot exchange rate (Section 3.3).

Figure 3.1: The relationship amongst the four parity conditions and the spot exchange rate



Source: Rosenberg (2003:113).

3.2 PURCHASING POWER PARITY

3.2.1 Introduction

This section will introduce the PPP phenomenon, which considers the factors influencing prices (exchange rates) in the goods market. Although a focus point of this study is only on the relationship amongst price differences over stock markets (of dual-listed stock, as discussed in Section 4.2) and the spot exchange rates, the PPP forms the first international parity condition that must be examined in order to enhance the understanding of exchange rate movements. This section will provide some explanation regarding the reason that some studies deviated from PPP (Section 3.2.5), the limitations of PPP (Section 3.2.8), and the attempts made to make the PPP theory a more appropriate (Section 3.2.6) approach for estimating exchange rate movements. The following section will start by discussing the law of one price, which will be followed by a discussion on the rise of the PPP theory.

3.2.2 The law of one price

The foundation of the PPP theory is the law of one price (Clark, 2002:72). The law of one price states that apart from factors such as tariffs, taxes and transportation costs, any good that is traded on the world market will sell for the same price when prices are expressed in a common currency (Pakko & Pollard, 2003:9). Therefore, as a fundamental principle of international finance, the PPP stipulates that the change in the exchange rate is determined by changes in the price levels of the two countries (Correia *et al.*, 2003:19–11). Furthermore, the change in the exchange rate should be equal to the difference between the changes in the foreign and domestic prices. In other words, the prices across countries should be equal in the same currency (Lan, 2002:9). The PPP can also be defined as the relationship between the inflation rates and the FX rates of two countries (Levy, 2002:447). The PPP theory can, therefore, be viewed as one of the main building blocks in international economics. Sarno and Taylor (2002:51) state that the PPP exchange rate between two countries links the national price level of each country if expressed in one common currency. However, in a floating exchange rate regime PPP does not appear to hold. PPP also appears to fail to reconcile persistent and volatile real exchange rates (Smallwood, 2008:1161).

In addition, when an item can be sold at a higher price in one country compared to the price at which it was bought in another country, arbitrage occurs. Arbitrage will cause the price to increase in the one country in which the price was low and to decrease in the country in which the price was high. Arbitrage will continue to adjust the prices in the two countries until the law of one price is restored (Pakko & Pollard, 2003:10). This leads to the following section that will discuss the rise of the PPP theory.

3.2.3 The rise of the Purchasing Power Parity theory

The PPP theory was developed when the exchange rates were considered not viable (Balassa, 1964:584) because of different inflation rates across different countries. After the outbreak of World War I, countries abandoned the gold standard, which led to the problem of resetting a

country's exchange rate without disrupting prices and government finance (Rogoff, 1996:648). Gustav Cassel was the first to treat PPP as an empirical theory (Officer, 1976:5) and promoted the concept of PPP for setting relative gold parities after the collapse of the gold standard (Rogoff, 1996:648–649). Cassel (1916:64) was the first to use the term “theoretical rate of exchange” to describe PPP. Furthermore, Cassel (1918:413) quoted the following: “At every moment the real parity between two countries is represented by this quotient between the purchasing power of the money in the one country and the other. I propose to call this parity the Purchasing Power Parity.” Later studies by Yeager (1958), Friedman and Schwartz (1963) and Gaillot (1970) helped establish the PPP theory amongst economists.

The magazine *The Economist* focused attention on the PPP theory in 1986 with the Big Mac hamburger example (Lan, 2002:9). The Big Mac PPP is the exchange rate that will equate the price of hamburgers in the U.S.A. and abroad (*The Economist*, 1998:58). The Big Mac PPP can, therefore, help with the valuation of a currency. According to Kanamori and Zhao (2006:31), Cassel once argued that without PPP, there would be no meaningful way to discuss the under- or overvaluation of a country's currency. By adjusting the following equation for the ZAR/USD exchange rate, the Big Mac PPP can be expressed in logarithmic form as follows (Ong, 1997:867):

$$r_{ct} \equiv \log \left(\frac{P_{ct} \div P_t^*}{S_{ct}} \right) = \log \frac{P_{ct}}{P_t^*} - \log S_{ct} \quad (3.1)$$

where:

- r_{ct} is the Big Mac PPP estimate;
- P_{ct} is the domestic currency price in country c in year t ;
- P_t^* is the price of in USD in year t ;
- S_{ct} is the spot exchange rate; and
- $\frac{P_{ct}}{P_t^*}$ is the Big Mac PPP.

According to Equation 3.1, a country's currency is overvalued if r_{ct} is greater than zero, undervalued if r_{ct} is less than zero, and at parity if r_{ct} is zero (Ong, 1997:867). In addition, Abel *et al.* (2008:480) state that the PPP theory can be given by the following equation:

$$P = \frac{P_{for}}{e_{nom}} \quad (3.2)$$

where:

- P is the price of the domestic good;
- P_{for} is the price of the foreign good; and
- e_{nom} is the nominal exchange rate⁴³.

According to Officer (1976:2), the PPP theory can incorporate two perspectives, which involve the short-run and long-run equilibrium exchange rates. The short-run equilibrium exchange rate is the rate that exists under a floating exchange rate system, while the long-run equilibrium exchange rate is a managed exchange rate that yields a balance of payments equilibrium and accounts for all cyclical fluctuations in the balance of payments (Officer, 1976:2). Furthermore, the PPP theory can also be divided into two variations, the absolute PPP and the relative PPP. Rogoff (1996:649) elaborates on the presence of these variations, stating that there is no correct variation of PPP, it only depends on the purpose of the PPP measurement. This leads to the following section that will describe these two variations of PPP.

3.2.4 Variations of the Purchasing Power Parity theory

The PPP can be divided in an absolute and relative PPP. The absolute PPP theory is the first theory that concerned the price relationship of goods, and where the value of the goods could be expressed in two different currencies (Kanamori & Zhao, 2006:31).

⁴³ The nominal exchange rate is the amount of foreign currency that can be purchased with one unit of domestic currency (Abel *et al.*, 2008:477).

3.2.4.1 Absolute Purchasing Power Parity

The absolute PPP determines the demand for currency, which is determined by the number of goods and services one unit of currency can buy (Officer, 1976:6). In other words, it is determined by the *internal* PPP (the inverse price level for goods and services). Officer (1976:6) states that the ratio of the price levels or the ratio of the internal purchasing powers can be defined as the absolute PPP. According to the absolute PPP, the nominal exchange rate can be determined by the ratio of the foreign relevant price level and the domestic relevant price level (Sarno & Taylor, 2002:58). Elaborating on this, Balassa (1964:584) explains that the absolute PPP is the ratio of consumer goods prices for any two countries, which tend to estimate the equilibrium exchange rate. Therefore, if PPP holds, Equation 3.2 can be rewritten as follows (Pakko & Pollard, 2003:10):

$$\frac{P_{for}}{P} \times \frac{1}{e} = 1. \quad (3.3)$$

The left-hand side of Equation 3.3 is known as the real exchange rate, which is adjusted by relative price levels (Pakko & Pollard, 2003:10). The real exchange rate is the number of foreign goods that can be acquired in exchange for one domestic good (Abel *et al.*, 2008:479). In addition, Taylor and Taylor (2004:141) state that the real exchange rate can be interpreted as a measure of deviation from PPP. Therefore, for the absolute PPP to hold the prices of each good must be equalised between the two countries and the goods baskets, and their weights must be the same in the two countries (Kanamori & Zhao, 2006:31). Thus, Equation 3.3 can be rewritten as follows:

$$P = SP^* \quad (3.4)$$

where:

- P is the price level of the good in the domestic currency;
- P^* is the price level of the good in the foreign currency; and
- S is the nominal exchange rate that expresses the price in foreign currency in terms of the domestic currency.

In addition, the absolute PPP is based on assumptions that may also be the reason that the absolute PPP does not hold. The absolute PPP holds in an integrated, competitive product market in which the world is assumed to be risk neutral and in which goods are traded freely without tariffs, export quotas or transport costs (Kanamori & Zhao, 2006:31). However, in reality this assumption seems unrealistic, as transport costs must arise in order to ensure consumers from different countries acquire the imported goods needed to maximise utility. Thus, the absolute PPP can be viewed as a condition of the goods market equilibrium. Nevertheless, as the absolute PPP is not concerned with the balance of international payments and money markets, it can only be considered a partial equilibrium theory (Kanamori & Zhao, 2006:31–32).

The absolute PPP is based on assumptions of a perfect market with high information efficiency in both the goods market and the FX market, but it is difficult to establish a common basket of goods, which prevents the implementation of the absolute PPP, and thus, a weaker version of PPP must be used (Van Marrewijk *et al.*, 2007:438). This led to the development of the relative PPP, as discussed in the following section. Sarno and Taylor (2002:58) state that the relative PPP stipulates that the changes in relative national prices are equal to the changes in the exchange rate.

3.2.4.2 Relative Purchasing Power Parity

Relative PPP describes the relationship of prices of the goods market to the exchange rate in two different countries (Kanamori & Zhao, 2006:32). The relative version of PPP is based on the movements of the price levels, which are measured by the changes in prices relative to a base period (Lan, 2002:14), where the base period is the actual exchange rate (Officer, 1976:8). Balassa (1964:584) explains that the changes in relative prices may indicate the required adjustments in the exchange rates. In order to derive the equation for relative PPP, it must be assumed that transaction costs are proportionately linked to the price level, which can be illustrated as follows (Kanamori & Zhao, 2006:32):

$$(1 + k)P_t = S_t P_t^* \quad (3.5)$$

where:

- kP_t is the transport costs;
- k is a constant;
- $(1 + k)P_t$ is the commodity that is equal to the price of foreign currency, multiplied by the exchange rate in terms of home currency;
- P_t is the home price of the commodity at time t ;
- P_t^* is the foreign price of the commodity at time t ; and
- S_t is the nominal exchange rate that expresses the price in foreign currency in terms of the domestic currency at time t .

In addition, by using the logarithm and performing a differential operation on each side of Equation 3.5, relative PPP can be expressed as follows (Kanamori & Zhao, 2006:32):

$$\frac{\Delta E_t}{E_t} = \frac{\Delta P_t}{P_t} - \frac{\Delta P_t^*}{P_t^*} \quad (3.6)$$

Equation 3.6 implies that the relative change of the exchange rate is equal to the inflation differential between two countries. Thus, by assuming that $\frac{\ln S_t}{S_t} = s_t, \frac{\ln P_t}{P_t} = p_t, \frac{\ln P_t^*}{P_t^*} = p_t^*$, Equation 3.6 can be rewritten as follows (Kanamori & Zhao, 2006:32):

$$s_t = p_t - p_t^* \quad (3.7)$$

Furthermore, Abel *et al.* (2008:482) state that the relative PPP is “the rate of appreciation of the nominal exchange rate equal to the foreign inflation rate minus the domestic inflation rate”. Thus, by assuming that the real exchange rate is denoted by the following ratio of national price levels the following equation can be formulated (Kanamori & Zhao, 2006:33):

$$q_t = \frac{S_t P_t^*}{P_t} \quad (3.8)$$

Equation 3.8 will be equal to one if the absolute PPP holds; however, Equation 3.8 will not necessarily be equal to one but will be constant if relative PPP holds. Equation 3.8 also indicates that if a fixed exchange rate regime is implemented, the relative PPP will indicate that domestic prices and foreign prices will change at the same speed. Kanamori and Zhao (2006:33) state that in the case in which the inflation rates in two countries are the same, the relative PPP will imply that the exchange rate will be a constant. Officer (1976:8) elaborated on this statement by explaining that the relative PPP in the current period will give the same estimates as the absolute PPP that is calculated for this specific period. However, this will only occur if the changes in the economies since the base period are of a monetary nature (Officer, 1976:8).

To summarise, even with the construction of a weaker form of PPP, namely relative PPP, the PPP theory still fails to produce accurate exchange rate equilibrium estimates. This yields strength to the possibility that PPP theory may not be a suitable exchange rate measure, but should only be used as a guide to establish the exchange rate equilibrium (Yeager, 1958:516).

In addition, Pippenger (1993:55) found that relative PPP holds over the long-run, which was confirmed by Hoontrakul (1999:7), who argues that these findings may explain why PPP is viewed as a long-run equilibrium condition and not as an informal relationship. Furthermore, the PPP theory does not explain why the real exchange rate should remain constant over a certain time horizon (Kanamori & Zhao, 2006:33). The reason that PPP theory still fails to explain persistent and volatile real exchange rates is also unclear. The following section will elaborate on some of the reasons for the PPP theory to fail, with the focus on discussing the deviations from the exchange rate that was generated from the PPP theory.

3.2.5 Deviations from the Purchasing Power Parity-generated exchange rate

With the introduction of flexible exchange rates in the 1970s, the high volatility of the real and nominal exchange rates led to reduced importance of the PPP theory (Lan, 2002:9). The following offers additional explanation regarding the deviation of the floating exchange rate from the exchange rate calculated by PPP (Bunting, 1939:283–284; Officer, 1976:9–10):

- Trade restrictions between two countries may be more severe in one direction than in the other. For example, if imports of a country are more restricted than its exports, it may cause the country's currency exchange value to exceed the PPP;
- Speculation against a country's currency may cause the exchange value of the currency to be lower than the PPP. Officer (1976:30) and Tsiang (1959:249) state that speculation may be a reason that the floating exchange rate may deviate from the long-run equilibrium;
- Greater inflation expectations in one country compared to the other may cause the exchange value of the currency to be lower than the PPP (for the country with the greater inflation expectations);
- Relative price changes indicate any real changes in the economy from the base period that cause the relative PPP to divert from the exchange rate equilibrium;
- Long-run capital movement may cause the exchange rate to move away from the PPP; and
- The government can intervene in the FX market, by increasing the bidding price of FX above PPP.

According to Pakko and Pollard (2003:16), there are also other factors that cause the deviations from the exchange rate generated from the PPP theory, which include the pricing of and the existence of barriers to trade:

- Barriers to trade lead to higher prices in one country and include the following (Pakko & Pollard, 2003:16):

- O Transportation costs: It may be costly to transport goods across borders, which can cause a gap between the prices of a good in different markets;
 - O Trade restrictions: This includes quotas, tariffs, and other legal restrictions – a tariff is a tax on imported goods and a quota is a limit on the number of goods that may be imported; and
 - O Taxes: it may happen that one country has a higher tax rate than the other, which may lead to an overvalued currency.
- Non-traded goods may also account for up to 94% of the price of a good (Ong, 1997:872) and include the following:
 - O Productivity: The per capita income levels of a country reflect its differences in labour productivity, whereas the wage differences in different countries indicate a difference in productivity (Balassa 1964:587–589; Samuelson, 1964:150). However, this theory may not be useful between countries with similar per capita incomes (Pakko & Pollard, 2003:18); and
 - O Current account deficits: The spending of traded goods increases when a country has a current account deficit, which may lead to a decrease in the prices of non-tradable goods (Krugman, 1990:183–185, Pakko & Pollard, 2003:21).

Besides the above-mentioned factors, Van Marrewijk *et al.* (2007:438) state that the factors that must be taken in consideration regarding the cause of the exchange rate deviating from PPP include differentiated goods, fixed investments and thresholds, and composition:

- Differentiated goods: Goods in different countries may not always be homogeneous goods, making it almost impossible to establish a common basket of goods in each country. It is, therefore, unsurprising that the absolute PPP may not hold. The importance of acquiring a common basket of goods was emphasised by Stern (1973:143), who stated that “the calculation of PPP on the basis of the absolute interpretation requires taking a common

basket of goods with a standard system of weighting for the individual countries". However, most studies do not compare identical baskets of goods (Froot & Rogoff, 1995:1650), instead, consumer and wholesale price indices are used, which consist of different mixes of goods and weights. This approach may not necessarily demonstrate whether PPP holds, unless the two countries have the same baskets of goods (Ong, 1997:866). By following this approach, Pigou (1922:67–68) found that the estimation of the actual price indices from the individual prices may lead to a deviation from PPP, which implies that the parity will vary, depending on the price indexes selected (Officer, 1976:13). Based on findings, it has been suggested that PPP may work better if it is based on indices made up only of tradable goods, rather than consumer price indices, or costs of production, especially if labour costs are used (Sarno & Chowdhury, 2003:322);

- Fixed investments and thresholds: Some form of a fixed investment cost must be paid if advantage of an arbitrage opportunity is to be taken, for which the investment cost may also differ for each basket of goods. Furthermore, the “arbitrage will be heavy once it is profitable enough to outweigh the initial fixed cost, but will stop short of returning the real rate to the PPP level because of the [...] arbitrage costs” (Sarno & Taylor, 2002:56); and
- Composition: The difficulty with using price indices is that the types of goods and the weights for the different categories differ per country.

Another explanation for the deviations from the exchange rate generated from the PPP theory is the ability to price to market, which depends on the difficulty of reselling a good across countries (Pakko & Pollard, 2003:21):

- With the ability to price goods in different countries, the elasticity of demand for these goods also determines whether the firm has the ability to maximise profits (Krugman, 1987:59–60);

- In order for the PPP to hold, perfect competitiveness in the market is required. However, in imperfect competitive markets, firms have market power that may lead to higher prices (Pakko & Pollard, 2003:21); and
- The exchange rate pass-through may be limited by firms that price to market in international markets. The exchange rate pass-through is the extent to which imported prices are changed by changes in the exchange rate (Pakko & Pollard, 2003:21). Findings suggest that the pass-through behaviour in a floating exchange rate system may be a significant source of the deviation from the PPP (Feenstra & Kendall, 1997:259).

Furthermore, the role of prices in the determination of the exchange rate may be considered an important factor, but the level of incomes must also be considered because it can influence the exchange rate and trading (Yeager, 1958:518). Although, price and income movements are still affected by changes in the business cycle that may influence the PPP (Yeager, 1958:518). However, PPP represents the long-run equilibrium exchange rate, which means that it will not respond to cyclical variations in income levels (Officer, 1976:16).

Another explanation for the deviations from the exchange rate may be the difficulty of interpreting the deviation of the relative PPP because of the sensitivity of selecting a base year for comparison (Rogoff, 1996:651). Selecting the base year is one of the first problems in estimating the relative PPP (Metzler, 1947:18). With a floating exchange rate it is difficult to select a base period exchange rate because the base period must be in equilibrium over the long-run (Officer, 1976:20). A second difficulty in choosing a base period is that the economy may have changed in some manner since the base period (Officer, 1976:20). Additional findings also suggested that changes in income may affect the short-run exchange rate equilibrium (Nurkse, 1950:10–12, Metzler, 1947:19–20). Thus, selecting a base period in different phases of the business cycle may reduce the accuracy of the PPP theory. Therefore, relative PPP requires the assumption that the national income is constant (Scammell, 1961:59). Hence, any structural changes in the economy may cause the relative PPP to diverge from the absolute

PPP, thus moving away from the long-run exchange rate equilibrium (Officer, 1976:21).

In addition, a criticism of absolute PPP is that the PPP theory views price levels as the causal factors and the exchange rate as the determined factors (Officer, 1976:17). The mutual causation of prices and of the exchange rates is compatible with the PPP theory only under normal circumstances, as long as causation of the price levels is greater than that of the exchange rate (Yeager, 1958:520–522). However, the influence of the exchange rate on price levels applies only over the short-run, whereas the PPP theory states that price levels are a long-run determinant of the equilibrium exchange rate (Officer, 1976:17).

Besides the role of prices as a possible cause of the deviations from PPP, the magnitude of interest rate differentials and the relative prices of traded goods are associated with the deviations from PPP to some extent (Feenstra & Kendall, 1997:257). Furthermore, it is argued that the deviations from PPP are mainly caused by the continuously clearing asset markets and the slow price adjustments of the goods market (Dornbusch, 1976:1162). On the other hand, Liu *et al.* (2002:14–16) argue that the real exchange rate may be associated with other factors, such as the preferences of consumers. This implies that tariff policies or tax policies may have the ability to change the real exchange rate (Kanamori & Zhao, 2006:33). This finding is confirmed by Kanamori and Zhao (2006:33), who found that deviations from PPP may be due to consumers' preferences regarding uncertainty and risk, and differences in production technology between two countries.

To recapitulate, a number of factors that may cause the exchange rate to deviate from the PPP-generated exchange rate were identified. Some of the first factors identified include trade restrictions between two countries, speculation against a country's currency, greater inflation expectations, relative price changes, the long-run capital movement, and government authority to intervene in the FX market. Additional factors were also identified, which include barriers to trade, non-traded goods, differentiated goods, fixed investments and thresholds, composition,

the ability to price to market, level of incomes, interest rate differentials, and the relative traded goods prices. In addition, continuous clearing of asset markets and the slow price adjustments of the goods market, consumers' preferences regarding uncertainty and risk, differences in production technology between two countries may also lead to deviations from the generated-PPP exchange rate.

However, Lutz (1966:13–14) states that despite these limitations support for the PPP theory is well established amongst journalists and government and international officials. He refers to the “indestructible popularity” of the PPP theory. These deviations led to modifications to the PPP theory, which will be discussed in the following section.

3.2.6 Modifications to Purchasing Power Parity

Several studies modified the PPP theory in an attempt to compensate for the factors discussed in the previous section that cause the exchange rate to deviate from PPP. The most significant of these modifications and studies are listed below:

- The Productivity Bias Hypothesis (PBH), formalised by Balassa (1964:586–587), has received probably the most criticism with regard to PPP research. The PBH states that the productivity growth in the tradable goods sector is greater than the productivity growth in the non-tradable goods sector (Ong, 1997:866). For example, if price deflators are used to estimate the real exchange rate, which include both tradable and non-tradable goods, the currency of the country with a greater productivity growth in the traded sector will be overvalued relative to its PPP levels (Ong, 1997:866);
- Another method of accounting for PPP, instead of the PBH, is the United Nations International Comparisons Project (ICP) method. The ICP is focused on the productivity differentials between two countries and enables the comparison of the price levels, not only the relative changes in price levels, between the two countries (Ong, 1997:866);

- Another modification includes adjustments to PPP in the level of government spending (Rogoff, 1996: 663). Government spending is associated as a determinant of the real exchange rate because government spending concentrates more on non-traded goods (Froot & Rogoff, 1991:270). Thus, an increase in government spending may lead to an increase in the real exchange rate; and
- The fourth PPP modification entails the theoretical correlation between the cumulated current account deficit and the long-run real exchange rate depreciation (Rogoff, 1996:662–663). Evidence suggests that there may be a correlation between the movement of the current account and the changes in the real exchange rate (Hooper & Morton, 1982:49–50).

In summary, owing to the factors causing deviations from PPP and despite the modifications made to PPP in an attempt to compensate for some of these, the term residual validity of PPP remains of consequence. The residual validity of PPP recognises the range of applicability of the PPP theory⁴⁴. The following section will briefly describe the residual validity of PPP.

3.2.7 Residual validity of Purchasing Power Parity

According to Haberler (1936:37–38), there are three situations in which the PPP theory is applicable:

- Under normal circumstances, which causes hardly any deviations from the equilibrium rate (Haberler, 1961:51);
- When relative prices changes are dominated by general price movements, which makes the relative PPP a useful instrument – but only “if cautiously used [...] PPP calculations have considerable diagnostic value, especially in periods of severe inflation” (Haberler, 1961:50); and

⁴⁴ See Officer (1976:24) for further reference. The term validity refers to the “conditions” for the PPP theory to be applicable.

- When the trade relationship between countries is disrupted, for example, by a war, the PPP can provide the equilibrium exchange rate required to resume normal trade relations – in addition, the relative PPP can help to provide estimates of new equilibrium exchange rates in countries with large inflation rates (Metzler, 1947:22–24).

In conclusion, PPP may continue to be used as a basis for estimating equilibrium exchange rates, despite criticism of the PPP theory (Ellsworth, 1950:600). Purchasing Power Parity can help countries with different inflation rates determine the necessary changes required in the exchange rates or in the price levels (Kindleberger, 1973:392). However, estimating PPP still poses certain problems, which will be discussed in the following section.

3.2.8 Problems in estimating Purchasing Power Parity

According to Van Marrewijk *et al.* (2007:440), there were many econometric problems with the early testing of the PPP theory. The first problem was the endogeneity problem, which was that the exchange rates were not determined by prices, rather both the exchange rates and the prices were determined simultaneously.

The second problem included co-integration and stationarity (Van Marrewijk *et al.*, 2007:440). For example, stage-one tests⁴⁵ were implemented to test for the possibility of non-stationarity in relative prices and exchange rates, but this led to spurious results (Froot & Rogoff, 1995:1669–1672). The introduction of more advanced time-series techniques led to the testing of the RWH in real exchange rates. However, it can become difficult to distinguish between a highly autocorrelated autoregression and a random walk (Adler & Lehmann, 1983:1483). Evidence contradicting the hypothesis of a highly stable autocorrelated autoregression was found, which indicates that a random walk may be present (Adler & Lehmann, 1983:1483). Other studies (see, for example, Enders, 1988:504,506–508) focused on the possibility of a co-integration relationship between nominal exchange rates and relative prices, but failed to find evidence of

⁴⁵ A simple linear regression, using PPP as the null hypothesis (Froot & Rogoff, 1995:1651).

such a relationship. The introduction of unit root econometrics lent more meaning to the PPP theory. With the help of unit root econometrics, Edison (1987:381–382, 385) found evidence of exchange rate convergence to PPP.

Nonetheless, even with improved econometric methods and the support for the validity of long-run PPP, the speed of PPP reversion is still found to be indolent (Taylor, 2006:8). It was found that the speed of PPP reversion, with a half-life⁴⁶ of about three to five years, was too long to be explained by models with nominal rigidities (Rogoff, 1996:648). Alternative econometric models, which include a state-space model, also indicate that it takes years for the nominal exchange rates to converge, while it takes only months for prices to converge (Engel & Morley, 2001:18). These findings were corroborated by Cheung *et al.* (2004:136), who found that approximately 60% to 90% of the real exchange rate convergence could be explained by nominal exchange rates, with a weak contribution of prices to PPP convergence.

In addition to the above-mentioned econometric models, Taylor *et al.* (2001:1019) considered the possibility that real exchange rates might follow a Smooth Transition Autoregressive (STAR) model⁴⁷, which emphasised transaction costs. Ordinarily generated-PPP exchange rate models do not include obstructions to trade (this includes transaction costs, transportation costs and trade restrictions). By not including these obstructions to international trade, the exchange rate may deviate from the generated-PPP exchange rate and lead to arbitrage opportunities (Sercu *et al.*, 1995:1310–1315). This led to the possibility of the existence of non-linear adjustments of deviations from PPP, which was also supported by Bec *et al.* (2004:383). These findings were also corroborated by Wu and Chen (2008:685), who found that if real exchange rates were found to be stationary and non-linear, a non-linear model would justify the issues on PPP convergence better than a linear vector error-correction model. It has also been argued that the use of fractional integration may be able to reduce half-life (Cheung & Lai, 2001:126).

⁴⁶ A half-life indicates the time it will take for a unit shock to dissolve the real exchange rate by half (Cheung & Lai, 2001:126).

⁴⁷ A non-linear model that can be used to capture regime-switches in economic time series data (Van Dijk *et al.*, 2002:3).

Acquiring heterogeneous dynamics in a panel context could also reduce the half-life of deviations from PPP (Imbs *et al.*, 2005:36). Evidence to support the presence of a fractional order of integration was also found, but this questioned the possibility of an integer order of integration for real exchange rates (Achy, 2003:543–547, 551–552).

Though, Smallwood (2008:1163) found that in the case of small deviations from PPP the real exchange rate can behave in the same manner as a random walk. However, with substantial deviations from PPP the process may become mean-reverting (Smallwood, 2008:1163). The presence of a threshold non-linear mean-reversion process in the real exchange rate was confirmed by Paya *et al.* (2003:429–434), who argued that half-life estimates based on autoregressive linear specifications may be biased.

However, it is easy to confuse non-linear models and regime-switching models⁴⁸ with fractional integration⁴⁹ (Krämer & Sibbertsen, 2002:235–236). This led to the use of alternative models, which include Exponential Smooth Transition Autoregressive (ESTAR) models, which allow for smooth transition between regimes (Smallwood, 2008:1162). Using the ESTAR model, Taylor *et al.* (2001:1033) found that the half-life of deviations from PPP could be reduced. Taylor *et al.* (2001:1033) investigated PPP convergence also using ESTAR, and found that the estimated half-life of real exchange rates was shorter than that calculated with linear models. Although STAR models can provide statistically significant evidence for exchange rate modelling, a shortcoming of these models is that the assumption is made that real exchange rates are stationary without testing for stationarity (Wu & Chen, 2008:685). Using the likelihood ratio (LR) test, Bec *et al.* (2004:389) rejected the unit root hypothesis against the non-linear Threshold Autoregressive (TAR) stationary process of real exchange rates. The above discussion, therefore, indicates that there is still no decisive evidence that signifies the existence of a single dominant econometric approach that can justify the use of the PPP theory in

⁴⁸ See Section 6.3.2.1 and Hamilton (1989) for further references on the Markov-regime switching model.

⁴⁹ See Section 2.3.4.2.1.

exchange rate dynamics.

Past studies have also found mixed evidence concerning whether PPP is a long-run or short-run theory. Pakko and Pollard (2003:14), for example, found that PPP holds over the short-run for both the absolute PPP and relative PPP. In contrast, Gaillot (1970:348), for example, found that PPP is a long-term theory, whereas Oh (1996:411–416) using ICP data found that the PPP holds in the long-run under flexible exchange rates for both Organization for Economic Cooperation and Development (OECD) and G6 countries. Over the long-run, the exchange rate between the two currencies should move towards a rate that leads to equal prices for the same basket of goods and services in both countries (The Economist, 1998:58). The bilateral exchange rate between the ZAR and a foreign country illustrates that there is a relationship between the fluctuations of the exchange value of the ZAR, the IRP in the short-run, and PPP in the long-run (Go, 2008:1). However, Acaravci and Acaravci (2007:171–172) investigated the time horizon from 1990 to 2006 and found evidence that the long-run PPP does not hold for South Africa.

To summarise, no dominant econometric model was found to estimate a PPP-generated exchange rate, and there is no significant evidence that proves whether PPP is only a long-run or only a short-run theory. This makes it difficult to determine whether the PPP theory can be used in this study to enhance the estimation of the future exchange rate.

3.2.9 Summary

There are four key international parity conditions that may provide an integrated picture of the factors driving the spot exchange rate. These conditions are the PPP, the Covered and Uncovered Interest Rate Parity, and the Fisher effect. The first part of this chapter has discussed the first parity condition, PPP, which links the inflation rate differential with the spot exchange rate. Variations of PPP (Section 3.2.4), causes of the deviations from PPP (Section 3.2.5), modifications of the PPP theory (Section 3.2.6), and problems regarding the estimation

of the PPP have all been discussed (Section 3.2.8). It was found that no single econometric approach is able to determine whether PPP holds. Furthermore, there is no conclusive evidence to confirm whether PPP is a long-run or a short-run theory. It was found that while PPP may not provide a good estimate of the current spot exchange rate movements independently, it still forms a basic explanatory fundamental that is required to formulate an exchange rate model.

Since specific investment decisions are made based on expected exchange rate investments, both investors and analysts will benefit from a more accurate estimation of the realized spot exchange rate. This can be achieved by investigating three of the most important parity relationships in the international financial markets, namely FX rate expectations, PPP and IRP. An understanding of these parity relationships can help investors to understand the reasons the financial markets react the way they do, and help them to determine the workings of the financial market movements. These parity relationships also serve as a benchmark and can help identify market anomalies, such as market inefficiency. As a policymaker, these parity conditions may help determine the effective exchange rate equilibrium for the purpose of implementing stabilisation regimes. The estimation of PPP exchange rates can help to determine the degree of misalignment of the nominal exchange rate, compare national income levels and assist in the setting of exchange rate parities. This chapter has already described the PPP theory as part of the partial equilibrium approach (Section 3.2). The second part of this chapter (Section 3.3) will conclude the partial equilibrium approach with a discussion on IRP theory, which considers only the factors influencing prices (exchange rates) in the financial market.

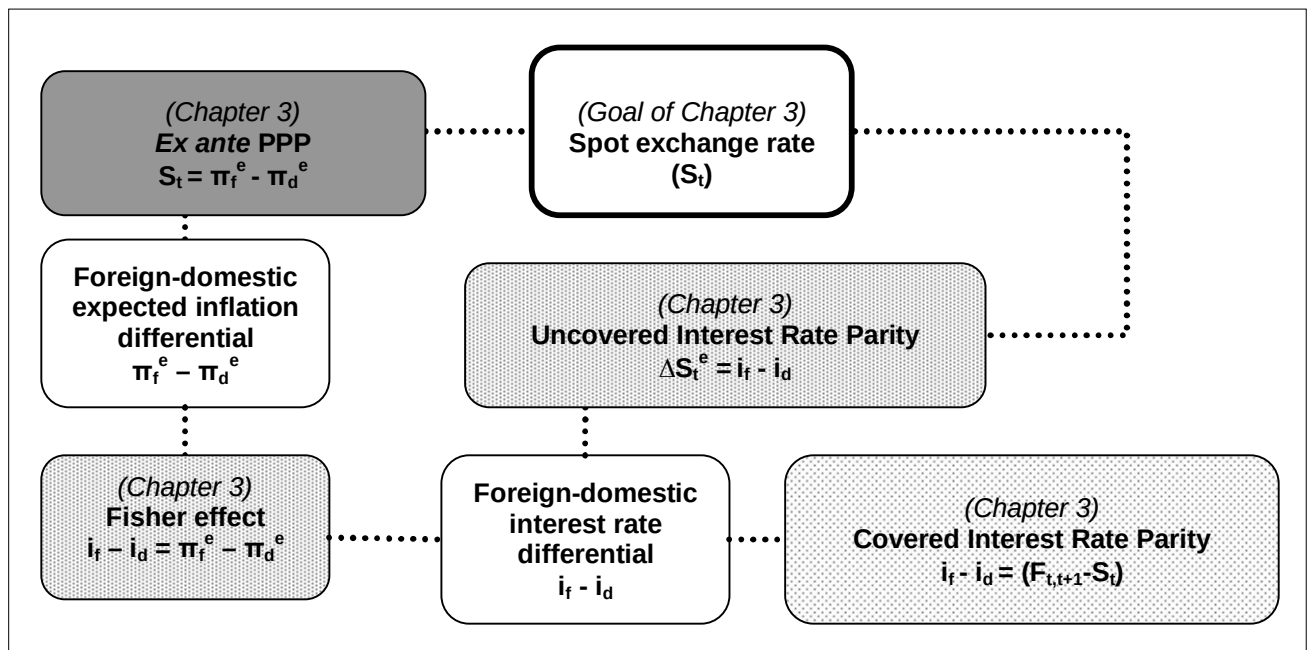
3.3 INTEREST RATE PARITY

3.3.1 Introduction

The previous section (Section 3.2) discussed PPP (dark coloured block in Figure 3.2), as a link between the inflation rate differential and the current spot exchange rate. The PPP theory was also applied to the inflation differential as the first determinant of spot exchange rate

movements. This section will extend the discussion on the four key international parity conditions. Here the interest rate differential (IRP) will be discussed as the second determinant of the current spot exchange rate, as well as the determinant of the forward exchange rate.

Figure 3.2: The four parity conditions and the spot exchange rate



Source: Rosenberg (2003:113).

Section 3.3.2.1 will commence by linking the inflation rate with the interest rate (Fisher effect); and then by linking the interest rate with $F_{t,t+1} - S_t$, which is called the Covered Interest Rate Parity (Section 3.3.3). This will be followed by a discussion on Uncovered Interest Rate Parity that will link the expected change in the spot exchange rate with the interest rate (Section 3.3.6). Covered Interest Rate Arbitrage will be discussed in (Section 3.3.5), while Uncovered Interest Rate Arbitrage will be discussed in Section 3.3.7. A discussion on the Real Interest Rate Parity theory will follow in Section 3.3.8,⁵⁰ which is followed by examining the factors that must be accounted for to ensure that IRP holds (transaction costs and the risk premium; Section 3.3.9).

⁵⁰ See Figure 3.2 for an illustration of this discussion on these parity conditions.

3.3.2.1 The rise of the Interest Rate Parity theory: The Fisher effect

The American economist Irving Fisher is well known for his contribution to interest rate theory. Fisher (1930) was the first to investigate the foundation of the underlying relationship between the inflation rate and the nominal interest rate (Cooray, 2002:2). This underlying relationship describes the response of the nominal interest rate to the inflation rate, which is called the Fisher effect (Hatemi-J., 2009:117). It stipulates that at any given period the nominal interest rate will be equal to the sum of the expected inflation rate and the real interest rate (Cooray, 2002:2). The Fisher effect also states that changes in the expected inflation rate will have no effect on the real interest rate because this may lead to an equivalent nominal interest rate change (Hatemi-J., 2009:117). According to Fisher (1930:408–412), there is a one-to-one relationship between the expected inflation rate and the nominal interest rate. Thus, by correcting the nominal interest rate for increases in price levels (inflation = π) the following equation (the Fisher equation/effect) can be used to demonstrate the calculation of the real interest rate (Van Marrewijk *et al.*, 2007:448):

$$r = i - \pi^e \quad (3.9)$$

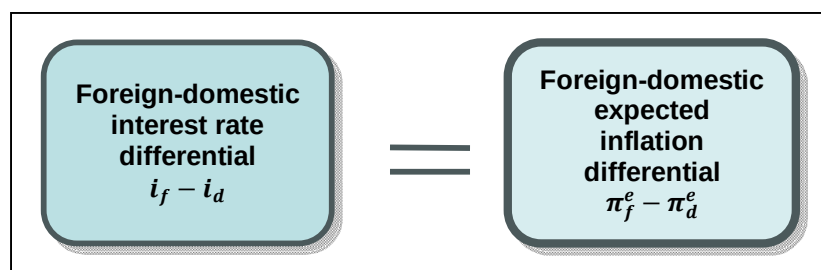
where:

- r is the real interest rate;
- i is the nominal interest rate; and
- π^e is the expected inflation rate.

According to Sundqvist (2002:11), the generalized version of the Fisher effect states that arbitrage equalizes the real returns that refer to an integrated capital market. Overall, the IRP theory can be considered one of the most common approaches to measuring the financial integration of two trading countries (Agénor & Montiel, 1999:200), where IRP indicates the possibility for an investor to save money in different locations (Chinn, 2007:1). With the assumption of foreign and domestic assets being perfect substitutes, a country with a higher real interest rate will experience a higher capital inflow compared to a country with a lower real

interest rate. This capital inflow will continue until the expected real returns are equalized (Sundqvist, 2002:11–12). Thus, the real interest rate will be equalized in a perfect capital market and if complete capital mobility is possible. The Fisher effect is illustrated in Figure 3.3.

Figure 3.3: The Fisher effect



Source: Rosenberg (2003:111).

There are additional factors that can prevent investors from taking advantage of the real interest rate differential. These factors include psychological barriers, legal constraints, transaction costs, taxes, political risk, and currency risk (Sundqvist, 2002:12). Thus, if a perfect capital market exists and if capital mobility is possible, the nominal interest rate differential will be equal to the expected inflation rate differential at equilibrium (Shapiro, 1998:164).

Despite this sound foundation of the Fisher effect, several empirical studies have not demonstrated support of the Fisher effect. Huizinga and Mishkin (1986:251) and Kandel *et al.* (1996:207), for example, found that there is a negative relationship between the expected inflation rate and the real interest rate. Crowder and Wohar (1999:316) found that the Fisher effect was usually less than one in the U.S.A., where the Fisher effect was also similar for both non-taxable and taxable interest rates. It has also been found that countries with a high inflation rate generally have higher interest rates (Shapiro, 1998:165). However, Coppock and Poitras (2000:181) contradict these findings, stating that the interest rate fails to adjust fully to inflation.

Several studies have found evidence to support the Fisher effect. For example, Fama (1975:269) found a relationship between the inflation rates and the nominal interest rate, while

Demirag and Goddard (1994:75) indicate that there is a relationship between the current interest rate and past inflation rates. Booth and Ciner (2001:269) confirm that there is a one-to-one relationship between the inflation rates and one-month Eurocurrency interest rates. Although there is support for the Fisher effect, according to Hatemi-J. (2008:117), there are five reasons that evidence of the Fisher effect may not be found:

- Investors shift their portfolios towards real assets if the expected inflation rate becomes extremely high (Tobin, 1969:20–21, 26);
- The money illusion phenomenon (Summers, 1983:243–244), which implies that currency are examined in nominal terms and not in real terms;
- The existence of peso problems⁵¹ in a market with nominal debt;
- If the liquidity premium in financial assets increases when the expected inflation rate increases; and
- Parameter instability.

According to Cooray (2002:2), another reason for not finding the full Fisher effect may be that there is no direct measure of inflation expectations and thus a proxy is usually used. To conclude, as with the PPP theory, there is no conclusive evidence to demonstrate whether the Fisher effect holds. However, despite inconclusive evidence of the Fisher effect, an international counterpart of the Fisher effect was also developed, which will be discussed in the following section. This International Fisher effect is a combination of the relative version of PPP and the generalized version of the Fisher effect.

⁵¹ Whenever less frequent regime shifts occur in a short-run compared to the actual sample. These shifts can have positive probabilities, which affect the future market expectations of short-run interest rates that oppose the expectations hypothesis of the term structure of interest rates (Lanne, 1999:7).

3.3.2.2 The rise of the Interest Rate Parity theory: The International Fisher effect

According to the generalized version of the Fisher effect, the real interest rate will be equalized across countries owing to arbitrage. The relative version of PPP states that the inflation rate differential will be offset by exchange rate changes. By combining these two versions the International Fisher effect can be illustrated by the following equation (Sundqvist, 2002:14–15):

$$\frac{(S_{t+1}-S_t)}{S_t} = \frac{(r_t-r_t^*)}{(1+r_t^*)} \quad (3.10)$$

where:

- S_t is the spot exchange rate;
- r_t is the domestic real interest rate at time t ; and
- r_t^* is the foreign real interest rate at time t .

The International Fisher effect proposes that the nominal interest rate differential will be equal to the changes in the spot exchange rate between two countries (Sundqvist, 2002:15). Evident from Figure 3.2, the International Fisher effect shows similarities of the Uncovered Interest Rate Parity theory (Section 3.3.6) (Horobet *et al.*, 2009:22).

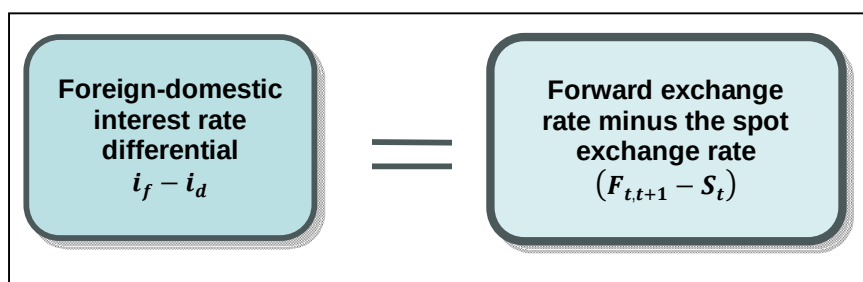
As with the generalized version of the Fisher effect, there is conflicting evidence concerning the existence of the International Fisher effect. Giddy and Dufey (1975:7–16, 27), for example, state that the interest rate differentials can help to explain exchange rate changes, while Robinson and Warburton (1980:18) found no support for the International Fisher effect. Kane and Rosenthal (1982:97–98,109), who examined the Eurocurrency market for six major currencies, found evidence of the International Fisher effect. Owing to this conflicting evidence, Demirag and Goddard (1994:77) state that the evidence for the International Fisher effect may be less convincing than the evidence found for the Fisher effect and for PPP. Thus, while no credible evidence was found for either the Fisher effect or the International Fisher effect, it is evident that there is a relationship between interest rates and price levels (inflation rate).

The IRP theory does not only consist of the Fisher effect and the International Fisher effect, but can also be divided into two relationships: the Covered and Uncovered Interest Rate Parity (Chen, 1998:198). The relationship between the interest rate differential and the expected change in the exchange rate is termed the Uncovered Interest Rate Parity (Section 3.3.6), while the relationship between the interest rate differential and the forward exchange rate margin is termed the Covered Interest Rate Parity (Chen, 1998:198), as discussed in the following section.

3.3.3 Covered Interest Rate Parity

According to Thornton (1989:55), Covered Interest Rate Parity implies that there may be a relationship amongst the spot exchange rate, the forward exchange rate, and the interest rate at an aggregated level (Figure 3.4). Ha and Reddell (1998:133) concur with there being a possibility of such a relationship, stating that interest rate differentials can be used as an indicator to where forward exchange rates are in the market.

Figure 3.4: The Covered Interest Rate Parity



Source: Rosenberg (2003:110).

Therefore, based on this parity condition a foreign currency investment, which is completely hedged against exchange rate risk, should yield the same return as a comparable domestic currency investment, in which both investments contain the same risk characteristics (Rosenberg, 2003:110). This means that arbitrage will cause the return of the domestic investments i_d to be equal to the return of the foreign investment i_f , minus the forward discount (FD).

According to Chinn (2007:1), investors can receive either interest rate i by saving domestically, or interest rate i^* by saving abroad by converting the amount by the spot exchange rate S , and then converting back to domestic currency by the forward rate F at time t , during a trade period of $t + 1$. Thus, if the gross return $(1 + i)$ is greater than $(1 + i_t^*) \times \frac{F_{t,t+1}}{S_t}$ investors will rather invest their capital domestically than abroad (Chinn, 2007:1). With capital mobility possible and investors searching for higher return, the returns from two countries will equalize. Thus, assuming that there is no risk in nominal terms, the following equation can be established (Chinn, 2007:1):

$$\frac{(i - i^*)}{(1 + i_t^*)} \times \frac{F_{t,t+1} - S_t}{S_t} \quad (3.11)$$

where:

- i is the domestic interest rate;
- i^* is the foreign interest rate;
- i_t^* is the foreign interest rate at time t ;
- $F_{t,t+1}$ is the forward exchange rate at time t ; and
- S_t is the spot exchange rate at time t .

Equation 3.11 is a condition that can be termed the Covered Interest Rate Parity because investors are “covered” against the nominal uncertainty with the help of the forward market. Equation 3.11 provides a crucial relationship between the spot exchange rate, the forward exchange rate, and the interest rates (Van Marrewijk *et al.*, 2007:452). By deriving the Covered Interest Rate Parity condition, the assets (options) involved are assumed to be perfect substitutes (and transaction costs are ignored). However, deviation from the Covered Interest Rate Parity condition will occur if the assumptions are not met (Van Marrewijk *et al.*, 2007:453).

Covered Interest Rate Parity can also be illustrated by applying the following equation, which was derived from Pietersz (2008a:1):

$$\frac{(1+r_{ZAR})}{1+r_{\$}} = \frac{(ZAR \div \$_f)}{(ZAR \div \$_s)} \quad (3.12.1)$$

where:

- r_{ZAR} is the ZAR interest rate until the date of the forward;
- $r_{\$}$ is the USD interest rate;
- $ZAR \div \$_f$ is the forward ZAR to USD rate; and
- $ZAR \div \$_s$ is the spot ZAR to USD rate.

By taking Equation 3.12.1 and subtracting one from both sides, the following equation illustrates that Covered Interest Rate Parity, under perfect money market conditions, is where the forward premium or discount on the FX market (right-hand side) is equal to the interest rate differential (left-hand side). This can be illustrated by Equation 3.12.2, which was derived from Clark (2002:74):

$$\frac{(r_{ZAR}-r_{\$})}{1+r_{\$}} = \frac{(ZAR \div \$_f)-(ZAR \div \$_s)}{(ZAR \div \$_s)} \quad (3.12.2)$$

Deniz (2007:4) states that Covered Interest Rate Parity can also be represented by the following equation:

$$f_t - s_t = i_t - i_t^* \quad (3.13)$$

where:

- f_t is the logarithm forward exchange rate at time t ;
- s_t is the logarithm spot exchange rate at time t ;
- i_t is the yield of a domestic instrument at time t ; and

- i_t^* is the yield of a foreign instrument at time t .

Equation 3.13 will hold regardless of the investor's preferences (Deniz, 2007:4). However, if the investor becomes risk averse, the forward rate will differ from the expected spot rate by an amount termed the risk premium. The risk premium serves as compensation for taking the possible risk associated with the particular currency. This scenario can be expressed in the following equation (Chinn, 2006:8):

$$f_t = E_t s_{t+1} + \eta_{t+1} \quad (3.14)$$

where:

- f_t is the logarithm forward exchange rate at time t ;
- $E_t s_{t+1}$ is the expected spot rate in the future $t + 1$; and
- η_{t+1} is the risk premium at time $t + 1$.

By substituting Equation 3.13 in Equation 3.14 and rearranging the equation, the following equation can be given (Deniz, 2007:4):

$$E_t s_{t+1} - s_t = i_t - i_t^* - \eta_{t+1} . \quad (3.15)$$

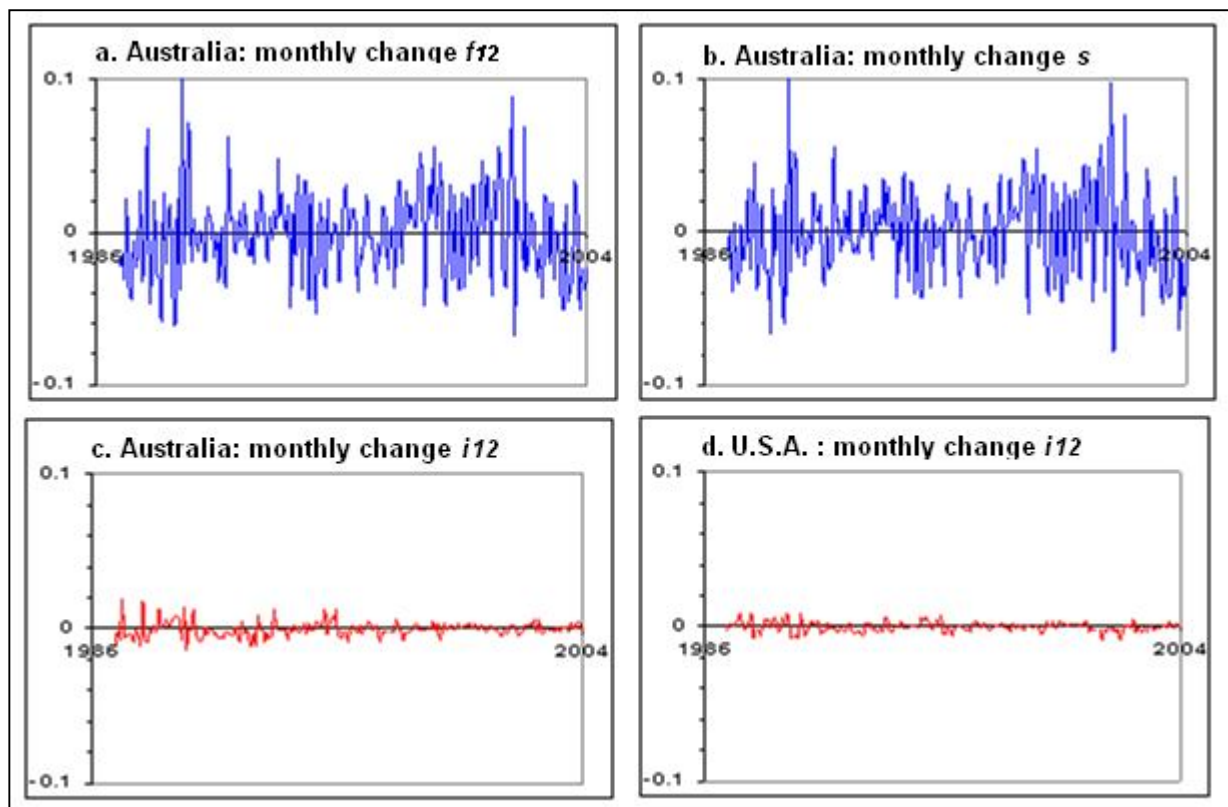
Equation 3.15 illustrates the Uncovered Interest Rate Parity condition that consists of the joint hypothesis of the Efficient Market Hypothesis (Section 2.3.4.2.1) and the assumption of rational expectations in the case of a risk-neutral investor (Deniz, 2007:4). The Uncovered Interest Rate Parity condition will be discussed in Section 3.3.6. However, before this can be done, it is necessary to establish whether Covered Interest Rate Parity holds. The following section will briefly discuss the testing of the Covered Interest Rate Parity.

3.3.4 Testing for Covered Interest Rate Parity

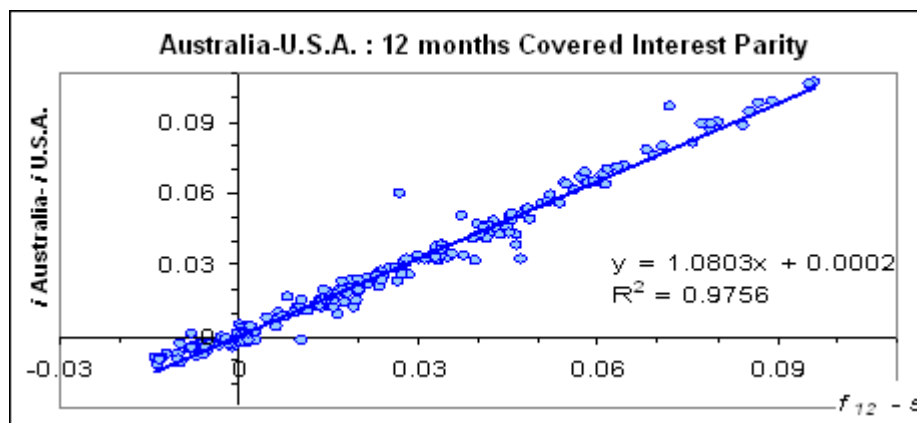
Van Marrewijk *et al.* (2007:454–455) plotted the volatility of exchange rates and interest rates of the U.S.A. and Australia, as illustrated in Figure 3.5. They found that the magnitude of the change of the interest rates and of the forward and spot exchange rates differs, which indicates that the Covered Interest Rate Parity may not always hold.

However, the Covered Interest Rate Parity may still hold if the difference in the forward exchange rate absorbs the difference in the spot exchange rate or *vice versa* (Van Marrewijk *et al.*, 2007:455). Using natural logarithms, it can be demonstrated that the Covered Interest Rate Parity condition does hold empirically, as illustrated in Figures 3.5 and 3.6.

Figure 3.5: U.S.A. and Australia - variability in interest rates and exchange rates



Source: Van Marrewijk *et al.* (2007:454).

Figure 3.6: U.S.A. and Australia - Twelve-month Covered Interest Rate Parity

Source: Van Marrewijk *et al.* (2007:456).

These figures clearly indicate that the difference between the spot exchange rate and the forward exchange rate is equal to the interest rate differential, which is clearly formulated in Equation 3.13. By testing the Covered Interest Rate Parity between the U.S.A. and the U.K., and between the U.S.A. and Canada, it was found that with the inclusion of transaction costs Covered Interest Rate Parity would hold for a three-month period (Frenkel & Levich, 1975:328–333). In testing whether Covered Interest Rate Parity would hold for a longer period amongst Japan, Canada, the U.K., the U.S.A., Switzerland and Germany, and within the Euromarket, Popper (1993:442–445) found that there were no noticeable differences when compared the longer period to a shorter period.

Furthermore, Thornton (1989:65–66) found that the Covered Interest Rate Parity generally holds amongst Germany, the U.S.A., the U.K., Canada, Switzerland, France and Japan, but found no evidence regarding market efficiency. Bhar *et al.* (2004:503) found a relationship between a 90-day Covered Interest Rate Parity condition and the FX market volatility amongst Germany, the U.S.A., the U.K. and Japan. In their study, they also determined that the transaction cost band (deviation from the exact Covered Interest Rate Parity) may be widening, depending on the volatility of the exchange rate regime (Bhar *et al.*, 2004:524).

However, the Covered Interest Rate Parity may not hold in the following situations (Van Marrewijk *et al.*, 2007:455):

- The foreign and domestic assets are comparable in terms of political risk, maturity and default;
- Transaction cost was not taken into consideration; and
- Common econometric problems led to inconclusive evidence.

In addition to the above-mentioned situations, Chinn (2007:4) stated that the Covered Interest differentials may be viewed as a political risk, which may be associated with restrictions placed on deposits in different locations by government authorities. In considering Covered Interest Rate Parity from a microeconomic perspective, the failure to hold will also indicate the following (Thornton, 1989:55):

- Costs, for example differences in political risks across countries, or borrowing constraints may not have been accounted for; and
- Traders may not take advantage of profit opportunities (that is, the interest rate differential), thus markets are inefficient; and
- Legal regulations and legal restrictions may exist, for example capital controls, which cause capital mobility to decrease.

Additional evidence suggested that compensation should also be made for market imperfections. The findings of Bhar *et al.* (2004:503–504) suggested that the relationship between the money market and the FX market (thus arbitrage) will hold under the Covered Interest Rate Parity if compensation is made for market imperfections, which include the risk premium, the tax rate differential between two countries, and transaction costs (Bhar *et al.*, 2004:503–504).

In summary, there is conflicting evidence regarding whether the Covered Interest Rate Parity holds. There is also no precise indication regarding the time horizon over which Covered Interest Rate Parity will hold. What is certain is that most of the deviations from Covered Interest Rate Parity are caused by capital controls, transaction costs and political risk. Covered Interest Rate Parity states that changes in the spot exchange rate should incorporate the real interest rate differential, otherwise an arbitrage opportunity will arise and Covered Interest Rate Parity will not hold. The next section will briefly describe Covered Interest Rate Arbitrage, which is the arbitrage opportunity that arises between countries from a difference in real interest rates.

3.3.5 Covered Interest Rate Arbitrage

Covered Interest Rate arbitrage is a true arbitrage strategy, which is the trading of a foreign currency fixed interest security (for example, a government bond), with a forward agreement to hedge against currency risk (Pietersz, 2008b:1). Covered Interest Rate arbitrage, therefore, involves the borrowing of an amount in one currency and then selling that borrowed amount on the spot market (Clark, 2002:73). The income made from selling the borrowed amount is then immediately bought back on the forward market (Clark, 2002:73). An arbitrage opportunity may arise were an investor take the following steps in this specific sequence (Pietersz, 2008a:1):

1. Borrow in the currency with the lower interest rate;
2. Convert the cash at the spot exchange rate;
3. Enter a forward contract to convert the cash and the expected interest at the same rate;
4. Invest the money at a higher interest rate;
5. Convert the money and interest rate back through a forward contract; and
6. Repay the interest and principle, with the cost of the forward contract being less than the interest received.

The following equation, which is derived from Equation 3.12.1, illustrates Covered Interest Rate Arbitrage clearly (Clark, 2002:74):

$$(1 + r_{ZAR}) = \frac{(ZAR \div \$_f)}{(ZAR \div \$_s)} (1 + r_{\$}) \quad (3.16.1)$$

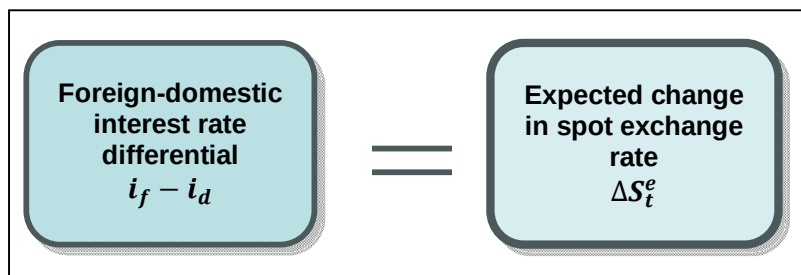
Covered Interest Rate arbitrage will be present if the domestic investment is smaller than the same amount invested abroad, which is illustrated by Equation 3.16.2 (Clark, 2002:74):

$$(1 + r_{ZAR}) < \frac{(ZAR \div \$_f)}{(ZAR \div \$_s)} (1 + r_{\$}) . \quad (3.16.2)$$

While Covered Interest Rate Arbitrage can be prevented, the forward rate bias must still be considered. A forward rate bias occurs when the currency markets overestimate changes in the exchange rates; the actual movements are smaller than the expected movements that is measured by the forward exchange rates (Pietersz, 2008c:1). The next section will discuss the second relationship of IRP, Uncovered Interest Rate Parity, which is the relationship between the interest rate differential and the expected change in the exchange rate.

3.3.6 Uncovered Interest Rate Parity

Under Uncovered Interest Rate Parity conditions, the expected return on a domestic currency investment must be equal to a comparable uncovered foreign currency investment (Rosenberg, 2003:110). The expected return on the domestic investment i_d is known with certainty, but the expected return on the uncovered foreign investment $i_f - e^e$ is not, as the expected change e^e , may differ from the actual change in the exchange rate (Rosenberg, 2003:110–111). Uncovered Interest Rate Parity, therefore, implies that no risk premium is required to compensate for the difference between the expected change and the actual change in the exchange rate. Thus, in the absence of a risk premium, the interest rate differential will adjust to equal the expected change in the exchange rate, which is illustrated in Figure 3.7.

Figure 3.7: The Uncovered Interest Rate Parity

Source: Rosenberg (2003:111).

The Uncovered Interest Rate Parity indicates the relation that holds between interest rate differentials and current spot exchange rate expectations. Uncovered Interest Rate Parity is, therefore, the exchange rate counterpart of the expectations hypothesis for interest rates (Ha & Reddell, 1998:133). This is important for investors, who can choose to invest domestically, generating $(1 + i)$, or abroad, generating $(1 + i^*)(L \div S_t)$, where i represents the domestic interest rate; i^* the abroad interest rate; and $(L \div S_t)$ the amount invested domestically that is divided by the spot exchange rate (Van Marrewijk *et al.*, 2007:457). If the decision to invest abroad, without hedging, in the following period is made, the investor will form an expectation of the future spot exchange rate S_{t+1}^e . This investment decision can be given by the following equation (Van Marrewijk *et al.*, 2007:457):

$$\frac{S_{t+1}^e(1+i_t^*)}{S_t} L . \quad (3.17)$$

Remember that the return from abroad is uncertain because of risk. However, assuming that market participants are risk neutral, the investor will focus on the expected return and not the risk if the returns are the same domestically and abroad. Under this assumption, the following equation can be derived, which indicates the Uncovered Interest Rate Parity condition (Van Marrewijk *et al.*, 2007:457):

$$S_{t+1}^e - S_t \approx i_{ZAR,t} - i_{\$,t} \quad (3.18)$$

According to Equation 3.18, the difference in foreign and domestic interest rates is equal to the expected appreciation/depreciation of the foreign currency. However, the expectations in

Equation 3.18 are difficult to estimate, which is substituted with the forward exchange rate that is being quoted in the market. This can be demonstrated by Equation 3.19 and 3.20, with the forward exchange rate being equal to the expected future spot exchange rate (Van Marrewijk *et al.*, 2007:457–458):

$$f - S \approx i_{ZAR} - i_{\$} \quad (3.19)$$

Equation 3.19 states that the difference between the forward and spot exchange rate is equal to the difference between the foreign and domestic interest rate.

$$f = S_{t+1}^e \quad (3.20)$$

Equation 3.20 is derived by combining the following Covered Interest Rate Parity condition (Equation 3.19) with Equation 3.18. However, Equation 3.20 still does not provide a suitable hypothesis, but by adding the assumption of rational expectations, it is possible to test the Uncovered Interest Rate Parity condition by estimating the following equation:

$$S_{t+1} = \gamma_0 + \gamma_1 f_t + \mu_t \quad (3.21)$$

Equation 3.21 can be used to test market efficiency, where μ_t is the forecasting error. The forecasting error term and the parameter γ_1 must be uncorrelated with the information at time t , under the risk neutrality and rational expectation hypothesis. Assuming rational expectations, no systematic forecasting error is made; however, the predictions must reflect all the available information. Any forecasting error must be uncorrelated with the information set available (Van Marrewijk *et al.*, 2007:458), to prevent the forecasting error from increasing over time.

By examining the joint hypothesis of rational expectations and Uncovered Interest Rate Parity, Chinn (2007:6) found that it holds over a long period. However, Chaboud *et al.* (2005:361) found that Uncovered Interest Rate Parity holds over extremely short periods.

In contrast to these studies that found Uncovered Interest Rate Parity to hold, Chinn (2005:ii, 13) found that the Uncovered Interest Rate Parity condition did not hold for non-G7 countries, which included South Africa. This implies that, as with Covered Interest Rate Parity, if the domestic and foreign real interest rates are not equal, arbitrage opportunities may arise and Uncovered Interest Rate Parity will not hold. This leads to the next section, which will briefly discuss Uncovered Interest Rate Arbitrage.

3.3.7 Uncovered Interest Rate Arbitrage

According to Chinn (2007:4), it is difficult to test whether the Uncovered Interest Rate Parity holds because changes in the expected exchange rate are unperceivable. Most Uncovered Interest Rate Parity tests assume the form of a joint test with the rational expectations hypothesis (see Equation 3.21; Chinn, 2007:4). Therefore, Uncovered Interest Rate arbitrage is slightly different to Covered Interest Rate Arbitrage (Section 3.3.5). In Uncovered Interest Rate Arbitrage, currency risk is not hedged, thus it is not a true arbitrage strategy (Pietersz, 2008d:1).

The following example serves to demonstrate Uncovered Interest Rate Arbitrage. If the difference in the interest rates is greater than the expected depreciation of currency \$ against currency £, and if the risk-free rate for currency \$ is higher than for currency £, then the following will happen (Pietersz, 2008d:1):

1. Currency £ will be sold to buy currency \$;
2. The amount of currency \$ will be invested in risk-free securities; and
3. When the securities mature, the holdings of currency \$ will be converted back into currency £.

Uncovered Interest Rate Arbitrage is not a true arbitrage strategy because this strategy does not provide a profit above the risk-free rate if the forecast errors are kept to a minimum (Pietersz, 2008d:1). Any arbitrage opportunities will also be limited in order for the Uncovered

Interest Rate Parity to hold.

To recapitulate, as with PPP (Section 3.2), the Fisher effect (Section 3.3.2.1) and Covered Interest Rate Parity (Section 3.3.3), there is conflicting evidence for the validity of the Uncovered Interest Rate Parity condition (Section 3.3.6). It is therefore clear that PPP, the Fisher effect, Covered and Uncovered Interest Rate Parity are limited in their ability to explain exchange rate movements individually. This leads to the following section, which discusses Real Interest Rate Parity. The Real Interest Rate Parity condition incorporates PPP, the Fisher effect, Covered and Uncovered Interest Rate Parity in an attempt to enhance the estimation of exchange rate movements. This will be followed by a brief description of the transaction costs and the risk premium (Section 3.3.9), which are considered factors that should be incorporated in a model in order for Uncovered Interest Rate Parity to hold.

3.3.8 Real Interest Rate Parity

Closer integration of international financial markets with the reduction of exchange rate regulations has linked international interest rate movements. This has led to the development of a new environment that requires future research to understand the workings of international interest rates (Camarero *et al.*, 2006:1). The linkage of international real interest rates is extremely important because the level of capital market integration, domestic monetary policies, and the soundness of the Uncovered Interest Rate Parity (Section 3.3.6) and of PPP (Section 3.2) are dependent on it (Shrestha & Tan, 1998:1). International capital markets have also become progressively more integrated, which means that foreign investors can invest in domestic assets and domestic investors can invest in foreign assets (Pipatchaipoom & Norrbin, 2006:2). The Real Interest Rate Parity assumes that the real interest rate of two countries should be the same if expectations are rational and if markets are frictionless (Liew & Ling, 2008:2). Real interest rates of return on identical assets must also be the same across countries, if the Real Interest Rate Parity holds (Chung & Crowder, 2001:2). Thus, assets with identical liquidity and risk should generate the same expected return, despite the location, if

Real Interest Rate Parity holds (Pipatchaipoom & Norrbin, 2006:2). Therefore, if real interest rates are equal across two countries, this indicates the presence of financial integration and capital mobility (Liew & Ling, 2008:2).

Furthermore, if Uncovered Interest Rate Parity (Section 3.3.6) does not hold, Real Interest Rate Parity will also not hold over a short periods (Chinn, 2007:7). Real Interest Rate Parity will only hold if Uncovered Interest Rate Parity, *ex ante* PPP (Section 3.2) and the Fisher relation (Section 3.3.2.1) in two countries hold (Chung & Crowder, 2001:1). From this, it is clear that the deviations from Real Interest Rate Parity are the sum of the deviations from Uncovered Interest Rate Parity (Section 3.3.6) and the deviations from PPP, as discussed in Section 3.2.5 (Camarero *et al.*, 2006:1). Additional factors such as transaction costs, country-specific risk, differential tax treatment, and information asymmetries may also cause the Real Interest Rate Parity not to hold over the short-run (Chung & Crowder, 2001:2).

According to Pipatchaipoom and Norrbin (2006:3), the Real Interest Rate Parity relies on the following four parity conditions: the domestic Fisher relation (Equation 3.9), the Uncovered Interest Rate Parity (Equation 3.18), the foreign Fisher relation (Equation 3.22), and the *ex ante* PPP (Equation 3.23). This is illustrated as follows:

$$r_t = i_t - \pi_{t+1}^e \quad (3.9)$$

$$S_{t+1}^e - S_t = i_t - i_t^* \quad (3.18)$$

$$r_t^* = i_t^* - \pi_{t+1}^{e*} \quad (3.22)$$

$$S_{t+1}^e - S_t = \pi_{t+1}^e - \pi_{t+1}^{e*} \quad (3.23)$$

where:

- r_t is the domestic real interest rate at time t ;
- r_t^* is the foreign real interest rate at time t ;
- i_t is the domestic nominal interest rate at time t ;
- i_t^* is the foreign nominal interest rate at time t ;

- π_{t+1}^e is the domestic expected inflation rate at time $t + 1$;
- π_{t+1}^{e*} is the foreign expected inflation rate at time $t + 1$;
- S_t is the spot exchange rate at time t ; and
- S_{t+1}^e is the expected spot exchange rate at time $t + 1$.

The domestic observed *ex post* inflation rate π_t is assumed to have a stationary inflation forecast error with a mean of zero. This is illustrated by the following equation (Shrestha & Tan, 1998:2):

$$\pi_t = \pi_t^e + \mu_t \quad (3.24)$$

where:

- μ_t is a zero-mean normally distributed variable.

The domestic expected *ex ante* real interest rate r_{t+1}^e differs from the *ex post* real interest rate r_t by a stationary inflation forecasting error and can be given as follows (Shrestha & Tan, 1998:2):

$$r_t^e = r_t - \pi_t + \mu_t = r_t + \mu_t \quad (3.25)$$

The following equation, which is derived by combining Equations 3.9, 3.24 and 3.25, illustrates the Real Interest Rate Parity condition (Shrestha & Tan, 1998:3):

$$r_t^e - r_t^{e*} = (r_t - \pi_t^e) - (r_t^* - \pi_t^{e*}) = [r_t - r_t^* - S_t^e] + [\pi_t^{e*} - \pi_t^e + S_t^e] \quad (3.26)$$

where:

- r_t^e is the expected domestic real interest rate at time t ;
- r_t^{e*} is the expected foreign real interest rate at time t ;
- r_t is the domestic real interest rate at time t ;

- r_t^* is the foreign real interest rate at time t ;
- π_t^e is the domestic expected inflation rate at time t ;
- π_t^{e*} is the foreign expected inflation rate at time t ;
- $[r_t - r_t^* - S_t^e]$ is the Uncovered Interest Rate Parity; and
- $[\pi_t^{e*} - \pi_t^e + S_t^e]$ is the PPP.

If the Uncovered Interest Rate Parity and the PPP conditions hold, then both terms will be equal to zero ($r_t^e - r_t^{e*} = 0$), which indicates that the Real Interest Rate Parity is valid (Shrestha & Tan, 1998:3).

Cumby and Mishkin (1986:9–10) used a utilized standard regression method to test for the existence of Real Interest Rate Parity, for which they assumed Real Interest Rates to be stationary. They found that interest rates did not equalize across countries (Cumby & Mishkin, 1986:19–21). Contrary to this, Ferreira and Leon-Ledesma (2003:22), found that the Real Interest Rate Parity does hold between developed countries. Using *ex post* realizations and *ex ante* measures to calculate real interest rates, Fujii and Chinn (2001:293–306) found that the Real Interest Rate Parity holds over different time frames with different strengths. In addition, their evidence suggested that Real Interest Rate Parity holds better over the long-run than over the short-run (Fujii & Chinn, 2001:290).

However, the validity of the Uncovered Interest Rate Parity (Section 3.3.6) is still being questioned, which implies that the soundness of the Real Interest Rate Parity theory is uncertain. Uncovered Interest Rate Parity is based on the assumption of the investor being risk neutral, which is not true in reality. If Uncovered Interest Rate Parity fails, Real Interest Rate Parity will also fail. Therefore, to ensure that Uncovered Interest Rate Parity holds, compensation for risk in the form of a risk premium is required. Additional evidence was found that changes in transaction costs and the risk premium could be of great importance in

explaining real interest rate differentials (Ferreira & Leon-Ledesma, 2003:22). This leads to the following section that will briefly discuss transaction cost and risk premium, which are two factors that may cause Uncovered Interest Rate Parity to hold.

3.3.9 Transaction costs and the risk premium

When investing abroad, the investor is exposed to FX risk. There are three types of exchange risk exposures: transaction exposure, translation exposure and economic exposure (Van Marrewijk *et al.*, 2007:458–459). Transaction exposure arises in transactions that are denominated in foreign currency, whereas translation exposure arises when assets and liabilities are denominated in foreign currency. Economic exposure refers to the changes in a firm's value in reaction to the changes in the exchange rates (Van Marrewijk *et al.*, 2007:459).

Under Uncovered Interest Rate Parity (Section 3.3.6), it is assumed that investors are risk neutral; however, in practice they are risk averse rather than risk neutral. Investors who hold high-risk assets will demand a form of compensation for holding these assets (a risk premium; Van Marrewijk *et al.*, 2007:459). This means that individuals or firms with additional bad credit will be forced to pay a higher interest rate in order to provide this compensation for investors. A risk premium can increase if the degree of risk aversion increases and if the alleged riskiness increases (Van Marrewijk *et al.*, 2007:459).

Uncovered Interest Rate Parity (Section 3.3.6) ignores transaction costs. By including the risk premium and the transaction costs, the following equation can be derived from Van Marrewijk *et al.* (2007:459):

$$i_{ZAR,t} = i_{\$,t} + (s_{t+1}^e - s_t) + \text{risk premium} + \text{transaction costs} \quad (3.27)$$

Equation 3.27 states that the return from a domestic investment is equal to the return from a foreign investment, plus the expected appreciation of the foreign currency when investing abroad, plus the risk premium as compensation for the FX risk, plus the transaction costs when

investing abroad. The implementation of a risk premium and transaction costs may narrow the band within which the Uncovered Interest Rate Parity may hold (Van Marrewijk *et al.*, 2007:459).

Many empirical studies to test the validity of the Efficient Market Hypothesis (Section 2.3.4.2.1) have been conducted, based on the joint hypothesis of rational expectations and risk neutrality. Bekaert and Hodrick (1993:132), for example, found that the risk premium has a non-linear nature. In testing the information content of the forward exchange rate, Clarida and Taylor (1997:360) found that significant information about spot FX markets movements is included in the forward FX premiums. It is, therefore, of great importance to incorporate risk premium in a model if the analyst wishes for Uncovered Interest Rate Parity (Section 3.3.6) to hold, as risk premium can explain a great deal of the deviation from the Uncovered Interest Rate Parity condition.

In summary, research has identified transaction costs and risk premium as factors that may increase the probability that the Uncovered Interest Rate Parity and the Real Interest Rate Parity will hold (Section 3.3.8) because the Real Interest Rate Parity depends on the validity of the Uncovered Interest Rate Parity. By including transaction costs and risk premium, it is possible to provide an improved estimation on the movements of future expected exchange rates.

3.3.10 Summary

The IRP theory forms the second part of the partial equilibrium approach and adds the second determinant of exchange rate movements, for example interest rates. The IRP theory links exchange rates with the interest rates in two countries, stating that the interest rate differential between two countries is equal to the differential between the spot exchange rate and the forward exchange rate. The discussion on the IRP theory began with the Fisher effect (Section 3.3.2.1), and went on to the Covered (Section 3.3.3), Uncovered (Section 3.3.6), and Real

Interest Rate Parity theories (Section 3.3.8). Literature indicates that there is conflicting evidence for the validity of the Fisher effect, as well as Covered, Uncovered and Real Interest Rate Parities. Furthermore, it has been demonstrated that no single parity condition can on its own provide convincing evidence to explain the mechanics of exchange rate movements. Thus, additional determinants of exchange rate movements must be identified in order to improve the accuracy of estimating exchange rate movements .

3.4 CHAPTER SUMMARY

As the forward exchange rate (estimated using forward points) is a biased estimate of the future spot exchange rate (the exchange rate puzzle, as discussed in Section 2.3.4), additional explanatory variables must be identified in order to improve the accuracy of the estimation of forward points. This chapter has formed the foundation to understanding the basic explanatory variables required for estimating the current spot exchange rate. This chapter has introduced the first three variables that were incorporated into the model developed in this study to estimate the realized spot exchange rate. These three variables are the inflation rate differential (drawn from the PPP theory in Section 3.2), the interest rate differential (drawn from the Fisher effect in Section 3.3.2.1), and the forward exchange rate (drawn from the IRP theory in Section 3.3).

Although the predictability of individual macroeconomic variables is in doubt, the basic explanatory variables identified in this chapter are still required to construct a standard exchange rate model. **The primary research objective of this thesis is to develop an exchange rate model, using current (time t) time series of economic fundamentals, identified in this chapter, in an effort to establish a theoretical forward exchange rate that reflects the realized future (time $t + i$) spot exchange to such an extent that market participants will take note of it. This research objective forms part of the main contribution of this study, which include determining if the exchange rate puzzle is a pseudo problem.** In Section 2.1, it was established that market expectations are essential in

estimating future exchange rates, but that it is difficult to incorporate market expectations in an exchange rate model successfully. In the next chapter, it is demonstrated that market expectations can be incorporated more effectively by including alternative ways to model the interaction of international financial markets. These approaches include the use of individual dual-listed stocks, which will substitute the use of stock indices. The next chapter will, therefore, introduce the CAPM, which can be used in the valuation of dual-listed stocks (Section 4.4). The next chapter will also discuss the international counterpart of the CAPM, the ICAPM (Section 4.7). The ICAPM explains the relationship between the activities in the financial market (stock market) with the fluctuations in the exchange rate.

CHAPTER 4

Dual-listed Stocks and Investment Theory

4.1 INTRODUCTION

The main contribution of this study resides in the revelation that the exchange rate puzzle may be a pseudo problem. The first research objective is to develop an exchange rate model, using current (time t) time series of economic fundamentals. This chapter introduces the price differences of dual-listed stocks as an additional explanatory variable that will be used in this study in order to improve the accuracy of existing models in estimating the realized future spot exchange rate. This variable may allow better incorporation of market expectations than the use of indices. The approach of including dual-listed stocks in an exchange rate model is based on Agmon's (1972:849) conclusion that there is co-movement amongst the stock markets of some industrial countries. Robichek and Eaker (1978:1017–1018) found evidence of the exchange rate puzzle that linked the exchange rate risk premium and the stock market risk premium in a static CAPM. Furthermore, Morley and Pentecost (1998:328) and Chiang (1991:360) found that stock excess return differentials⁵² are related to exchange rate excess returns⁵³, this is known as the International Equity Parity theory. The International Equity Parity theory forms the final explanatory variable that will be incorporated in this study's exchange rate model.

Based on Jiang and Chiang's (2000:102–103) conclusion that exchange rate excess returns are correlated to the volatility of stock and currency markets, this study also incorporated the interaction of two financial markets (JSE and the NYSE), in an exchange rate model. This will be accomplished by incorporating the volatility spillover effect between the JSE and the NYSE through generating a speed of adjustment series using the VEC model (Section 5.4.4).

⁵² This variable can be used to measure the stock market risk factor (Morley & Pentecost, 1998:317). See also Section 2.3.4.2.5.

⁵³ Also known as the exchange rate risk premium (Morley & Pentecost, 1998:317).

The speed of adjustment series enables the investor to determine the change required for any two dual-listed stocks to return to equilibrium after a shock. The price differences of dual-listed stocks include a time difference (lag) component owing to the different trading hours of the JSE and the NYSE. This lag period may provide additional information regarding the estimation of the future exchange rate.

Before the use of the price differences of dual-listed stocks as an additional explanatory variable can be demonstrated, the concept of dual-listed stocks must first be explained. Dual-listed stocks are stocks that are listed on more than one exchange (Marx *et al.*, 2006:25). Dual-listed stocks allow informed traders to split their trading activities across markets (Rath, 2007:379). The valuation of dual-listed stocks is necessary to determine which stock to buy in order to maximize the value of an investor's portfolio. Valuation determines the present value of the expected future return from a stock (Correia *et al.*, 2003:6–12). The Gordon growth model (Dividend growth model) can be used for the valuation of a stock, and can be formulated as follows (Correia *et al.*, 2003:6–12):

$$V_0 = \frac{D_1}{k-g} \quad (4.1)$$

where:

- V_0 is the value of the stock;
- D_1 is the next period's dividend;
- k is the required rate of return; and
- g is the growth rate in future dividends.

By applying this model, an investor would select the stock with the highest future returns, or highest future dividend. Investors must bear in mind that the growth rate of future dividends of a dual-listed stock must be the same in both markets or else an arbitrage opportunity will arise. An arbitrage opportunity allows individuals to take advantage of price differentials (Koch & Macdonald, 2003:866). The single market hypothesis elaborated further by stating that the

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. These price differences may provide additional information regarding the future movement of the spot exchange rate (market expectations).

In order to comprehend the ability of dual-listed stock prices to supply information on market expectations, the information composition (Section 2.3.2.1) used to construct these prices must be consulted, which is also determined by the efficiency of the market (Section 2.3.4.2.1). The concept of market efficiency forms the centre of financial theory (Hirschey & Nofsinger, 2008:162). An efficient market can be defined as a market in which all available information is fully reflected in stock prices (Hirschey & Nofsinger, 2008:162). Stock traders' decisions depend on information generated from both domestic and foreign stock markets (Koutmos & Booth, 1995:747). These decisions are, therefore, consistent with the Efficient Market Hypothesis⁵⁴ because the pricing of domestic stocks incorporates information from both domestic and foreign stock markets. Thus, understanding of the manner in which the stock markets interact may help investors to improve their trading and hedging strategies (Koutmos & Booth, 1995:747).

Before this interaction can be understood, some basic knowledge of the investor must first be established. Investors produce the supply and demand for stocks, which causes stock markets to interact. It is, therefore, important to first establish the foundations of investors' behaviour and their decision-making processes, which are based on investment theory. Hence, this chapter will commence with a discussion on the rise of dual-listed stocks as an asset class and the purpose of dual-listed stocks (Section 4.2). This will be followed by a discussion on the factors that will determine the inclusion of dual-listed stocks in the investor's portfolio in order to increase his wealth. To demonstrate this point, basic investment theory will be discussed. The basic investment theory discussion will first consider risk and return, focusing on the division of risk into systematic and unsystematic risk (Section 4.3.2), and thereafter different risk measures.

⁵⁴ See Section 2.3.4.2.1.

Following this, return will be discussed in the form of the CAPM (Section 4.4), which can be used to determine the required rate of return. A brief discussion on the volatility spillover effect will then follow, in which the reasons for selecting a VEC model rather than an Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) model to generate a volatility spillover variable will become clear (Section 4.8). This volatility spillover variable represents one of the proxies generated (Section 5.4.4) in an attempt to incorporate the interaction of international financial markets into an exchange rate model.

4.2 THE DEVELOPMENT AND PURPOSE OF DUAL-LISTED STOCKS

4.2.1 Introduction

The speed of globalization in the capital markets increased the ability to trade stocks from around the world. As a result, stocks became an important source of cross-border capital flows (Karolyi, 2004:2). This caused stock exchanges to increase their competitiveness in order to attract more international listings and trading volumes. The number of dual-listed companies that traded on major exchanges outside their home country increased during the 1990s, reaching a number of 4 700 companies (Karolyi, 2004:2). However, it appears that the speed of dual-listing has decreased after the 1990s due to political factors, global macroeconomic factors, and regulatory and institutional factors (Karolyi, 2004:8). Even though the speed of dual-listing has decreased, there is still a need for dual-listing. The following section will discuss several of the reasons for and the purpose of dual-listing.

4.2.2 Reasons and purpose of dual-listing

Companies may still consider dual-listing as a means of avoiding the barriers to cross-border stock investments, cost and information problems, and regulatory restrictions (Karolyi, 2004:5). Two additional reasons that companies may list their stock on more than one exchange are to provide investors with an additional avenue through which the investor can trade their stock and to add liquidity to the stock (Investopedia, 2009a:1). However, the most common reason for dual-listing is the need to be listed in two different countries as a result of the merger of

companies that are listed in different countries, or in order to gain access to more capital from a larger market (Pietersz, 2009a:1). Furthermore, the increase in security liquidity, access to tax advantages, provision of diversification gains for foreign investors, improvement of information disclosure, and improvement of investor protection may play a significant role in the decision-making process regarding overseas dual-listings (Sarkissian & Schill, 2004:775). Factors reflecting the closeness between countries (which include cultural, economic, and industrial proximity) also show significant importance in the decision-making process for overseas host markets for companies from non-G5 countries⁵⁵ (Sarkissian & Schill, 2004:771).

The reasons behind the dual-listing of stocks also provides insight into the following (Karolyi, 2004:2–3):

- The significance of global stock offerings;
- The effect of multi-market trading on price discovery, liquidity, and arbitrage;
- Corporate governance and agency conflicts between controlling and public investors;
- The information environment of the firms and strategic disclosure strategies;
- The valuation effects and cost of capital of listings, the spillover effect of listings on domestic markets, and risk diversification opportunities for investors; and
- The decision to list overseas due to factors such as culture, trade and geography.

Having knowledge of the above factors provides the currency trader with additional insight into future currency movements. In order to better understand the relationship between stock prices listed on more than one exchange and its ability to explain the realized future ZAR/USD exchange rate, this study will focus on the following two exchanges, the Johannesburg Stock Exchange (JSE) and the New York Stock Exchange (NYSE). The JSE represents the South African stock market and the NYSE represents the U.S.A. stock market. The following sections

⁵⁵ G5 countries include France, Japan, the U.K., Germany and the U.S.A. (Investopedia, 2010a:1).

will provide a broad overview of the dual-listed stocks that are listed on both the JSE and the NYSE (Section 4.2.3.), thus providing more insight regarding the possible dual-listed stock variables that can be incorporated into an exchange rate model. This will also be followed by a discussion on the possible reasons why South African companies may choose to list on the NYSE as a secondary listing (Section 4.2.4), as a justification to why the NYSE can be considered as an important secondary listing.

4.2.3 Dual-listed stocks on the Johannesburg Stock Exchange and the New York Stock Exchange

Table 4.1 lists the only six dual-listed stocks that are primarily listed on the JSE and secondarily listed on the NYSE.

Table 4.1: Dual-listed stocks that are listed on the JSE and the NYSE

Stock	Sector	Listings	
ANGLOGOLD ASHANTI LIMITED	Gold mining	JSE NYSE	(Primary listing) (Secondary listing)
GOLD FIELDS LIMITED	Gold mining	JSE NYSE	(Primary listing) (Secondary listing)
HARMONY GOLD MINING COMPANY LIMITED	Gold mining	JSE NYSE	(Primary listing) (Secondary listing)
SAPPI LIMITED	Paper	JSE NYSE	(Primary listing) (Secondary listing)
SASOL LIMITED	Oil- integrated	JSE NYSE	(Primary listing) (Secondary listing)
TELKOM SA LIMITED	Information and communication technology	JSE NYSE	(Primary listing) (Secondary listing)

Source: JSE (2009).

The following sections will briefly elaborate on each of the dual-listed companies given in Table 4.1.

4.2.3.1 AngloGold Ashanti Limited

AngloGold Ashanti Limited produced 4.98 million ounce of gold from its 21 operations during 2008, making it the third largest producer in the world. South Africa's deep-level underground operations contributed 40% of world production, while surface operations

contributed 2% (AngloGold, 2009). Other countries contributing to this total production were Ghana (11%), Australia (9%), Brazil (8%), Mali (8%), Guinea (7%), Tanzania (6%), the U.S.A. (5%), Argentina (3%), and Namibia (1%). AngloGold Ashanti Limited was first listed on the JSE on 11 August 1944 and on the NYSE on 5 August 1998 (AngloGold, 2009).

4.2.3.2 Gold Fields Limited

Gold Fields Limited is one of the world's largest producers of gold. Gold Fields Limited produces 3.64 million ounce of gold per annum from 8 operating mines in South Africa, Ghana, and Australia. It has ore reserves of 83 million ounce and mineral resources of 251 million ounce (Gold Fields, 2009). The company was first listed on the JSE on 5 May 1999 (JSE, 2009), and on the NYSE on 9 May 2002 (NYSE, 2009).

4.2.3.3 Harmony Gold Mining Company Limited

Harmony Gold Mining Company Limited is also one of the world's largest gold producers. In 2008, Harmony Gold Mining Company Limited produced 1.55 million ounce of gold. Harmony's South African operations are located in Gauteng, the North-West Province, Mpumalanga and the Free State (Harmony, 2009). The company was first listed on the JSE on 15 June 1998 (JSE, 2009) and on the NYSE on 27 November 2002 (NYSE, 2009).

4.2.3.4 Sappi Limited

Sappi Limited is a leading producer of coated fine paper, and chemical cellulose. It also produces uncoated graphic, newsprint, business papers, a range of coated speciality papers, premium quality packaging papers, and a range of paper grade pulp (Sappi, 2009). It produces 6.9 million tons of paper, 3.3 million tons of paper pulp and 800 000 tons of chemical cellulose per annum (Sappi, 2009). The company was first listed on the JSE on 8 August 1973 (JSE, 2009) and on the NYSE on 5 November 1998 (Sappi, 2009).

4.2.3.5 Sasol Limited

Sasol Limited is a chemical and integrated energy company that converts natural gas and coal into synthetic fuels and chemicals (NYSE, 2009). The company mines coal (Sasol, 2009), refines crude oil and retails liquid fuels in South Africa (NYSE, 2009). Sasol Limited also produces oil in Gabon and gas in Mozambique (Sasol, 2009:1), and operates through three segments: the South African energy cluster, the chemical cluster, and the international energy cluster (NYSE, 2009). It was first listed on the JSE on 31 October 1979 and on the NYSE on 9 April 2003 (Sasol, 2009).

4.2.3.6 Telkom SA Limited

Telkom SA Limited is Africa's largest integrated communications company (Telkom, 2009). In 2007, Telkom SA Limited acquired Africa Online, the largest Pan-African Internet service provider in Sub-Saharan Africa, and acquired 75% of Multi-links Telecommunications Ltd, Nigeria's largest telecommunications operator. In 2009, Telkom acquired the remaining 25% of Multi-Links (Telkom, 2009). Telkom SA Limited listed on the JSE and on the NYSE on 4 March 2003 (JSE, 2009).

In seeking to determine the reasons that these six South African companies listed on the NYSE, the next section will briefly posit possible reasons for the secondary listing. In order to present these reasons, it will first also explain the concept of American Depositary Receipts (ADRs).

4.2.4 Reasons for listing on the New York Stock Exchange

Before discussing the reasons for listing on the NYSE, the concept of ADRs must first be discussed. The primary way for a non-U.S.A. company to list on the NYSE is by means of an ADR (Tan, 2006:50). An ADR is a negotiable certificate that represents a foreign company's publicly traded stocks. The purpose of creating an ADR is to assist a broker when delivering a foreign company's stock to the depositary's local custodian bank, such as the Bank of New York (Tan, 2006:50). American Depositary Receipts offer advantages such as liquidity, transparency

and ease of trade of the U.S.A. markets to emerging markets (Moel, 2000:3). American Depositary Receipts are quoted in USD. Applying a universal currency makes the exchangeability of ADRs easier.

According to Tan (2006:44–49), the most common reasons for a dual-listing can be classified into one of the following four categories: the market segmentation hypothesis (Section 4.2.4.1), the liquidity hypothesis for cross-listing (Section 4.2.4.2), changes in the information environment (Section 4.2.4.3), and the corporate governance and “bonding” hypothesis (Section 4.2.4.4). These four categories will be discussed in the following sections.

4.2.4.1 The market segmentation hypothesis

According to the market segmentation hypothesis, dual-listing aids investors in avoiding cross-border barriers to investment (Tan, 2006:44). These cross-border barriers are the result of regulatory restrictions and information access difficulties, such as a lack of knowledge regarding a particular security (Merton, 1987:501). This hypothesis further stipulates that a firm’s stock price will increase (Tan, 2006:44), while the subsequent expected returns or cost of capital will decrease (Foerster & Karolyi, 1999:982) in response to a dual-listing. Findings have indicated that returns, based on close-to-close prices of a stock, have a positive reaction to a dual-listing (Jayaraman *et al.*, 1993:94). There is also evidence pointing to a 14% decrease in stock excess returns after the event of a dual-listing (Foerster & Karolyi, 1999:1008). These findings were corroborated by Errunza and Miller (2000:597–598), who found evidence of a decrease in cost of capital after the event of a dual-listing.

4.2.4.2 The liquidity hypothesis for cross-listing

According to Tan (2006:45), improved liquidity has a significant influence on dual-listing, and the possibility of increased trading liquidity significantly influences management’s decision to dual-list (Mittoo, 1992:48). Evidence was also found that ADR listings decrease market liquidity (Moel, 2000:14), and that the liquidity of the dual-listed stock tends to shift to the market in

which the primary listing is (Pietersz, 2009b:1).

Furthermore, companies tend to be less committed to the market in which the secondary listings are (Pietersz, 2009b:1). The disadvantages of dual-listing are that stocks may be less liquid in one market than the other, the legal aspects of the structure may add bureaucracy, and stocks may be traded at a discount in one market (Pietersz, 2009a:1). However, according to Lins *et al.* (2005:131–132), companies become less dependent on external capital after their listing on the NYSE, which results in these companies becoming less dependent on cash flows in their investment decisions.

4.2.4.3 Changes in the information environment

This reason assumes that some form of market incompleteness or information asymmetry exists (Tan, 2006:46). Under a more strict disclosure requirement regime, dual-listing can enable a company to signal to investors that they are of a higher quality than similar companies (Tan, 2006:46). A NYSE listing is associated with increased media attention and analyst coverage, providing thus more information that can be used by investors (Baker *et al.*, 2002:518). Furthermore, dual-listed companies experience abnormal returns before and after announcement dates, which demonstrates the importance of information flow to the decision to dual-list (Miller, 1999:104).

4.2.4.4 The corporate governance and “bonding” hypothesis

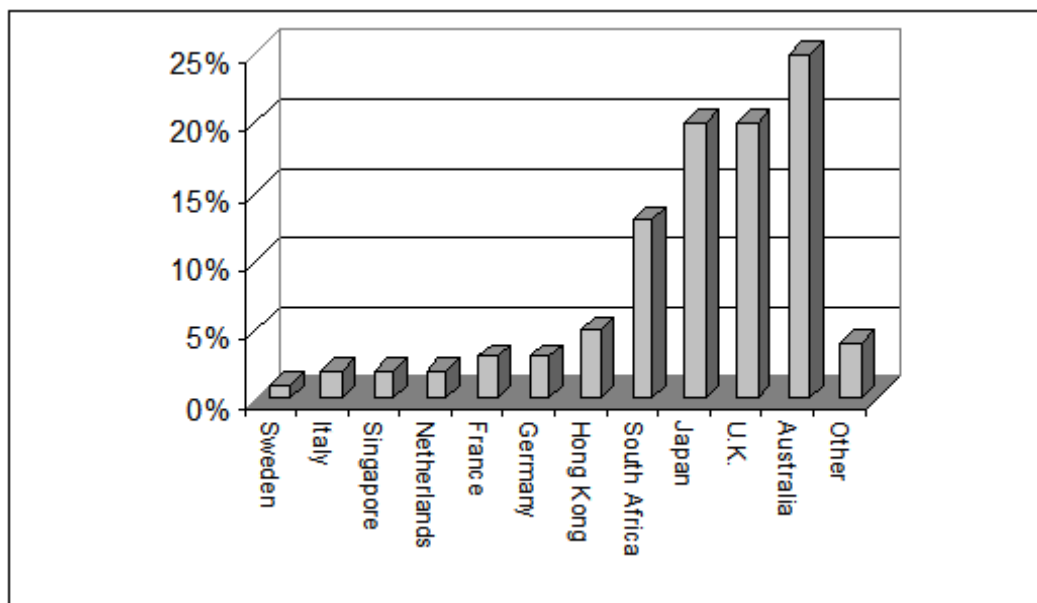
Evidence from Coffee (2002:1762, 1786) indicates that companies in countries with poor corporate governance qualities tend to dual-list their stocks on stock markets that are located in countries with high government standards. Reese and Weisbach (2002:65) examined the relationship between the level of investor protection in the dual-listed company's home country and the number of U.S.A. dual-listings, and found that dual-listings may increase with stock issues. In this regard, they found that the greater the investor protection, the more likely that such companies will issue stock in the U.S.A. (Reese & Weisbach, 2002:66).

The following section will briefly list the countries whose stocks are dual-listed on the NYSE. This overview signifies the importance of the NYSE by other countries and thus the overall significance to consider listing on the NYSE.

4.2.5 The New York Stock Exchange composition

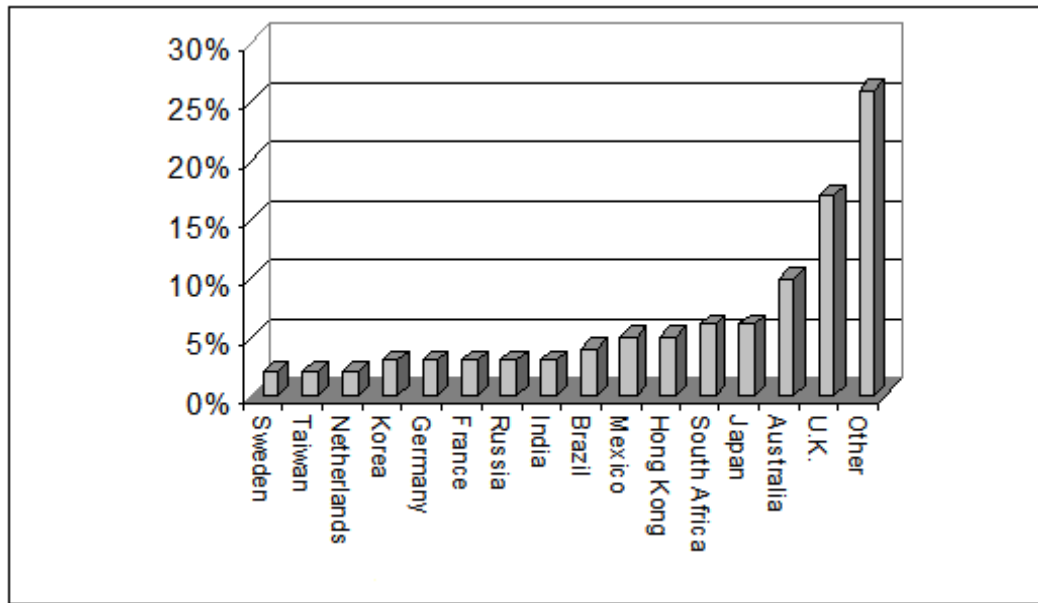
Figures 4.1 and 4.2 illustrate the composition of dual-listing in the U.S.A. market. Figure 4.1 illustrates the distribution of the U.S.A. market concerning non-U.S.A. countries in 1990, and Figure 4.2 illustrates the distribution of the U.S.A. market concerning non-U.S.A. countries in 2003.

Figure 4.1: The ADR listing composition of the U.S.A. market in 1990



Source: Karolyi (2004:53).

These figures only include ADRs, the number of participants in the U.S.A. market increased from 30 to 83 from 1990 to 2003. Companies from Australia, Japan, the U.K. and South Africa formed the largest group (78%) of dual-listings in the U.S.A. market during this period; however, this decreased to 39% in 2003 (Karolyi, 2004:9–10).

Figure 4.2: The ADR listing composition of the U.S.A. market in 2003

Source: Karolyi (2004:53).

Table 4.2 illustrates the size and volume of the NYSE and the JSE, compared to the total number of exchanges around the world. The NYSE has experienced a larger number of entries of foreign companies and higher daily returns compared to the JSE. Thus, it is reasonable to conclude that the volatility spillover effect will be greater from the NYSE to the JSE than *vice versa*. This fact is relevant to the discussion of the volatility spillover effect in Section 4.8 because this study focuses on the estimation of the ZAR/USD realized future spot exchange rate.

Table 4.2: Size and volume of the NYSE and the JSE in 2004

Exchange	Total companies	Domestic companies	Foreign companies	Total value of stock trading (in USD millions)	Foreign (in %)	Newly listed foreign companies in 2004	Average daily turnover (in USD millions)
NYSE	2 293	1834	459	11 618 150.70	8	20	46 103.80
JSE	389	368	21	161 072.80	28	1	641.70
Total globally	37 586	34 954	2 632	42 121 577	12	253	166 980

Source: World Federation of Exchanges (2004).

In summary, there are six dual-listed stocks on the JSE and the NYSE. These six dual-listed stocks are AngloGold Ashanti Limited, Gold Fields Limited, Harmony Gold Mining Company Limited, Sappi Limited, Sasol Limited and Telkom SA Limited. The reasons for a secondary listing on the NYSE have been discussed: the ability to avoid regulatory restrictions and

information problems, the ability to access additional capital, the ability to increase the liquidity of stocks, and the ability to avoid poor corporate governance qualities.

Now that the six dual-listed stocks being traded on the JSE and NYSE have been identified, the problem is to select the appropriate dual-listed stock(s) that will be included in this study's exchange rate model. This study will use the price differences of dual-listed stock in order to incorporate the interaction of two international financial markets, and thus attempting to increase the ability to explain the realized future spot exchange rate with greater accuracy. However, these price differences are the result of supply and demand forces, which is generated by the decision-making process of investors in the market. It is, therefore, important to investigate the fundamentals of an investor's decision-making process before a further investigation can continue on the general models used to price stocks (Section 4.4-4.7). This section will thus provide the overview required to understand how an investor will formulate its buy (demand) and sell (supply) decisions, which will provide more insight in the formulation of a dual-listed stock price, because it is the stock price that will be used to improve the explanation of the realized future spot exchange rate.

4.3 INTRODUCTION TO THE INVESTOR'S BASIC DECISION-MAKING PROCESS

4.3.1 Introduction

In the stock market, prices adjust immediately because investors wish to capitalize on new information, for example economic changes and companies announcing changes (Solnik, 1996:131). Therefore, if an opportunity presents itself, investors will wish to evaluate the risk and return of all the new possible investments. The investor is risk averse and according to his preferences will desire a minimum expected or required rate of return on an investment in order to consider it a good investment. This minimum rate of return, also termed the required rate of return, must thus compensate for the uncertainty of expected financial benefits, changes in the expected inflation rate and the time committed by the investor (Marx *et al.*, 2006:3).

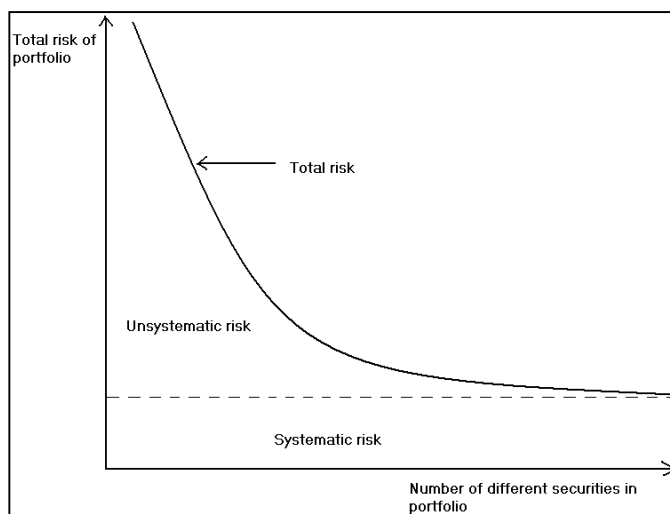
For the investor, there exists a trade-off between risk and return (Hirschey & Nofsinger, 2010:93). The expected return or required rate of return can be calculated with the help of the CAPM. Once the expected return has been determined, the risk, as the probability of the variation from the expected return, can be estimated. Risk can be calculated using the standard deviation (σ), covariance and correlation (Hirschey & Nofsinger, 2010:100–102). Market efficiency models, such as CAPMs, offer insight into the risk-reward relationship and allow investors to construct an optimal portfolio (Hirschey & Nofsinger, 2008:126). Although the asset pricing theory may be a useful tool in understanding and predicting real-world stock market performance, the CAPM has limited ability to predict future returns (Hirschey & Nofsinger, 2008:126–127). The following section will introduce the discussion of the risk-reward relationship by describing the risk component (Section 4.3.2), which will be followed by a description of the return component (Section 4.3.3).

4.3.2 Systematic and unsystematic risk

The total risk of any security can be divided into two types of risk: systematic risk (or market risk) and unsystematic risk (or unique or non-market risk; Alexander *et al.*, 1993:174). Both of these two risks contribute to the total amount of volatility experienced by an investor, while only systematic risk may have a greater influence on the expected rate of return (Hirschey & Nofsinger, 2008:132). Systematic risk is the return volatility of an individual security that cannot be diversified away (Hirschey & Nofsinger, 2008:132), which is tied to the overall market. Systematic risk includes changing economic factors such as the inflation rate, exchange rate and interest rate (Marx *et al.*, 2006:34). Unsystematic risk, which is also known as diversifiable risk or firm-specific risk, can be eliminated by means of diversification (Hirschey & Nofsinger, 2008:132). Thus, after portfolio diversification only systematic risk or non-diversifiable risk remains, and because systematic risk cannot be eliminated the investor must be awarded a form of compensation for any increase in systematic risk (Hirschey & Nofsinger, 2008:132). Systematic risk can be estimated by beta, which will be discussed in Section 4.4.2. Figure 4.3 illustrates systematic risk (non-diversifiable risk) and unsystematic risk (diversifiable risk).

Bearing in mind that risk cannot be entirely avoided, an investor aims to construct a portfolio that offers maximum expected returns for each level of risk and that offers minimum risk for each level of expected return – in brief an efficient portfolio (Gitman & Joehnk, 1990:697–698). These two conditions are termed the efficient frontier or the efficient set (Alexander *et al.*, 1993:161). The following section will discuss the process of determining an efficient portfolio, which entails consideration of the Markowitz efficient frontier.

Figure 4.3: Systematic and unsystematic risk



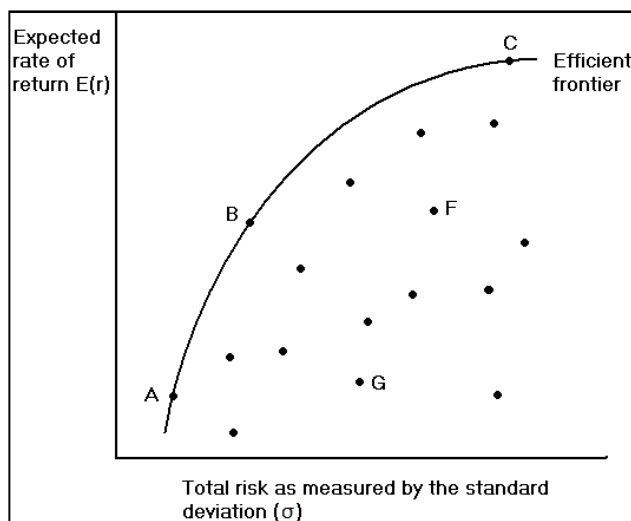
Source: Marx *et al.* (2006:35).

4.3.3 The Markowitz efficient frontier

The Markowitz efficient frontier uses the variability or the fluctuations of returns on investments as a proxy of the risk of investments (Mittra & Gassen, 1981:524). The Markowitz efficient frontier is a quadratic programming technique that indicates the manner in which to reduce risk to a minimum for each level of return by selecting individual securities with unique characteristics (Mittra & Gassen, 1981:526). It offers the highest achievable expected rate of return for each level of portfolio standard deviation or portfolio risk (Bodie *et al.*, 1998:180–181). By applying Markowitz diversification, the level of systematic risk can be decreased if the securities in the portfolio are negatively correlated; however, very few securities possess negative correlations, rather investors must choose amongst securities with the lowest positive correlation possible (Francis, 1993:607).

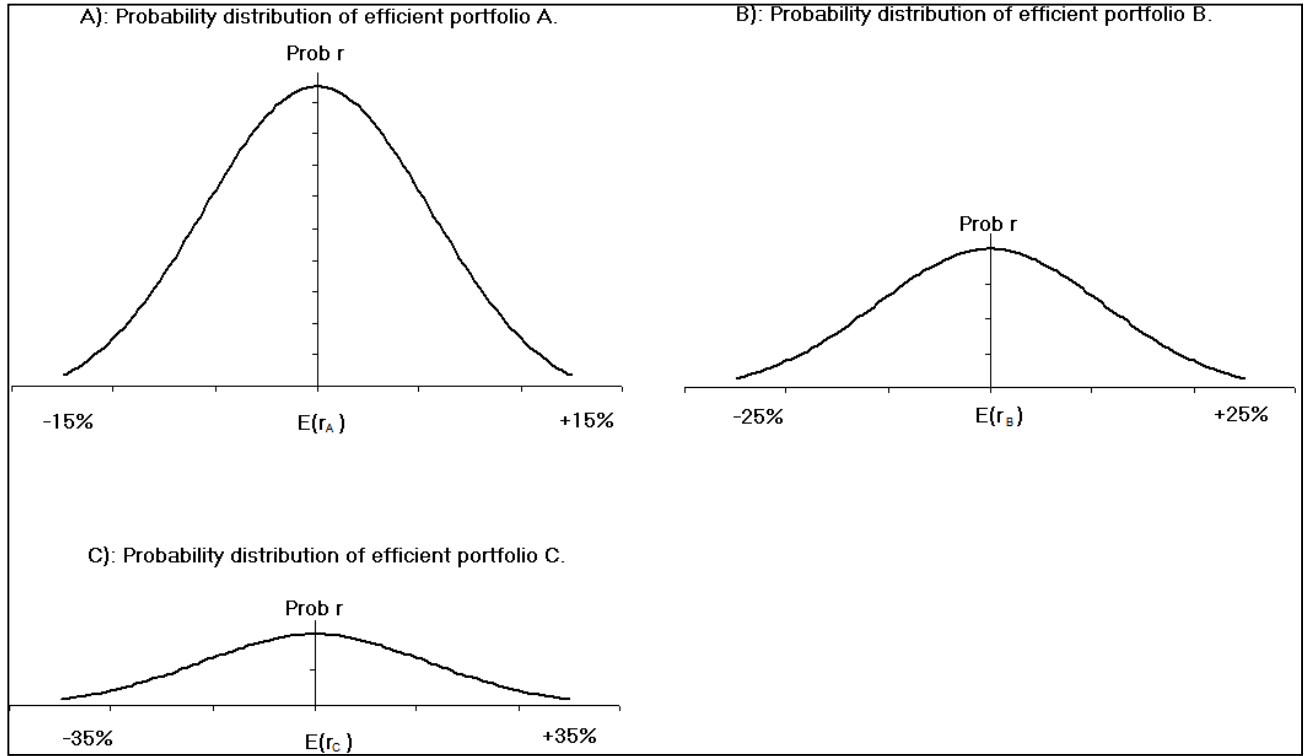
In addition, portfolios generated by means of Markowitz diversification will dominate simply diversified portfolios (Francis, 1993:608–609). Figure 4.4 illustrates the Markowitz efficient frontier, where each letter represents a different portfolio. A portfolio that lies on the efficient frontier represents an efficient portfolio, for example portfolios A, B and C. Portfolios such as G and F represent inefficient portfolios (Marx *et al.*, 2006:35). Each investor has his own risk preferences and accordingly will select an efficient portfolio depending on the extent to which he is risk averse. For example, a more aggressive investor will select portfolio C, where the probability distribution is more widely spread, indicating greater risk for each level of expected return.

Figure 4.4: The efficient frontier



Source: Francis (1993:608).

A more risk-averse investor will select portfolio A, where the probability distribution is smaller and, therefore, indicates reduced risk for each level of expected return (Francis, 1993:608–609). Each efficient portfolio's probability distribution is illustrated in Figure 4.5.

Figure 4.5: The probability distribution of each efficient portfolio

Source: Francis (1993:608).

The greater the σ , the wider the distribution of the rate of return, and thus the more risky the investment. A wider distribution indicates a decrease in the probability of an outcome and thus an increase in the uncertainty of an investment's rate of return (Marx *et al.*, 2006:9–10). Standard deviation can be calculated using the following equation (Marx *et al.*, 2006:8):

$$\sigma = \sqrt{\sum_{n=1}^n (k_i - \bar{k}_i)^2 \times P_{ki}} \quad (4.2)$$

where:

- σ is the standard deviation;
- n is the number of possible states;
- $\bar{k}_i$ is the expected return;
- k_i is the outcome associated with the i^{th} state; and
- P_{ki} is the probability associated with the i^{th} outcome.

The second measure of risk is correlation. Once the standard deviation and the expected return have been determined, the extent to which two securities correlate or co-vary can be calculated. The correlation coefficient (r) can range from +1.0 to -1.0, where a positive r indicates that the two securities move together and a negative r indicates that the securities move inversely (Marx *et al.*, 2006:250). A portfolio manager will prefer a negative coefficient to improve diversification (Hirschey & Nofsinger, 2008:102). The correlation coefficient (r) can be calculated using the following equation (Marx *et al.*, 2006:250):

$$\text{Correlation}(r) = \frac{\text{Covariance}_{(A,B)}}{(\sigma_A \times \sigma_B)} \quad (4.3)$$

where:

- σ_A is the standard deviation of security A ; and
- σ_B is the standard deviation of security B .

The third measure of risk is covariance. Covariance is the absolute measure that determines the extent to which two securities and/or portfolios move together (Reilly & Brown, 2003:102). As covariance is an absolute measure, it can range from $+\infty$ to $-\infty$ (Reilly & Brown, 2003:103). Covariance can be calculated using the following equation (Marx *et al.*, 2006:250):

$$\text{Covariance}_{(A,B)} = \sum \text{probability} \times (\text{return}_A - k_A) \times (\text{return}_B - k_B) \quad (4.4)$$

where:

- return_A is the real return of security A ;
- return_B is the real return of security B ;
- k_A is the expected return of security A ; and
- k_B is the expected return of security B .

All the assets in an efficient portfolio are risky assets, thus they all have $\sigma > 0$. What would happen to the efficient portfolio if a risk-free security was added? As a risk-averse investor, effective diversification will demand that a part of the efficient portfolio consist of risk-free assets, thus if the risky assets perform poorly the risk-free assets will still provide continuity in the portfolio by providing a consistent rate of return. A risk-free asset has zero variance and thus zero correlation with other risky assets (Marx *et al.*, 2006:33). The most common risk-free asset is Treasury Bills (T-Bills), as these have a shorter investment horizon and are, therefore, insensitive to changes in interest rates (Bodie *et al.*, 1998:153). Risk-free assets have a standard deviation (σ_{Rf}) of zero, which means that the actual return will be equal to the expected return (Marx *et al.*, 2006:33). Therefore, including a risk-free, interest-bearing instrument in a portfolio will greatly simplify the shape of the efficient frontier, which will be illustrated by the Security Market Line (Section 4.4.3) and the Capital Market Line (Section 4.4.4) in the following sections.

Until now the Markowitz efficient frontier has helped to identify potential portfolios concerning the risk-return relationship, however, it has not been able to predict the expected or required rate of return of these portfolios? Prior to the CAPM, an investor required a certain expected return from an asset (also termed cost of capital), which depended on the manner in which the asset was financed (Bierman & Smidt, 1966:40, 143–144). The Weighted Average Cost of Capital (WACC) approach is appropriate for determining the weighted cost of capital in a portfolio, according to the pooling-of-fund theory (Correia *et al.*, 2003:7–3, 7–4). However, determining the value of the cost of capital for stocks is sometimes difficult. In order to overcome this problem, Gordon and Shapiro (1956:106) developed a model that can be used to determine a stock's cost of capital, the Gordon growth model (as illustrated in Equation 4.1 in Section 4.1).

However, even if the stock's cost of capital is known, calculating the future growth rate of the returns of a stock is almost impossible, although, based on Equation 4.1, companies with a high

growth rate will be considered to have a high cost of capital. The CAPM indicates that it is unnecessary to connect future growth with the cost of capital (Perold, 2004:5). In the pre-CAPM, risk was not yet directly included in the estimation of the cost of capital (Perold, 2004:5). Furthermore, no model has yet been able to explain satisfactorily what determines the size of risk discount and the manner in which it relates to other variables (Modigliani & Miller, 1958:262). The Security Market Line (SML) however may serve as an indicator to reflect the best combination of risk and return available on investments (Marx *et al.*, 2006:33). This leads to the following sections, which will discuss the Security Market Line (Section 4.4.3) and the Capital Market Line (Section 4.4.4), with the help of CAPM (Section 4.4). The CAPM helps to determine what the required or expected rate of return on a risky asset should be (Reilly & Brown, 2003:247).

4.4 THE SINGLE-FACTOR MODEL: THE CAPITAL ASSET PRICING MODEL

4.4.1 Introduction

Jacob and Pettit (1988:225) state that the CAPM describes a set of principles that explains the manner in which market participants behave and in this way provides a rational basis for current practices in the investment industry (Alexander *et al.*, 1993:217). Furthermore, the CAPM can be seen as an equilibrium model that is based on utility maximization and on a portfolio opportunity set (Blake, 2000:489), and thus determines the equilibrium risks, returns and prices for the different stocks (Jacob & Pettit, 1988:225). The study of Bodie *et al.* (1998:199) argues that the CAPM forecasts the relationship between the equilibrium expected returns on risky assets and the risk associated with these assets. The CAPM can thus be considered to describe the relationship (trade-off) between the expected return and the risk used in pricing risky securities (Investopedia, 2009b), which assists investors in various investment decisions (Gitman & Joehnk, 1996:165).

In order to understand the CAPM, the key assumptions underlining the construction of the CAPM must first be discussed. These key assumptions include the following (Alexander *et al.*, 1993:218–219):

- Portfolios are evaluated by comparing the standard deviation (risk) and the expected returns of portfolios over a one-period time horizon. This implies that investors will hold an efficient portfolio, which is one in which higher risk involves higher expected returns (Hirschey & Nofsinger, 2008:128). In other words, investors wish to operate on the efficient frontier (Marx *et al.*, 2006:36). Furthermore, investors are rational mean-variance optimizers (Bodie *et al.*, 1998:199);
- Investors are never satisfied and will continuously search for and select identical portfolios with a higher expected return;
- Investors are risk averse and will thus select the portfolio with the lower standard deviation (risk);
- The individual investments are infinitely divisible, thus investors are able to buy a fraction of any portfolio or asset;
- Investors cannot affect the prices of individual trades (Bodie *et al.*, 1998:199), that is, price continuity is present (Jacob & Pettit, 1988:226);
- There is a risk-free rate (R_f) at which the investor are able to borrow money or to lend (invest) money (Alexander *et al.*, 1993:218). Thus, unlimited borrowing and lending is possible (Hirschey & Nofsinger, 2008:128);
- The risk-free rate is the same for all investors;
- Transaction costs and taxes are irrelevant (Alexander *et al.*, 1993:218). Thus, investors will not be concerned about the dividend or the capital gain differences (Bodie *et al.*, 1998:199).
- All investors have the same one-period time horizon (same holding period; Bodie *et al.*, 1998:199);
- Information is instantaneously and freely available to all investors;

- Investors have homogeneous expectations, which means that each investor has the same expectation regarding the standard deviation (risk), the covariance of securities and expected returns (Alexander *et al.*, 1993:219), and holds the same world economic view (Bodie *et al.*, 1998:199);
- Inflation rates are fully anticipated (Hirschey & Nofsinger, 2008:128); and
- The capital markets are in equilibrium (Hirschey & Nofsinger, 2008:128), thus all assets are appropriately priced in terms of their risk levels (Marx *et al.*, 2006:36).

The above-mentioned assumptions form the foundation for effective portfolio decisions or portfolio selection. As mentioned in Section 4.3, a competent investor is capable of eliminating diversifiable risk by diversifying his portfolio; thus, the only relevant risk is non-diversifiable risk. Each portfolio and security has its own level of non-diversifiable risk, which can be measured using beta. In the following section, the calculation and interpretation of beta will be discussed.

4.4.2 Calculating and interpreting beta

Beta is a standardized measure of systematic risk and indicates the manner in which the price of a security responds to market forces (Reilly & Brown, 2003:248). The higher the beta value, the more responsive the price of the security or portfolio to changes in market forces (Gitman & Joehnk, 1990:197). Beta can thus be used to assess market risk and gain greater insight into the impact of the changing market on the expected or required rate of return on stocks (Gitman & Joehnk, 1996:165). Although, most beta values have a positive sign, a beta value can have a positive or negative sign (Gitman & Joehnk, 1996:164). Thus, a positive beta value indicates that a stock moves in the same direction as the general market, while a negative beta value indicates that a stock moves in the opposite direction to the general market (Gitman & Joehnk, 1996:164). The beta value for the entire market is 1. Thus, a beta value of greater than 1 indicates that the stock is more responsive to market changes.

In order to calculate beta the basic equation for the CAPM must first be established. The equation that is used for the CAPM is as follows (Marx *et al.*, 2006:36):

$$E(R_i) = R_f + \beta_i(k_m - R_f) \quad (4.5)$$

where:

- $E(R_i)$ is the expected or required rate of return;
- R_f is the risk-free rate of return;
- k_m is the return on the market portfolio; and
- $(k_m - R_f)$ illustrates the market risk premium.

Beta can be calculated as follows (Marx *et al.*, 2006:36):

$$\beta = \frac{\text{Systematic risk of security } i}{\text{Market risk}} \quad (4.6)$$

or

$$\beta = \frac{\text{Covariance}_{i,m}}{\text{Variance}_m} \quad (4.7)$$

or

$$\beta = \frac{\text{Correlation}_{i,m} \sigma_i \sigma_m}{\sigma_m^2} \quad (4.8)$$

A security with a greater beta value than that of the market is known as an aggressive stock (Blake, 2000:494). A greater beta value means that the price of the security is more volatile than that of the market (Blake, 2000:494). As a result, the security's price will rise more than that of the market in a bull phase and will fall more in a bear phase. A greater beta value indicates greater systematic risk and a higher required rate of return (Blake, 2000:494).

A security with a beta value lower than that of the market is termed a defensive stock. This means that the security's price is less volatile than that of the market. Consequently, the security's price will rise by less than that of the market in a bull phase and will decrease by less

in a bear phase (Blake, 2000:494). A lower beta value indicates a smaller systematic risk and a lower required rate of return (Blake, 2000:494). These interpretations are summarised in Table 4.3.

The basic equation of the CAPM illustrated graphically is termed the Security Market Line. The slope of the Security Market Line is the beta (Gitman & Joehnk, 1996:164) and the risk-free rate (R_f) forms the y-intercept (Hirschey & Nofsinger, 2008:130). A beta value greater than 1 indicates that the security is more responsive to market changes, and thus more risky, and will thus have a steeper slope. A beta value smaller than 1 indicates that the security is less responsive to market changes, and thus less risky, and will thus have a flatter slope. A higher beta value means the level of required or expected return must be higher to compensate for the greater risk and *vice versa*. This leads to the next section in which the Security Market Line will be discussed as an efficient frontier. A discussion on the Capital Market Line, which considers borrowing and lending as an additional investment opportunity, will then follow (Section 4.4.4).

Table 4.3: Interpretation of various beta values

Beta	Movement	Interpretation
2.0	Security moves in the same direction as the market.	Security is twice as responsive as the market.
1.0		Security has the same risk and response as the market.
0.5		Security is half as responsive as the market.
0	Security is unaffected by any market movement.	
-0.5	Security moves in the opposite direction as the market.	Security is half as responsive as the market.
-1.0		Security has the same risk and response as the market.
-2.0		Security is twice as responsive as the market.

Source: Gitman and Joehnk (1990:198).

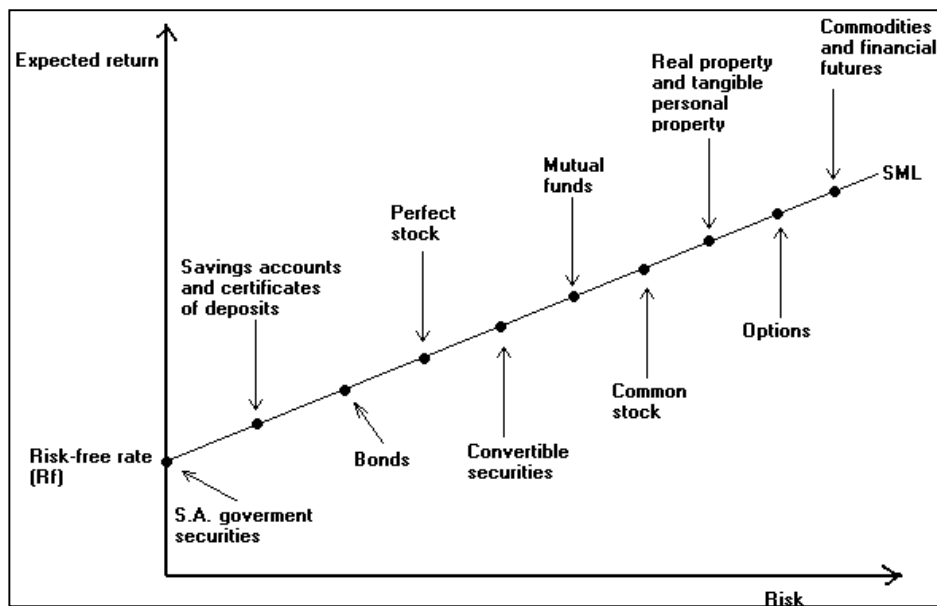
4.4.3 The Security Market Line

The SML indicates the best combination of risk and return available on investments (Marx *et al.*, 2006:33). The SML illustrates the relationship between systematic risk and the expected return on individual securities (Hirschey & Nofsinger, 2008:133), in other words the trade-off between risk and return (Gitman & Joehnk, 1990:201). The SML can also be used as a benchmark to

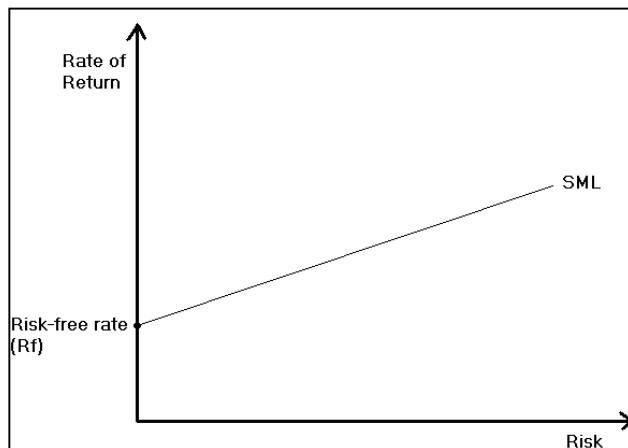
evaluate the performance of a specific investment (Bodie *et al.*, 1998:205). Figure 4.6 illustrates the trade-off between the risk and return of various types of investments.

The most relevant risk measure for individual risky assets is the covariance thereof with the market portfolio ($Cov_{i,m}$). The SML thus illustrates the relationship between risk and return, with the systematic risk variable ($Cov_{i,m}$) as the measure of risk (Reilly & Brown, 2003:247). Beta, as discussed in the previous section, indicates the sensitivity of an asset to market movements (Solnik, 1996:139), and can be used to signify the covariance of a security (Alexander *et al.*, 1993:227). The SML represents the expected return–beta relationship (Bodie *et al.*, 1998:204). It thus, illustrates the individual asset's risk premiums as a function of asset risk (Bodie *et al.*, 1998:205), where any asset will fall on the SML under the equilibrium conditions (Luenberger, 1998:181). The best combination for a portfolio consisting of a risk-free asset and combinations of alternative risky assets is reflected by the SML as shown in Figure 4.7 (Marx *et al.*, 2006:33).

Figure 4.6: Trade-off between the risk and return of various types of investments

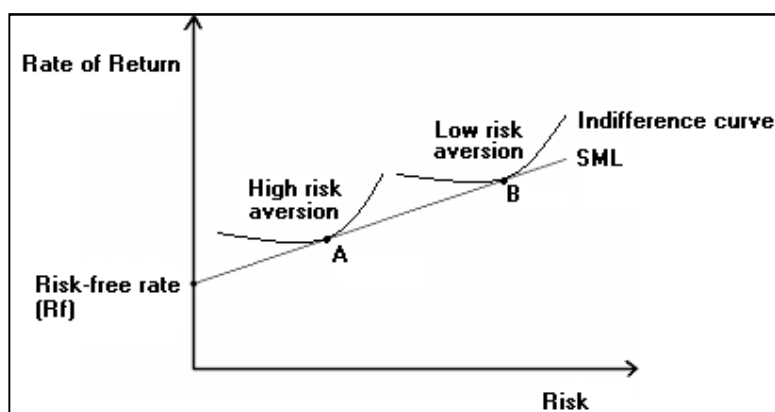


Source: Gitman and Joehnk (1990:202).

Figure 4.7: The Security Market Line

Source: Marx *et al.* (2006:33).

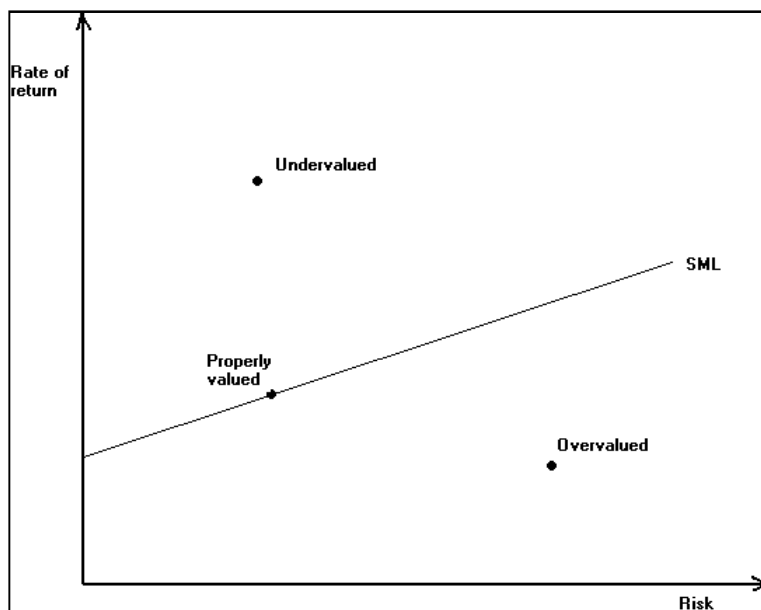
As stated earlier, each investor has his own risk preference, which can be illustrated by a risk indifference curve (Marx *et al.*, 2006:33). Figure 4.8 illustrates the different efficient portfolios A and B located on the SML. For each portfolio, the indifference curve intersects the SML, indicating that at these points the investor is pleased with the level of risk (preference) for the current rate of return. An investor interested in portfolio A will be more risk averse because the risk faced is low and thus a lower rate of return will be accepted. An investor interested in portfolio B will be less risk averse because the risk of portfolio B is higher and, therefore, a higher rate of return will be expected (Marx *et al.*, 2006:33). Thus, the less steep the indifference curve, the lower the investor's risk aversion and *vice versa*.

Figure 4.8: The Security Market Line and risk indifference curves

Source: Marx *et al.* (2006:33).

As mentioned previously, the CAPM can help determine the expected return for a given level of systematic risk (Hirschey & Nofsinger, 2008:135). According to the CAPM, all stocks are fairly valued at any point in time. The CAPM equation can be illustrated graphically with a SML; therefore, if a stock's returns lie above the SML (greater expected return–beta combination), the stock is undervalued. This means that the expected rate of return will lie above the predicted expected rate of return of the CAPM (Hirschey & Nofsinger, 2008:135). If a stock's returns lie under the SML, the stock is overvalued (smaller expected return–beta combination). This means that the expected rate of return will lie below the predicted expected rate of return of the CAPM (Hirschey & Nofsinger, 2008:135). This is illustrated in Figure 4.9.

Figure 4.9: Over- and undervaluation of stock



Source: Marx *et al.* (2006:39).

A disadvantage of the SML is that it does not provide borrowing and lending as an investment opportunity in the efficient portfolio, which lies on the SML. In order to provide borrowing and lending capabilities, a new efficient frontier must be calculated, which is called the Capital Market Line (CML). The new frontier includes a risk-free asset, thus simulating reality in that the investor can freely borrow or lend at the risk-free rate (the rate derived from a risk-free asset; Luenberger, 1998:165). The CML is a linear line with the risk-free rate (R_f) the y-intercept and

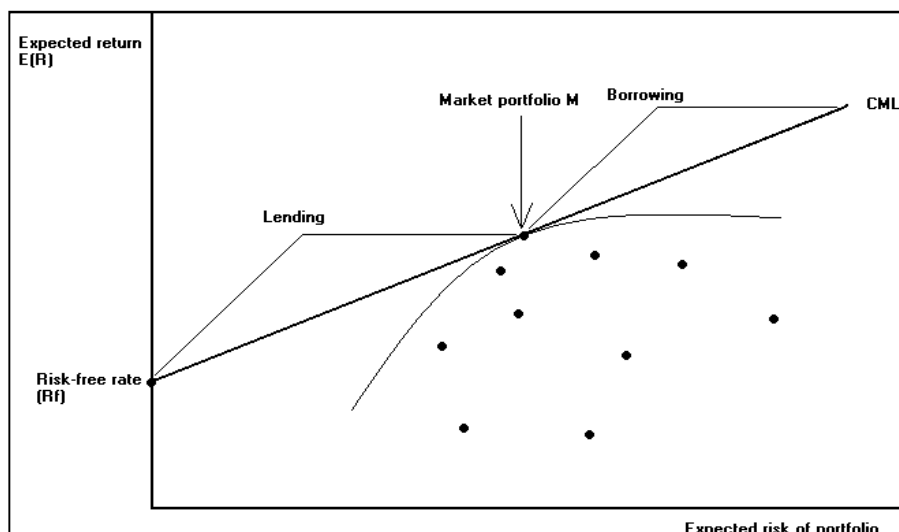
beta (β) the coefficient (see Figure 4.10). As with the SML, each portfolio on the CML is perfectly positively correlated (Marx *et al.*, 2006:37). The following section will discuss the CML as an efficient frontier for portfolios.

4.4.4 The Capital Market Line

The CML provides a wider range of desirable investment opportunities than the SML, such as borrowing and lending (Francis, 1993:616). Like the SML, it characterizes the relationship between the risk and the expected rate of return for portfolios. Furthermore, the CML provides the link between traditional portfolio theory and the CAPM (Hirschey & Nofsinger, 2008:133), and thus illustrates the linear efficient set of the CAPM (Alexander *et al.*, 1993:222).

Figure 4.10 illustrates the additional investment opportunities mentioned above. The market portfolio M, which includes all the risky assets proportional to their market value, is located on the CML. Figure 4.10 further illustrates that as borrowing in the portfolio increases, the expected risk of portfolio M will increase and *vice versa* if lending increases. If borrowing increases, the expected risk of portfolio M increases because the borrowed money is used to invest in more risky assets, thereby increasing the overall risk (Marx *et al.*, 2006:37–38).

Figure 4.10: The CML assuming borrowing and lending at the risk-free rate



Source: Marx *et al.* (2006:38).

Although the CAPM is the most popular model in investment theory, which was used as a base to help explain the CML and SML, it does have some disadvantages. In the CAPM the beta value actually explains very little of the variation in expected returns. In addition, there appears to be a non-stationary beta problem, which means that the estimated year-to-year beta value varies. The CAPM assumes that the beta value is solely able to explain the systematic risk, while in fact the beta value reflects only one of a company's many risk factors (Hirschey & Nofsinger, 2008:140–141; White & Fan, 2006:196), which need to be included in a model (Blake, 2000:501). Thus, the CAPM is a single-factor model (Luenberger, 1998:205).

This suggests that a more complex model is needed to incorporate the multiple aspects of risk, in order to improve the explanation of average-return anomalies, in other words, a multi-factor model is needed. Fama and French (1993:5) identified three factors that cause fluctuations in monthly stock returns: a market factor (for example, the return on the market index), a book-to-market factor (for example, the difference in returns between a stock index with a low book-to-market ratio and a stock index with a high book-to-market ratio) and a size factor (for example, the difference in returns between a large cap index and a small cap index). Sharpe (1982:7–9) found that beta, dividend yield, excess returns (alpha) and company size were statistically significant. One approach that considers multiple factors as given above is the arbitrage pricing theory (APT), which will be discussed in the next section.

4.5 THE MULTI-FACTOR MODEL: THE ARBITRAGE PRICING THEORY

4.5.1 Introduction

The APT links the factor sensitivities of an asset to its expected rate of return, thereby signifying the importance of factor risk in asset pricing (Gilles & Leroy, 1991:213). It also provides a characterization of expected returns on assets by following a factor structure and assumes that there are no arbitrage opportunities (Gilles & Leroy, 1991:1). In addition, the APT predicts the relationship between a single asset's return and the return of a portfolio through a linear combination of various macroeconomic variables (Investopedia, 2009c).

The APT, therefore, attempts to capture some of the non-market influences that cause asset returns to move together (Paavola, 2006:6), thus accounting for a larger number of factors that affect the rate of return (Cuthbertson, 2004:61).

The APT considers a linear relationship between k number of factors under the following assumptions (Van Rensburg, 1997:60):

- The capital market is frictionless and perfectly competitive with no asymptotic arbitrage opportunities (Altay, 2003:1);
- Competitive forces quickly eliminate arbitrage profit opportunities (Paavola, 2006:7); and
- Investors are risk averse and they favour more wealth to less wealth.

Its fewer assumptions make APT a less restrictive and a more attractive approach (Altay, 2003:1).

The APT depends on the law of one price (Section 3.2.2) and it categorises an asset's risk into two components (Altay, 2003:1). These two components are systematic risk and unsystematic risk (Section 4.3.2). Systematic risk is the risk that results from more than one factor (Altay, 2003:1), that is macroeconomic factors (Paavola, 2006:7). These systematic forces influence the asset market as a whole and cannot be diversified away (Paavola, 2006:7). The systematic forces that influence stock returns are those macroeconomic variables that change the expected cash flows and the discount factors (Shaharudin & Fung, 2009:101). According to the APT, unsystematic risk originates from factors unique to each individual asset. Unlike systematic risk, unsystematic risk can be diversified away (Paavola, 2006:7).

The APT was proposed as an alternative to the CAPM, as it has the advantage that it can be applied to a subset of investments (Solnik, 1996:234), while retaining many of the advantages

of the CAPM (Ross, 1976:342). The APT assumes that the return R_{it} of the i^{th} security is generated by a multi-index model (Paavola, 2006:7):

$$R_{it} = a_i + b_{t1}F_{t1} + \dots + b_{iJ}F_{Jt} + e_{it} \quad i = 1, 2, \dots, N, \quad (4.9)$$

where:

- F_{Jt} are factors ($j = 1, 2, \dots, J$);
- b_{iJ} are the factor sensitivities; and
- e_i is the random error with $E(e_i) = 0$, $E(e_i^2) = \sigma_i^2$, $E(e_i e_k) = 0$, $i \neq k$ and $cov(e_i F_i) = 0$ for all i and j , with N number of assets (Groenewold & Fraser, 1997:1369).

Equation 4.9 illustrates that each stock i has its own unique sensitivity to each F_{Jt} . The F_{Jt} of each stock has the same value and any F_{Jt} affects more than one stock (Paavola, 2006:8). The APT is expressed in the following equation as the relationship between the expected rate of return $E(r_i)$ and the factor sensitivities (Paavola, 2006:7):

$$E(R_{it}) = \lambda_0 + \lambda_1 b_{t1} + \dots + \lambda_j b_{iJ} + \varepsilon_{it} \quad (4.10)$$

where:

- λ_0 is usually equal to the risk-free rate of return; and
- λ_1 is the expected return of a portfolio (price of risk) with unit sensitivity to factor j and zero sensitivity to all other factors (Cheng, 1995:130–131).

The assumptions are made that there are no arbitrage opportunities and that the average of a random sample from a large population will be close to the mean of the whole population (Paavola, 2006:7). Equation 4.10 illustrates that λ_1 is the extra expected return required because of a security's sensitivity to the i^{th} attribute of the security. The APT has the problem

that the F_{Jt} term is not defined in exact terms in the theoretical exposition (Elton *et al.*, 2003:370), in other words, there are no specified number of factors that have to be included in the equation.

In addition, Equation 4.11 focuses on the systematic forces that influence the returns of equities, which include those forces that change the expected cash flow $E(D_t)$ and the discount factors or both (Chen *et al.*, 1986:385). In Section 4.1, Equation 4.1 illustrated the basic model for calculating the price of a stock (the Gordon growth model). Equation 4.11 is an improvement to Equation 4.1, where the price of the stock now depends on more components, such as expected cash flow and the discount factor. Furthermore, any economic announcements that affect the components of Equation 4.11 will lead to a change in the stock price (Morel, 2001:316).

According to Paavola (2006:8), the stock prices can be written as expected discounted dividends:

$$P_0 = \sum_{t=1}^{\infty} \frac{E(D_t)}{(1+r)^t} \quad (4.11)$$

where:

- P_0 is the stock price;
- E is the expectations operator;
- r is the discount rate; and
- D_t is the dividend paid at the end of period t .

It is now relevant to determine which economic factors have a significant effect on the asset returns and prices. The greatest deficiency of the APT model (Paavola, 2006:9) is that there is no formal guidance in the theory that specifies a certain number of factors that must be included or the identity of all the factors (Azeez & Yonezawa, 2006:576; Elton *et al.*, 2003:370).

It is doubtful that a single macroeconomic variable has the ability to capture all of the variance in a stock's returns (Shaharudin & Fung, 2009:112). However, Berry *et al.* (1988:30) provide an APT framework to determine what kind of variables qualify as justifiable risk factors. These justifiable risk factors must possess the following three properties: firstly, the factors must be completely unpredictable at the beginning of the period; secondly, each factor must have a persistent influence on stock returns; and thirdly, the factors must have non-zero prices; thus, they must influence expected returns. Paavola (2006:10) discusses two methods that can be used to determine which factors should be included in the APT model: the first method (introduced by Gehr, 1978:94–101) selects factors through multivariate statistical models, and the second method (Roll & Ross, 1980:1079–1091) selects factors through a macroeconomic variable model. The most common multivariate statistical model used is the two-step approach. The first step involves the use of time-series data to estimate a set of factor loadings for each asset, that is, it uses factor-analysis techniques to estimate common factors (Paavola, 2006:10). The second step entails regressing the sample mean returns on the factor loadings in a cross-sectional regression (Paavola, 2006:10) to help determine which factors to choose.

However, Dhrymes *et al.* (1984:337) criticize the factor-analysis approach, stating that the significance tests of individual risk premium are not valid. Furthermore, the number of factors increases as the number of assets in the sample increases (Dhrymes *et al.*, 1984:323). For example, there are approximately five to six inter-group factors in two industry security groups that determine their daily returns (Cho, 1984:1499). However, these factors are not constant amongst countries; for example, Groenewold and Fraser (1997:1374) found three factors for the Australian stock market for the example above.

The second method is based on the two-step procedure by Fama and MacBeth (1973:614–618) that was used to investigate the CAPM. The appropriate macroeconomic variables should sufficiently explain asset returns, the actual asset returns should display sensitivities to the realization of these variables, investors should pass the statistical tests necessary to qualify as

justifiable APT factors, and the factors should have non-zero APT prices (Berry *et al.*, 1988:31). According to Azeez and Yonezawa (2006:570), the second method offers advantages to the first method because economic interpretations can be given to the factors themselves and to their APT prices, while the factor-analysis approach lacks the ability to indicate which factors must be priced. Moreover, macroeconomic factors provide additional information that links macroeconomic events to asset price behaviour (Azeez & Yonezawa, 2006:570). One of the most common models used is the three-factor model of Fama and French (1993:5), which has been used to explain the international portfolio/investment environment (Wu, 2008:175).

A number of studies examined the possibility of using different macroeconomic variables to explain asset price behaviour. The study of Page (1986:42) argues that macroeconomic variables that determine the return-generating process can be divided into variables that have a great influence on the mining and industrial sector. Another study indicated that company size can be used to help explain stock returns (Reinganum, 1981:316). Although, further evidence indicated that the size effect is not stable over different time periods (Brown *et al.*, 1983:34-35), which was confirmed by Reinganum (1992:60), who demonstrated that the small firm effect was a long-run phenomenon. Other studies, for example Shaharudin and Fung (2009:112), found evidence of a strong relationship between stock returns of companies of different sizes and macroeconomic variables such as the industrial production index, interbank money market transactions, 3-month and 6-month T-Bills discount rates, M3 money supply and the crude oil prices. Basher and Sadorsky (2006:249) found that oil price changes have a positive statistically significant effect on stock market returns of twenty-one emerging economies. Furthermore, Muradoglu *et al.* (2000:43–44) investigated the relationship between emerging market returns and inflation, industrial production, exchange rates and interest rates, and found that these relationships were mainly due to the size of the stock market and their integration with world markets. Türsoy *et al.* (2008:52) provide a summary of earlier studies concerning which macroeconomic variables should be included. This summary is given in Table 4.4.

Table 4.4: Macroeconomic variables employed in various APT studies

Macroeconomic variables	Previous studies that employed indicated variables
Industrial production	Özçam (1997), Altay (2003)
Inflation	Chen & Jordan (1993), Altay (2003)
Oil price	Chen & Jordan (1993), Clare & Thomas (1994)
Money supply	Özçam (1997), Altay (2003)
Export	Beenstock & Chan (1988)
Interest rate	Özçam (1997), Altay (2003)
Gross domestic product	Kryzanowski & Zhang (1992), Cheng (1995)
Gold price	Yörük (2000), Clare & Thomas (1994)
Import	Altay (2003)
Exchange rate	Özçam (1997)
Unemployment rate	Clare & Thomas (1994)

Source: Türsoy *et al.* (2008:52).

In summary, the most significant problem with regard to the APT model is that there is no formal theoretical guidance that specifies the appropriate group of economic factors that should be included. This explains the conflicting evidence in the empirical results of past studies. Despite this, the APT model offers advantages to the CAPM. The next sections will briefly discuss the deficiencies of the CAPM (Section 4.6.1), compare the APT model to the CAPM (Section 4.6.2), and list the advantages and disadvantages of the APT model (Section 4.6.3).

4.6 COMPARING THE ARBITRAGE PRICING THEORY MODEL TO THE CAPITAL ASSET PRICING MODEL

This section will briefly discuss the disadvantages of the CAPM, compare the APT to CAPM and summarise the advantages and disadvantages of the APT.

4.6.1 Disadvantages of the Capital Asset Pricing Model

The first disadvantage of the CAPM is that it considers that the risk premium depends only on the systematic factor. For this reason, the APT model is of greater practical value to investors (Treyner, 1993:11) because it includes a wider range of factors. A second disadvantage is the great number of unrealistic assumptions and its empirical shortcomings, such as the overestimating of the risk-free rate and the underestimating of the market risk premium (Paavola, 2006:15). A third disadvantage is the use of beta to predict the returns

on assets (Paavola, 2006:15), as the returns on stocks with a high beta value will tend to be overestimated, while the returns on stocks with a low beta value will tend to be underestimated (Groenewold & Fraser, 1997:1367).

In addition, the multi-factor model was found to have the ability to capture the value premium in international returns (Fama & French, 1998:1985). However, the problem with the multi-factor model is that it assumes that the capital markets are integrated and investors are not worried about the deviations from PPP (Section 3.2). This means that this multi-factor model overlooks other risk factors that might affect expected returns (Wu, 2008:175).

4.6.2 Comparison of the Arbitrage Pricing Theory model to the Capital Asset Pricing Model

In comparing the APT model to the CAPM, it was determined that the APT model appears to address some of the shortcomings of the CAPM. The comparison between the models is summarised in Table 4.5.

Table 4.5: Comparing the APT model and the CAPM

APT model	CAPM
Considers a greater number of factors that can influence asset returns (Marx <i>et al.</i> , 2006:40; Dhankar & Esq, 2005:14).	Considers beta as the only factor that influences asset returns (Marx <i>et al.</i> , 2006:40; Dhankar & Esq, 2005:14).
Assumes that unique risk can be diversified away in a large portfolio (Marx <i>et al.</i> , 2006:40).	Assumes that unique risk can be diversified away in a large portfolio (Marx <i>et al.</i> , 2006:40).

In addition to the comparison in the table above, Berry *et al.* (1988:29) argued that the APT model explains stock returns better than the CAPM model. The evidence found by Josev *et al.* (2001:158, 161) emphasised this statement by illustrating that the results were in favour of the APT model. A further investigation also indicated that the APT, with multiple factors, has the ability to provide a better indication of asset risk and improved estimates for the required rate of return, compared to the CAPM, where beta is used as the single market of risk (Dhankar & Esq, 2005:14). The study of Elton *et al.* (2003:382) argued that the APT has the ability to supply a

more comprehensive description of returns than the CAPM. From the above comparison, it is apparent the APT model is the more superior model. The following section will present the advantages and disadvantages of the APT in order to justify this claim.

4.6.3 The advantages and disadvantages of the Arbitrage Pricing Theory model

There are no assumptions made about the empirical distribution of asset returns. Only the following three assumptions are made (Paavola, 2006:15; Lofthouse, 2001:67):

- There are no taxes and no market frictions, which means that short selling is unrestricted;
- Several securities are available to diversify the idiosyncratic risk away; and
- There are no transaction costs.

The APT model admits a wider range of risk sources, which improves the forecasting ability (Paavola, 2006:15). Also, The APT model has no role for the market portfolio, whereas the CAPM needs the market portfolio to be efficient (Paavola, 2006:15).

The APT model lacks the ability to identify influential factors (Paavola, 2006:17) and provides no information concerning prices (Gilles & Leroy, 1991:229). The number of influential factors increases as the number of securities being analyzed increases (Dhrymes *et al.*, 1984:323). Another problem with the APT model is that it assumes that there are no arbitrage opportunities and that the asset returns are linearly related to unspecified factors (Paavola, 2006:17).

It has been demonstrated that the APT model addresses some of the deficiencies of the CAPM. Despite the advantages of APT, alternative models were developed in an attempt to improve the explanation of asset price behaviour. One of these alternative models includes

the International Capital Asset Pricing Model (ICAPM) that was developed by Solnik (1983:451–454). However, due to the deficiencies of the standard CAPM, Solnik (1983:451-454) developed the International Arbitrage Pricing Theory, which can be beneficial for examining asset price behaviour, but has the tendency to become too complex.

To summarise, although the APT model proved to be a better model than the CAPM, there is also an extension of the CAPM developed in an attempt to incorporate some of its shortcomings, especially when using for multination portfolios. In addition, the study of Solnik (1974:500) stated that ‘the development of international investment is evidenced by the rapidly growing share of investors.’ Furthermore, ‘when considering an international investment, a fundamental dimension should be added to the analysis: the exchange risk. Anyone investing abroad will bear not only the risk due to the real characteristics of the investment, but also an exchange risk’ (Solnik ,1973:8). This led to the development of the International Capital Asset Pricing Model (ICAPM), which is of great significance to this study, because the ICAPM provides the final link needed for the empirical study. This link includes the relationship between dual-listed stock returns and the exchange rate. This model will be discussed in the following section.

4.7 THE INTERNATIONAL CAPITAL ASSET PRICING MODEL

4.7.1 Introduction

Adler and Dumas (1983:928) found that the heterogeneity of investor behaviour with regard to selecting portfolios limits the aggregation of individual demands into a CAPM when PPP does not hold. The specifications of the CAPM should be restrictive, and must allow the returns to vary over time (Campbell, 1985:21–33). Additionally, the volatility of financial returns may not be constant over time and demonstrated volatility clustering, in other words, prolonged periods of low and high volatilities (Koopman & Uspensky, 2001:667).

Using Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models⁵⁶, Fabozzi *et al.* (2004:91) also found the presence of volatility clustering in the Chinese stock markets.

Furthermore, international investment has developed as is evidenced by the rapidly growing number of international investors (Solnik, 1974:500). The exchange risk is a fundamental factor to be considered in international investment, as investors abroad will bear both the risk due to the real characteristics of the investment and exchange risk (Solnik, 1973:8). According to Roll and Solnik (1977:162), under ideal circumstances, “the fact that francs were used in one location and pounds, yen, or cruzeiros used in others would only constitute a multinational version of the ‘veil of money.’ Real interest rates would be equal everywhere as would the real price of risk, and capital asset pricing relations would be identical for the residents of all countries. In such idealized circumstances, real exchange rate risk would be absent”. However, in reality exchange risk is present and the standard domestic CAPM (Section 4.4) does not have the ability to address this matter properly (Litterman, 2003:56). These findings led to the development of the ICAPM, which is of great significance to this study, because the ICAPM includes the relationship between dual-listed stock returns and the exchange rate.

This leads to the following section, which will discuss the reason for the development of the ICAPM (Section 4.7.2). This will be followed by a discussion on past empirical studies of the ICAPM and a brief comparison between the ICAPM and the APT (Section 4.7.3).

4.7.2 Reasons for the development of the International Capital Asset Pricing Model

The ICAPM was developed to address the problem of exchange rate risk in foreign investments when PPP (Section 3.2) does not hold (Wu, 2008:175). With the assumption of an integrated money market, the IRP (Section 3.3) will hold, which may lead to the same level of expected real risk-free rates across countries (Armitage, 2005:242). However, if IRP does not hold, risk-

⁵⁶ The GARCH model is extended from the ARCH model. The GARCH process is generalized to allow lagged and current conditional variances. The GARCH process also allows the past realization of the disturbance term to affect the sample generating model (Brorsen & Yang, 1989:138-139).

free rates will not be the same across countries, which implies that the interest rate differential will not be equal to the expected change in the exchange rate, thereby causing uncertainty about future exchange rate movements and leading to the possibility of exposure to exchange rate risk. Furthermore, if IRP (more precisely, Uncovered Interest Rate Parity, as discussed in Section 3.3.6) does not hold this implies an inefficient market, which will offer hedge fund managers profitable opportunities in exploiting market mispricing (Adrangi *et al.*, 2007:30). Thus, if PPP (Section 3.2) or IRP (Section 3.3) does not hold, then investors from different countries may evaluate the returns on the same asset differently (Ng, 2004:191). This premise violates the CAPM's assumption (Section 4.4) that investors have homogeneous expectations of returns. This may affect asset pricing procedures, where it may become difficult to aggregate individual portfolios into an asset pricing equation (Ng, 2004:191).

In addition, Dumas and Solnik (1995:477) argue that FX rate risk should be incorporated in asset pricing models by allowing for time variation in the rewards for the exposure to exchange rate risk, which lead to the development of the ICAPM. In contrast to CAPM, ICAPM includes wealth and state variables that forecast changes in the distribution of future returns or income (Cochrane, 2001:166). The ICAPM has the ability to generate linear discount factor models, which consist of state variables that determine the maximization of an investor's portfolio decisions (Cochrane, 2001:166); however, the ICAPM lacks the ability to describe the identity of the state variables (Cochrane, 2001:171). Furthermore, the ICAPM lacks the ability to explain the returns in a cross-section of national value portfolios (Fama & French, 1998:1984).

Besides these shortcomings the ICAPM provide an improvement to the CAPM, as it includes time-varying investment opportunities and longer investment horizons in the investor's decision-making process (Cochrane, 2001:172), thus also adding the option of hedging against currency risk (Litterman, 2003:56). Moreover, ICAPM has an assumption that investors ignore the nominal return in the currency of their country, but focus on the real return of the financial assets per unit of risk (Vaihekoski, 2000:72). To provide more insight into the ICAPM the next section

will discuss the past empirical studies of the ICAPM with regard to the most important historical ICAPM developments and empirical results.

4.7.3 Past empirical studies of the International Capital Asset Pricing Model

The three most commonly used versions of the ICAPM are documented in Solnick (1974), Grauer *et al.* (1976), and Black (1989). Each of these are discussed below. Solnick (1974:502) developed an ICAPM that holds the following assumptions:

- The world exchange rate is flexible;
- There are no international capital flow constraints;
- Investors invest only in their own country;
- All investors have homogeneous expectations regarding the type of currency and the exchange rate fluctuations. Thus, all investors face the same efficient frontier of risky securities (Elton & Gruber, 1999:346);
- Capital markets are always in equilibrium;
- Capital markets are perfect, thus no capital control, tax or transaction costs are present. Investors are therefore price takers;
- Assets can be sold short; and
- There is a market in each country for borrowing and lending at the same rate.

Solnick (1974:520) provides mutual fund theorems with regard to the development of the ICAPM, according to which all investors are indifferent to selecting a portfolio consisting of the original assets. The study by Solnick (1974:520) continued by stating that the mutual fund theorems assume that investors are also indifferent in selecting one of the following: a risk-free asset of the investor's own country; a portfolio of bonds, which can be used to speculate in the exchange rate dimensions; or a portfolio of stocks, which can be used to hedge against exchange risk.

Grauer *et al.* (1976:237) developed an ICAPM based on an unrestricted and costless international exchange of goods and assets. They constructed an ICAPM that holds the following assumptions (Grauer *et al.*, 1976:254):

- There is a linear relationship between the world market portfolio of assets and the real rate of returns on assets;
- There is a costless and unrestricted exchange of assets and goods; and
- There are multiplicative, multi-commodity utility functions present.

Grauer *et al.* (1976:255) concluded that under uncertainty a country's demand for riskless capital and for risk depends on risk preferences of both foreign and domestic residents, the world real rate of interest, and it depends on "the market value of its holdings on securities relative to the market value of all securities".

Black (1989:16) was the first to introduce universal hedging to the ICAPM. According to Black (1989:16), in a situation in which hedging against changes in the real exchange rates is possible and in which no international investment barriers exist a universal constant can be formulated. This universal constant provides the optimal hedge ratio, which illustrates the fraction of an investor's foreign investment that should be hedged. Furthermore, Black (1989:16) found that investors around the world should hedge the same significant fraction of their foreign currency risk, depending on the degree of risk aversion of the investor. In other words, this universal hedging approach depends on three factors: the average exchange rate volatility, the expected return on the world market portfolio, and the volatility of the world market portfolio (Black, 1989:16). However, this approach also has three rules that must be applied in order for it to be successful: equities must be hedged equally for all countries, the hedging of the investors' foreign equities, and investors may not hedge 100% of their foreign equities (Black, 1989:16).

Studies more recent than Solnick (1974), Grauer *et al.* (1976) and Black (1989) have focused empirically on currency and market risk. These studies include Harvey (1991:155), who rejected the market risk ICAPM, and O'Brien and Dolde (2000:15) and Carrieri (2001:261), who supported the currency risk ICAPM. Merton (1973:868) states that the intertemporal setting should be considered, but it only forms part of the foundation for the standard CAPM (Section 4.4). The intertemporal setting implies that a current decision may affect the options or choices to maximize the portfolio in the future (Investopedia, 2009d). Owing to market factors and market risk, investors wish to hedge their exposure to variation in the set of investment opportunities. This implies that both currency hedging risk and market hedging risk should be priced in addition to the currency and market risks (Chang *et al.*, 2005:174). According to Chang *et al.* (2005:175), the exchange rate risk is of more importance than the intertemporal hedging risk.

In addition, De Santis and Gérard (1998:410) recommended an ICAPM that includes FX risk and market risk. An ICAPM with constant beta values was used by Lessard (1974:391), who found that both domestic and global factors have an influence on asset returns. De Santis and Gérard (1998:377) used a GARCH model and found that global market risk is time varying. By applying conditional international asset pricing models using multivariate GARCH methods, Antell and Vaihekoski (2007:2588) too found that domestic risk and global risk are time varying.

Additionally, Fama and French (1998:1997) argue that a multi-factor model that incorporates the international environment has the ability to explain the premium in international returns, while the standard CAPM (Section 4.4) is unable to do so. Although, the three-factor model (Section 4.5) is claimed to be the more dominant, the three-factor model has a shortfall in that it assumes that investors are not concerned whether PPP (Section 3.2) holds and that capital markets are integrated (Wu, 2008:175). In other words, the three-factor model ignores other risk factors that may have the ability to affect expected returns (Wu, 2008:175). In examining the ICAPM with and without exchange risk, compared to the international version of the three-factor

model (Section 4.5) that incorporated a size effect, Zhang (2006:302) found that the ICAPM that included exchange risk performed the best. Cochrane (2001:183) found that the largest difference between the ICAPM and the APT model (Section 4.5) is in the manner in which factors are chosen. According to the APT, factors are chosen initially through a statistical analysis of the covariance matrix of returns and to identify portfolios that characterize common movements. According to the ICAPM, factors are chosen initially through assessing state variables that describe the conditional distribution of future asset returns (Cochrane, 2001:183).

The ICAPM that includes one exchange rate risk (a foreign currency) is illustrated as follows (Wu, 2008:177):

$$R - F = \alpha + \beta_1(M - F) + \beta_2(X - F) + \varepsilon_t \quad (4.12)$$

where:

- R represents the expected returns of a domestic stock or portfolio;
- F represents the risk-free asset return;
- M represents the global market return;
- X represents the FX rate;
- α is the intercept;
- β_1 and β_2 represent the coefficients; and
- ε_t represents the error term at time t .

If an investor has a foreign investment for two periods, which is expressed in two different currencies, the returns $(1 + i_2)$ must be converted back to the domestic currency after two periods. The domestic returns on this foreign investment can be calculated by $\frac{S_1(1+i_2)}{S_2}$, where S_1 is the FX rate at the end of period two and S_2 is the domestic exchange rate at the end of period two. In order to obtain a continuous net return, the returns must also be converted into natural

logarithm format (Wu, 2008:177). If the $\ln\left(\frac{S_1}{S_2}\right)$ is positive, the investor will gain more than the foreign risk-free returns, but if it is negative, the investor will gain less than the foreign risk-free returns (Wu, 2008:177). However, with a relatively constant risk-free rate the return on the investment will largely reflect the exchange rate risk present (Wu, 2008:177).

In summary, it was found that the standard CAPM is not a suitable model to use for a multinational portfolio. Furthermore, the beta used in the standard CAPM is insufficient, as a beta value does not reflect all the factors that have the ability to affect the expected returns of an investment. This led to the development of models that incorporated an international environment, which included the APT model and the ICAPM. It was found that the ICAPM, which includes exchange risk, outperforms the APT model, which renders the ICAPM the more suitable model to use for multinational portfolios. The ICAPM will, therefore, be considered as a possible proxy for representing the interaction between two international financial markets in an exchange rate model (Section 5.4.3). Although the beta value of a multinational portfolio, which consists of dual-listed stocks, may include an enhanced risk measure, the ICAPM is unable to explain the impact of both domestic and foreign market fluctuations (volatility spillover effect). Each investor has the knowledge that the NYSE has a significant impact on the JSE, thus the aim is to be able to distinguish between domestic volatility fluctuations and foreign volatility fluctuations because the ability to determine the volatility fluctuations in the JSE caused by the NYSE may provide more insight regarding market expectations.

Understanding the source of volatility in a stock market may provide more insight on the pricing of domestic stocks, asset allocation decisions and global hedging strategies, and the evaluation of regulatory proposals, with the latter focusing on the restriction of international capital flows (Ng, 2000:207). Thus, the next step is to determine the manner in which past empirical studies have derived the volatility (spillover) from the daily stock closing prices. The following section will briefly describe the measuring of the interaction between international financial markets by

discussing the volatility spillover effect.

4.8 VOLATILITY SPILLOVER EFFECT

4.8.1 Introduction

The volatility of stock prices may have a significant impact on the real economy in terms of cost of capital and wealth effects (Caporale *et al.*, 2006:377). It was found that the returns and volatility between two stock markets may be related to, amongst others, the following factors: growing financial market integration, a close link between the investing and trading of countries, market contagion, and international asset pricing models (Lin *et al.*, 1994:508). In addition, there are two reasons for investigating the nature of stock market integration (Hüseyin, 2005:2): firstly, the market integration process can increase the correlation between world markets and emerging markets and can lead to a lower expected return (Bekaert & Harvey, 2003:4); secondly, effective diversification can be attained by forming an international portfolio with asset returns that have a low correlation (Hüseyin, 2005:2).

Evidence was found of a relationship between information flow (Section 2.3.2.1) and volatility (Ross, 1989:16). Additional findings suggested that the interdependence amongst different financial markets may have a fundamental influence on investors' perceptions about foreign financial news. This may cause an increase in the volatility across markets and the correlation between stock returns (Hamao *et al.*, 1991:483). Evidence also indicates that co-movement between markets has increased in recent years (Booth *et al.*, 1997:811–812). Bonds may sometimes be used by portfolio managers as a risk reduction instrument when the stock market's volatility is expected to increase. Thus, if the volatility changes between the bond and stock markets are highly correlated, bonds may provide the risk reduction required for enhancing a portfolio (Fleming *et al.*, 1998:112). According to Caporale *et al.* (2006:376), the financial sector and macroeconomic links can help to explain the contagion between two countries, which can be useful in examining the effects of the financial crises of 2008/2009. However, the cause of this contagion is difficult to identify, which is confirmed

by Alba *et al.* (1998:53), who found that there may be similarities between the fundamentals of financial crises and of volatility spillovers, but no definitive evidence have yet been found.

Engle *et al.* (1990:526) calls the volatility spillover effect amongst international financial markets “meteor showers”, which may be an indication of a failure in market efficiency. They give the following two reasons for the presence of meteor showers: stochastic policy coordination amongst industrial countries, where a policy change announcement in one country causes volatility in another (Ito *et al.*, 1992:222); and the dissemination of private information by rational agents (Ito *et al.*, 1992:222). Understanding the spillover in international mean returns and volatility may be important for the following three reasons (Abhyankar, 1995:76): firstly, to help identify the factors causing the transfer of national financial disturbances to other financial markets; secondly, to help understand the notion of investors having the ability to trade on other exchanges located in different time zones, using electronic exchange systems; and thirdly, to help understand the dynamics of international price movements when trading with stocks across national exchanges (Abhyankar, 1995:76). Further evidence also indicates that the relationship between two stock markets may be due to differences in industrial structures, different construction of indexes, and different exchange rate policies and behaviours (Roll, 1992:4).

Many earlier studies on volatility have considered only first-order dependence in a linear regression⁵⁷, in other words, only first moment linkages were investigated (Caporale *et al.*, 2006:377). There is a need to expand this to the empirical investigation of second moment linkages. According to Cheung and Ng (1996:34) “the concept of causation in the second moment” is an extension of the Wiener-Granger causality in mean, for expanding empirical studies to second moment linkages. Various models are used for testing the presence of a volatility spillover effect between two countries. These are discussed in the following section.

⁵⁷ See for example Hilliard (1979) and Koch and Koch (1991).

4.8.2 Different models used in past empirical studies

There has been great variation in the models used to test for relationships between financial markets. Sander and Kleimeier (2003:175, 177) used the Granger causality test and co-integration analysis to study contagion in four historical Asian crises, and found new and changed causality patterns on a regional base. Susmel and Engle (1994:4) found that the reason earlier studies indicated that a spillover effect was present was due to the use of non-robust estimators, which was also associated with error terms that were too small.

ARCH models have generally been used to model financial time series data (Bollerslev *et al.*, 1992:6). However, it has been found that “GARCH models provide a marginally better fit and a more plausible learning mechanism than the ARCH model” (Bollerslev, 1986:308). According to Caporale *et al.* (2006:377), the GARCH model, in its various forms, dominates all the other estimation techniques in analysing the relationships between different financial markets. Also, the GARCH model is extremely useful when a more flexible lag structure is needed in the model (Bollerslev *et al.*, 1992:9). Furthermore, Karolyi (1995:17) states that the spillover effect is also better explained by the GARCH model than by the Vector Autoregressive (VAR) model because the VAR model appears to overestimate the dependence between markets.

Liu and Pan (1997:50) used a two-stage GARCH approach to estimate the international transmission of stock volatility and return amongst the U.S.A., Japan and four Asian stock markets. Their results indicated that the Japanese market had more influence on the Asian market than the U.S.A. market did. Liu and Pan (1997:60) found that there was instability in the international volatility transmission and in the international mean return. Hamao *et al.* (1990:306) used an ARCH model to explore the spillover effect in volatility and price changes amongst the Japanese, U.K., and U.S.A. stock markets. Their results indicated that there was a spillover effect from the U.K. and U.S.A. markets to the Japanese market (Hamao *et al.*, 1990:306). Using a signal extraction model with GARCH processes Lin *et al.* (1994:536) found a relationship between the Tokyo and New York stock markets.

However, GARCH models do have some flaws, which include the following (Nelson, 1991:347):

- They impose parameter restrictions that may restrict the dynamics of the conditional variance process, and are often violated by estimated coefficients;
- Evidence of a negative correlation between future returns and current returns volatility has been found, which is in contrast with the GARCH assumptions; and
- The persistence of shocks to the conditional variance is difficult to interpret in GARCH models.

In an attempt to enhance the capture of the asymmetric impact of shocks on volatility Nelson (1991:350–353) developed the Exponential GARCH (EGARCH) model⁵⁸. A rival model called the Quadratic GARCH model⁵⁹ that allowed volatility to respond asymmetrically to innovations was proposed by Engle (1990:103–105). However, it was found that a Quadratic GARCH model does not capture the asymmetric effect or leverage (Engle & Ng, 1993:1752), which makes the EGARCH model a more superior model (Alaganar & Bhar, 2002:60). The Quadratic GARCH model tended to under-predict the volatility that was associated with negative innovations and over-predict with positive innovations (Engle & Ng, 1993:1757). In comparing the standard GARCH model and the EGARCH model, Engle and Ng (1993:1753) mentioned the following in favour of the EGARCH model: firstly, EGARCH allows imminent news to have a larger impact on volatility; and secondly, EGARCH allows bad news and good news to have different effects on volatility (Engle & Ng, 1993:1753). Also, the EGARCH model does not require parameter restrictions to ensure positive variances at all times (Koutmos & Booth, 1995:749). The study of Hamao *et al.*, (1990:292–305) emphasised this notion, because their results indicated that there are coefficients in the conditional variance specification that violated the non-negative assumption, which is in contrast with the assumptions of the standard GARCH model.

⁵⁸ The EGARCH model has the ability to model the negative correlation between stock returns and the changes in return volatility (Haug & Czado, 2007:961).

⁵⁹ The Quadratic GARCH model focuses on the asymmetric parametrization of the conditional variance (Brännäs & De Gooijer, 2004:155).

Karolyi (1995:12) found a relationship between the Canadian and the U.S.A. stock markets. These results were obtained with the use of a bivariate EGARCH model⁶⁰. Booth *et al.* (1997:817) also used the EGARCH model to estimate the volatility spillover effect between Scandinavian stock markets. They found that the Danish, Swedish, Finnish and Norwegian markets are weakly related to each other (Booth *et al.*, 1997:821). By using multivariate GARCH techniques, Colavecchio and Funke (2008:647) found evidence of volatility spillover effects amongst seven Asian countries and China. Using a univariate GARCH estimator, Hamao *et al.* (1991:491–492) found pre-crash, daily volatility spillovers between London and Tokyo and between New York and London. Also applying a bivariate GARCH model, Alaganar and Bhar (2002:69) were able to demonstrate that asymmetric information flow (Section 2.3.2.1) has a substantial influence on the world stock markets. Xu and Fung (2002:567, 586) used a bivariate Autoregressive Moving Average (ARMA)-GARCH model⁶¹ and found that the domestic market played a more important role in pricing processes, whereas foreign markets played a greater role in the volatility spillover effect. Theodossiou *et al.* (1997:220) employed a Multivariate Generalized Autoregressive Heteroskedasticity (MGARCH)⁶² and established that there is a volatility spillover effect amongst the Japanese, U.K. and U.S.A. stock markets.

Each of these models is based on the basic GARCH model. The greatest weakness of the GARCH models is that it generates only one estimate for the whole period under investigation, thus making it impossible to generate a daily/weekly/monthly volatility spillover series that can be used to distinguish between volatility fluctuations caused domestically and volatility fluctuations caused by foreign markets. This means that other alternatives must be identified that may be able to capture the interaction amongst international financial markets more effectively (Section 5.4). This study focused on the co-integration relationships between dual-

⁶⁰ This model is an extension of the EGARCH model and allows the estimation of both a dynamic and static forecast of the conditional variance, the mean, and the forecast standard error (Qayyum & Kemal, 2006:7). See also Cho and Engle (1999) for further reference.

⁶¹ This model allows the examining of the information flow in terms of the first and second moments, which characterises the linkages between markets (Xu & Fung, 2002:566).

⁶² This model is a multivariate extension of the ARCH and GARCH frameworks, which has the ability to capture the interdependent effect across different markets (Yip & So, 2009:327).

listed stocks and generated a speed of adjustment series using a VEC model, as one of the proxies that will be used to incorporate the interactions between two international financial markets (JSE and the NYSE). This will be discussed in the following chapter.

4.9 CHAPTER SUMMARY

The first research objective of this study is to develop an exchange rate model, using current (time t) time series of economic fundamentals. This chapter has introduced the final explanatory variable required for this study's exchange rate model, which is the interaction between two international financial markets. Using the price differences of dual-listed stocks to determine the interaction between financial markets (volatility spillover) may enhance the ability of explaining the realized future spot exchange rate. The following chapter will discuss the methodology that will be applied to formulate an exchange rate model.

In order to understand the interaction between two international financial markets, knowledge of investor behaviour and decision-making processes is required. The supply and demand forces that are the source of the interaction between financial markets depend on investor behaviour and decision-making processes. Thus, the foundation on which investor behaviour and decision-making processes are built were investigated, which entailed a discussion on basic investment theory (Section 4.3).

This chapter started by discussing the rise of dual-listed stocks as an asset class and the reason for companies dual-listing (Section 4.2). The basic investment theory discussion covered risk (Section 4.3.2) and returns (Section 4.3.3). This was followed by a discussion of the CAPM (Section 4.4), in which it was stated the CAPM forms the basis for calculating the risk and return relationship. A disadvantage of the CAPM is that the beta value actually explains very little of the variation in expected returns. This meant that a more complex model was needed to incorporate the multiple aspects of risk and to improve the explanation of average-return anomalies, which led to the development of multi-factor models (Section 4.5).

However, the APT model, a multi-factor model, does not offer formal guidance that specifies the appropriate group of economic factors that should be included. A second drawback is that neither the APT nor the standard CAPM includes exchange risk. This led to the development of the ICAPM (Section 4.7), and multi-factor models that had an international environment framework. Past studies have found that the ICAPM provides the best results when used for multinational portfolios and will thus be considered as a possible variable to include in this study's exchange rate model (Section 5.4.3). The ICAPM will, therefore, serve as a proxy for the relationship between the financial market and exchange rate fluctuations.

This study will establish an appropriate explanatory variable that has the ability to capture the interaction of financial markets (volatility spillovers) that can be incorporated into an exchange rate model. A model's ability to distinguish between volatility spillovers (Section 4.8) caused domestically and volatility spillovers caused by foreign factors may enhance its ability to incorporate market expectations. Thus focusing only on the volatility spillovers caused by foreign factors may provide the required explanatory variable that best represents the interaction between the JSE and the NYSE (market expectations). However, generating daily/weekly/monthly volatility spillover series is extremely difficult, as GARCH models are built to generate only one estimate for the entire period under investigation. Thus, an alternative method had to be devised to overcome this shortcoming of GARCH models. The next chapter will discuss this method, which entailed the compilation of a speed of adjustment series using a VEC model (Section 5.4.4) and an ICAPM series (Section 4.7 & 5.4.3), which will illustrate the interaction between the JSE and the NYSE. The following chapter will only discuss the empirical methods that will be applied in this study, whereas the results will be reported in Chapter 6.

CHAPTER 5

Methodology

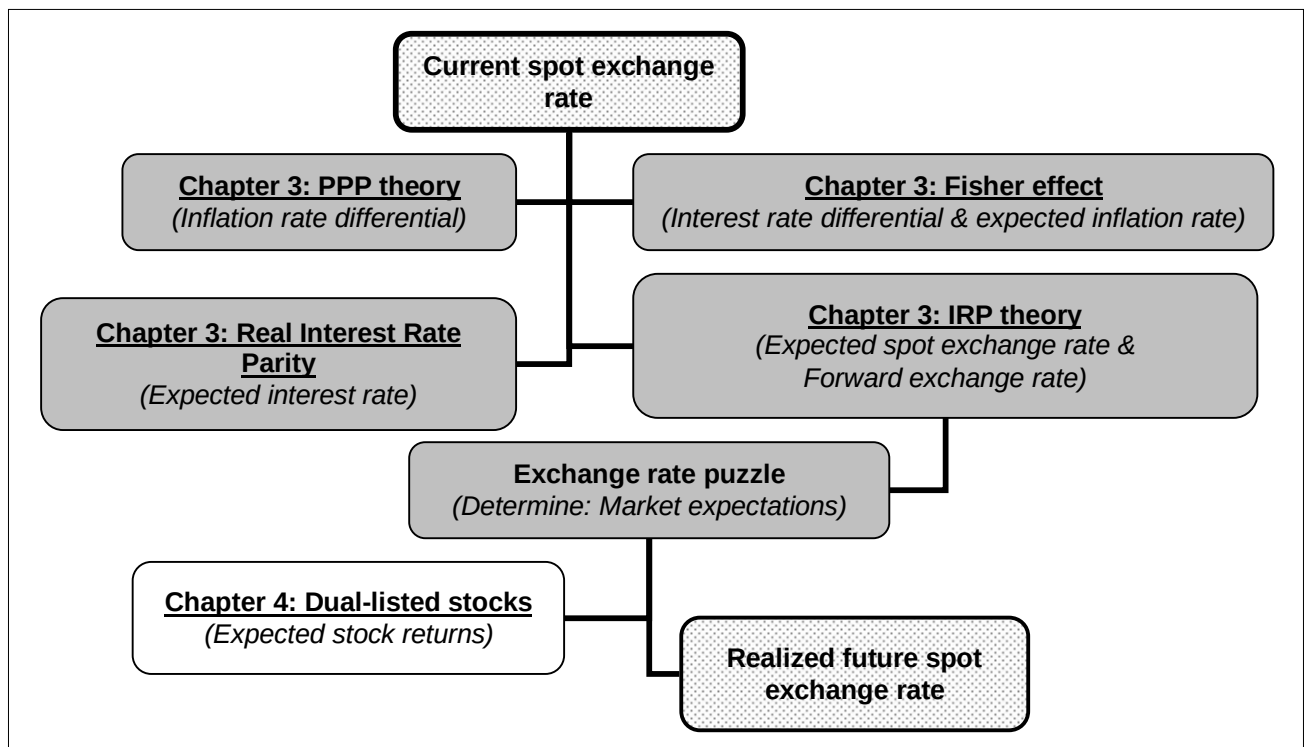
5.1 INTRODUCTION

Investors receive daily quoted forward points in the FX market as an indicator to help estimate the future exchange rate (forward exchange rate). This forward exchange rate is then used in foreign market transactions and decision-making processes of traders. However, the forward exchange rate, which is presently estimated using forward points, and the realized future spot exchange rate differ substantially. Recent research by Diamandis *et al.* (2008:358) and Albuquerque (2008:461) state that the forward exchange rate is a biased estimate of the realized future spot exchange rate. Section 1.2 also indicated that the forward exchange rate is not based on economic fundamentals, as implied by past literature studies, thus making the use of the forward exchange rate to estimate the future exchange rate insufficient. **The first research objective of this study is, therefore, to formulate an exchange rate model that is able to more accurately estimate the realized future spot exchange rate**, and thereby aid both the investor and the policy-maker in their decision-making processes. **The second research objective is to determine if the exchange rate puzzle is a pseudo problem, which forms the main contribution of this study.**

In order to model the realized future spot exchange rate, this empirical study will consist of two main approaches. The first approach is the use of **stationary economic time series** to model the realized future spot exchange rate. This will be discussed in Sections 5.2 to 5.4. The second approach is the use of **non-stationary economic level data** to model the realized future spot exchange rate, which will be discussed in Section 5.5. This chapter will, however, only explain the methods used in the empirical study, whereas the results will be reported in Chapter 6.

Before these two approaches can be applied, the presence of long-memory/mean-reversion (Section 5.3.2.1), in the ZAR/USD exchange rate, must be determined. Only with the presence of mean-reversion can economic fundamentals be used to estimate the realized future spot exchange rate.⁶³ These basic economic fundamentals were identified in the literature review in Chapters 2 to 4. Three variables of special importance were identified in Chapter 3 as illustrated in Figure 5.1: inflation rates (the PPP theory from Section 3.2), interest rates (the IRP theory from Section 3.3), and the equity premium (Section 2.3.4.2.5). Chapter 4 discussed the implementation of the interaction of the international financial market (Section 4.8) as an explanatory variable of the future exchange rate, by using stock closing prices, also illustrated in Figure 5.1. The methodology of Chiang and Yang (2007) was selected as the preliminary model because this methodology is able to incorporate all the economic fundamentals (variables), as illustrated in Figure 5.1, into one exchange rate model.

Figure 5.1: Composition of the literature review



Source: Compiled by author.

⁶³ See also Section 2.3.3.1 for a discussion on the random walk phenomenon.

The first research objective of this study is to formulate an exchange rate model that is able to more accurately estimate the realized future spot exchange rate. This will be accomplished by using the variables identified in the literature review, with a focus on better incorporating the interaction of the international financial markets as an explanatory variable of the future spot exchange rate. The first approach introduces an alternative approach of generating expected inflation rates and expected stock returns, using an exponential weighting procedure and an EWMA model (Section 5.3.2.1.3), which is able to incorporate both historical and future expectations. In addition, in order to incorporate the impact of financial market dynamics on the exchange rate, the following will be done:

- Expected stock returns (indices) will be generated from stock closing prices (Section 5.4.2);
- The indices will be substituted with expected stock returns generated from individual dual-listed stocks. Dual-listed stocks may have the ability to incorporate market expectations, and thus the interaction of international financial markets, more explicitly. The price differences of the dual-listed stocks may provide information regarding the investor's perception of the exchange rate (market expectations). The time lag between the two exchange markets may also provide the ability to predict the future exchange rate (Section 5.4.2);
- The stock return variable will be substituted with an ICAPM series that will be generated using dual-listed stocks. The purpose of using the ICAPM is to incorporate the presence of exchange rate risk of an international portfolio (Sections 4.7 and 5.4.3); and
- The stock return variable will be substituted with a speed of adjustment series that will be generated with a Vector Error Correction (VEC) model (Section 5.4.4). Using the speed of adjustment series as a proxy for the interaction between two international financial markets (JSE and the NYSE) may provide information regarding market expectations (the volatility spillover effect, as discussed in Section 4.8).

After the best exchange rate model has been determined the *ex post* prediction ability of the exchange rate model will be estimated to provide additional credibility for the exchange rate model.⁶⁴

This chapter will start with the first approach, which will commence by providing a brief overview of previous exchange rate models used in an attempt to solve the exchange rate puzzle (Section 5.2.2). This will be followed by testing the credibility of the forward points (Section 5.2.3), the inflation rate, the interest rates (Section 5.2.4), and the interaction of the financial market (Section 5.2.5) as explanatory variables of the future spot exchange rate. These explanatory variables will be incorporated into a multi-variable model, which will be discussed in Section 5.2.6. In addition to using this multi-variable model, this study sought to improve the incorporation of the financial market by substituting the expected stock return variable with a series generated from an ICAPM (Section 5.4.3) and a speed of adjustment series that will be generated from a VEC model (Section 5.4.4). A discussion on the measuring of the *ex post* forecasting ability of the best approach will then follow in Section 5.6, which will determine the viability of this study's exchange rate model. The second approach of using non-stationary, level time series data will be discussed in Section 5.5, as well as the data used in the empirical study. Take in consideration that this chapter will only provide the empirical methods that will be applied in this study, whereas the reporting of the empirical results will follow in Chapter 6.

5.2 THE FIRST APPROACH: USING STATIONARY ECONOMIC TIME SERIES DATA TO MODEL THE REALIZED FUTURE SPOT EXCHANGE RATE

5.2.1 Introduction

This section will commence by providing a brief literature review of past exchange rate models and variables used in an attempt to solve the exchange rate puzzle (Section 5.2.2).

⁶⁴ The forecasting of exchange rates fall outside the scope of this study, thus no forecasting will be done after the best exchange rate model is determined. The Theil coefficient will only serve as an additional measure to determine the more dominant EWMA model. However, it may be used as additional information regarding the possible *ex post* prediction ability of the exchange rate model, which can serve as inspiration for further future studies.

This literature review will explain the use of the Chiang and Yang (2007) methodology as a preliminary model.

5.2.2 Literature review

Previous economic models have failed to explain the exchange rate puzzle (Section 2.3, Bansal, 1997:370). The problem arises with the estimation of the future movement of the exchange rate (Fukao, 1987:80) because the forward exchange rate does not reflect all the information regarding the future spot exchange rate and the expectations of investors (Section 2.3.3.1. Lin *et al.*, 2002:169, 191). There are as yet no theories and thus no models that can accurately explain the behaviour of exchange rates, which is also emphasised by Sarno (2005:2).

However, according to Lafuente and Ruiz (2002:2) the presence of the exchange rate puzzle (Section 2.3) can be explained by the following.⁶⁵ firstly, owing to the presence of time-varying risk premia (Section 2.3.4.2.3); secondly, the nature of generating expectations (Section 5.3); and thirdly, the peso problem, where a future discrete policy shift, outside the sample period that is analysed, can be anticipated by means of the rational learning process of market participants. Baillie and Bollerslev (2000:486) suggest that the use of small sample sizes and the presence of autocorrelation may also lead to results that support the exchange rate puzzle. The presence of the exchange rate puzzle may also vary for each country. The exchange rate puzzle may, for example, be smaller for emerging currencies, such as South Africa, than for more advanced currencies (Frenkel & Poonawala, 2010:595).

In support of the previous statement, the testing of the Uncovered Interest Rate Parity hypothesis forms the cornerstone of the exchange rate puzzle (Bacchetta & Van Wincoop, 2005:i). The Uncovered Interest Rate Parity (Section 3.3.6) states that the expected change in

⁶⁵ See also Lewis (1995) for future references.

the nominal exchange rate and the nominal interest rate differential should be positively related and that the coefficient should be equal to one (Bansal, 1997:369). However, earlier studies by Bilson (1981:441) and Hodrick and Srivastava (1985:26) found a negative relationship between the expected change in the nominal exchange rate and the nominal interest rate differential. These results contributed to the development of the unbiased forward hypothesis (Section 2.3.4), which was also rejected by more recent studies that include Chernenko *et al.* (2004:i), Lin (1999:209), and Lin *et al.* (2002:191). Bansal and Dahlquist (2000:116) state that the Uncovered Interest Rate Parity (Section 3.3.6) holds better for emerging countries than for developed countries, while further evidence also indicates that the Uncovered Interest Rate Parity fails in non-G7 countries, such as South Africa (Chinn, 2005:ii,13). Thus, with the failure of the unbiased forward hypothesis (Section 2.3.4), various alternative models have been developed over the past 20 years.

Some of these alternative models include the term structure model (Section 5.2.4), used by Backus and Zin (1994), as well as Nielson and Saá-Requejo (1994), which captures interest rate risk that explains bond returns and movements of the nominal term structure. Bekaert (1996) and Backus *et al.* (1993) used consumption and money-based general equilibrium models in an attempt to explain the exchange rate puzzle. In addition to these models, Hai *et al.* (1997:732) implemented a Kalman filter⁶⁶ and found inconclusive evidence that the difference between the forward exchange rate and the realized spot exchange rate included a compensation for risk. In order to compensate for risk, Alvarez *et al.* (2005), Verdelhan (2005), and Hau and Rey (2007) all used the standard asset pricing framework (Section 4.4), which was based on systematic risk (Section 4.3.2). However, as stated in Section 4.6.1, the standard CAPM model has many flaws that led to the development of the ICAPM model (Section 4.7). Lustig (2008:29) states that the ability to identify “the economic mechanism that drives the relationship between macroeconomic risk and asset prices” is key to “understanding the dynamics of currency markets”.

⁶⁶ See also Section 2.3.4.2.2.

The development of econometrics led to the use of more advanced models, including co-integration models (Section 5.4.4) and non-linear models. Studies that implemented non-linear models include Kuan and White (1994), who used an Artificial Neural Network (ANN) model, and Medeiros *et al.* (2001), who used a Neuro-Coefficient Smooth Transition Autoregression (NCSTAR) to determine the future spot exchange rate. Studies that used the co-integration model (Section 5.4.4) include Diamandis *et al.* (2008), Kumar and Mukherjee (2007), and Aggarwal *et al.* (2006) and sought to determine the relationship between the spot exchange rate and the forward exchange rate. It is also argued that a possible reason for the failure to explain the exchange rate puzzle may be attributed to expectations errors and to risk premia (Aggarwal *et al.*, 2006:12).

Regarding the generating of suitable expectations, a wide range of methods have been used, for example Chiang and Yang (2007:186) used the Autoregressive Integrated Moving Average (ARIMA) model. Another common method is to use the values at time $t + 1$ as proxies. This may, however, lead to error terms that are correlated with the explanatory variables (Chiang & Yang, 2007:186). In their study, Kumar and Mukherjee (2007:64) found that the difference between the forward exchange rate and the realized spot exchange rate (forecasting error⁶⁷) can be explained by information captured in the future spot exchange rate, which was unavailable to market participants when the forward exchange rate was estimated. For this reason, this study introduces an alternative method of generating an expected inflation rate and expected stock return values using an exponential weighting procedure and an EWMA model (Section 5.3.2.1.3). This alternative method is able to incorporate both historical expectations and future expectations into present expectations.

To summarise, there are no dominant exchange rate models that have the ability to estimate the future spot exchange rate accurately. In an attempt to combine previous models into a more

⁶⁷ See also Section 2.3.4.2.1.

comprehensive model, this study identified the methodology of Chiang and Yang (2007) as a starting point. Chiang and Yang (2007:185) formulated a unique model that incorporated some of the earlier approaches as stated above. This model consisted of a linear combination of the International Equity Parity (Section 4.1), the PPP (Section 3.2), the Uncovered Interest Rate Parity (Section 3.3.6), and the expected hypothesis of the domestic term structure of interest rates (Section 2.3.4.2.4). The Chiang and Yang (2007) methodology, therefore, forms the preliminary platform required for formulating a basic exchange rate model. This study will contribute to the estimation of the future spot exchange rate by introducing an alternative approach of generating inflation rate and stock return expectations (Section 5.3.2.1.3) and incorporate the international financial market using different strategies. This includes the use of the ICAPM (Section 5.4.3) to incorporate exchange rate risk and the VEC model, which is based on the Johansen (1991) co-integration model (Section 5.4.4). The VEC model is able to generate a speed of adjustment series, which has the ability to incorporate the volatility spillover effect, as discussed in Section 4.8.

This chapter will examine each explanatory variable individually (Section 5.2.3–5.2.5) before formulating the multi-variable model (Section 5.2.6). This provides information regarding which variables may improve the estimation of the realized future spot exchange rate with more accuracy. However, before these explanatory variables can be examined, the presence of long-memory (mean-reversion) in the ZAR/USD exchange rate must first be tested. Only the presence of long-memory will justify the use of economic fundamentals to explain future spot exchange rate movements, which will eliminate the random walk phenomenon (Section 2.3.3.1). The discussion on long-memory (mean-reversion) will continue in Section 5.3.2.1, which was also used in the process of generating inflation rate and stock return expectations (Section 5.3).

This leads to the following sections, which will determine the presence of the exchange rate puzzle (Section 5.2.3), by using the forward points as an explanatory variable of the future spot exchange rate. This will be followed by an examination of the inflation and interest rates

(Section 5.2.4), and the interaction of the international financial markets (Section 5.2.5) as explanatory variables of the future spot exchange rate.

5.2.3 Forward points as an explanatory variable

It was shown in the discussion above that the forward points form the foundation of the estimation of the future exchange rate. It was also highlighted that the inability of current models to estimate the future exchange rate more accurately led to the persistence of the exchange rate puzzle (Section 2.3). This part of the empirical study, therefore, investigates whether the ZAR/USD forward exchange rate generated from the forward points is a biased or unbiased estimate of the realized ZAR/USD spot exchange rate. The following equation was adjusted and used to test the ability of the forward points to explain the realized future spot exchange rate (Chiang & Yang, 2007:184):

$$s_{t+k} - f_t = v_0 + v_1(f_t - s_t) + \varepsilon_{t+k} \quad (2.3)$$

where:

- 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 intercept;
- v_1 is the exchange rate premium coefficient; and
- ε_{t+k} is the random error.

If the forward exchange rate is a biased estimate of the future spot exchange rate, additional explanatory factors must be identified to enhance the explanation of the exchange rate puzzle (see Section 6.2.3 for the results). Chiang and Yang (2007:184) state that the forward premium lacks a theoretical base and reveals no economic insight. In order to address this shortcoming, the literature review identified the explanatory variables that will be used in this study: inflation

rates (Section 3.2), interest rates (Section 3.3), and the equity premium (Section 2.3.4.2.5). The first two explanatory variables that will be discussed in the following section are the inflation rate and the interest rate.

5.2.4 The inflation rate and the interest rate as explanatory variables

By studying the PPP theory (Section 3.2), the inflation rate was identified as the first explanatory variable to be included in a basic exchange rate model. The IRP theory (Section 3.3) also identified interest rates to help enhance the estimation of forward exchange rates. This study, therefore, used the interest rate in real terms to determine whether the estimated forward points can be enhanced (see Section 6.2.4.3.1 for the results). As indicated in Equation 2.8, the expected inflation rate is subtracted from the risk-free interest rate to estimate a real risk-free interest rate differential, whereas the expected inflation rates were estimated using an exponential weighting procedure and an EWMA model (Section 5.3.2.1.3 & Section 6.2.4.2 for the results). The following equation was adjusted and estimated (Chiang & Yang, 2007:187):

$$s_{t+k} - f_t = v_0 + v_2[(r_t - \Delta p_{t+k}^e) - (r_t^* - \Delta p_{t+k}^{*e})] + \varepsilon_{t+k} \quad (2.8)$$

where:

- 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 intercept;
- v_2 is the real risk-free interest rate differential coefficient;
- ε_{t+k} is the random error;
- Δp_{t+k}^e and Δp_{t+k}^{*e} are the expected inflation rates of South Africa and the U.S.A., respectively; and

- r_t and r_t^* are the South African 91-day Treasury Bill (T-Bill) rates and the U.S.A. 91-day T-Bill rates, respectively.

Had the real risk-free interest rate differential not yielded statistically significant results, an alternative approach would have been to incorporate the expected inflation rates and the 91-month T-Bill rates individually into the model. Lagged interest rate variables might also have been a possible solution because changes in the interest rates are used as policy instruments to affect inflation rate changes.

However, the inclusion of short-run interest rates only may have limited the exchange rate model to short-run expectations. In order to expand the model, long-run interest rates were also necessary, and incorporated in the form of the expected hypothesis of the domestic term structure of interest rates (Section 2.3.4.2.4). Thus, by including both short-run interest rates and long-run interest rates the yield curve was incorporated into the model (see Section 6.2.4.3.1 for the results). The following adjusted equation illustrates the expected hypothesis of the domestic term structure of interest (Chiang & Yang, 2007:185):

$$s_{t+k} - f_t = v_0 + v_3[(r_t^L - r_t) - (r_t^{L*} - r_t^*)] + \varepsilon_{t+k} \quad (2.9)$$

where:

- 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 intercept;
- v_3 is the risk-free, long-short interest rate differential coefficient;
- r_t and r_t^* are the South African 91-day T-Bill rates and the U.S.A. 91-day T-Bill rates, respectively;

- r_t^L and r_t^{L*} are the long-run, ten-year government bond yields rates of South Africa and the U.S.A., respectively; and
- ε_{t+k} is the random error.

Had the long-short spread failed as an explanatory variable, the alternative would have been to incorporate short-run and long-run interest rates individually into the model. Lagged long-run interest rate variables may also have provided improved results. Owing to the relationship between the inflation rate and interest rates (Section 3.3.2.1), any changes caused by inflation will spill-over to short-run interest rates, and will eventually cause long-run interest rates to change, but at a lagged period.

This leads to the following section, which will discuss the third explanatory variable identified in the literature review (Section 4.8), namely, the interaction of the international financial markets.

5.2.5. The interaction of the international financial markets as an explanatory variable

This section is based on the results of Chiang (1991:360), Morley and Pentecost (1998:317), and Korajczyk and Viallet (1992:215), who found a relationship between the exchange rate risk premium and the expected equity premiums. This study implements different approaches (Section 5.4) to incorporate the interaction between two international financial markets (JSE and the NYSE). The first and second approaches are the generating of annualized expected stock returns from stock indices and from individual dual-listed stocks, respectively (see Section 6.5.4.2 for results). A risk-free interest rate is subtracted from these expected annualized stock returns R_{t+k}^e in order to estimate the risk-free stock return differential (Chiang & Yang, 2007:188), as illustrated between brackets in the adjusted Equation 2.10 (see Section 6.2.4.3.2 for results). The expected annualized stock return was generated from the stock indices and individual dual-listed stocks (Section 5.3), respectively.

$$s_{t+k} - f_t = v_0 + v_4[(R_{t+k}^e - r_t) - (R_{t+k}^{*e} - r_t^*)] + \varepsilon_{t+k} \quad (2.10)$$

where:

- 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 intercept;
- v_4 is the risk-free, annualised return differential coefficient;
- r_t and r_t^* are the South African 91-day T-Bill rates and the U.S.A. 91-day T-Bill rates, respectively;
- R_{t+k}^e and R_{t+k}^{*e} are the expected dual-listed stock returns of South Africa and the U.S.A., respectively; and

These expected stock returns are generated with the use of an exponential weighting procedure and an EWMA model (Section 5.3.2.1.3). However, this study also made use of additional approaches to generate proxies for the interaction of the international financial markets. The third and fourth approaches are substituting the $[(R_{t+k}^e - r_t) - (R_{t+k}^{*e} - r_t^*)]$ bracket with a series generated from the ICAPM (Section 5.4.3) and from a VEC model (Section 5.4.4), respectively.

The JSE Resource Index (RESI 20) and the NYSE Energy Index were used. The RESI 20 represents the JSE's top 20 resource companies ranked by their full market value (see Section 6.2.2.3 for results). The reason for selecting resource indices is that the majority of the dual-listed stocks,⁶⁸ excluding Telkom SA Limited, are resources stocks. Moreover, as Telkom SA Limited was first listed on 4 March 2003, its data range is too limited to generate a suitable

⁶⁸ Section 4.2.3 indicated that these resource dual-listed stocks include AngloGold Ashanti Limited, Gold Fields Limited, Harmony Gold Mining Company Limited, Sappi Limited, and Sasol Limited.

expected stock return series.⁶⁹ For this reason, Telkom SA Limited was excluded from this empirical study. As the NYSE stock exchange does not have a resource index, the NYSE Energy Index was considered the best alternative to the RESI 20.⁷⁰

In addition to these different approaches, the expected stock returns of both the indices and the dual-listed stocks had to be converted into an effective annualized rate. This is because the risk-free rates r_t and r_t^* , are already annualized and must be subtracted from the expected stock returns. In order to annualize the weekly stock returns the following equation was derived from Faure *et al.* (1991:85) and modified for weekly stock returns:

$$return = \frac{365}{(t_2 - t_1)} \ln \left(\frac{S_{t_2}}{S_{t_1}} \right) \quad (5.1)$$

where:

- t_1 and t_2 each represent the number of the estimate under investigation, thus $t_2 - t_1 = 1$; and
- S_{t_1} and S_{t_2} represent the price of the dual-listed stock at time t_1 and t_2 .

After each of the individual explanatory variables has been examined, the model that incorporates all the variables will be discussed. These variables include the forward points, inflation rate, interest rates (short-run and long-run), and the proxies for the interaction of the international financial markets. This leads to the following section, which will discuss the multi-variable model.

5.2.6 The multi-variable model

By using the Chiang and Yang (2007) methodology as a preliminary model, the formulation of a linear combination of the International Equity Parity (Section 4.1), the PPP (Section 3.2),

⁶⁹ Section 5.7 will discuss that a data series spanning from May 2002 to February 2009 was needed to generate a suitable expected stock return series.

⁷⁰ For more on the use of indices to generate the expected stock returns see Chaing (1991), Morley and Pentecost (1998), and Chiang and Yang (2007).

the Uncovered Interest Rate Parity (Section 3.3.6), and the expected hypothesis of the domestic term structure of interest rates (Section 2.3.4.2.4), a proxy generated from the ICAPM model (Section 5.4.3), and a proxy generated from the VEC model (Section 5.4.4) was made possible (see Section 6.2.4.3.3 for results). The multi-variable model is illustrated in the following adjusted equation (Chiang & Yang, 2007:185):

$$s_{t+3} - f_t = \alpha + \rho[(r_t - \Delta p_{t+k}^e) - (r_t^* - \Delta p_{t+k}^{*e})] + \delta[(R_{t+k}^e - r_t) - (R_{t+k}^{*e} - r_t^*)] + \gamma[(r_t^L - r_t) - (r_t^{*L} - r_t^*)] + \varepsilon_t \quad (5.2)$$

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 intercept;
- 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 coefficient;
- Δp_{t+k}^e and Δp_{t+k}^{*e} 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_{t+k}^e and R_{t+k}^{*e} are the expected returns generated from stock indices or from individual resource dual-listed stocks of South Africa and the U.S.A., respectively;

- r_t^L and r_t^{*L} 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 $[(R_{t+k}^e - r_t) - (R_{t+k}^{*e} - r_t^*)]$ bracket was also replaced by the proxy generated from the ICAPM and VEC models (see Section 6.2.5.2.5 for results). Section 5.4.2 will discuss the approach of generating expected stock returns to use as a proxy for the interaction of the international financial markets. This will be followed by a discussion of the process of generating the ICAPM proxy (Section 5.4.3) and VEC proxy (Section 5.4.4) that substituted the expected stock return variable. This leads to the following section, which will introduce the alternative method of generating expected inflation rate expectations, which was also used to generate the expected stock return values.

5.3 GENERATING EXPECTATIONS

5.3.1 Introduction

This section will introduce an alternative method of generating expectations that can be used instead of Monte Carlo simulations, ARIMA models, or random walk models. This method entails an exponential weighting procedure and an EWMA model, **which were used to generate the inflation expectations and the stock return expectations**. This section will start by discussing the procedure of generating expected values, which will be followed by a discussion of the linear interpolation process, which was used to convert the monthly inflation rate series into a weekly series (Section 5.3.3).

5.3.2 The procedure of generating expected values

The following models were used to generate the expected values:

- An Autoregressive Fractionally Integrated Moving Average (ARFIMA) model;

- An exponential weighting procedure; and
- An EWMA model.

The first step in generating expected values is to apply an ARFIMA model to test for the presence of long-memory (mean-reversion).⁷¹ The South African PPI and the U.S.A. PPI series (for generating inflation expectations; see Section 6.2.2.2 for results), the RESI 20 and the NYSE Energy Index, and individual resource dual-listed stocks (for generating stock return expectations; see Section 6.2.2.3 for results) were tested for long-memory (mean-reversion). Only with the presence of long-memory can the use of historical data to generate expected values be justified. The OxMetrics™ 5 package⁷² (Doornik *et al.*, 2007) was used to estimate the ARFIMA model. The following sections will discuss the ARFIMA model in more detail (Section 5.3.2.1.1) and the manner in which to interpret the ARFIMA output generated in OxMetrics™ 5 (Section 5.3.2.1.2). After establishing the presence of long-memory, the next step was to generate the expected values by using an exponential weighting procedure and the EWMA model (Section 5.3.2.1.3 & see Section 6.2.4.2 for results). However, the inflation expectations was still in its original, monthly year-on-year format, while all the other daily data had been converted into a weekly format. The linear interpolation process that was used to convert the monthly year-on-year inflation expectations into a weekly format will be discussed in Section 5.3.3.

5.3.2.1 Testing for long-memory

The first step in testing for long-memory is to test the level of stationarity (Section 5.4.4.1). Time series data is considered to be stationary if its mean, variance, and autocovariance remain the same. This implies that the time series can be considered as being time invariant (Gujarati, 2003:798). Such time series data tends to return to its mean and fluctuates around it, implying

⁷¹ The ARFIMA model was also used to test for the presence of mean-reversion in the ZAR/USD exchange rate in order to justify the use of economic fundamentals to estimate the future spot exchange rate. The presence of long memory will also rule out the possibility of a random walk in the ZAR/USD exchange rate.

⁷² OxMetrics™ is a software package that provides an integrated solution for the econometric analysis of time series data, financial econometric modelling, forecasting, and for the statistical analysis of panel and cross-section data (OxMetrics™, 2011:1).

long-memory (mean-reversion). A discussion on the ARFIMA model will then follow in Section 5.3.2.1.1, which will be used to formally test for the presence of long-memory. The manner in which to interpret the results from the ARFIMA estimation will then be discussed in Section 5.3.2.1.2. The data must have long-memory in order to justify the use of historical values to generate future values because without the presence of long-memory the EWMA model (Section 5.3.2.1.3) cannot be implemented.

5.3.2.1.1 The Autoregressive Fractionally Integrated Moving Average model

The ARFIMA model has the ability to model the long-run behaviour of a time series in a flexible manner and can also be seen as an extension of the Autoregressive Moving Average (ARMA (p, q)) model (Doornik *et al.*, 2007:101). The ARFIMA model can be divided into three components, the autoregressive (AR) component, the moving average (MA) component, and the integrated component. Parameter p denotes the AR component, parameter q denotes the MA component, and parameter d denotes the integrated component, indicating the order of differencing required (Doornik *et al.*, 2007:101). The autoregressive component will indicate whether the current observation component, y_t , can be determined by a weighted sum of the p previous observations, plus the random error term ε_t . This is illustrated in the following equation (Torre *et al.*, 2007:89):

$$y_t = \sum_{i=1}^p \phi_i y_{t-i} + \varepsilon_t . \quad (5.3)$$

The influence of the i th previous value is given as ϕ_i in Equation 5.3, and the assumption is made that ϕ_i decays progressively over time (Torre *et al.*, 2007:89).

The moving average component states that the current observation depends on the random error that affects the q preceding observations, plus its own specific error term. The moving average component is illustrated as follows (Torre *et al.*, 2007:89):

$$y_t = \sum_{i=1}^q \theta_i \varepsilon_{t-i} + \varepsilon_t. \quad (5.4)$$

The integrated component determines whether the observed values are modelled directly or if the differences between successive observations are modelled instead. The d -parameter indicates the amount of differencing required (to make the series stationary) before the equation can be estimated (Torre *et al.*, 2007:89–90).

Thus, by combining these three components, the ARFIMA model can be designated by the three combined processes as (p, d, q) (Torre *et al.*, 2007:90). Accordingly, an ARFIMA (1,1,1) model is illustrated as follows (Torre *et al.*, 2007:90):

$$y_t - y_{t-1} = \phi_1(y_{t-1} - y_{t-2}) + \theta_1 \varepsilon_{t-1} + \varepsilon_t. \quad (5.5)$$

By estimating the d -parameter, the quantification of the intensity of the long-run correlation in the series can also be determined, where the d -parameter is also related to the spectral exponent β (Torre *et al.*, 2007:90). This is illustrated in the following equation (Torre *et al.*, 2007:90):

$$\beta = 2d. \quad (5.6)$$

Where the d -parameter is bounded between the interval of $[-0.5; 0.5]$. The ARFIMA model can, therefore, only account stationary signals with β between -1 and +1 (Torre *et al.*, 2007:90).

However, determining the best ARFIMA model is not without its challenges because the model that provides the best likelihood score, determined by the fitting procedure, and with the minimum number of free parameters is considered the best model. In other words, the best model is determined by the trade-off between parsimony and accuracy (Torre *et al.*, 2007:91). This can be achieved by means of the following two popular methods: the Akaike Information

Criterion (AIC) or the Bayes Information Criterion (BIC)⁷³. This study made use of the AIC to evaluate the goodness-of-fit of the different ARFIMA model specifications.

The AIC is able to provide a clear interpretation in model fitting (Mutua, 1994:237) and is considered a measure that can identify the optimal model from a number of competing models (Mutua, 1994:235). The main reason for using the AIC instead of the BIC is that the ARFIMA model generates only an AIC estimate as the main goodness-to-fit measurement. Therefore, a model with the lowest AIC estimate will indicate a higher goodness-of-fit (Bhansali & Kokoszka, 2001:130) and was thus considered the desired model for this study.

The AIC is illustrated in the following equation (Torre *et al.*, 2007:91):

$$AIC = -2\log L + 2k \quad (5.7)$$

where:

- L represents the maximum likelihood for the model; and
- k represents the number of free parameters in the model.

Note that OxMetrics™ 5 (Doornik *et al.*, 2007) provides three estimation methods to estimate the d -parameter⁷⁴: the Modified Profile Likelihood (MPL), the Exact Maximum Likelihood (EML) and the Non-linear Least Squares (NLS) methods. The MPL and EML methods impose the restriction of $-1 < d < 0.5$, while Doornik *et al.* (2007:102) also emphasise that the MPL method may be preferred over the EML method when using models that include regressor variables with a sample that is not very large. The NLS method also allows for $d > -0.5$ and is appropriate for estimating models for non-stationary processes, without a priori differencing⁷⁵ (Doornik *et al.*,

⁷³ The BIC information criterion, used for model selection, is based on the Bayesian approach for hypothesis testing that was developed by Jeffreys (1961).

⁷⁴ The d -parameter is also known as the fractional differencing parameter (Dark, 2007:2).

⁷⁵ Differencing is sometimes required to make a series stationary. See Section 5.4.4.1 for the method used to determine if differencing is required, in other words, determining the order of integration.

2007:102). Whereas, the EML method can be considered as a benchmark for other estimators (Doornik & Ooms, 2003:334). This study will, therefore, make use of the EML method to determine if long-memory is present. This leads to the following section, which will discuss the interpretation of the ARFIMA results.

5.3.2.1.2 The interpretation of the Autoregressive Fractionally Integrated Moving Average results

In comparing each ARFIMA model's specifications, there are three main estimates that must be compared, in order to decide on the best model. These three components include the following:

- The model with the lowest AIC estimate indicates the model with the best goodness-of-fit;
- The t-probability of the d -parameter, the AR component, and the MA component, must be below 0.05 for it to be statistically significant; and
- The coefficient of the d -parameter can be interpreted with the help of Table 5.1.

Table 5.1: Interpreting the d -parameter

$d = 0$	Implies that the time series is a white noise process*.
$-0.5 \leq d \leq 0$	Implies stationary with short memory.
$d = 1$	Defines a non-stationary series.
$0 \leq d < 1$	Will exhibit mean-reversion, but shock is not permanent and transitory.
$d < 1$	Implies mean-reverting.
$0 < d < 0.5$	Implies stationary and mean-reverting (long-memory).
$0.5 < d < 1$	Implies covariant and non-stationary (mean-reversion/long-memory).
$d \geq 1$	Implies non-stationary and non-mean-reverting.
$-0.5 \geq d \geq -1$	Implies non-stationary with short memory

* See Section 2.3.3.1 for an explanation of a white noise process.

Source: Styger *et al.* (2008:340) and Gallegati (2008:3071).

In this study, the d -parameter must indicate that the historical series has long-memory, in other words, it is mean-reverting, because this will justify the use of historical data to generate an expected series. After establishing the existence of mean-reversion, the next step is to generate

expected values by means of an exponential weighting procedure and the EWMA model (Section 5.3.2.1.3).

Note that if the d -parameter is negative, intermediate memory is present, in other words, the process is over-differenced (Doornik *et al.*, 2007:102). It also indicates the presence of short memory, thus supporting the weak-form Efficient Market Hypothesis (EMH), which was also discussed in Section 2.3.3.1. However, Gujarati (2003:798–799) states that if the time series is stationary, thus if $-0.5 \leq d \leq 0$, it does not support the weak-form EMH. After the presence of long-memory had been confirmed, historical values were used to generate expected values. In the following section, the use of the exponential weighting procedure and the EWMA model to generate expected values will be discussed.

5.3.2.1.3 The exponential weighting procedure and the Exponential Weighted Moving Average model

In the exponential weighting procedure, different weights b , will be assigned to different lags, with the largest weight being assigned to the most recent period and the smallest weight being assigned to the oldest period. This implies that the most recent value will have the largest impact on the expectations that will be generated. The weights will be calculated using the following equation (Styger & Van Heerden, 1986:31–32):

$$b = e^{-t\lambda} \quad (5.8)$$

where:

- $e^{-t\lambda}$ is the exponent to the power of lag (t) and λ . Different combinations of λ and t were used.

Next, the appropriate number of lagged values to be used to generate an efficient expected inflation rate and stock return series was determined. Stock and Watson (1998:15–16) used the

Consumer Price Index (CPI) and the GDP deflator as a leading indicator for the U.S.A. business cycle and found that this leading indicator led the business cycle by 2 quarters. Nelson (1998:306) found that the U.S.A. inflation rate took 13 quarters to respond fully to a 1% monetary innovation. Roberts (1997:173) used a survey that consisted of 12-month inflation expectations and used a 6-month CPI index. He found that the U.S.A. inflation is not sticky and that inflation expectations were not perfectly rational. In addition to these results, Moolman (2003:297) found that the South African CPI leads the South African business cycle by 5 to 6 months.

Based on these findings, the following exponential weighting procedure specifications and EWMA model specifications were evaluated and used to generate 1-month ahead historical expected inflation rate values. These specifications are: $\lambda=0.25$, $\lambda=0.5$ and $\lambda=0.75$; and $t=4$, $t=6$ and $t=12$. In other words, 4 weeks (1 month), 6 weeks (1½ months), and 12 weeks (3 months) were evaluated (see Section 6.2.4.2 for results).

Regarding the appropriate lag values for generating expected stock return values, Kallunki and Martikainen (1997:42) stated that in the Finnish stock market stock prices tend to predict year t 's earnings already in year $t - 1$. Moolman (2003:297) found that the Commercial Stock Price Index on the JSE leads the South African business cycle by 6 months. However, McQueen *et al.* (1996:891) found that the returns of large stock portfolios reacted to news in the same month, and that these returns can be used as a proxy for macroeconomic news, as stocks are traded frequently. Conrad and Kaul (1989:226) found that the time variation in weekly expected stock returns decayed rapidly on the NYSE and on the American Stock Exchange, where the effects of expected return shocks dissipated after a month. Therefore, the same model specifications ($\lambda=0.25$, $\lambda=0.5$ and $\lambda=0.75$; and $t=4$, $t=6$ and $t=12$) were evaluated (see Section 6.2.4.2 for results).

By using the EViews 6 program⁷⁶ (QMS, 2007a), each series generated from each specification was regressed on the actual series. The series with the best R-squared, lowest standard error estimate, lowest AIC estimate, and lowest Theil's equality coefficient (Section 5.6) was then considered the best possible series to use in this study. This series will be called the historical expected series $(t + 1)b$ because these expected values are only based on historical figures. However, to incorporate uncertainty (future expectations) in present expectations an EWMA model was formulated, making use of the same weighting procedure as the exponential weighting procedure discussed earlier.

The EWMA model forecasts a 3-month ahead series using the $(t + 1)b$ series. This 3-month ahead series, therefore, incorporated the future uncertainty factor into the final expected series. This series was then back-cast to generate a 1-month ahead future series, the $(t + 1)f$ series. However, the objective of this model was to generate a present 1-month ahead series of both historical and future expectations, the $(t + 1)$ series. In order to generate a $(t + 1)$ series, the historical expectations, the $(t + 1)b$ series, and the future expectations, the $(t + 1)f$ series, were combined. This was done by determining the best weight split combination, as indicated in Table 5.2.

In this manner, the best weights to assign to the historical series $(t + 1)b$ and to the future series $(t + 1)f$ in order to generate the best $(t + 1)$ series were determined. From each weight split, a $(t + 1)$ series was generated and then regressed on the actual inflation rate series. By using the EViews 6 program (QMS, 2007a), the $(t + 1)$ series providing the best R-squared, lowest standard error estimate, and lowest AIC estimate was considered the best series to use.

In order to verify the accuracy of the best $(t + 1)$ series, the Theil's equality coefficient (Section 5.6) was also used to determine the best model. The Theil's equality coefficient was also used

⁷⁶ EViews 6 provides sophisticated data regression, analysis, and forecasting tools that is able to accommodate financial analysis, scientific data analysis and evaluations, macroeconomic forecasting, sales forecasting, cost analysis, and simulations (QMS, 2007a).

to estimate the *ex post* forecasting ability of the best exchange rate model (see Section 6.2.4.2 for results).

Table 5.2: Weight split combinations tested

Weight split combination	
Model specifications	Weights assigned
	Historical = 90% Future = 10%
	Historical = 80% Future = 20%
[t=4 $\lambda=0.25$]	Historical = 70% Future = 30%
[t=4 $\lambda=0.5$]	
[t=4 $\lambda=0.75$]	Historical = 60% Future = 40%
[t=6 $\lambda=0.25$]	
[t=6 $\lambda=0.5$]	Historical = 50% Future = 50%
[t=6 $\lambda=0.75$]	
[t=12 $\lambda=0.25$]	Historical = 40% Future = 60%
[t=12 $\lambda=0.5$]	
[t=12 $\lambda=0.75$]	Historical = 30% Future = 70%
	Historical = 20% Future = 80%
	Historical = 10% Future = 90%

Source: Compiled by author.

In summary, the results of the ARFIMA model will be reported on in Chapter 6 in order to determine the presence of long-memory. Had long-memory been present, then historical values could be used to generate expected values. In addition to these results, the exponential weighting procedure and the EWMA model were used to generate an expected inflation rate and expected stock return values.

The year-on-year monthly inflation rates were used to generate the inflation expectations. The inflation expectations had to be converted into a weekly format because all the other data series were already in a weekly format. This was done by means of the linear interpolation process that will be discussed in the following section.

5.3.3 The linear interpolation process

Interpolation consists of a method that is used for the approximate calculation of values by using known values or using other values related to it. In other words, interpolation entails the ability to generate pieces of a function (Hultquist, 1988:133). This study uses algebraic interpolation that is also called linear interpolation, owing to its superior simplicity.

Suppose there are a set of n points, $\{x_k\}$, and a corresponding set of functional values, $\{f(x_k)\}$, for $k = 1, 2, \dots, n$, where $1 \leq k \leq n$. In order to estimate the function $f(x)$ it must be substituted with a set of straight-line segments that join $(x_k, f(x_k))$ and $(x_{k+1}, f(x_{k+1}))$ for all values of k . This process generates a set of linear functions, $L_k(x)$, which can be joint to form a continuous function over a desired domain. Each straight-line segment can be illustrated by the following equation (Hultquist, 1988:131–133):

$$y = \alpha f(x_{k+1}) + (1 - \alpha)f(x_k) \quad (5.9)$$

where:

- α denotes a local variable that ranges between 0 and 1, over the interval (x_k, x_{k+1}) ;
and
- α can be seen as a fractional distance between x_k and x_{k+1} or can be illustrated as $(x - x_k) \div (x_{k+1} - x_k)$.

The equation for linear interpolation, with two nodes x_k and x_{k+1} , can, therefore, be illustrated as follows (Hazewinkel & Scientific Board, 1990:143):

$$L_1(x) = \frac{x - x_k}{x_{k+1} - x_k} [f(x_{k+1}) - f(x_k)] + f(x_k) \quad (5.10)$$

where:

- $x_k \leq x \leq x_{k+1}$.

Thus, by using Equation 5.10 both the South African and the U.S.A. monthly year-on-year PPI inflation rates were converted into a weekly format. (The reason for using PPI instead of CPI will be discussed in Section 5.7). This concludes generating the expected inflation rate variables needed for Equations 2.8 and 5.2. The following section will discuss the generating of a proxy for the interaction of the financial markets (JSE and the NYSE), which is required for Equations 2.10 and 5.2.

5.4 GENERATING A PROXY FOR THE INTERACTION OF THE FINANCIAL MARKETS

5.4.1 Introduction

With the objective of identifying explanatory variables that have the ability to improve the accuracy of the estimation of the realized spot exchange rate, Section 2.3.4.2.5 indicated that there is a relationship between the equity premium (financial market) and the future spot exchange rate. Although, in an attempt to determine the best proxy to represent the interaction of the international financial market, this section will discuss the generating of expected stock return series from both stock indices and individual resource dual-listed stocks (Section 5.4.2); the substitution of expected stock returns with an ICAPM series that was generated with the use of dual-listed stocks (Section 5.4.3); and substituting expected stock returns with a speed of adjustment series that was generated with a VEC model (Section 5.4.4).

5.4.2 Generating the expected stock returns from stock indices and dual-listed stocks

The same procedure will be followed, as discussed in Section 5.3, to generate the expected stock return values from both stock indices and individual resource dual-listed stocks (see Section 6.2.2.3 & 6.2.4.2 for results). This procedure contributes to the first two approaches that will be followed to generate a proxy for the interaction between the two international financial markets. However, this study will, in addition, apply alternative approaches to generate proxies for the interaction of the international financial markets. This leads to the following sections that

will discuss the use of the ICAPM model (Section 5.4.3) and the VEC model, to generate a speed of adjustment series (Section 5.4.4).

5.4.3 Generating the International Capital Asset Pricing Model proxy

Section 4.7 stated that the presence of exchange rate risk should be incorporated into an asset pricing model, which led to the development of the ICAPM model (see Section 6.2.5.2.5 for results). This feature is especially important when managing an international portfolio, which consists of dual-listed stocks. The ICAPM proxy will serve as a possible replacement for the expected stock return proxy if it does not provide statistically significant results. The following equation was used to generate the ICAPM proxy (Wu, 2008:177):

$$R - F = \alpha + \beta_1(M - F) + \beta_2(X - F) + \varepsilon_t \quad (4.12)$$

where:

- R represents the expected returns of a domestic stock or portfolio;
- F represents the risk-free asset return;
- M represents the global market return;
- X represents the FX rate;
- α is the intercept;
- β_1 and β_2 represent the coefficients; and
- ε_t represents the error term at time t .

This study also applied an alternative strategy by implementing a co-integration approach. This leads to the following section, which will discuss the process of generating a speed of adjustment series with the use of a VEC model.

5.4.4 Generating the Vector Error Correction proxy

This approach attempted to provide an enhanced variable that has the ability to incorporate the interaction between two international financial markets (JSE and the NYSE) more explicitly. This approach, therefore, substituted the expected stock returns variable (generated using the EWMA model) with a speed of adjustment series, estimated with the use of a VEC model (see Section 6.2.5.2.5 for results). The speed of adjustment series illustrates the intermittent association (co-integration relationship) between the JSE and the NYSE. Therefore, this approach primarily focused on individual dual-listed stocks and not indices because the market expectations integrated in the price differences between individual dual-listed stocks may provide more significant information than that of stock indices. The price differences of dual-listed stocks also include a time difference (lag) component as a result of the different trading hours of the JSE and the NYSE. This lag period may enable an exchange rate model to incorporate expectations in estimating the future exchange rate.

The foundation of this approach is to determine the presence of a relationship (also called a co-integration relationship) between the two prices of a dual-listed stock. Granger (1981) was the first to suggest the concept of co-integration, while Engle and Granger (1987:251–252) elaborated on the dynamics of co-integration. In order to obtain significant results from a co-integration model, the level of stationarity must first be established. An Ordinary Least Squares (OLS) model depends on stationary variables in order to obtain significant results because a spurious estimation will be the result of regressing a non-stationary (unit root) time series on another non-stationary time series (Gujarati, 2003:822).⁷⁷

However, the linear combination of the two non-stationary time series may cancel out the stochastic trends, where the error term u_t , may be stationary, thus $I(0)$. Therefore, the two variables are co-integrated (Gujarati, 2003:822). Co-integration states that there exists a long-

⁷⁷ Individual time series may have a unit root, in other words, they may be integrated to the order of one $I(1)$, which indicates that the time series have stochastic trends (Gujarati, 2003:822).

run relationship between variables that will not drift too far apart over time (Engle & Granger, 1987:253). Also, an equation will only be meaningful if it is consistent, with the explanatory right-hand side of the equation “producing the major properties of the variables being explained” (Granger, 1981:121).

The first step of the VEC proxy approach is to test for the presence of a unit root (non-stationary) in the dual-listed stock closing price data (see Section 5.7 for results). If a unit root is present or the two prices are at the same order of integration, then a co-integration approach can be followed. However, remember that each variable must be integrated to the same order for the co-integration approach to be efficient (Granger, 1986:216). The Augmented Dicky-Fuller (ADF) unit root test was performed to determine the order of integration and will be discussed in the following section. The order of integration is also important as a preliminary indicator for long-memory, because if time series data is stationary it returns to its mean and continues to fluctuate around its (Gujarati, 2003:798), thus suggesting the possibility of long-memory/mean-reversion (Section 5.3.2.1). The following section will only discuss the method, whereas the results will be reported in Section 5.7.

5.4.4.1 The Augmented Dicky-Fuller unit root test

In basic unit root theory,⁷⁸ consider the following autoregressive to be an order of one, AR(1), process (QMS, 2007b:92):

$$y_t = \rho y_{t-1} + x_t' \delta + \varepsilon_t \quad (5.11)$$

where:

- x_t are optional exogenous regressors that can consist of a constant and a trend, or only a constant;
- ρ and δ are parameters to be estimated; and
- ε_t is assumed to be white noise.

⁷⁸ See also Section 5.5 that discusses the limitations of unit root models regarding spurious regressions.

Therefore, if $|\rho| \geq 1$, y is a non-stationary series and the variance of y increases with time and approaches infinity. However, if $|\rho| < 1$, then y will be a stationary series (trend series).

Thus, the basic unit root test can be evaluated according to the absolute value of ρ . The unit root test's null hypothesis is $H_0: \rho = 1$ versus $H_1: \rho < 1$ (QMS, 2007b: 92). Thus, if the absolute value of ρ is smaller than 0.05, the null hypothesis is rejected, which indicates that there is no unit root present. However, if the absolute value of ρ is greater than 0.05, the null hypothesis is not rejected, which indicates that there is a unit root present (QMS, 2007b:92).

In order to determine if ρ is statistically equal to 1, y_t can simply be regressed on its lagged value (one period back), y_{t-1} . Therefore, if ρ is equal to 1 then y_t will be non-stationary (Gujarati, 2003:814). Thus by subtracting y_{t-1} from both sides of Equation 5.11 the following equation can be estimated (QMS, 2007b:92):

$$\Delta y_t = \alpha y_{t-1} + x_t' \delta + \varepsilon_t \quad (5.12)$$

where:

- $\alpha = \rho - 1$.

The alternative and the null hypothesis can, therefore, be illustrated as follows (QMS, 2007b:92):

$$\begin{aligned} H_0: \alpha &= 0 \\ H_1: \alpha &< 0. \end{aligned} \quad (5.13)$$

If α is equal to zero, it will imply that $\rho = 1$, thus the time series will be non-stationary (Gujarati, 2003:814). The appropriate test to use to determine if the estimated coefficient in Equation 5.12,

y_{t-1} , is zero or not is to use the tau test⁷⁹, which is also known as the Dickey-Fuller test (Gujarati, 2003:814-815).

With the Dickey-Fuller test the assumption is made that ε_t is a white noise, however, if ε_t are correlated an Augmented Dickey-Fuller (ADF) test can be used (Gujarati, 2003:817). The ADF test can be formulated by means of a parametric correction for a higher-order correlation by assuming that the y series follows an $AR(\rho)$ process and by adding ρ lagged difference terms of the dependent variable y to the right-hand side of the test regression, which is illustrated in the following equation (QMS, 2007b:93):

$$\Delta y_t = \alpha y_{t-1} + x'_t \delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \dots + \beta_\rho \Delta y_{t-\rho} + v_t. \quad (5.14)$$

This ADF specification tests Equation 5.12 by using the t -ratio from Equation 5.15. Note that the asymptotic distribution of the t -ratio for α is independent of the number of lagged first differences that are included in the ADF regression.

$$t_\alpha = \frac{\hat{\alpha}}{se(\hat{\alpha})} \quad (5.15)$$

where:

- $\hat{\alpha}$ is the estimate of α ; and
- $se(\hat{\alpha})$ is the coefficient standard error.

The ADF unit root test was performed in the EViews 6 program (QMS, 2007a). **In this study each ADF unit root test will include an intercept in the equation.** Note that if two variables have a unit root, (or are at the same order of integration), one variable can be regressed on the other variable in order to perform a unit root test on the residuals. The two variables will only be co-integrated if the residuals contain no unit roots (Maddala & Kim, 2000:40). This leads to the

⁷⁹ See Dickey and Fuller (1979) for further references.

following section, which will discuss co-integration, which is the starting point for estimating a VEC proxy that can be used as an alternative proxy to incorporate the interaction of two international financial markets.

5.4.4.2 Co-integration

Two non-stationary time series can be stationary in a linear equation, which is also called a co-integration equation. This co-integration equation can be interpreted as a long-run equilibrium between the variables used in the equation (QMS, 2007b:363). The Vector Autoregression (VAR)-based co-integration tests were performed in EViews 6 (QMS, 2007a), based on the methodology of Johansen (1991). A VAR is used to analyze the dynamic impact of random disturbances on variables, where there is no need for structural modelling by treating endogenous variables as a function of the lagged values of all the endogenous variables (QMS, 2007b:345).

The first step in the co-integration process was to estimate a standard VAR model with a lag of 1-2 specification, as illustrated in the EViews 6 program (QMS, 2007a). The second step was to determine whether the correct dependent variable had been chosen. This was done by executing a Granger causality/Block exogeneity test. Also, the VAR model must be stable, which was determined by means of the AR root table and graph. The final step before executing the Johansen (1991) co-integration test was to determine a suitable lag structure. By using the lag length criteria in EViews 6 (QMS, 2007a), which determines the required number of lags, statistically significant results can be assured when estimating a co-integration test and a VEC model. However, only with the presence of a co-integration relationship can a VEC model be estimated.

When executing the Johansen (1991) co-integration test in EViews 6 (QMS, 2007a), the null hypothesis to be tested was that there is no co-integration present. By considering the process X_t as integrated to the order of one if it can be defined by an unrestricted VAR system of order

$(n \times 1)$, it is possible to express this process in a Vector Error Correction (VEC) model. The VEC model is a restricted VAR that is used with non-stationary series that are known to be co-integrated (QMS, 2007b:377). A VEC model of the process X_t is illustrated in the following equation (Johansen, 1988:232):

$$X_t = \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \dots + \Pi_k X_{t-k} + u_t \quad (5.16)$$

where:

- $X_t = (n \times 1)$ is the vector of $I(1)$ variables;
- $\Pi_i = (n \times n)$ $i = 1, 2, \dots, k$ is the matrix of unknown parameters to be estimated;
- u_t is the independent and identically distributed (i.i.d) $(n \times 1)$ vector of error terms; and
- $t = 1, 2, \dots, m$ observations.

According to Asteriou and Hall (2007:310), an Error Correction Model (ECM) has the advantage of including both a short-run and long-run effect in a model. It is illustrated as follows (Asteriou & Hall, 2007:312):

$$\Delta Y_t = \gamma_0 \Delta X_t - (1 - \alpha) \left[Y_{t-1} - \frac{\alpha_0}{1 - \alpha_1} - \frac{\gamma_0 + \gamma_1}{1 - \alpha_1} X_{t-1} \right] \quad (5.17)$$

where:

- γ_0 denotes the short-run effect (impact multiplier) of Y_t after a change in X_t ;
- $\frac{\gamma_0 + \gamma_1}{1 - \alpha_1}$ denotes the long-run elasticity between X and Y ;
- it is assumed that $\alpha_1 < 1$ in order for the short-run model to convert to a long-run solution; and
- $(1 - \alpha_1)$ or π is the speed of adjustment needed (feedback effect or adjustment effect) in the case of a disequilibrium.

By incorporating $\Delta = (1 - L)$, where L is the lags operator, Equation 5.16 can be parameterised in the following error correction form (Johansen & Juselius, 1990:170):

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-k} + u_t \quad (5.18)$$

where:

- $\Gamma_i = \sum_{j=1}^{k-1} \Pi_j - I \quad i = 1, 2, \dots, k-1$;
- $\Pi = \sum_{j=1}^k \Pi_j - I$;
- ΔX_t is an $I(0)$ vector; and
- I is a $(n \times n)$ identity matrix.

Johansen (1988:233–237) incorporated independent errors to derive the maximum likelihood estimators of the co-integration vectors for the autoregressive process. According to Johansen and Juselius (1990:169), the $(n \times n)$ matrix Π can also be illustrated as the product of the two matrices β and α , each of the rank r , in order for $\Pi = \alpha\beta'$. If the matrix Π has reduced rank $r < k$, then there exist $k \times r$ matrices α and β , each with a rank r . The α is also known as the adjustment parameter in the VEC model (QMS, 2007b:364), or it can be considered the matrix of the weighting elements (Johansen & Juselius, 1990:169). The number of co-integration relations can be symbolized by r and each column of β is the co-integration vector (Johansen & Juselius, 1990:169). Equation 5.18 can, therefore, be rewritten as follows (Johansen & Juselius, 1990:170–171):

$$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + (\alpha\beta')X_{t-k} + u_t. \quad (5.19)$$

The hypothesis of r co-integration relationships between the elements of X_t can now be tested (Johansen & Juselius, 1990:170):

$$H_0: \Pi = \alpha\beta'. \quad (5.20)$$

The null hypothesis of no co-integration relationships is thus where $r = 0$ that implies $\Pi = 0$. By executing the Johansen (1991) co-integration test in EViews 6 (QMS, 2007a), the Π matrix from an unrestricted VAR was estimated and used to determine whether the restrictions, implied by the reduced rank of Π , could be rejected or not (QMS, 2007b:364). In other words, by examining whether the Eigenvalues of Π are significantly different to zero, the rank r of the Π matrix (or the number of co-integrating vectors) can be determined. According to Johansen and Juselius (1990:181), the Trace (Tr) statistic and the maximum Eigenvalue (L-max) statistic can be used to evaluate the rank of the Π matrix. The Tr likelihood ratio statistic is illustrated as follows (Johansen, 1991:1555):

$$-2\ln Q = -T \sum_{i=r+1}^{p=2} (1 - \hat{\lambda}_i) \quad (5.21)$$

where:

- $\hat{\lambda}_{r+1}, \dots, \hat{\lambda}_p$ are the estimated $p - r$ smallest Eigenvalues.

The null hypothesis states that there are at most r co-integrating vectors. Thus, the rejection of the first null hypothesis $r \leq s - 1$ will imply that $r \geq 1$, while the next null hypothesis will be $r \leq s$ and will then be reduced to $r = s$. This process will continue until the null hypothesis is not rejected (Burke & Hunter, 2005:102–103).

In the L-max statistic, the null hypothesis of r co-integrating vectors $r = 0$, is tested against the alternative $r + 1$ co-integrating vector $r = 1$. The original $r + 1$ co-integrating vector ($r = 1$) is then tested against the other alternative $r + 1$ co-integrating vector $r = 2$, and so forth (Burke & Hunter, 2005:100). The L-max statistic is illustrated in the following equation (Burke & Hunter, 2005:100):

$$-2\ln Q = -T \ln(1 - \hat{\lambda}_{r+1}). \quad (5.22)$$

When executing the Johansen (1991) co-integration test, there are five options regarding the method of including a deterministic trend⁸⁰ (Johansen, 1995:80–84). The first option excludes a deterministic trend from the level data y_t and the co-integration equations include no intercepts (Equation 5.23). This option should be used when the series have a zero mean (QMS, 2007b:365).

$$H_2(r): \Pi y_{t-1} + Bx_t = \alpha \beta' y_{t-1} \quad (5.23)$$

The second option also excludes a deterministic trend from the level data y_t , but includes intercepts in the co-integration equations. This option should be used when none of the series have a trend (QMS, 2007b:365).

$$H_1^*(r): \Pi y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0) \quad (5.24)$$

The third option includes a linear trend in the level data y_t , but excludes intercepts in the co-integration equations (Equation 5.25). This option should be used when the trends of the series are stochastic (QMS, 2007b:365).

$$H_1(r): \Pi y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0) + \alpha_{\perp} \gamma_0 \quad (5.25)$$

The fourth option includes linear trends in the level data y_t and in the co-integration equations (Equation 5.26). This option should be used when the trends of the series appear to be stationary (QMS, 2007b:365).

$$H^*(r): \Pi y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0 + \rho_1 t) + \alpha_{\perp} \gamma_0 \quad (5.26)$$

The fifth option includes quadratic trends in the level data y_t and linear trends in the co-integration equations (Equation 5.27). This option is able to produce a good in-sample fit, but it may produce implausible estimates in the case of out-sample forecasts (QMS, 2007b:365).

⁸⁰ See Gujarati (2003:802–803) for a further reference on a deterministic trend.

$$H(r): \Pi y_{t-1} + Bx_t = \alpha (\beta' y_{t-1} + \rho_0 + \rho_1 t) + \alpha_{\perp} (\gamma_0 - \gamma_1 t) \quad (5.27)$$

The terms $\alpha_{\perp}$ are the deterministic terms that lie outside the co-integration relations. Johansen (1995) states that the $\alpha_{\perp}$ term is the null space of α such that $\alpha' \alpha_{\perp} = 0$. EViews 6 (QMS, 2007a) identifies the part inside the error correction term by regressing the co-integration relationships $\beta' y_t$ on a constant and on a linear trend (QMS, 2007b:366).

The Johansen (1991) co-integration test generates two estimates that can be used to evaluate the presence of a co-integration relationship at the given lag length. The Trace and maximum Eigenvalue statistics utilise a sequential testing procedure, where the rank/number of co-integration equations (r) tested depends on the number of variables (p) in the co-integration model, and can continue as long as $r \leq p$ (Mitchell-Innes, 2006:63). This implies that as long as the Trace and maximum Eigenvalue statistics are smaller than the critical value, the hypothesis will be rejected, with a maximum number of hypotheses of p . For example, if the null hypothesis ($r = 0$) is rejected then the sequential testing procedure will continue to the next hypothesis ($r \leq 1$), and to the alternative of $r + 1$ co-integration equations. This process will continue for a maximum of p co-integration equations until the hypothesis is not rejected, which means that the Trace and maximum Eigenvalue statistics will be greater than the critical value (Mitchell-Innes, 2006:63).

After a co-integration relationship had been established, the VEC model was estimated. The following section will discuss the manner in which to interpret the VEC model output generated by EViews 6 (QMS, 2007a).

5.4.4.3 Interpreting the output of a Vector Error Correction model

A VEC model estimates the speed of adjustment to equilibrium from two non-stationary variables that are co-integrated. The equilibrium is the co-integrated relationship (mean)

between the two non-stationary variables. In other words, the VEC model determines the adjustment required for a non-stationary variable to return to equilibrium (mean) for each period. For example, if a dual-listed stock on the NYSE experienced a shock, the VEC model will determine the period it will take for the dual-listed stock on the JSE and for the dual-listed stock on the NYSE to return to equilibrium. In VEC model output generated by EViews 6, (QMS, 2007a), the CointEq1 and the CointEq2 estimate represent the speed of adjustment required, which will be referred to as π . The π estimate is also known as the error-correction coefficient or the adjustment coefficient (Asteriou & Hall, 2007:314). As illustrated in Equation 5.17, a speed of adjustment series can be generated by using the following equation:

$$\pi = Y_{t-1} - \frac{\alpha_0}{1-\alpha_1} - \frac{\gamma_0+\gamma_1}{1-\alpha_1} X_{t-1}. \quad (5.28)$$

The π estimate ranges between 0 and 1, with $\pi = 1$ illustrating that a 100% adjustment will take place in one time period and an estimate of $\pi = 0$ indicating that no adjustment will take place.⁸¹ Note that all the terms in a VEC model are also stationary, which implies that a standard OLS approach will be valid (Asteriou & Hall, 2007:312).

To summarise, the first step of the VEC proxy approach was to establish the presence of a unit root or the same level of stationarity. The co-integration process could only be implemented if the two variables consisted of the same level of stationarity. Before the final co-integration model was estimated, a stable VAR model was first established with the required lag length. Only then could a statistically significant co-integration model be estimated. With the presence of co-integration established, where the Trace and maximum Eigenvalue statistics exceeded the critical value, the final step was executed. In this step, a speed of adjustment series for each of the dual-listed stocks was generated by estimating a VEC model. This approach, therefore,

⁸¹ For more on this, see Asteriou and Hall (2007:312–314).

forms the final approach in generating an alternative proxy for the interaction of the international financial markets (see Section 6.2.5.2.5 for results).

However, different approaches were implemented to generate a proxy for the interaction of the international financial markets. Incorporating each of these proxies, respectively in Equation 5.2 provided an R-squared that illustrated which approach was superior. However, using the highest R-squared as the only indicator to determine the best model was insufficient. The best model's *ex post* forecasting ability must also be determined, which was done using the Theil's equality coefficient. This coefficient was also used to justify the decision on the best expected stock returns and expected inflation rate series, as discussed in Section 5.3. Although, before discussing the Theil's equality coefficient, in Section 5.6, the second approach will be discussed in the following section.

5.5 THE SECOND APPROACH: USING NON-STATIONARY ECONOMIC LEVEL DATA TO MODEL THE REALIZED FUTURE SPOT EXCHANGE RATE

5.5.1 Introduction

The rigorous doctrine of thought at universities enforces the notion that stationary economic data must be used in the modelling of exchange rate theory. The fear of spurious results scared researchers away from any investigation into non-stationary, level economic time series. However, in practice investors and policy-makers look at the economic fundamentals in level terms (non-stationary current time series data) and not in returns (stationary current time series data). This implies the importance of reconsidering the use of the second approach to model exchange rate theories in order to obtain a real-world market participant perception of exchange rate modelling. This leads to the following section, which will investigate the reason for fear of using non-stationary, level data.

5.5.2 Implementing the second approach

The traditional econometric approach of modelling exchange rate models makes the assumption that the underlying time series are already stationary. Stationarity implies that the variance and mean are constant over time and that the value of the covariance between two time periods are only depended on the distance between the two time periods and not on the actual time at which the covariance was computed (Gujarati, 2003:793). Precaution must also be taken for the presence of serial correlation amongst explanatory variables (autocorrelation), which can be due to the underlying non-stationarity of the time series used (Gujarati, 2003:793).

Before modelling the economic fundamentals, it is, therefore, important to determine whether each time series possesses a unit root, which implies that it is non-stationary (see Section 5.7 for results). The most popular unit root test includes the ADF test (Section 5.4.4.1), which indicates the required level of differencing to make each time series stationary. Time series data that has to be adjusted for the presence of a unit root is sometimes called a weakly stationary series, a second-order stationary series, or a stochastic process (Gujarati, 2003:797).

Also, when estimating an OLS model preventative measures should be taken for spurious regressions that imply OLS models with high R-squares⁸², a low Durbin Watson statistic⁸³, and highly statistically significant coefficients (Gujarati, 2003:806). These results may imply that the model may have been mis-specified, or irrelevant variables are present, or autocorrelation is present amongst the residuals (Granger & Newbold, 1974:117). In other words, spurious regressions can provide false indications of statistically significant relationships among variables. This can be resolved by using logged variables or first differences, but information within the time series can be lost. Thus, using level data or changes may prevent information from being lost from the time series (Granger & Newbold, 1974:118). The study by Mehl (2000:363) argued that macroeconomic time series may be better characterised as unit root

⁸² The R-squared statistic measures the goodness of fit. In other words, it measures the ability of a regression in explaining the values of the dependent variable, within the sample (QMS, 2007b:13).

⁸³ The Durbin Watson statistic is used to determine the presence of autocorrelation among the residuals (Kirchgässner & Wolters, 2007:18).

processes. However, Ventosa-Santaulària (2009:16) argues that this rule of thumb may be statistically insignificant and that differencing a series may not always prevent spurious estimates. Additional warning signs of spurious regressions in OLS models that incorporate stationary and highly persistent variables are inconsistent standard errors that were used in the t-ratios. (Ventosa-Santaulària, 2009:4). However, there are alternative processes that can be used to prevent these problems, such as the Johansen (1991) co-integration model (Section 5.4.4).

Furthermore, unit root processes have limitations when modelling economic theories because a unit root model can be rejected “in favour of a trend ‘alternative’”, which is in fact an alternative representation of the unit process itself (Phillips, 1998:1317). This also further implies that neither unit root models nor deterministic 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, such as the potential for interpreting results incorrectly because results can be misleading if causality and correlation are confused. This contributed to the notion of differentiate non-stationary time series data when estimating regressions or when attempting to de-trend time series data by fitting trend lines in the estimation of Least Squares models (Ventosa-Santaulària, 2009:3).

Therefore, this study incorporated the following procedure to prevent the possibility of spurious results when using non-stationary, level current economic time series data (see Section 6.3.2 for results):

- Firstly, non-stationary, level data was incorporated into a standard OLS model to acquire preliminary results. These results will justify the presence of a spurious regression.
- Secondly, a Breusch-Godfrey serial correlation LM test was applied to determine the presence of serial correlation amongst the explanatory variables. This was followed by

testing for the presence of heteroskedasticity⁸⁴ with a White heteroskedasticity test. The second step is required because based on the study by Yule (1926:53), who first discovered the presence of a spurious regression, correlation between two variables can still persist in non-stationary time series data.

- Thirdly, an ARCH model or a GARCH model was applied, using the model with the lowest Schwarz Information Criterion (SIC) and AIC estimate. ARCH and GARCH models are able to eliminate the presence of serial correlation and heteroskedasticity.
- Fourthly, recheck the presence of any remaining heteroskedasticity within the model (remaining ARCH effects).
- Fifthly, the ARCH/GARCH model's residuals were tested for the presence of a unit root (no unit root will confirm that no spurious results are present). This was followed by testing if the residuals are normally distributed, to ensure that the variance of the residual is identical and uncorrelated (white noise⁸⁵).

In addition, the best model's *ex post* forecasting ability was determined that will be discussed in the following section.

5.6 FORECASTING ACCURACY

The indicator that was applied in order to determine the accuracy of the forecasts obtained is the Theil's inequality coefficient or the inequality coefficient (U). The Theil's inequality coefficient is illustrated in the following equation (Koutsoyiannis, 1977:492–493):

$$U^2 = \frac{\sum (P_i - A_i)^2 / n}{\sum A_i^2 / n} \quad (5.29)$$

⁸⁴ 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.

⁸⁵ See Section 2.3.3.1.

where:

- P_i denotes the forecasted change in the dependent variable;
- A_i denotes the realized change in the dependent variable;
- n denotes the number of observations; and
- $0 \leq U \leq \infty$, where the smaller the inequality coefficient, the better the forecast accuracy.

With $P_i = A_i$, the inequality coefficient is equal to zero, which indicates a perfect forecast. With $P_i = 0$, then the inequality coefficient is equal to one, which indicates that the forecast is no better than a zero-change prediction. However, if $U > 1$, then the forecast model is worse than a zero-change prediction (Koutsoyiannis, 1977:493). Therefore, the model with the lowest inequality coefficient will be considered the exchange rate with the best forecasting ability (see Section 6.2.4.2 for results).

However, even with a statistically significant approach established that has the ability to improve the accuracy of the estimation of the realized spot exchange rate, the lack of quality data can lead to inconsequential results. This leads to the final section of this chapter, which includes a description of the data that was used for this study.

5.7 THE DATA

Data was collected from a number of databases, spanning from 1 May 1994 to 31 May 2008, thus covering a period of 14 years. This time frame starts just before the election of Nelson Mandela as South African president, which took place on 9 May 1994, and ends before the outbreak of the world financial crisis, which started approximately on 9 September 2008 when Lehman Brothers announced their bankruptcy. However, as two dual-listed stocks used in this study did not have data points for this particular time frame, an alternative time frame was selected. The data on Harmony started at 1 December 2002, while the data on Sasol started at 1 May 2003. Therefore, the time frame that was selected for this study was from 1 May 2003 to

31 May 2008. In addition, after converting each time series into a weekly format, this time frame contained 244 observations.

Regarding the data, the daily ZAR/USD spot exchange rate data was obtained from the McGregor BFA database (2010). Daily 3-month forward points were supplied by Rand Merchant Bank (2010). Weekly South African and U.S.A. 91-day T-Bills were obtained from the South African Reserve Bank's (SARB) (2010) website and from the Federal Reserve Board of Governors' (2010) 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 (2010) and daily 10-year U.S.A. government yield rates were obtained from the U.S.A. Department of the Treasury's (2010) website. The 10-year South African government yield rates were 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 (2010) website. Monthly U.S.A. PPI data was obtained from the U.S.A. Department of Labour, Bureau of Labour Statistics' (2010) website. Monthly year-on-year PPI inflation rate series, spanning from May 2002 to February 2009, was used in an attempt to improve the accurate estimation of inflation expectations. The reason for using a longer period compared to the other time series is that better mean-reversion estimates can be reported with reliable time series data that spans over longer horizons (Balvers *et al.*, 2000:746). After the monthly inflation expectations were generated with the use of the exponential weighting procedure and the EWMA model (Section 5.3.2.1.3), the linear interpolation process (Section 5.3.3) was used to convert the year-on-year monthly PPI data into a weekly format. Note also that year-on-year monthly PPI data were used instead of CPI data. The reason for the use of the PPI is that it is related to international trade, where CPI only has a domestic focus. The PPI may, therefore, provide a broader view regarding international transactions. The PPI can also be considered a leading indicator of CPI, thus providing insight regarding future movements of CPI.

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 (2010)⁸⁶. 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 obtained from finance.yahoo.com (2010). Each stock closing price series spanned from May 2002 to February 2009, in an attempt to improve the estimation of more accurate stock return expectations (Section 5.4.2). The daily Euro/ZAR exchange rate, Pound/ZAR exchange rate, and daily gold price and Brent oil prices were obtained from the MetaStock database (2010). Weekly ZAR/USD Nominal Effective Exchange Rate (NEER)⁸⁷ data was also obtained from the SARB's (2010) website.

The first step in analyzing the data was to test the level of stationarity⁸⁸ of the following variables as indicated in Table 5.3, of both South Africa and the U.S.A. **Different formats were also examined in order to make the data stationary, which include the log-format and the first differencing format and the fractional differencing format⁸⁹.** The first differential format entailed the use of the change in the variables from period t to period $t + 1$, that yielded the best results. This approach was applied throughout the empirical study. Granger and Newbold (1974:118) supported this approach, arguing that no information in the time series will be lost by using changes, which is also the reason that level data was preferred. The level of stationarity provides additional insight regarding the possibility of long-memory⁹⁰ and is also important when estimating a Johansen (1991) co-integration model (Section 5.4.4.2). Only with the presence of long-memory in the ZAR/USD exchange rate will the use of economic fundamentals to estimate the future spot exchange rate and to eliminate the possibility of random walk (Section 2.3.3.1) be justified. The presence of long-memory in the South African and in the U.S.A. PPI justifies the use of historical values to estimate future values (Section 5.3.2.1).

⁸⁶ Section 5.2.5 discussed the reason for excluding Telkom SA Limited from the empirical study.

⁸⁷ See Section 2.4.2 for the discussion on the NEER.

⁸⁸ The ADF unit root test is used to test the presence of a unit root, as discussed in Section 5.4.4.1.

⁸⁹ The fractional differencing format will only be applied in Section 6.3.2.3 as a comparison to the results found when applying the first differencing format.

⁹⁰ Also known as mean-reversion, as discussed in Section 5.3.2.1.

This section will, therefore, illustrate the results found in the implementation of the ADF unit root test. **Each ADF unit root test will include an intercept in the equation.** Table 5.4 will start with the results for the monthly year-on-year South African and U.S.A. PPI figures⁹¹. This will be followed by the results found for the resource dual-listed stocks and the stock indices, as illustrated in Table 5.6 and Table 5.5, respectively.

Table 5.3: Variables tested for a unit root

PPI
91-day T-Bill rates
10-year government bond yield rates
Closing prices of the RESI 20 and the NYSE Energy Index
Closing prices of AngloGold Ashanti, Sappi Limited, Harmony Gold Mining Company Limited, Sasol Limited and Gold Fields Limited
ZAR/USD spot exchange rate, USD/Euro spot exchange rate, USD/Pound spot exchange rate, ZAR/Pound spot exchange rate, ZAR/Euro spot exchange rate, ZAR/USD forward exchange rate ⁹² , <i>ex post</i> ZAR/USD exchange rate realized 3 months ahead and NEER

Source: Compiled by author.

Table 5.4: ADF unit root test for the South African PPI and for the U.S.A. PPI

		t-statistic	t-probability
SOUTH AFRICA	ADF test statistic	0.186	0.971
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
U.S.A.	ADF test statistic	-1.188	0.680
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	

Source: Compiled by author.

Table 5.4 reported that the South African PPI and the U.S.A. PPI do have a unit root, thus the series are not stationary at the 5% level. Further evidence from Table 5.5 also reported that RESI 20 and the NYSE Energy Index have a unit root, thus they are both not stationary at

⁹¹ The monthly year-on-year South African and U.S.A. PPI data were first tested for a unit root, the presence of long memory, which was followed by the process of generating expected values (Section 5.3.2). The monthly year-on-year expected inflation rate values were then transformed into a weekly format with the use of linear interpolation (Section 5.3.3), whereas, all the other variables were transformed into a weekly format at the beginning of the empirical analysis.

⁹² The ZAR/USD forward exchange rate was estimated with the use of the 3-month forward points.

the 5% level⁹³.

Table 5.5: ADF unit root test for RESI 20 and the NYSE Energy Index

		t-statistic	t-probability
RESI 20	ADF test statistic	-1.140	0.701
	1% level	-3.452	
	5% level	-2.871	
	10% level	-2.572	
NYSE ENERGY INDEX	ADF test statistic	-1.511	0.527
	1% level	-3.452	
	5% level	-2.871	
	10% level	-2.572	

Source: Compiled by author.

Table 5.6 presents the results of the ADF test for all the individual resource dual-listed stocks. The table demonstrates that the South African and U.S.A. AngloGold Ashanti dual-listed stock and the South African Harmony Gold Mining Company Limited dual-listed stock do not have a unit root, which indicates that these dual-listed stocks are stationary at the 5% level. All the other resource dual-listed stocks do have a unit root, which indicates non-stationarity at the 5% level. These results also illustrate that all the resource dual-listed stocks, except for the Harmony dual-listed stock, have the same level of stationarity for both South Africa and the U.S.A. (see Table 5.7 for summary), which makes them suitable to use in the VEC proxy approach (Section 5.4.4) that is based on the implementation of a co-integration approach. Only with the same level of stationarity can two variables be tested for a co-integration relationship, which is essential to the VEC proxy approach (Section 5.4.4).

⁹³ Variables were also tested in log format, but failed to provide statistically significant results.

Table 5.6: ADF unit root test for the South African and U.S.A. resource dual-listed stocks

		t-statistic	t-probability
South African AngloGold Ashanti	ADF test statistic	-3.127	0.026*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
U.S.A. AngloGold Ashanti	ADF test statistic	-3.045	0.032*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
South African Sappi Limited	ADF test statistic	-2.684	0.078
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
U.S.A. Sappi Limited	ADF test statistic	-2.588	0.097
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
South African Gold Fields Limited	ADF test statistic	-2.427	0.135
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
U.S.A. Gold Fields Limited	ADF test statistic	-2.376	0.150
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
South African Harmony Gold Mining Company Limited	ADF test statistic	-2.928	0.044*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
U.S.A. Gold Harmony Gold Mining Company Limited	ADF test statistic	-2.849	0.053
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
South African Sasol Limited	ADF test statistic	0.734	0.993
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
U.S.A. Gold Sasol Limited	ADF test statistic	0.741	0.993
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	

*Reject null hypothesis for the presence of a unit root.

Source: Compiled by author.

Table 5.7: Summary of the level of stationarity of the resource dual-listed stocks

Stocks	Same level of stationarity	
	Yes	$I(0)$
South African AngloGold Ashanti U.S.A. AngloGold Ashanti	Yes	$I(0)$
South African Sappi Limited U.S.A. Sappi Limited	Yes	$I(1)$
South African Gold Fields Limited U.S.A. Gold Fields Limited	Yes	$I(1)$
South African Harmony Gold Mining Company Limited U.S.A. Harmony Gold Mining Company Limited	No	-
South African Sasol Limited U.S.A. Sasol Limited	Yes	$I(1)$

Source: Compiled by author.

In addition, Table 5.8 presents the results of the ADF unit root test for the different spot exchange rates: the ZAR/USD exchange rate, the USD/Euro exchange rate, the USD/Pound exchange rate, the ZAR/Pound exchange rate, and the ZAR/Euro exchange rate. This is followed by the results of the ADF unit root test for the ZAR/USD forward exchange rate, which was estimated with the use of the 3-month forward points and the *ex post* ZAR/USD exchange rate realized 3 months ahead.

As is evident from the results given in Table 5.8, the different exchange rates do have a unit root, which means that all exchange rates are not stationary at the 5% level. Furthermore, Table 5.9 presents the results of the ADF unit root test for the ZAR/USD forward exchange rate, the *ex post* ZAR/USD exchange rate realized 3 months ahead, and the NEER. The results indicate that all the exchange rates do have a unit root, thus all are not stationary at the 5% level.

Table 5.8: ADF unit root test for the different spot exchange rates

		t-Statistic	t-prob.
ZAR/USD spot exchange rate	ADF test statistic	-2.226	0.198
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
ZAR/Pound exchange rate	ADF test statistic	-1.302	0.629
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
ZAR/Euro exchange rate	ADF test statistic	-0.617	0.863
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
USD/Euro exchange rate	ADF test statistic	-0.477	0.892
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
USD/Pound exchange rate	ADF test statistic	-2.380	0.148
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	

Source: Compiled by author.

Table 5.9: ADF unit root test for additional exchange rates

		t-statistic	t-probability
Ex post ZAR/USD exchange rate realized 3 months ahead	ADF test statistic	-2.193	0.209
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
ZAR/USD forward exchange	ADF test statistic	-2.152	0.225
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
NEER	ADF test statistic	-0.566	0.874
	1% level	-3.458	
	5% level	-2.874	
	10% level	-2.573	

Source: Compiled by author.

To summarise, the data was tested for the presence of a unit root (not stationary) using the ADF unit root test (Section 5.4.4.1). The level of stationarity is essential to the VEC proxy approach (Section 5.4.4). Only if the two variables have the same level of stationarity can an effective co-integration process (Section 5.4.4.2) be executed. The level of stationarity also provides additional insight regarding the possibility of long-memory, which was formally tested with the ARFIMA model (Section 5.3.2.1.1). Only with the presence of long-memory in the inflation rate data and stock closing price data can the process of using historical values to generate future values be justified. The presence of long-memory was also required in the ZAR/USD spot exchange rate because without the presence of long-memory, economic fundamentals could not have been used to estimate the future spot exchange rate, as will be reported in Section 6.2.2.1.

5.8 CHAPTER SUMMARY

As forward points are considered an insufficient measure to estimate the realized spot exchange rate, as illustrated by the exchange rate puzzle (Section 2.3), alternative methods were investigated. The empirical study entailed two approaches. In the first approach, stationary economic time series were used to model an exchange rate. In the second approach, non-stationary economic level data was used to model an exchange rate.

In addition, the stationary component approach used the methodology of Chiang and Yang (2007) only as a preliminary platform, while this study set out to improve the accuracy of the estimation of the realized spot exchange rate. This was done by formulating a model that consisted of a linear combination of the International Equity Parity (Section 4.1), the PPP (Section 3.2), the Uncovered Interest Rate Parity (Section 3.3.6) and the expectations hypothesis of the domestic term structure of interest rates (Section 2.3.4.2.4). Furthermore, this study contributed to the knowledge of exchange rate dynamics by introducing different proxies that can be used to incorporate the interaction of the international financial market (JSE and the NYSE) into an exchange rate model. This was done by altering the International Equity Parity

theory, which states that there is a relationship between expected stock returns (financial market) and the future spot exchange rate, by implementing the following approaches:

- Generating stock return expectations from resource indices (Section 5.2.2);
- Substituting indices with stock return expectations generated from individual dual-listed (Section 5.2.2);
- Substituting the stock return variable with an ICAPM series (Section 5.4.3) that was generated with the use of the dual-listed stocks; and
- Substituting the stock return variable with a speed of adjustment series that was generated with a VEC model (Section 5.4).

In addition to these different approaches, this study also introduced an alternative method of generating inflation and stock return expectations. This alternative method entails the use of an exponential weighting procedure and the EWMA model (Section 5.3.2.1.3). The EWMA model has the ability to incorporate both historical expectations and future (uncertainty) expectations into a 1-month ahead, presently expected inflation rate/stock return series. However, by estimating a model with an expected stock return variable, with an ICAPM variable and with a speed of adjustment series of each dual-listed stock, respectively, there still remained inconclusive evidence regarding which model has the best forecasting abilities. The Theil's equality coefficient (Section 5.6) was estimated for the exchange rate model with the best R-squared. The lower the equality coefficient, the better the accuracy of the exchange rate model.

This chapter has also described the data (Section 5.7) that was used in the empirical study. Furthermore, the variables' level of stationarity was tested with the use of the ADF unit root test (Section 5.4.4.1). The level of stationarity is important for the co-integration process (Section 5.4.4.2), because only if the two variables have the same level of stationarity can an effective co-integration process be executed. The level of stationarity can also be used as a preliminary

indicator for the possibility of long-memory (mean-reversion). However, the presence of long-memory was formally tested with the ARFIMA model (Section 5.3.2.1.1) and will be reported in Section 6.2.2. Only with the presence of long-memory/mean-reversion (Section 5.3.2.1) can economic variables be used to improve the accuracy of the estimation of the forward points as an explanatory variable of the realized spot exchange rate. Also, the data must have long-memory in order to justify the use of historical values to generate future values because without the presence of long-memory the EWMA model (Section 5.3.2.1.3) cannot be implemented (see Section 6.2.4.2 for results). This leads to the following chapter, which will report the results found using the methodology discussed in this chapter.

CHAPTER 6

Empirical Results

6.1 INTRODUCTION

This chapter reports the results of the empirical investigation into the different approaches, as discussed in Chapter 5, in order to solve the exchange rate puzzle and to understand the reason that the realized spot exchange rate differs to the forward exchange rate to such an extent. As stated in Chapter 1, **the first research objective of this study is to formulate an exchange rate model that improves the accuracy of the estimation of the realized future spot exchange rate from current economic fundamental data.** It was already explained in Chapter 1 that the forward exchange rate is the result of a mechanistic process. It is, therefore, the premise of this study that if more is known about the economic fundamentals that have an impact on the future exchange rate movements, supply and demand of market participants may result in a forward exchange rate that is a better indicator of the realized future spot exchange rate. This implies that the difference between the forward exchange rate and the realized future spot exchange rate can, over time, decrease because the forward exchange rate will reflect the current economic fundamentals more accurately. **This will lead to the main contribution of this study that will determine if the exchange rate puzzle is a pseudo problem.**

This chapter consists of two main parts. In the first part, the results of the investigation using stationary economic time series will be reported and discussed (Section 6.2). In the second part, the results of the analysis of the non-stationary, level economic data will be reported and discussed (Section 6.3).

6.2 ESTIMATION OF THE REALIZED FUTURE SPOT EXCHANGE RATE FROM STATIONARY ECONOMIC TIME SERIES DATA

6.2.1 Introduction

The objective of this investigation was to use the knowledge gained from the literature review to estimate the realized future spot exchange rate from time series that represented the current economic fundamentals. This approach followed the methodology of Chiang and Yang (2007) that was described in Chapter 5. This investigation, however, also extended the Chiang and Yang (2007) methodology with the introduction of different approaches towards the theoretical formulation and the empirical estimation of the main components of the exchange rate model.

This section will start by reporting the results of the investigation into the presence of long-memory (Section 6.2.2). This will be followed by the establishing and estimation of the expected inflation rate and the expected stock return values (Section 6.2.4.2) used in the exchange rate model, as discussed in Section 5.3.2.1.3. The results of the implementation of the preliminary Chiang and Yang (2007) methodology will be discussed in Section 6.2.4, which will be followed by the results of the extension (Section 6.2.5) of the Chiang and Yang (2007) methodology. This extension (Section 6.2.5) includes the re-examining of the PPP theory (Section 3.2), the Uncovered Interest Rate Parity theory (Section 3.3.6), Covered Interest Rate Parity theory (Section 3.3.3) and the Fisher effect (Section 3.3.2.1) in order to improve the components of the Chiang and Yang (2007) methodology. Lastly, a summary of the results will be given, as well as a final view on the viability of stationary economic time series data (Section 6.3.2.3).

6.2.2 The presence of long-memory

The first step in testing for the presence of long-memory was to test for the level of stationarity.⁹⁴ In Section 5.7, the level of stationarity was already reported for each variable, which indicated that all the variables, except the closing prices of the South African AngloGold Ashanti and

⁹⁴ See Section 5.5 regarding the weakness of following unit root processes in modelling economic theories.

Harmony Gold Mining Company Limited dual-listed stock and of the U.S.A. AngloGold Ashanti dual-listed stock, had a unit root, thus implying that they were not stationary at the 5% level. The next step was to use the EML method (Section 5.3.2.1.1) to formally test for the presence of long-memory amongst the variables as illustrated in Table 6.1.

Table 6.1: Variables applicable to the EML method

ZAR/USD spot exchange rate
PPI
Closing prices of the RESI 20 and the NYSE Energy Index
Closing prices of AngloGold Ashanti, Sappi Limited, Harmony Gold Mining Company Limited, Sasol Limited, and Gold Fields Limited

Source: Compiled by author.

It is essential that the ZAR/USD spot exchange rate have long-memory in order to justify the use of economic fundamentals to estimate the realized future spot exchange rate and thus to eliminate the possibility of a random walk (Section 2.3.3.1). Also, it is essential that the South African and U.S.A. monthly year-on-year PPI inflation rate, the RESI 20 and the NYSE Energy Index, and the resource dual-listed stocks⁹⁵ have long-memory in order to justify the use of the exponential weighting procedure and the EWMA model (Section 5.3.2.1.3) to generate future values from historical values. These future values are then incorporated into the approach of Chiang and Yang (2007) as discussed in Section 5.2.5.

The next step is, therefore, to use the ARFIMA model to test for long-memory (Section 5.3.2.1). The EML method (Section 5.3.2.1.1) was used to test for the presence of long-memory (mean-reversion). The long-memory results are reported with reference to Table 6.2. The model with the lowest AIC values (Section 5.3.2.1.1), and where both the AR and MA components and the d -parameter were statistically significant at the 10% level was selected as the model with the best fit.

⁹⁵ Section 4.2.3 indicated that these resource dual-listed stocks include AngloGold Ashanti Limited, Gold Fields Limited, Harmony Gold Mining Company Limited, Sappi Limited and Sasol Limited.

Table 6.2: Interpreting the d -parameter

$d = 0$	Implies that the time series is a white noise process*.
$-0.5 \leq d \leq 0$	Implies stationary with short memory.
$d = 1$	Defines a non-stationary series.
$0 \leq d < 1$	Will exhibit mean-reversion, but shock is not permanent and transitory.
$d < 1$	Implies mean-reverting.
$0 < d < 0.5$	Implies stationary and mean-reverting (long-memory).
$0.5 < d < 1$	Implies covariant and non-stationary (mean-reversion/long-memory).
$d \geq 1$	Implies non-stationary and non-mean-reverting.
$-0.5 \geq d \geq -1$	Implies non-stationary with short memory

* See Section 2.3.3.1 for explanation of a white noise process.

Source: Styger *et al.* (2008:340) and Gallegati (2008:3071).

This leads to the following sections, where the long-memory results of each variable, as listed in Table 6.1, will be discussed. This includes the ZAR/USD exchange rate (Section 6.2.2.1), the South African PPI and U.S.A. PPI (Section 6.2.2.2), and the resource stock indices and the individual resource stocks (Section 6.2.2.3).

6.2.2.1 Long-memory of the ZAR/USD exchange rate

This section reports whether the ZAR/USD exchange rate was found to have long-memory, by using an AR(1) EML method. Only with the presence of long-memory could the possibility of random walk be eliminated and economic fundamentals used to estimate the realized future spot exchange rate.

Table 6.3: EML estimation for ZAR/USD exchange rate

ZAR/USD exchange rate	$d = 0.311$	t-prob. = 0.027*	AIC = -1.172

* Statistically significant at the 5% level.

Source: Compiled by author.

The results in Table 6.3 indicate that the ZAR/USD exchange rate does have long-memory, because the d -parameter is between 0 and 0.5. These results confirmed that economic fundamentals could be used to estimate the realized future spot exchange rate, because these

fundamentals consisted of historical information that could be used to estimate future events. The presence of long-memory amongst the PPI inflation rates, stock indices, and the individual dual-listed stocks will be reported in the following section.

6.2.2.2 Long-memory of the South African and U.S.A. PPI

Table 6.4 reports the results of testing the South African PPI and the U.S.A. PPI for long-memory, by using an AR(1) EML method. From the table, it is evident that both the South African PPI and the U.S.A. PPI have long-memory, as the d -parameters of both the South African PPI and the U.S.A. PPI are between 0 and 0.5. The presence of long-memory, therefore, justified the use of historical values to generate future values and the use of the EWMA model (Section 5.3.2.1.3) to generate the expected inflation rates and the expected stock returns required to model an exchange rate model.

Table 6.4: EML estimation for PPI

South Africa	$d = 0.498$	t-prob. = 0.000*	AIC = -1.105
U.S.A.	$d = 0.497$	t-prob. = 0.000*	AIC = 0.492

Source: Compiled by author.

6.2.2.3 Long-memory of the resource indices and the individual resource dual-listed stocks

Table 6.5 reports the results of testing the RESI 20 and the NYSE Energy Index for long-memory, by applying an AR(1) EML method. The table indicates that the RESI 20 does not have long-memory, because the d -parameters was statistically insignificant. Although, the NYSE Energy Index does exhibit long-memory. Due to the inconsistency in the presence of long-memory among the indices, the indices could not be implemented as the first strategy of incorporating the interaction of the two international financial markets (JSE and NYSE) into an exchange rate model, as mentioned in Section 5.8.

Table 6.5: EML estimation for RESI 20 and NYSE Energy Index

South Africa (RESI 20)	$d = 0.076$	t-prob. = 0.128	AIC = 17.731
U.S.A. (NYSE Energy Index)	$d = 0.138$	t-prob. = 0.014*	AIC = 14.445

* Statistically significant at the 5% level.

Source: Compiled by author.

In addition, the following results determined which of the individual resource dual-listed stocks to use in the second strategy of incorporating the interaction of the two international financial markets (JSE and NYSE) into an exchange rate model. An AR(1) EML method was applied to determine the presence among the individual resource dual-listed stocks. The resource dual-listed stocks with long-memory were used in the EWMA model (Section 5.3.2.1.3) to generate expected stock returns. Table 6.6 reports that all the individual resource dual-listed stocks have a d -parameter that falls between 0 and 0.5, except the Sasol Limited dual-listed stock that reported a statistically insignificant d -parameter. These results, therefore, justified the use of historical values to generate future values. Thus, all the individual resource dual-listed stocks, except the Sasol Limited dual-listed stocks, could be used in the second strategy of incorporating the interaction of the two international financial markets (JSE and NYSE) into an exchange rate model.

Table 6.6: EML estimations for South African and U.S.A. dual-listed stocks

South African AngloGold Ashanti	$d = 0.357$	t-prob. = 0.006*	AIC = 4.058
U.S.A. AngloGold Ashanti	$d = 0.357$	t-prob. = 0.006*	AIC = 3.995
South African Sappi Limited	$d = 0.195$	t-prob. = 0.071*	AIC = 1.619
U.S.A. Sappi Limited	$d = 0.242$	t-prob. = 0.031*	AIC = 1.456
South African Gold Fields Limited	$d = 0.430$	t-prob. = 0.001*	AIC = 2.541
U.S.A. Gold Fields Limited	$d = 0.421$	t-prob. = 0.020*	AIC = 2.532
South African Harmony Gold Mining Company Limited	$d = 0.427$	t-prob. = 0.000*	AIC = 2.711
U.S.A. Harmony Gold Mining Company Limited	$d = 0.424$	t-prob. = 0.000*	AIC = 2.215
South African Sasol Limited	$d = 0.043$	t-prob. = 0.402	AIC = 3.705
U.S.A. Sasol Limited	$d = 0.051$	t-prob. = 0.329	AIC = 3.660

* Statistically significant at the 5% level.

Source: Compiled by author.

Furthermore, by combining the results reported on the level of stationarity (Section 5.7) and the presence of long-memory, the following conclusions are made (Table 6.7). The same level of stationarity was required to conduct a co-integration analysis (Section 5.4.4), which forms one of the components in generating a speed of adjustment series, as used in the fourth strategy of incorporating the interaction of the two international financial markets (JSE and NYSE) into an exchange rate model. Table 6.7, therefore, reports that the individual resource dual-listed stocks best suited to the empirical study included the AngloGold Ashanti, Gold Fields Limited, and Sappi Limited dual-listed stocks.

Table 6.7: Combined results from testing for stationarity and long-memory

Stocks	Same level of stationarity	Long-memory present
South African AngloGold Ashanti U.S.A. AngloGold Ashanti	Yes	Yes
South African Sappi Limited U.S.A. Sappi Limited	Yes	Yes
South African Gold Fields Limited U.S.A. Gold Fields Limited	Yes	Yes
South African Harmony Gold Mining Company Limited U.S.A. Harmony Gold Mining Company Limited	No	Yes
South African Sasol Limited U.S.A. Sasol Limited	Yes	No

Source: Compiled by author.

However, the AngloGold Ashanti and Gold Fields Limited dual-listed stocks are both gold stocks. A Breusch–Godfrey Serial Correlation LM test demonstrates that there was serial correlation amongst the AngloGold Ashanti and Gold Fields Limited dual-listed stocks (Table 6.8). In order to eliminate serial correlation, only one of the gold dual-listed stocks could be used in the empirical study. Using market capitalization as a benchmark, this study found that AngloGold Ashanti's market capitalization of USD17.24 billion was greater than Gold Fields Limited's market capitalization of USD11.02 billion, and thus AngloGold Ashanti was used as the more dominant stock. Therefore, the two dual-listed stocks that were used in this study are the AngloGold Ashanti and the Sappi Limited dual-listed stocks.

Table 6.8: Breusch–Godfrey Serial Correlation LM test between AngloGold Ashanti and Gold Fields Limited

	<u>F-statistic</u>	<u>Obs.* R-squared</u>	<u>Prob. (F-statistic)</u>	<u>Prob. (chi-square)</u>
South Africa	768.897	211.060	0.000*	0.000*
U.S.A.	754.926	210.534	0.000*	0.000*

* Reject the null hypothesis of no serial correlation.

Source: Compiled by author.

To recapitulate, the presence of long-memory and the level of stationarity were established, which were needed in order to execute all the strategies described in the previous chapter. However, before continuing to the modelling of all the economic fundamentals, the presence of the exchange rate puzzle was first determined. This will be achieved by determining whether the forward exchange rate (estimated with the 3-month forward points) is a biased or unbiased estimate of the future spot exchange rate. Only if the forward exchange rate fails (biased) to explain the future spot exchange rate will additional economic fundamentals be needed to explain and estimate the realized future spot exchange rate (such as inflation rates, interest rates and stock returns). This leads to the following section, which will report on the presence of the exchange rate puzzle in the ZAR/USD exchange rate.

6.2.3 The presence of the exchange rate puzzle (forward premium hypothesis)

This section reports on the testing of whether the ZAR/USD forward exchange rate is a biased or unbiased estimator of the future ZAR/USD spot exchange rate realized in 3 months' time. The presence of the exchange rate puzzle was tested by estimating Equation 2.3:

$$s_{t+k} - f_t = v_0 + v_1(f_t - s_t) + \varepsilon_{t+k} \quad (2.3)$$

where:

- 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 intercept;
- v_1 is the exchange rate premium coefficient; and
- ε_{t+k} is the random error.

Based on the results reported in Section 5.7, the change in the variables from period t to period $t + 1$ was used because the level data of the variables were not stationary. This method (first differencing format) was also applied throughout the study, which is reported as the difference of a variable in the tables^{96,97}. The results reported in Table 6.8 were obtained by estimating an OLS model that indicated that the present premium ($f_t - s_t$) could only explain 16% of the future premium ($s_{t+3} - f_t$), which indicated that an exchange rate puzzle was present in the ZAR/USD exchange rate.

Table 6.8: The forward premium hypothesis (OLS)

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*
Intercept (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 author.

The Durbin Watson statistic and the Ramsey Reset⁹⁸ test indicated that the model was misspecified. These results, therefore, emphasised the presence of an exchange rate puzzle in the ZAR/USD exchange rate and the need for additional explanatory variables to improve the

⁹⁶ Note that the implementation of the Chiang and Yang (2007) methodology requires the generating of new variables, which entails additional ADF unit root testing to ensure that the new variables are all stationary when incorporated in a model. These additional ADF unit root test results are reported in Table 19, Table 20, and Table 21 in the appendix.

⁹⁷ Note that the future premium, the AngloGold Ashanti stock return differential, the Sappi Limited stock return differential, and the ($s_{t+3} - s_t$) variable do not have a unit root. However, they are differenced in order to ensure that all the variables in each of the upcoming models have the same order of integration. The fact of overdifferencing is considered and additional results are reported in Section 6.3.2.3, where fractionally differenced variables are used.

⁹⁸ The Ramsey Reset test is used to determine if there is a regression specification error in the model (QMS, 2007b:175-176). The results are reported in Table 1 in the appendix.

estimation abilities of the forward points⁹⁹. The results in Table 6.9 present additional information regarding the possibility that the forward exchange rate is a biased estimate of the future spot exchange rate.

Table 6.9: The second forward premium hypothesis (OLS)

Dependent: Difference of S_{t+3}				Coefficient	Std. error	t-prob.
Difference of the forward exchange rate				0.119	0.063	0.060**
Intercept (v_0)				0.001	0.009	0.909
R-squared	0.015	Prob. (F-statistic)	0.060			
Adjusted R-squared	0.011	AIC	-1.152	Durbin Watson		1.609

** Statistically significant at the 10% level.

Source: Compiled by author.

In this model, only the historical spot exchange rate that will realize in 3 months was used as the dependent variable and only the forward exchange rate as the independent variable. The forward exchange rate, which was estimated with the use of 3-month forward points, could provide a statistically significant explanation of only 2% of the spot exchange rate that will realize over 3 months. These results, therefore, emphasised that the forward exchange rate is indeed a biased estimate of the realized future spot exchange rate. The results further implied that forward points was a weak estimator of the future spot exchange rate, which increased the need to incorporate additional explanatory variables/economic fundamentals.

To summarise, as the ZAR/USD exchange rate has long-memory (mean-reversion) economic fundamentals could be used to estimate the realized future spot exchange rate. The results confirmed the presence of an exchange rate puzzle in the ZAR/USD exchange rate and the need for additional explanatory variables to improve the accuracy of the estimations of the forward points. This leads to the following section, which will discuss the results based on the methodology of Chiang and Yang (2007). This methodology included the equity premium (International Equity Parity in Section 4.1), the inflation rate (PPP in Section 3.2), the interest rate (Uncovered Interest Rate Parity in Section 3.3.6), and the expectations hypothesis of the

⁹⁹ Note that detailed interpretations of the coefficients of all the models are not provided until the best exchange rate model is determined. Only with the best exchange rate model can comprehensive interpretations be ensured.

domestic term structure of interest rates (Section 2.3.4.2.4). The initial objective was to determine the impact of each explanatory variable on the future premium ($s_{t+3} - f_t$), before including them in a multi-variable model.

6.2.4 Implementing the methodology of Chiang and Yang (2007)

6.2.4.1 Introduction

Based on Equation 5.2, the two series that had to be generated included the expected inflation rate series and the expected stock returns series of both South Africa and the U.S.A. This section will start by discussing the generating of the expected inflation rate series, which will be followed by a discussion of the generating of the expected stock returns (Section 6.2.4.2). The results of applying the methodology of Chiang and Yang (2007) will follow in Section 6.2.4.3.

6.2.4.2 Generating expected inflation rates and expected stock returns

The first step was to generate a historical series $(t + 1)b$ with the help of the exponential weighting procedure, where the weights assigned were estimated with the help of Equation 5.8 (Section 5.3.2.1.3). The following specifications were evaluated: $\lambda = 0.25$, $\lambda = 0.5$ and $\lambda = 0.75$; and $t = 4$, $t = 6$ and $t = 12$. Each series generated from each specification was regressed on the actual series and the series with the best R-squared was considered the best historical series $(t + 1)b$ to use. The smallest Theil inequality (U) estimate (Section 5.6) and the standard error estimate were also used to determine the best model. The results reported in Table 6.10 demonstrate that the best model specifications¹⁰⁰ for the expected South African and the expected U.S.A. PPI were $t = 4$ and $\lambda = 0.75$.

However, these expected inflation figures $(t + 1)b$ were only based on historical data. In order to incorporate uncertainty (future expectations) into present inflation expectations, an EWMA model was formulated (Section 5.3.2.1.3), making use of the same weighting procedure. The next step was to generate the future series $(t + 1)f$ with the help of the EWM model and then to

¹⁰⁰ The results from the other specifications are available on request from the author.

generate the 1-month-ahead inflation expectation series $(t + 1)$ by combining the $(t + 1)b$ and the $(t + 1)f$ series. In order to estimate a 1-month-ahead inflation expectation series $(t + 1)$, the best weight split combination had to be determined. Thus, the best weights to assign to the historical series $(t + 1)b$ and to the future series $(t + 1)f$ in order to generate the best $(t + 1)$ series were determined.

Table 6.10: Generating the best historical $(t + 1)b$ series for the South African PPI and for the U.S.A. PPI

Model specification: $t = 4$; $\lambda = 0.75$							
South African PPI				U.S.A. PPI			
R-squared	0.989	t-prob.	0.000*	R-squared	0.912	t-prob.	0.000*
Adjusted R-squared	0.988			Adjusted R-squared	0.910		
Prob. (F-statistic)	0.000	Std. error	0.014	Prob. (F-statistic)	0.000	Std. error	0.040
Theil (U)	0.184	AIC	1.376	Theil (U)	0.019	AIC	2.413

* Statistically significant at the 5% level.

Source: Compiled by author.

Based on the best R-squared estimate, the lowest standard error estimate, the lowest AIC estimate and the lowest Theil (U) estimate, the following 1-month-ahead inflation expectation series for South Africa and the U.S.A. are reported in Tables 6.11 and 6.12.

Table 6.11: Generating the best 1-month-ahead inflation expectation series $(t + 1)$ for the South African PPI

Model specification: $t = 12$; $\lambda = 0.25$					
R-squared	0.989	t-prob.	0.000*	Historical weight	90%
Adjusted R-squared	0.989	Std. error	0.015	Future weight	10%
Prob. (F-statistic)	0.000	AIC	1.326	Theil (U)	0.144

* Statistically significant at the 5% level.

Source: Compiled by author.

Table 6.12: Generating the best 1-month-ahead inflation expectation series $(t + 1)$ for the U.S.A. PPI

Model specification: $t = 12$; $\lambda = 0.25$					
R-squared	0.878	t-prob.	0.000*	Historical weight	90%
Adjusted R-squared	0.876	Std. error	0.053	Future weight	10%
Prob. (F-statistic)	0.000	AIC	2.886	Theil (U)	0.006

* Statistically significant at the 5% level.

Source: Compiled by author.

According to Table 6.11, the model specification to generate the best $(t + 1)$ series was $t = 12$ and $\lambda = 0.25$, with a weight distribution of 90% to historical values and 10% to future values. This model specification produced the highest R-squared, the lowest standard error and the lowest AIC estimate, and provided the lowest Theil (U) estimate.

In addition, the results reported in Table 6.12 indicate that the best model specification for the U.S.A. PPI was also $t = 12$ and $\lambda = 0.25$, with a weight distribution of 90% to historical values and 10% to future values. This model specification provided the highest R-squared, the lowest standard error and the lowest AIC estimate, and gave the lowest Theil (U) estimate. This leads to the generating of the expected stock returns. The first step was also to generate a $(t + 1)b$ series with the help of the exponential weighting procedure, where the weights assigned were estimated with the help of Equation 5.8 (Section 5.3.2.1.3). The following specifications were evaluated: $\lambda = 0.25$, $\lambda = 0.5$ and $\lambda = 0.75$; and $t = 4$, $t = 6$ and $t = 12$. Each series generated from each specification was regressed on the actual series, and the series with the best R-squared, the lowest standard error, the lowest AIC estimate and the lowest Theil (U) estimate were considered the best $(t + 1)b$ series to use. The results in Tables 6.13 and 6.14 report that the best model specifications for South Africa and the U.S.A. were $t = 4$ and $\lambda = 0.75$.

Table 6.13: Generating the best historical $(t + 1)b$ series for the South African dual-listed stocks

Model specification: $t = 4; \lambda = 0.75$							
South Africa AngloGold Ashanti				South Africa Sappi Limited			
R-squared	0.982	t-prob.	0.000*	R-squared	0.986	t-prob.	0.000*
Adjusted R-squared	0.982			Adjusted R-squared	0.986		
Prob. (F-statistic)	0.000	Std. error	0.009	Prob. (F-statistic)	0.000	Std. error	0.008
Theil (U)	0.001	AIC	6.379	Theil (U)	0.003	AIC	4.025

* Statistically significant at the 5% level.

Source: Compiled by author.

Table 6.14: Generating the best historical $(t + 1)b$ series for the U.S.A. dual-listed stocks

Model specification: $t = 4; \lambda = 0.75$							
U.S.A. AngloGold Ashanti				U.S.A. Sappi Limited			
R-squared	0.978	t-prob.	0.000*	R-squared	0.981	t-prob.	0.000*
Adjusted R-squared	0.978			Adjusted R-squared	0.981		
Prob. (F-statistic)	0.000	Std. error	0.010	Prob. (F-statistic)	0.000	Std. error	0.009
Theil (U)	0.000	AIC	2.743	Theil (U)	0.013	AIC	0.158

* Statistically significant at the 5% level.

Source: Compiled by author.

However, these historical expected inflation figures $(t + 1)b$ were only based on historical data. In order to incorporate uncertainty (future expectations) in present inflation expectations, an EWMA model was formulated (Section 5.3.2.1.3), making use of the same weighting procedure. The next step was to generate the $(t + 1)f$ series with the help of the EWM model and then to generate the 1-month-ahead inflation expectation series $(t + 1)$ by combining the $(t + 1)b$ and the $(t + 1)f$ series. The results in Table 6.15 report that the best model specification¹⁰¹ with the highest R-squared estimate, the lowest standard error, the lowest AIC estimate and the lowest Theil (U) estimate was $t = 6$ and $\lambda = 0.25$, with a weight distribution of 90% to historical values and 10% to future values. This model specification was applicable to the South African AngloGold Ashanti, the South African Sappi Limited, the U.S.A. AngloGold Ashanti and the U.S.A. Sappi Limited dual-listed stocks.

To recapitulate, the most applicable expected inflation rate and stock returns required to implement in the preliminary Chiang and Yang (2007) methodology approach were generated based on the highest R-squared estimate, the lowest standard error, the lowest AIC estimate and the lowest Theil (U) estimate. This leads to the following section, which will discuss the results of Chiang and Yang (2007) methodology as the preliminary model.

¹⁰¹ The results from the other specifications are available on request from the author.

Table 6.15: Generating the best 1-month-ahead expectation series ($t + 1$) for individual South African dual-listed stocks and U.S.A. dual-listed stocks

Model specification: $t = 6; \lambda = 0.25$	R-squared	Adjusted R-squared	t-prob.	Prob. (F-statistic)	Std. error	AIC	Theil (U)	Weight distribution	
South African AngloGold Ashanti	0.971	0.971	0.000*	0.000	0.012	6.843	0.037	Historical weight	90%
								Future weight	10%
U.S.A. AngloGold Ashanti	0.972	0.972	0.000*	0.000	0.012	2.979	0.005	Historical weight	90%
								Future weight	10%
South African Sappi Limited	0.980	0.980	0.000*	0.000	0.010	4.420	0.000	Historical weight	90%
								Future weight	10%
U.S.A. Sappi Limited	0.976	0.976	0.000*	0.000	0.011	0.387	0.001	Historical weight	90%
								Future weight	10%

* Statistically significant at the 5% level.

Source: Compiled by author.

6.2.4.3 The Chiang and Yang (2007) methodology as preliminary model

This section will discuss the results of the estimation of the models discussed in Sections 5.2.4, 5.2.5 and 5.2.6. This section will commence by reporting the results of using the inflation rate and the interest rates as the first two explanatory variables (Section 5.2.4), in an attempt to improve the accuracy of the estimation of the realized future spot exchange rate by introducing other economic fundamental time series.

6.2.4.3.1 Inflation rates and interest rates as explanatory variables

By estimating Equation 2.8, the results reported in Table 6.16 were obtained:

$$s_{t+k} - f_t = v_0 + v_2[(r_t - \Delta p_{t+k}^e) - (r_t^* - \Delta p_{t+k}^{*e})] + \varepsilon_{t+k} \quad (2.8)$$

where:

- 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 intercept;

- v_2 is the real risk-free interest rate differential coefficient;
- ε_{t+k} is the random error;
- Δp_{t+k}^e and Δp_{t+k}^{*e} are the expected inflation rates of South Africa and the U.S.A., respectively; and
- r_t and r_t^* are the South African 91-day Treasury Bill (T-Bill) rates and the U.S.A. 91-day T-Bill rates, respectively.

Table 6.16: Inflation rate and interest rate as explanatory variables (OLS)

Dependent: Difference of $(S_{t+3} - f_t)$				Coefficient	Std. error	t-prob.
Difference of the real-interest rate differential				0.013	0.037	0.726
Intercept (v_0)				0.001	0.012	0.956
R-squared	0.001	Prob. (F-statistic)	0.726			
Adjusted R-squared	-0.004	AIC	-0.558	Durbin Watson		1.620

Source: Compiled by author.

The results in Table 6.16 indicate that the real-interest rate differential was not a statistically significant variable. These results indicate that additional variables may be required in order to improve the explanation of the future premium $(s_{t+3} - f_t)$.

Next, long-run interest rates were introduced, which were incorporated in the form of the expectations hypothesis of the domestic term structure of interest rates (Section 2.3.4.2.4). The constructed variable $[(r_t^L - r_t) - (r_t^{*L} - r_t^*)]$ will be called the long-short spread. By estimating Equation 2.9, the results reported in Table 6.17 were obtained:

$$s_{t+k} - f_t = v_0 + v_3[(r_t^L - r_t) - (r_t^{*L} - r_t^*)] + \varepsilon_{t+k} \quad (2.9)$$

where:

- 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 intercept;
- v_3 is the risk-free, long-short interest rate differential coefficient;
- r_t and r_t^* are the South African 91-day T-Bill rates and the U.S.A. 91-day T-Bill rates, respectively;
- r_t^L and r_t^{L*} are the long-run, ten-year government bond yields rates of South Africa and the U.S.A., respectively; and
- ε_{t+k} is the random error.

Table 6.17: Long-short spread (OLS)

Dependent: Difference of the ($s_{t+3} - f_t$)				Coefficient	Std. error	t-prob.
Difference of the long-short spread				-0.037	0.052	0.480
Intercept (v_0)				0.001	0.012	0.945
R-squared	0.002	Prob. (F-statistic)	0.480			
Adjusted R-squared	-0.002	AIC	-0.559	Durbin Watson		1.619

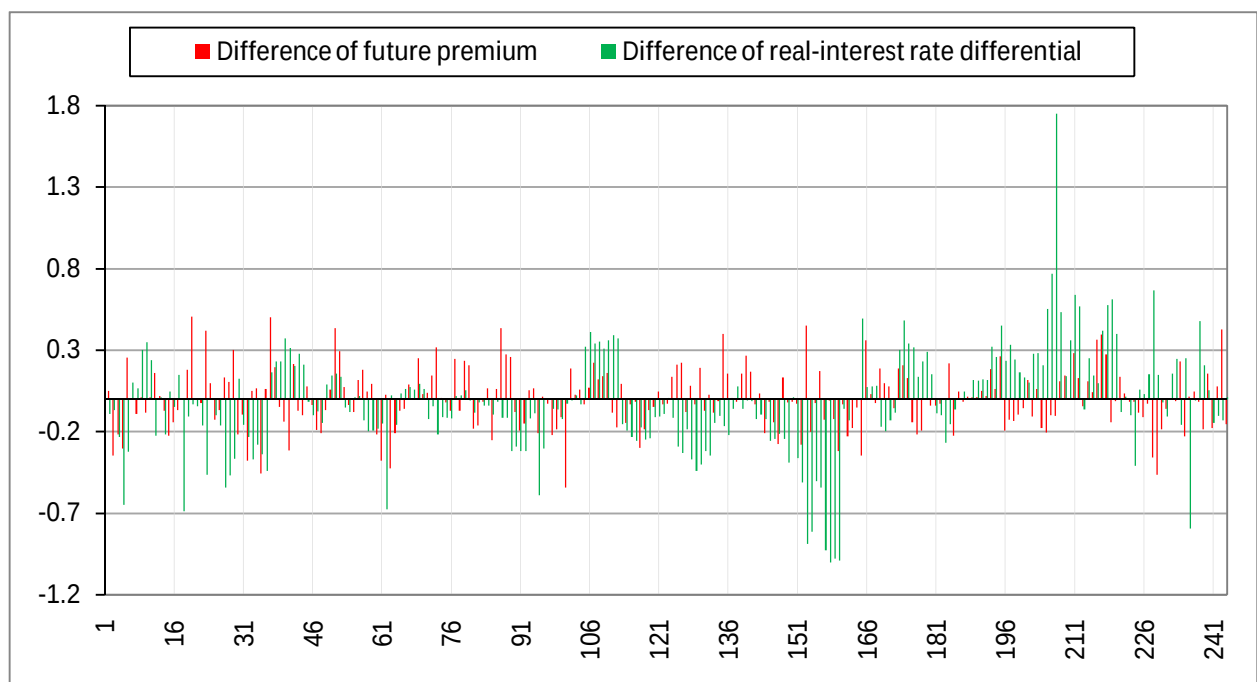
Source: Compiled by author.

The results in Table 6.17 indicate that the use of the long-short spread was not statistically significant and thus failed to explain the future premium ($s_{t+3} - f_t$). In an attempt to improve on the results reported in Tables 6.16 and 6.17, the inverse of the real-interest rate differential was incorporated. The reason for using the inverse of the real-interest rate differential can be explained by Figure 6.1. Figure 6.1 illustrates that the future premium ($s_{t+3} - f_t$) and the real-interest rate differential moves in the opposite direction, implying a inverse relationship.

As indicated in Table 6.18, the inverse of the real-interest rate differential (including short-run interest rates and the inflation rate) and the long-short spread failed to provide a statistically significant explanation of the future premium ($s_{t+3} - f_t$). Owing to a low Durbin Watson statistic, an AR(1) variable was included to eliminate the presence of serial correlation. The inverse of the real-interest rate differential was closer to the 10% significant level than the long-short spread was. This implies that the inverse of the real-interest rate differential may be a

better variable to use in further empirical studies. Although, the long-short spread did not provide significant results, it was included in the multi-variable model (Section 6.2.4.3.3) because it represented the total yield curve, in other words, both short- and long-run interest rates. Furthermore, including the expected stock return variables might still have had a positive influence on the t-probability of the long-short spread coefficient.

Figure 6.1: The relationship between the future premium and the real-interest rate differential



Source: Compiled by author.

Table 6.18: Improved model on interest rates and inflation rates (OLS)

Dependent: Difference of $(S_{t+3} - f_t)$				Coefficient	Std. error	t-prob.
Inverse of the real-interest rate differential				-0.043	0.028	0.122
Difference of the long-short spread				-0.037	0.055	0.500
AR(1)				0.207	0.064	0.001*
Intercept (v_0)				0.002	0.015	0.874
R-squared	0.048	Prob. (F-statistic)	0.009			
Adjusted R-squared	0.036	AIC	-0.586	Durbin Watson		1.975

* Statistically significant at the 5% level.

Source: Compiled by author.

This leads to the following section that will discuss and illustrate the use of stock returns as an explanatory variable of the future spot exchange rate.

6.2.4.3.2 Stock returns as an explanatory variable

In Section 6.2.2.3, it was established that the two dual-listed stocks that were used in this study are the AngloGold Ashanti and the Sappi Limited dual-listed stocks. By estimating Equation 2.10, the results reported in Table 6.19 were obtained for the AngloGold Ashanti stock and those reported in Table 6.20 were obtained for the Sappi Limited dual-listed stock:

$$s_{t+k} - f_t = v_0 + v_4[(R_{t+k}^e - r_t) - (R_{t+k}^{*e} - r_t^*)] + \varepsilon_{t+k} \quad (2.10)$$

where:

- 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 intercept;
- v_4 is the risk-free, annualised return differential coefficient;
- r_t and r_t^* are the South African 91-day T-Bill rates and the U.S.A. 91-day T-Bill rates, respectively;
- R_{t+k}^e and R_{t+k}^{*e} are the expected dual-listed stock returns of South Africa and the U.S.A., respectively; and
- ε_{t+k} is the random error.

Table 6.19: AngloGold Ashanti stock returns as an explanatory variable (OLS)

Dependent: Difference of ($s_{t+3} - f_t$)				Coefficient	Std. error	t-prob.
Difference of the AngloGold Ashanti stock return differential				0.005	0.002	0.010*
Intercept (v_0)				0.000	0.012	0.998
R-squared	0.027	Prob. (F-statistic)	0.010			
Adjusted R-squared	0.023	AIC	-0.585	Durbin Watson		1.503

* Statistically significant at the 5% level.

Source: Compiled by author.

The results in Table 6.19 demonstrate that the AngloGold Ashanti stock return differential was statistically significant at the 5% level. However, the AngloGold Ashanti stock return differential

was only able to explain 3% of the future premium ($s_{t+3} - f_t$). Also, based on the results reported in Table 6.20, the Sappi Limited stock return differential was not statistically significant. This implied that the AngloGold Ashanti dual-listed stocks were a better explanatory variable than the Sappi Limited dual-listed stocks. Therefore, the AngloGold Ashanti dual-listed stocks were included in the multi-variable model (Section 6.2.4.3.3).

Table 6.20: Sappi Limited stock returns as an explanatory variable (OLS)

Dependent: Difference of ($s_{t+3} - f_t$)				Coefficient	Std. error	t-prob.
Difference of the Sappi Limited stock return differential				0.003	0.003	0.197
Intercept (v_0)				0.000	0.012	0.998
R-squared	0.007	Prob. (F-statistic)	0.196			
Adjusted R-squared	0.003	AIC	-0.564	Durbin Watson		1.555

Source: Compiled by author.

This leads to the following section that will report the results of the multi-variable model, as already discussed in Section 5.2.6.

6.2.4.3.3 The multi-variable model

The Chiang and Yang (2007) methodology, which was used as a preliminary model, formulates a linear combination of the International Equity Parity (Section 4.1), the PPP (Section 3.2), the Uncovered Interest Rate Parity (Section 3.3.6), the expectations hypothesis of the domestic term structure of interest rates (Section 2.3.4.2.4) and the equity premium differential (Section 2.3.4.2.5). Owing to a low Durbin Watson statistic, an AR(1) variable was included to eliminate the presence of serial correlation. Intercept dummies^{102,103} were also included to improve the accuracy of the estimation of the multi-variable model. The Chow breakpoint¹⁰⁴ and Cusum test¹⁰⁵ indicated that two dummies were required. Dummy 1 ranged from the second

¹⁰² The intercept dummies used in this empirical study can be linked to historical events, as discussed in Section 6.3.2.2.

¹⁰³ Slope dummies did not provide any statistically significant contribution to this entire study.

¹⁰⁴ The Chow breakpoint test tests whether there is a structural change in all of the equation parameters (QMS, 2007b:170).

¹⁰⁵ The Cusum test finds parameter instability if the cumulative sum of the recursive residuals goes outside the area between the two critical lines (QMS, 2007b:178).

week in July 2006 to the fourth week in May 2008, and Dummy 2 ranged from the second week in August 2007 to the fourth week in May 2008. By estimating Equation 5.2, the results reported in Table 6.21 were obtained.

$$s_{t+3} - f_t = \alpha + \rho[(r_t - \Delta p_{t+k}^e) - (r_t^* - \Delta p_{t+k}^{*e})] + \delta[(R_{t+k}^e - r_t) - (R_{t+k}^{*e} - r_t^*)] + \gamma[(r_t^L - r_t) - (r_t^{*L} - r_t^*)] + \varepsilon_t \quad (5.2)$$

where:

- t is the number of months;
- k is the number of months forecast 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 intercept;
- 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 coefficient;
- Δp_{t+k}^e and Δp_{t+k}^{*e} 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_{t+k}^e and R_{t+k}^{*e} are the expected returns generated from stock indices or from individual resource dual-listed stocks of South Africa and the U.S.A., respectively;
- r_t^L and r_t^{*L} 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.

Table 6.21: The multi-variable model (OLS)

Dependent: Difference of ($S_{t+3} - f_t$)				Coefficient	Std. error	t-prob.
Inverse of the real-interest rate differential				-0.071	0.028	0.012*
Difference of the AngloGold Ashanti stock return differential				0.008	0.002	0.000*
Difference of the long-short spread				-0.041	0.055	0.450
Dummy 1				0.085	0.052	0.104
Dummy 2				-0.072	0.040	0.073**
AR(1)				0.276	0.065	0.000*
Intercept (α)				0.018	0.020	0.374
R-squared	0.120	Prob. (F-statistic)	0.000			
Adjusted R-squared	0.097	AIC	-0.640	Durbin Watson		
				1.965		

* Statistically significant at the 5% level.

** Statistically significant at the 10% level.

Source: Compiled by author.

All the variables, except the long-short spread variable, the intercept, Dummy 1 and Dummy 2, were statistically significant at the 5% level. However, all these variables were only able to explain 12% of the future premium ($s_{t+3} - f_t$). These results, therefore, demonstrate that the economic variables proposed by the Chiang and Yang (2007) methodology were unable to estimate the realized future spot exchange rate. To determine the manner in which to improve the multi-variable model, this study returned to the economic theories on which the multi-variable model was built. Examining each of the underlying economic theories individually provided more insight regarding the explanatory significance of each economic fundamental and, therefore, gave guidance on the manner in which to improve the multi-variable model. The economic theories that were investigated were the PPP (Section 3.2), the Uncovered Interest Rate Parity (Section 3.3.6), the Covered Interest Rate Parity (Section 3.3.3) and the Fisher effect (Section 3.3.2.1).

6.2.5 A re-examination of the components of the Chiang and Yang (2007) methodology

Two approaches were followed: a co-integration (Section 5.4.4.2) estimation approach and an OLS estimation approach. Each approach was used to examine the PPP theory (Section 3.2), the short- and long-run Fisher effect (Section 3.3.2.1), the long- and short-run Covered Interest Rate Parity (Section 3.3.3), Uncovered Interest Rate Parity (Section 3.3.6) and the equity

premium hypothesis (Section 2.3.4.2.5). This section will report the results of the Johansen (1991) co-integration estimation approach (Section 6.2.5.1) on each economic theory, which will be followed by the results of the OLS estimation approach (Section 6.2.5.2). These results determined which economic time series were to be used to improve the accuracy of the estimation of the realized future spot exchange rate.

6.2.5.1 The co-integration estimation approach

Before the results of the OLS estimation approach or of the co-integration estimation approach can be reported, the formulation of each economic theory must first be re-examined to determine the relationship incorporated in each economic theory. The *ex post* PPP theory (Equation 3.7), the Fisher effect (Equation 6.1), the Covered Interest Rate Parity (Equation 6.2), the Uncovered Interest Rate Parity (Equation 6.3) theories and the equity premium hypothesis¹⁰⁶ (Equation 6.4) were formulated by the following equations:

$$s_t = \pi_t^e - \pi_t^{e*} \quad (3.7)$$

$$i_t - i_t^* = \pi_t^e - \pi_t^{e*} \quad (6.1)$$

$$(f_t - s_t) = i_t - i_t^* \quad (6.2)$$

$$s_t^e = i_t - i_t^* \quad (6.3)$$

$$s_{t+3} = R_{t+k}^e - R_{t+k}^{*e} \quad (6.4)$$

where:

- s_t is the spot exchange rate at time t ;
- π_t^e is the domestic expected inflation rate at time t ;
- π_t^{e*} is the foreign expected inflation rate at time t ;
- i_t is the domestic short-run nominal interest rate at time t ;
- i_t^* is the foreign short-run nominal interest rate at time t ;

¹⁰⁶ Although the AngloGold Ashanti and the Sappi Limited expected stock return differential are $I(0)$ and the ZAR/USD spot exchange rate at time $t + 3$ is $I(1)$, these co-integration tests were only used as additional information, helping with further investigation in order to construct the best exchange rate model. However, it was still important to investigate the co-integration relationship in level format, whereas investors' perspectives are in level format.

- f_t is the forward exchange rate at time t ;
- s_t^e is the expected/realized future spot exchange rate at time t ;
- s_{t+3} is the ZAR/USD spot exchange rate at time $t + 3$;
- δ is the risk-free stock return differential coefficient;
- t is the number of months;
- k is the number of months forecast ahead; and
- R_{t+k}^e and R_{t+k}^{*e} are the expected dual-listed stock returns or the expected stock returns generated from the stock indices of South Africa and the U.S.A., respectively.

In each co-integration model, the maximum number of co-integration relationships (r) that could be present was equal or smaller than the number of variables present in each economic theory. If the Trace statistic and the maximum Eigenvalue statistic¹⁰⁷ were greater than the critical value than the current hypothesis was rejected, however, if the Trace statistic and the maximum Eigenvalue statistic were smaller than the critical value than the current hypothesis was not rejected. The following hypotheses were tested:

$$H_0: r = 0 \text{ (no co-integration relationships present)} \quad (6.5)$$

$$H_1: r \leq 1 \text{ (one co-integration relationship present)} \quad (6.6)$$

$$H_2: r \leq 2 \text{ (two co-integration relationships present)} \quad (6.7)$$

The results reported in the following tables demonstrate that there were no co-integration relationships between the expected inflation rates and the current ZAR/USD exchange rate (Tables 6.22 and 6.23), between the expected inflation rates and long-run interest rates (Tables 6.26 and 6.27), and between long-run interest rates and the spot exchange rate realized in

¹⁰⁷ See Section 5.4.4.2 for a discussion on the Trace statistic and the maximum Eigenvalue statistic.

3 months' time (Tables 6.34 and 6.35). In each of these co-integration models, the Trace statistic and the maximum Eigenvalue statistic were smaller than the critical value at the H_0 hypothesis, implying that the H_0 hypothesis could not be rejected and thus zero co-integration relationships were present. Therefore, the *ex post* PPP theory, the long-run Fisher effect and the long-run Uncovered Interest Rate Parity theory failed to hold between South Africa and the U.S.A.

However, the results demonstrate that there was a co-integration relationship between short-run interest rates and the expected inflation rates (Tables 6.24 and 6.25), between the short-run interest rates and the present premium (Tables 6.28 and 6.29), between the long-run interest rates and the present premium (Tables 6.30 and 6.31), between the short-run interest rates and the spot exchange rate realized over 3 months (Tables 6.32 and 6.33), between the AngloGold Ashanti stock return differential and the spot exchange rate realized over 3 months (Tables 6.36 and 6.37), and between the Sappi Limited return differential and the spot exchange rate realized over 3 months (Tables 6.38 and 6.39). In each of these co-integration models, the Trace statistic (Tr) and the maximum Eigenvalue statistic (L-max) were greater than the critical value at the H_0 hypothesis, implying that the H_0 hypothesis could be rejected but not the H_1 hypothesis, which stated that there was one co-integration relationship present. These results, therefore, found that the short-run Fisher effect, the short- and long-run Covered Interest Rate Parity theory and the short-run Uncovered Interest Rate Parity theory do hold between South Africa and the U.S.A.

Table 6.22: The *ex post* PPP theory (Tr statistic)

<u>Hypothesized</u>	<u>Trace statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	14.553	25.872	0.612
$H_1: r \leq 1$	4.864	12.518	0.616

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

Source: Compiled by author.

Table 6.23: The ex post PPP theory (L-max statistic)

<u>Hypothesized</u>	<u>L-max statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	9.689	19.387	0.652
$H_1: r \leq 1$	4.864	12.518	0.616

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

Source: Compiled by author.

Table 6.24: The short-run Fisher effect (Tr statistic)

<u>Hypothesized</u>	<u>Trace statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	33.637	25.872	0.004*
$H_1: r \leq 1$	8.517	12.518	0.212

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.25: The short-run Fisher effect (L-max statistic)

<u>Hypothesized</u>	<u>L-max statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	25.120	19.387	0.007*
$H_1: r \leq 1$	8.517	12.518	0.212

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.26: The long-run Fisher effect (Tr statistic)

<u>Hypothesized</u>	<u>Trace statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	15.688	25.872	0.518
$H_1: r \leq 1$	5.562	12.518	0.518

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

Source: Compiled by author.

Table 6.27: The long-run Fisher effect (L-max statistic)

<u>Hypothesized</u>	<u>L-max statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	10.126	19.387	0.605
$H_1: r \leq 1$	5.562	12.518	0.518

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

Source: Compiled by author.

Table 6.28: The short-run Covered Interest Rate Parity theory (Tr statistic)

<u>Hypothesized</u>	<u>Trace statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	51.540	25.872	0.000*
$H_1: r \leq 1$	10.021	12.518	0.126

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.29: The short-run Covered Interest Rate Parity theory (L-max statistic)

<u>Hypothesized</u>	<u>L-max statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	41.519	19.387	0.000*
$H_1: r \leq 1$	10.021	12.518	0.126

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.30: The long-run Covered Interest Rate Parity theory (Tr statistic)

<u>Hypothesized</u>	<u>Trace statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	42.571	25.872	0.000*
$H_1: r \leq 1$	5.251	12.518	0.561

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.31: The long-run Covered Interest Rate Parity theory (L-max statistic)

<u>Hypothesized</u>	<u>L-max statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	37.327	19.387	0.000*
$H_1: r \leq 1$	5.251	12.518	0.561

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.32: The short-run Uncovered Interest Rate Parity theory (Tr statistic)

<u>Hypothesized</u>	<u>Trace statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	36.962	25.872	0.001*
$H_1: r \leq 1$	11.576	12.518	0.071

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.33: The short-run Uncovered Interest Rate Parity theory (L-max statistic)

<u>Hypothesized</u>	<u>L-max statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	25.386	19.387	0.006*
$H_1: r \leq 1$	11.576	12.518	0.071

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.34: The long-run Uncovered Interest Rate Parity theory (Tr statistic)

<u>Hypothesized</u>	<u>Trace statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	22.952	25.872	0.111
$H_1: r \leq 1$	7.205	12.517	0.324

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

Source: Compiled by author.

Table 6.35: The long-run Uncovered Interest Rate Parity theory (L-max statistic)

<u>Hypothesized</u>	<u>L-max statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	15.747	19.387	0.156
$H_1: r \leq 1$	7.205	12.518	0.324

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 2 lag interval.

Source: Compiled by author.

Table 6.36: The equity premium hypothesis – AngloGold Ashanti (Tr statistic)

<u>Hypothesized</u>	<u>Trace statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	74.591	25.872	0.000*
$H_1: r \leq 1$	12.369	12.518	0.053

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 1 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.37: The equity premium hypothesis – AngloGold Ashanti (L-max statistic)

<u>Hypothesized</u>	<u>L-max statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	62.222	19.387	0.000*
$H_1: r \leq 1$	12.369	12.518	0.053

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 1 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.38: The equity premium hypothesis – Sappi Limited (Tr statistic)

<u>Hypothesized</u>	<u>Trace statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	54.776	25.872	0.000*
$H_1: r \leq 1$	11.742	12.518	0.067

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 4 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

Table 6.39: The equity premium hypothesis – Sappi Limited (L-max statistic)

<u>Hypothesized</u>	<u>L-max statistic</u>	<u>0.5 critical value</u>	<u>t-prob.</u>
$H_0: r = 0$	43.034	19.387	0.000*
$H_1: r \leq 1$	11.742	12.518	0.067

Intercept and trend was allowed in co-integration equation, but not in VAR, with a 4 lag interval.

* Reject the hypothesis.

Source: Compiled by author.

To summarise, by following a co-integration estimation approach, it was established that all the economic theories hold, except the *ex post* PPP theory, the long-run Fisher effect and the long-run Uncovered Interest Rate Parity theory. In order to improve the investigation regarding the validity of each economic theory the OLS estimation approach was followed, the results of which will be reported in the following section.

6.2.5.2 The Ordinary Least Squares estimation approach

This section will first investigate the PPP theory (Section 6.2.5.2.1), which will be followed by the Fisher effect in Section 6.2.5.2.2, the Covered Interest Rate Parity in Section 6.2.5.2.3, the Uncovered Interest Rate Parity in Section 6.2.5.2.4, and the equity premium hypothesis in Section 6.2.5.2.5.

6.2.5.2.1 The Purchasing Power Parity theory

This section starts by investigating the *ex post* PPP theory. The results reported in Table 6.40 illustrate that expected inflation rate does not provide a statistically significant explanation of the current ZAR/USD spot exchange rate. These results, therefore, demonstrate that the *ex post* PPP theory does not hold between South African and the U.S.A. In addition, actual inflation rates were used instead of expected inflation rates and the following results were obtained, as reported in Table 6.41.

Table 6.40: The *ex post* PPP theory

Dependent: Difference of S_t				Coefficient	Std. error	t-prob.
Difference of the expected inflation rate differential				0.061	0.035	0.078**
Intercept				0.000	0.009	0.999
R-squared	0.013	Prob. (F-statistic)	0.078			
Adjusted R-squared	0.009	AIC	-1.156	Durbin Watson		1.604

** Statistically significant at the 10% level.

Source: Compiled by author.

The evidence indicated that the actual inflation rate differential, which was lagged with 2 periods¹⁰⁸, had a statistically significant impact on the current ZAR/USD spot exchange rate. These results proved that actual inflation rates may provide better results than expected inflation rates.

Table 6.41: The PPP theory

Dependent: Difference of S_t				Coefficient	Std. error	t-prob.
Difference of the actual inflation rate differential (-2)				0.069	0.020	0.001*
Intercept				-0.001	0.008	0.874
R-squared	0.047	Prob. (F-statistic)	0.001			
Adjusted R-squared	0.043	AIC	-1.211	Durbin Watson		1.652

* Statistically significant at the 5% level.

Source: Compiled by author.

¹⁰⁸ Note that upcoming models consist of lagged variables. Although the lags vary from each model, each specific lag was carefully considered in order to make sense in economic theory. For example, some lags illustrate the cyclical nature of that specific variable. These lagged variables also provided the most statistically significant results.

Owing to the shortcoming of using the mechanical forward exchange rate, as discussed in Section 1.2, this study attempted to improve the accuracy of the estimation of the realized spot exchange rate. Therefore, the actual inflation rates were tested on the ZAR/USD spot exchange rate realized over 3 months, as the new dependent variable, as reported in Table 6.42.

Table 6.42: The *ex ante* PPP theory

Dependent: Difference of S_{t+3}				<u>Coefficient</u>	<u>Std. error</u>	<u>t-prob.</u>
Difference of actual inflation rate differential (-1)				-0.024	0.021	0.238
Intercept				0.002	0.009	0.837
R-squared	0.006	Prob. (F-statistic)	0.238			
Adjusted R-squared	0.002	AIC	-1.140	Durbin Watson		1.598

Source: Compiled by author.

The results in Table 6.42 demonstrate that the actual inflation rate differential coefficient lagged with 1 period provided an insignificant explanation of the ZAR/USD spot exchange rate realized over 3 months. These results further implied that the traditional approach of investigating the relationship between inflation rate differentials and the spot exchange rate may provide inconclusive results. This, therefore, suggested the possibility of using South African and U.S.A. inflation rates individually when modelling an exchange rate model, compared to the traditional approach of using the inflation rate differentials. The results from this section also confirmed the results from Section 6.2.5.1, which reported that the PPP theory failed to hold between South African and the U.S.A.

The next economic fundamental that was re-examined included interest rates and the relationship between inflation rates and interest rates. This leads to the following section that will investigate the long- and the short-run Fisher effect.

6.2.5.2.2 The Fisher effect

This section starts by examining the short-run Fisher effect, which is followed by the long-run Fisher effect. The results reported in Tables 6.43 and 6.44 illustrate the relationship between

expected inflation rates and the short-run interest rates,¹⁰⁹ and the relationship between actual inflation rates and the short-run interest rates, respectively. The results reported in Table 6.43 demonstrate that the expected inflation rate differential lagged with 2 periods has an insignificant relationship with the short-run interest rate differential. Based on previous results that reported that actual inflation rates may provide better results than expected inflation rates, the relationship between actual inflation rates and short-run interest rates (short-run Fisher effect) and the relationship between actual inflation rates and long-run interest rates (long-run Fisher effect) were also investigated. The results reported in Table 6.44 demonstrate that the actual inflation rate differential coefficient lagged with 3 periods provided a weak insignificant explanation of short-run interest rates. These results contradicted the results reported in Section 6.2.5.1 that the short-run Fisher effect does hold.

Table 6.43: The short-run Fisher effect (expected inflation)

Dependent: Difference of short-run interest rate differential				Coefficient	Std. error	t-prob.
Difference of the expected inflation rate differential (-2)				-0.043	0.050	0.390
Intercept				-0.011	0.013	0.382
R-squared	0.003	Prob. (F-statistic)	0.390			
Adjusted R-squared	-0.001	AIC	-0.429	Durbin Watson		
				1.334		

Source: Compiled by author.

Table 6.44: The short-run Fisher effect (actual inflation)

Dependent: Difference of short-run interest rate differential				Coefficient	Std. error	t-prob.
Difference of actual inflation rate differential (-3)				0.033	0.030	0.263
Intercept				-0.012	0.013	0.355
R-squared	0.005	Prob. (F-statistic)	0.263			
Adjusted R-squared	0.001	AIC	-0.431	Durbin Watson		
				1.291		

Source: Compiled by author.

The long-run Fisher effect was also investigated. The results reported in Tables 6.45 and 6.46 were obtained by estimating Equation 6.1 with long-run interest rates (10-year government bond yield rates). The results reported in Tables 6.45 and 6.46 demonstrate that the expected inflation rate and the actual inflation rate, lagged with 2 periods, provided a weak significant

¹⁰⁹ 91-day T-Bill rates were used for short-run interest rates.

explanation of the long-run interest rate differential. These results justified the results given in Section 6.2.5.1, which reported that the long-run Fisher effect failed to hold.

Table 6.45: The long-run Fisher effect (expected inflation)

Dependent: Difference of the long-run interest rate differential				Coefficient	Std. error	t-prob.
Difference of the expected inflation rate differential				0.069	0.041	0.091**
Intercept				0.001	0.010	0.938
R-squared	0.012	Prob. (F-statistic)	0.091			
Adjusted R-squared	0.008	AIC	-0.828	Durbin Watson		1.479

** Statistically significant at the 10% level.

Source: Compiled by author.

Table 6.46: The long-run Fisher effect (actual inflation)

Dependent: Difference of long-run interest rate differential				Coefficient	Std. error	t-prob.
Difference of actual inflation rate differential (+2)				0.040	0.024	0.099**
Intercept				0.001	0.010	0.939
R-squared	0.011	Prob. (F-statistic)	0.099			
Adjusted R-squared	0.007	AIC	-0.820	Durbin Watson		1.479

** Statistically significant at the 10% level.

Source: Compiled by author.

In summary, actual inflation rates may have proven to be a more dominant variable¹¹⁰ than the expected inflation rates in the PPP theory and the Fisher effect, although the PPP theory and the short- and long-run Fisher effect still failed to hold between South African and the U.S.A., based on the results of the OLS estimation approach. This leads to the following section, which will re-examine the short- and long-run Covered Interest Rate Parity theory.

6.2.5.2.3 The Covered Interest Rate Parity theory

The results demonstrate that the short-run interest rate differential can provide a significant explanation of the present premium ($f_t - s_t$). These results, therefore, demonstrate that the short-run Covered Interest Rate Parity may hold between South Africa and the U.S.A., which confirms the results reported in Section 6.2.5.1.

¹¹⁰ Although the t-probability and AIC statistic are very much alike, is the standard error of actual inflation much lower than that of the expected inflation, thus indicating a better fit.

Table 6.47: The short-run Covered Interest Rate Parity theory

Dependent: Difference of ($f_t - s_t$)				Coefficient	Std. error	t-prob.
Difference of the short-run interest rate differential				0.009	0.001	0.000*
Intercept				0.000	0.000	0.765
R-squared	0.170	Prob. (F-statistic)	0.000			
Adjusted R-squared	0.167	AIC	-8.339	Durbin Watson		1.609

* Statistically significant at the 5% level.

Source: Compiled by author.

However, owing to the shortcoming of using the mechanical forward exchange rate, this study directed the focus to estimating the spot exchange rate realized in 3 months' time. By substituting the forward exchange rate with the spot exchange rate realized in 3 months' time, the results reported in Table 6.48 were obtained. The results demonstrate that the short-run interest rates provided a significant, but weak explanation of the ($S_{t+3} - S_t$) coefficient. These results indicated that the short-run interest rate differential may not be an appropriate explanatory variable to use when modelling the exchange rate. Furthermore, an alternative approach would be to test the explanatory impact of the long-run interest rate differential and then short- and long-run interest rates as individual explanatory variables.

Table 6.48: The adjusted short-run Covered Interest Rate Parity theory

Dependent: Difference of ($S_{t+3} - S_t$)				Coefficient	Std. error	t-prob.
Difference of the short-run interest rate differential				-0.102	0.060	0.090**
Intercept				-0.001	0.012	0.925
R-squared	0.012	Prob. (F-statistic)	0.090			
Adjusted R-squared	0.008	AIC	-0.587	Durbin Watson		1.596

** Statistically significant at the 10% level.

Source: Compiled by author.

In addition to the results reported for the short-run, the results regarding the tangibility of the long-run Covered Interest Rate Parity theory will be reported. The results reported in Table 6.49 demonstrate that the long-run interest rate differential was able to explain only 12% of the present premium ($f_t - s_t$), although the results reported in Section 6.2.5.1 indicated that there is a co-integration relationship between the present premium ($f_t - s_t$) and the short-run interest rates.

Table 6.49: The long-run Covered Interest Rate Parity theory

Dependent: Difference of ($f_t - s_t$)				Coefficient	Std. error	t-prob.
Difference of the long-run interest rate differential				0.009	0.002	0.000*
Intercept				0.000	0.000	0.434
R-squared	0.120	Prob. (F-statistic)	0.000			
Adjusted R-squared	0.117	AIC	-8.281	Durbin Watson		1.445

* Statistically significant at the 5% level.

Source: Compiled by author.

This leads to the next section that will report the results on the short- and long-run Uncovered Interest Rate Parity theory. For this theory, the spot exchange rate realized in 3 months' time as the dependent variable was investigated instead of the forward exchange rate.

6.2.5.2.4 The Uncovered Interest Rate Parity theory

The results reported in Table 6.50 demonstrate the short-run interest rate differential failed to explain the spot exchange rate realized in 3 months' time, which contradicted the results reported in Section 6.2.5.1 that there is a co-integration relationship between the short-run interest rates and the spot exchange rate realized in 3 months' time. Also, the results reported in Table 6.51 demonstrate that there was no relationship between the spot exchange rate realized in 3 months' time and the long-run interest rate differential, which confirmed the results reported in Section 6.2.5.1. These results, therefore, demonstrate that the Uncovered Interest Rate Parity theory failed to hold between South Africa and the U.S.A. over the long-run and the short-run, based on the OLS estimation approach.

Table 6.50: The short-run Uncovered Interest Rate Parity theory

Dependent: Difference of S_{t+3}				Coefficient	Std. error	t-prob.
Difference of the short-run interest rate differential				0.007	0.045	0.884
Intercept				0.001	0.009	0.894
R-squared	0.000	Prob. (F-statistic)	0.884			
Adjusted R-squared	-0.004	AIC	-1.138	Durbin Watson		1.605

Source: Compiled by author.

Table 6.51: The long-run Uncovered Interest Rate Parity theory

Dependent: Difference of S_{t+3}				<u>Coefficient</u>	<u>Std. error</u>	<u>t-prob.</u>
Difference of the long-run interest rate differential				-0.007	0.055	0.899
Intercept				0.001	0.009	0.899
R-squared	0.000	Prob. (F-statistic)	0.899			
Adjusted R-squared	-0.004	AIC	-1.138	Durbin Watson		1.602

Source: Compiled by author.

Further investigation was required to confirm the weak explanatory power of both the short- and long-run interest rate differentials. An additional OLS model was estimated with the short-run interest rate differential lagged with 3 periods and the long-run interest rate differential lagged with 1 period (Table 6.52). The Chow breakpoint test and the Cusum test also indicated that intercept dummies were needed. Dummy 1 spanned from the third week in July 2005 to the fourth week in May 2008, and Dummy 2 spanned from the second week in July 2006 to the fourth week in May 2008.

The results reported in Table 6.52 demonstrate that combining the short- and the long-run interest rate differential would provide an enhanced explanation of the spot exchange rate realized in 3 months' time. However, the long-run interest rates were insignificant, whereas the short-run interest rates were statistically significant at the 10% level. These results, therefore, confirmed that the use of interest rate differentials may provide inconclusive results. An alternative approach would be to use short- and long-run interest rates individually when modelling an exchange rate model. Although, the results reported in Table 6.18 demonstrated that the inverse of the real interest rate differential may improve the estimating abilities of an exchange rate model. These findings were revisited in the modelling of an improved exchange rate model after all the economic theories were re-examined. This leads to the final economic theory that will be examined in the following section, the equity premium hypothesis.

Table 6.52: The adjusted Uncovered Interest Rate Parity theory

Dependent: Difference of S_{t+3}				Coefficient	Std. error	t-prob.
Difference of short-run interest rate differential (-3)				0.086	0.049	0.082**
Difference of long-run interest rate differential (-1)				0.056	0.061	0.361
Dummy 1				0.033	0.029	0.261
Dummy 2				-0.044	0.030	0.145
AR (1)				0.189	0.064	0.004*
Intercept				0.000	0.017	0.982
R-squared	0.062	Prob. (F-statistic)	0.010			
Adjusted R-squared	0.042	AIC	-1.137	Durbin Watson		1.962

* Statistically significant at the 5% level.

** Statistically significant at the 10% level.

Source: Compiled by author.

6.2.5.2.5 The equity premium hypothesis

The equity premium hypothesis states that there is a relationship between the exchange rate and the expected stock returns (Section 2.3.4.2.5). As reported in Section 6.2.4.3.2 evidence were already obtained of the weak explanatory power of the AngloGold Ashanti stock return differential (3%) and the Sappi Limited stock return differential (0.7%). However, these results were obtained using the future premium $(s_{t+3} - f_t)$, as the dependent variable. This study has already argued that the forward exchange rate is a mechanically variable, which is not based on economic fundamentals. One of the research objectives of this study is to seek to improve the accuracy of the estimation of the realized spot exchange rate. Therefore, all the different proxies introduced in this study to incorporate the interaction of the international financial market (Section 5.4) were investigated as explanatory variables of the spot exchange rate realized in 3 months' time.

A stock return differential (Equation 6.8), an ICAPM series (Equation 4.12) and a speed of adjustment series (Equation 5.28) were generated for the AngloGold Ashanti and the Sappi Limited dual-listed stocks as proxies for the interaction between the JSE and the NYSE. The following equations were generated:

$$s_{t+3} = \alpha + \delta[(R_{t+k}^e - r_t) - (R_{t+k}^{*e} - r_t^*)] + \varepsilon_t \quad (6.8)$$

$$R - F = \alpha + \beta_1(M - F) + \beta_2(X - F) + \varepsilon_t \quad (4.12)$$

$$\pi = Y_{t-1} - \frac{\alpha_0}{1-\alpha_1} - \frac{\gamma_0+\gamma_1}{1-\alpha_1} X_{t-1} \quad (5.28)$$

where:

- t is the number of months;
- k is the number of months forecast ahead;
- α is the intercept;
- s_{t+3} is the spot ZAR/USD exchange rate at time $t + 3$;
- δ is the risk-free stock return differential coefficient;
- ε_t is the random error at time t ;
- 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_{t+k}^e and R_{t+k}^{*e} are the expected dual-listed stock returns or the expected stock returns generated from the stock indices of South Africa and the U.S.A., respectively;
- R represents the expected returns of a domestic stock or portfolio;
- F represents the risk-free asset return;
- M represents the global market return;
- X represents the FX rate;
- β_1 and β_2 represent the coefficients;
- γ_0 denotes the short-run effect (impact multiplier) of Y_t after a change in X_t ;
- $\frac{\gamma_0+\gamma_1}{1-\alpha_1}$ denotes the long-run elasticity between X and Y ;
- it is assumed that $\alpha_1 < 1$ in order for the short-run model to convert to a long-run solution;
- and
- $(1 - \alpha_1)$ or π is the speed of adjustment needed (feedback effect or adjustment effect) in the case of a disequilibrium.

The results reported in Tables 6.53 and 6.54 demonstrate that both the AngloGold Ashanti and Sappi Limited stock return differentials provided a weak and insignificant explanation of the spot exchange rate realized in 3 months' time. The Sappi Limited stock return differential provided the best explanation and had the lowest t-probability.

Table 6.53: The AngloGold Ashanti stock return differential

Dependent: Difference of S_{t+3}				Coefficient	Std. error	t-prob.
Difference of the AngloGold Ashanti expected stock return differential				-0.001	0.002	0.440
Intercept (α)				0.001	0.009	0.894
R-squared	0.002	Prob. (F-statistic)	0.440			
Adjusted R-squared	-0.002	AIC	-1.140	Durbin Watson		1.613

Source: Compiled by author.

Table 6.54: The Sappi Limited stock return differential

Dependent: Difference of S_{t+3}				Coefficient	Std. error	t-prob.
Difference of the Sappi Limited expected stock return differential				-0.003	0.002	0.116
Intercept (α)				0.001	0.009	0.878
R-squared	0.010	Prob. (F-statistic)	0.116			
Adjusted R-squared	0.006	AIC	-1.148	Durbin Watson		1.612

Source: Compiled by author.

The ICAPM series were already stationary, thus no compensation for non-stationarity was needed. The results reported in Tables 6.55 and 6.56 demonstrate that both the AngloGold Ashanti and the Sappi Limited ICAPM variables failed to provide a significant explanation of the spot exchange rate realized in 3 months' time, although, the Sappi Limited ICAPM provided the best results compared to the AngloGold Ashanti ICAPM.

Table 6.55: The AngloGold Ashanti ICAPM

Dependent: Difference of S_{t+3}				Coefficient	Std. error	t-prob.
AngloGold Ashanti ICAPM				0.010	0.023	0.653
Intercept (α)				0.016	0.034	0.641
R-squared	0.001	Prob. (F-statistic)	0.653			
Adjusted R-squared	-0.003	AIC	-1.138	Durbin Watson		1.603

Source: Compiled by author.

Table 6.56: The Sappi Limited ICAPM

Dependent: Difference of S_{t+3}				Coefficient	Std. error	t-prob.
Sappi Limited ICAPM				0.031	0.022	0.166
Intercept (α)				0.044	0.032	0.171
R-squared	0.008	Prob. (F-statistic)	0.166			
Adjusted R-squared	0.004	AIC	-1.146	Durbin Watson		1.623

Source: Compiled by author.

The speed of adjustment series were also already stationary, thus no compensation from non-stationarity was needed¹¹¹. The results reported in Tables 6.57 and 6.58 demonstrate that none of the speed of adjustment series was statistically significant, but the AngloGold Ashanti Speed provided the best explanation (0.7%) of the spot exchange rate realized in 3 months' time.

Table 6.57: The AngloGold Ashanti speed of adjustment series

Dependent: Difference of S_{t+3}				Coefficient	Std. error	t-prob.
AngloGold Ashanti speed of adjustment series				-0.025	0.021	0.231
Intercept				0.005	0.009	0.562
R-squared	0.007	Prob. (F-statistic)	0.231			
Adjusted R-squared	0.002	AIC	-1.232	Durbin Watson		1.609

Source: Compiled by author.

Table 6.58: The Sappi Limited speed of adjustment series

Dependent: Difference of S_{t+3}				Coefficient	Std. error	t-prob.
Sappi Limited speed of adjustment series				-0.027	0.043	0.523
Intercept				0.003	0.009	0.730
R-squared	0.002	Prob. (F-statistic)	0.523			
Adjusted R-squared	-0.003	AIC	-1.126	Durbin Watson		1.618

Source: Compiled by author.

To summarise, by re-examining all the economic theories¹¹² on which the Chiang and Yang (2007) methodology is based, additional knowledge was gained on the manner in which to improve the estimation of the realized spot exchange rate. From the PPP theory, the Fisher effect, the Covered Interest Rate Parity theory and the Uncovered Interest Rate Parity theory, it

¹¹¹ See Table 20 in the appendix for the ADF unit root test results.

¹¹² These economic theories are the PPP theory (Section 6.2.5.2.1), the short- and long-run Fisher effect (Section 6.2.5.2.2), the long- and short-run Covered Interest Rate Parity theory (Section 6.2.5.2.3), Uncovered Interest Rate Parity theory (Section 6.2.5.2.4) and the equity premium hypothesis (Section 6.2.5.2.5).

was found that actual inflation rates and the short-run interest rates provided the best results. However, further evidence also suggested that including these variables individually may improve the accuracy of the estimation of the realized spot exchange rate. Also, the equity premium hypothesis indicated that the Sappi Limited stock return differential, the AngloGold Ashanti speed of adjustment series, and the Sappi Limited ICAPM best explain the realized spot exchange rate. This leads to the following section, which will report on the estimation of an improved exchange rate model based on the previous results.

6.2.5.2.6 The improved multi-variable model

The results reported in Table 6.18 demonstrate that the inverse of the real interest rate differential may improve the accuracy of the estimation of an exchange rate model. Also, all the Sappi Limited proxies provided insignificant results; thus, only AngloGold Ashanti proxies were 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, as reported in Sections 6.2.5.2 and 6.2.5.2.4, it was still included in an attempt to include long- and short-run interest rates. However, the long-run interest rate differential still provided insignificant results and was eliminated from the model.

Furthermore, the Chow breakpoint test and the Cusum test indicated that there may be structural breaks, which required intercept dummies. Dummy 1 spanned from the first week in July 2006 to the fourth week in May 2008, Dummy 2 spanned from the second week in July 2006 to the fourth week in May 2008, and Dummy 3 spanned from the first week in February 2006 to the third week in April 2006. The current spot exchange rate was also included as an explanatory variable because all the previous evidence implied that the flawed manner of calculating the forward exchange rate only considered the present spot exchange rate and a small carry cost. The current spot exchange rate also had a significant impact on the improved multi-variable model. Furthermore, the NEER was examined and included as an additional possible explanatory variable, but failed to provide a statistically significant contribution and

was, therefore, removed from the improved multi-variable model. The improved results are reported in Table 6.59.

The results reported in Table 6.59 demonstrate that none of the variables were insignificant, except for the actual inflation rate differential and the AngloGold Ashanti ICAPM variable, and were able to explain 19% of the realized spot exchange rate. The actual inflation rate differential, the inverse of the real interest rate differential and the AngloGold Ashanti stock return differential were lagged with one period. The AngloGold Ashanti ICAPM was also lagged with 2 periods, while the AngloGold Ashanti speed of adjustment variable was lagged with 6 periods. All the variables had a positive relationship with the realized spot exchange rate, except the actual inflation rate differential, Dummy 2, the AngloGold Ashanti ICAPM variable, and the Anglogold Ashanti stock return differential variable. However, including more than one AngloGold Ashanti proxy variable into a model may have led to a decrease in degrees of freedom. Thus, an alternative was to generate an AngloGold Ashanti principal component¹¹³, consisting of the AngloGold Ashanti stock return differential, the AngloGold Ashanti speed of adjustment proxy and the AngloGold Ashanti ICAPM proxy.

Table 6.59: Improved multi-variable model

Dependent: Difference of S_{t+3}				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)				0.052	0.021	0.014*
Difference of the AngloGold Ashanti expected stock return differential (-1)				-0.005	0.002	0.036*
Dummy 1				0.363	0.130	0.006*
Dummy 2				-0.351	0.133	0.009*
Dummy 3				0.096	0.044	0.032*
AngloGold Ashanti ICAPM (-2)				-0.054	0.035	0.126
AngloGold Ashanti speed of adjustment series(-6)				0.044	0.019	0.025*
AR(1)				0.154	0.072	0.034*
Intercept				-0.085	0.050	0.087**
R-squared	0.194	Prob. (F-statistic)	0.000			
Adjusted R-squared	0.153	AIC	-1.370	Durbin Watson		
				1.984		

* Statistically significant at the 5% level.

** Statistically significant at the 10% level.

Source: Compiled by author.

¹¹³ The AngloGold Ashanti principal component was generated in the EViews 6 program (QMS, 2007a), with the ordinary regression method (with 3 extractions).

The impact of the principal component is reported in Table 6.60. The AngloGold Ashanti principal component was lagged with 5 periods, while both the actual inflation rate differential and the inverse of the real interest rate differential were lagged with 1 period. The results demonstrate that the AngloGold Ashanti principal component had a negative effect on the improved multi-variable model, as it caused the current spot exchange rate to become statistically insignificant. This model's ability to explain the realized spot exchange rate also decreased to 16%. However, in order to understand the full effect of the AngloGold Ashanti principal component, the realized spot exchange rate was substituted with the future premium ($s_{t+3} - f_t$) as the dependent variable, as used in the Chiang and Yang (2007) methodology. The results reported in Table 6.61 demonstrate that these specific variables, as listed in Table 6.60, have improved the Chiang and Yang (2007) approach (Table 6.21). This improved model has increased the explanatory power of the future premium by 43%, although the AngloGold Ashanti principal component was not statistically significant at the 10% level. Furthermore, all the coefficients had a positive relationship with the future premium, except the current spot exchange rate, the actual inflation rate differential and Dummy 2.

Table 6.60: Improved multi-variable model with AngloGold Ashanti principal component

Dependent: Difference of S_{t+3}				Coefficient	Std. error	t-prob.
Difference of S_t				0.103	0.071	0.145
Difference of the actual inflation rate differential (-1)				-0.041	0.022	0.062**
Inverse of the real interest rate differential (-1)				0.057	0.021	0.007*
AngloGold Ashanti principal component (-5)				0.008	0.007	0.220
Dummy 1				0.313	0.127	0.015*
Dummy 2				-0.294	0.130	0.025*
Dummy 3				0.087	0.045	0.055**
AR(1)				0.162	0.070	0.021*
Intercept				-0.013	0.014	0.362
R-squared	0.163	Prob. (F-statistic)	0.000			
Adjusted R-squared	0.129	AIC	-1.356	Durbin Watson		1.991

* Statistically significant at the 5% level.

** Statistically significant at the 10% level.

Source: Compiled by author.

Table 6.61: Improved Chiang and Yang (2007) model

Dependent: Difference of ($S_{t+3} - f_t$)				Coefficient	Std. error	t-prob.
Difference of S_t				-0.913	0.070	0.000*
Difference of the actual inflation rate differential (-1)				-0.041	0.022	0.060**
Inverse of the real interest rate differential (-1)				0.056	0.021	0.008*
AngloGold Ashanti principal component (-5)				0.009	0.007	0.206
Dummy 1				0.307	0.127	0.017*
Dummy 2				-0.291	0.130	0.026*
Dummy 3				0.086	0.045	0.056**
AR(1)				0.161	0.070	0.023*
Intercept				-0.012	0.014	0.394
R-squared	0.545	Prob. (F-statistic)	0.000			
Adjusted R-squared	0.527	AIC	-1.358	Durbin Watson		1.989

* Statistically significant at the 5% level.

** Statistically significant at the 10% level.

Source: Compiled by author.

Nonetheless, these results are still incapable of providing a suitable explanation of the future premium ($s_{t+3} - f_t$), which implies that an alternative approach must be considered or alternative variables must be considered

All the empirical results above are based on the first approach, where all the variables were integrated to the same level, before incorporating them into an exchange rate model. The problem with this approach is that the buyers of forward exchange rate cover require protection at a specific exchange rate (level) and not for the change in the exchange rate because they conclude international trade contracts at a specific exchange rate. While it is commonly believed that current non-stationary, level economic data will lead to spurious results, evidence suggesting otherwise was already discussed in Section 5.5. This leads to the following section that will discuss the approach that incorporated current non-stationary economic fundamental time series data, for which the data was used in level format. This section will illustrate the manner in which non-stationary economic fundamentals may influence the results of the Chiang and Yang (2007) model, as reported in Tables 6.60 and 6.61.

6.3 ESTIMATION OF THE REALIZED FUTURE SPOT EXCHANGE RATE FROM NON-STATIONARY ECONOMIC TIME SERIES DATA

6.3.1 Introduction

The objective of this approach was to extend the knowledge gained from the previous section by estimating the realized future spot exchange rate with the use of current (time t) non-stationary, level economic time series data. In Section 1.2, it was demonstrated that the forward exchange rate is a mechanically determined variable that does not reflect the economic fundamentals underlying the exchange rate. This caused, amongst others, the exchange rate puzzle as already discussed in Section 2.3. The results from the previous section also proved that the forward exchange rate is a biased estimate of the realized future spot exchange rate. However, besides this fundamental problem it may be possible that the exchange rate puzzle may be a pseudo problem owing to the rigorous doctrine taught at universities that stationarity must be assessed in the modelling of exchange rate theory.

The fear of spurious results scared researches away from any investigation into non-stationary, level economic time series. However, in practice the buyers of forward exchange rate cover look at the economic fundamentals in level terms. Ventosa-Santaullària (2009:16) argues that differencing a series may not always prevent spurious estimates. Also, 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 may also be inaccurate (Ventosa-Santaullària, 2009:16). As already discussed in Section 5.5, 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 indicated that neither unit root models nor deterministic trends have the ability to model economic theory adequately (Ventosa-Santaullària, 2009:2). Therefore, the study modelled the economic theory/fundamentals using level economic time series (non-stationary

data) in an attempt to replicate real-world behaviour of the participants in the FX market. The results of this modelling will be reported in the following section.

6.3.2 Modelling non-stationary current level economic data

The starting point of this section is to report on the estimation of the best multi-variable model from the previous section with current (time t) level time series (Section 6.3.2.1). This will be followed by a discussion of the improved multi-variable model that incorporated previous findings, estimating also current (time t) level time series (Section 6.3.2.2). This section will be concluded by an extension of the new evidence, providing a more comprehensive overview of the validity of using non-stationary current level economic data (Section 6.3.2.3).

6.3.2.1 Estimation of the Chiang and Yang (2007) methodology

From the results reported in Table 6.62, it is evident that this approach, applied to composite variables (differentials), yields weak statistically significant results. With highly significant results, except for the AngloGold Ashanti principal component, a high R-squared value and a low Durbin Watson statistic indicate possibly spurious results. This implies that the Chiang and Yang (2007) approach of using composite variables may be unsuitable and that the economic fundamentals should be individually incorporated in the model, as already reported in Section 6.2.4.3.3. The Breusch–Godfrey serial correlation LM test and the White test¹¹⁴ indicated that there were serial correlations and heteroskedasticity, which implied that an ARCH model or a GARCH model was required. This leads to the following section that will report the results on the improved multi-variable model, which was estimated using individual non-stationary current level economic fundamentals.

¹¹⁴ The White test and the Breusch–Godfrey serial correlation LM test results are reported in Table 2 and Table 3, respectively in the appendix.

Table 6.62: Estimation of the Chiang and Yang (2007) methodology with level format (OLS)

Dependent: S_{t+3}				Coefficient	Std. error	t-prob.
Current spot exchange rate (S_t)				0.249	0.076	0.001*
Actual inflation rate differential				-0.027	0.010	0.006*
Inverse of the real interest rate differential				0.194	0.074	0.009*
AngloGold Ashanti principal component				0.025	0.019	0.187
Dummy 1				2.132	0.461	0.000*
Dummy 2				-1.116	0.4550	0.015*
Dummy 3				0.443	0.116	0.000*
Intercept				4.645	0.489	0.000*
R-squared	0.652	Prob. (F-statistic)	0.000			
Adjusted R-squared	0.641	AIC	0.779	Durbin Watson		
				0.243		

* Statistically significant at the 5% level.

Source: Compiled by author.

6.3.2.2 Incorporation of individual non-stationary current level economic fundamentals

In attempt to improve upon the results presented in Table 6.62, individual economic fundamentals were first examined and evidence was found that the current spot exchange rate was not statistically significant, which implied that it should be eliminated from further exchange rate modelling. Also, the ARCH model provided more statistically significant results in Table 6.63 to Table 6.65, compared to the results found for the GARCH model, and thus eliminated serial correlation and heteroskedasticity¹¹⁵. Further evidence indicated (Table 6.63) that the U.S.A. expected inflation rate, the South African actual inflation rate, the South African and the U.S.A. 91-day T-Bill rates, and the U.S.A. 10-year government bond yield rates provided the best statistically significant results of all the individual variables. By re-examining the impact of financial proxies on the model, the Sappi Limited ICAPM proxy was also selected¹¹⁶. However, regarding the proxy based on the AngloGold Ashanti dual-listed stock, all proxies as discussed in Section 5.4 provided statistically insignificant results (Table 6.63). An alternative that was not considered earlier was found to be suitable for this model as an AngloGold Ashanti proxy. This alternative was the difference between the weekly closing prices of the AngloGold Ashanti dual-listed stock of the JSE and the NYSE, expressed in USD terms.

¹¹⁵ The results reported on the remaining ARCH effects can be viewed in the appendix.

¹¹⁶ Although the Sappi Limited ICAPM proxy did not provide statistically significant results in Section 6.2.4, its contribution in explaining the realized future spot exchange in Section 6.3 increased significantly.

It is known that the ZAR/USD exchange rate is also affected by the relevant cross-exchange rates, including the USD/Euro, the USD/Pound, the ZAR/Euro, and the ZAR/Pound exchange rates. This led to the incorporation of the cross-exchange rates: the Euro/USD and the Pound/USD exchange rate expressed in ZAR. A cross-exchange rates is the price of a currency that is expressed in terms of another exchange rate. Cross-exchange rates may be useful in modelling exchange rates for two reasons: firstly, both the Euro and the Pound have a significant spillover 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. Furthermore, the NEER was examined and included as an additional possible explanatory variable, but failed to provide a statistically significant contribution and was, therefore, removed from this study for future investigation. The results reported in Table 6.63 demonstrate that all the variables, including the variance residual¹¹⁷, were statistically significant at the 5% level and explain 66% of the realized future spot exchange rate.

The AIC and SIC were relatively low, implying a good fit. Also, the log likelihood statistic was relatively high, thus also signifying the goodness-of-fit of this model. The presence of a unit root amongst the residuals was also rejected, which implied that this is not a spurious model. Furthermore, there were no remaining ARCH effects¹¹⁸ in the model and the Jarque-Bera probability statistic indicated that the hypothesis of normally distributed residuals could not be rejected¹¹⁹.

¹¹⁷ 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.

¹¹⁸ An ARCH LM test was used to determine if there were any remaining ARCH effects in the model.

¹¹⁹ The results on the residual normality, on the unit roots of the residuals, and on the remaining ARCH effects are reported in Table 6, Table 7, and Table 8, respectively in the appendix.

Table 6.63: 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*
Intercept				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 author.

However, the Chow breakpoint test and the Cusum test indicated that this model consisted of structural breaks, which implied that the following three dummies had to be incorporated in the model. Dummy 1 that spanned from the third week in July 2007 to the fourth week in May 2008 may be due to the preliminary shocks of the financial crisis. Also, Dummy 2 and Dummy 3 that spanned 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, may be due to the Russian gas crisis. Dummy 4 spanned from the first week in March 2005 to the fourth week in May 2008 and may be due to a number of events. Some of these events may include the aftershock regarding 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 that caused the dramatic increase of metal and energy prices (from 2007 to 2008).

Although intercept dummies were needed to accommodate these structural breaks, an alternative approach was first followed before including the dummies in the exchange rate model. As most of these events that caused 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 realized spot exchange rate by including the gold price and Brent oil price as

additional explanatory variables. These variables may also compensate for the structural breaks, which may decrease the number of intercept dummies required in the exchange rate model. The results reported in Table 6.64 demonstrate that including the gold and Brent oil price increased the explanation of the realized spot exchange rate from 66 to 71%. All the variables were statistically significant at the 5% level, with a relatively low AIC statistic and SIC statistic.

Table 6.64: 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*
Intercept				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 author.

Also, a relatively high log likelihood estimate emphasised the goodness-of-fit of the model. No unit root was found amongst the residuals¹²⁰, which implied that this was not a spurious model. Evidence also indicated that there were no remaining ARCH effects present in the model and the residuals were normally distributed, as reported by the Jarque-Bera probability statistic¹²¹.

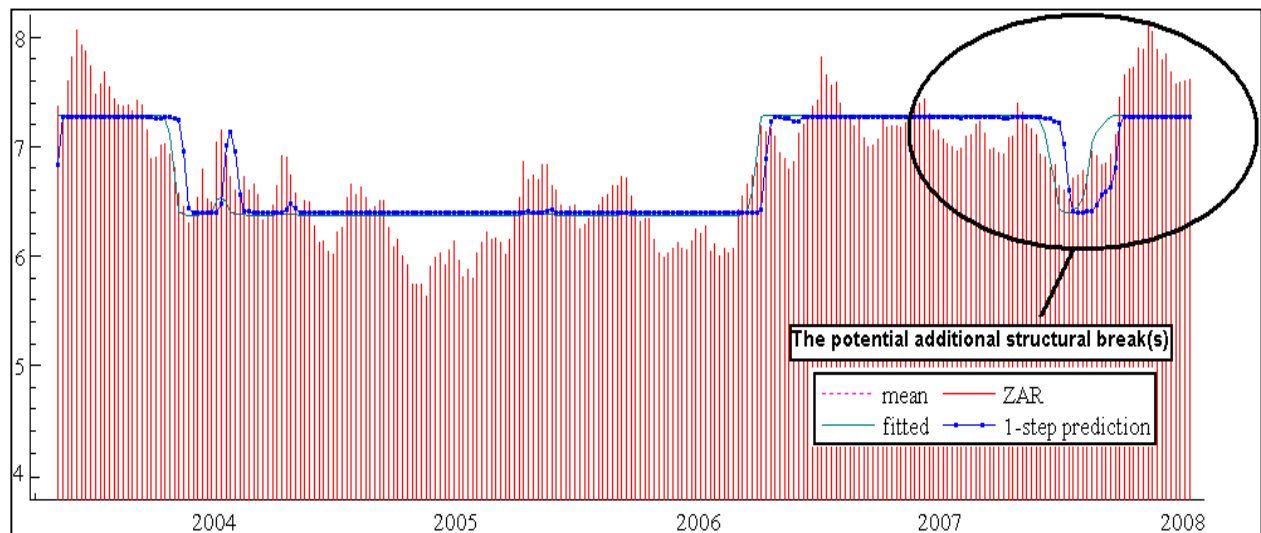
However, the Chow breakpoint test and the Cusum test still indicated that there were structural breaks, implying that including the gold and Brent oil price did not compensate for all the structural breaks. Additional to this study, a Markov Switching Vector Autoregressive (MS-VAR)

¹²⁰ See Table 12 in the appendix.

¹²¹ The normality test and the ARCH LM test results are reported in Table 11 and Table 13, respectively in the appendix.

model¹²² was used, with an additional Cusum test, to determine whether all the structural breaks (regime switches) had been accounted for (Figure 6.2).

Figure 6.2: Fitted values of MS-VAR model



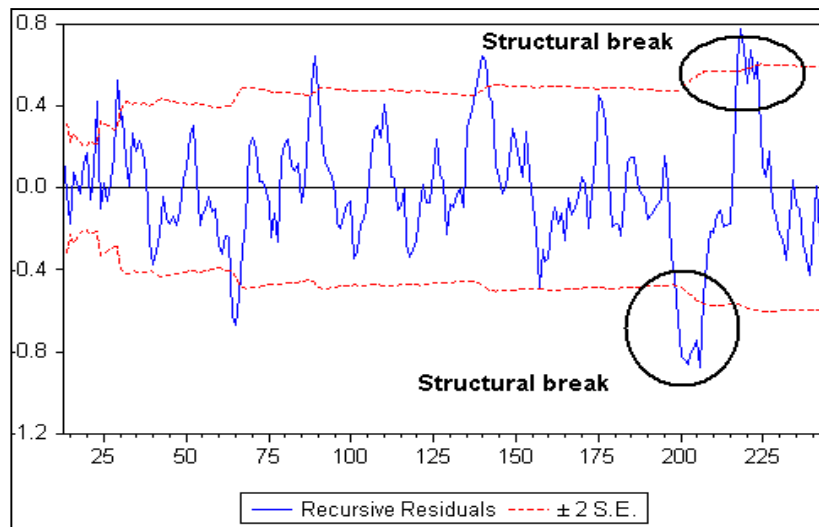
Source: Compiled by author.

However, some of the already identified structural breaks were not identified by the MS-VAR model, which may be due to the use of weekly data instead of monthly or because some economic fundamentals may sometimes be independent and identically distributed (i.i.d.)¹²³.

This was also justified by a Cusum test, where the recursive residuals were plotted with 2 standard deviation bands (Figure 6.3). The additional intercept dummy needed, apart from the four dummies already identified, spanned from the fourth week in October 2007 to the fourth week in May 2008, but was statistically insignificant when included in the exchange rate model.

¹²² See Hamilton (1989) regarding Markov-regime switching models.

¹²³ This implies that some economic fundamentals may sometimes follow a random walk, where fluctuations are not caused by other changing economic fundamentals.

Figure 6.3: Cusum test

Source: Compiled by author.

In addition to the findings from Table 6.64, the intercept dummies that were initially identified were included in the exchange rate model with the gold and the Brent oil price variables. Accordingly, the results from Table 6.65 reported that the explanation of the realized spot exchange rate increased from 71 to 80%. All the variables in the ARCH(1,0) model were statistically significant at the 5% level, including the residual variance coefficient. The model also required that the Brent oil price variable be lagged with 1 period. 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 competitiveness of these countries, where higher product prices may lead to a decrease in the demand for South African goods, which will lead to a decrease in the demand for ZAR. The U.S.A. 10-year government bond yield rate, the AngloGold Ashanti price difference in USD terms and the Sappi ICAPM were also negatively related to the ZAR/USD realized spot exchange rate. This may be due to the negative relationship between bond/stock prices and returns, where a depreciation of the ZAR may lead to an increase in the prices of U.S.A. government bonds (or stocks) for South African investors, thus causing the return on the bond/stock to decrease. The U.S.A. 91-day T-Bill rate coefficient was also negative, which implied that an increase in U.S.A. interest rates may lead to an increase in U.S.A. investments, causing the ZAR/USD spot exchange rate to depreciate.

Table 6.65: Best ARCH(1,0) estimation in level format

Dependent: S_{t+3}				Coefficient	Std. error	t-prob.
U.S.A. expected inflation rate				-0.028	0.009	0.002*
U.S.A. 91-day T-Bill rate				-0.154	0.026	0.000*
U.S.A. 10-year government bond yield rate				-0.117	0.049	0.016*
South African 91-day T-Bill rate				0.193	0.016	0.000*
South African actual inflation rate				-0.090	0.010	0.000*
AngloGold Ashanti price difference in USD terms				-0.044	0.017	0.011*
Sappi Limited ICAPM				-0.045	0.021	0.032*
Euro/USD exchange rate in ZAR terms				-0.318	0.046	0.000*
Pound/USD exchange rate in ZAR terms				0.388	0.061	0.000*
Brent oil price(-1)				0.005	0.003	0.032*
Gold price				0.001	0.000	0.013*
Dummy 1				-0.962	0.095	0.000*
Dummy 2				1.370	0.099	0.000*
Dummy 3				-0.977	0.106	0.000*
Dummy 4				0.601	0.063	0.000*
Intercept				5.936	0.454	0.000*
Variance equation						
Intercept				0.008	0.002	0.000*
Residual(-1)^2				1.064	0.215	0.000*
R-squared	0.805	AIC	-0.403	Log likelihood		66.960
Adjusted R-squared	0.792	SIC	-0.144	Sum squared residuals		14.845
				Theil (U)		0.007

* Statistically significant at the 5% level.

Source: Compiled by author.

Furthermore, according to Table 6.65, the Euro/USD exchange rate expressed in ZAR has a negative relationship with the ZAR/USD realized spot exchange rate. However, it was found that the ZAR/USD realized spot exchange rate was positively related to the Pound/USD exchange rate expressed in ZAR, the gold price and the Brent oil price. Table 6.65 also reports a relatively low AIC and SIC statistic and a relative high log likelihood estimate, implying the goodness-of-fit of the model. There was no unit root found amongst the residuals¹²⁴, which implies that this is not spurious model. Further evidence also indicated that there were no remaining ARCH effects in the model¹²⁵.

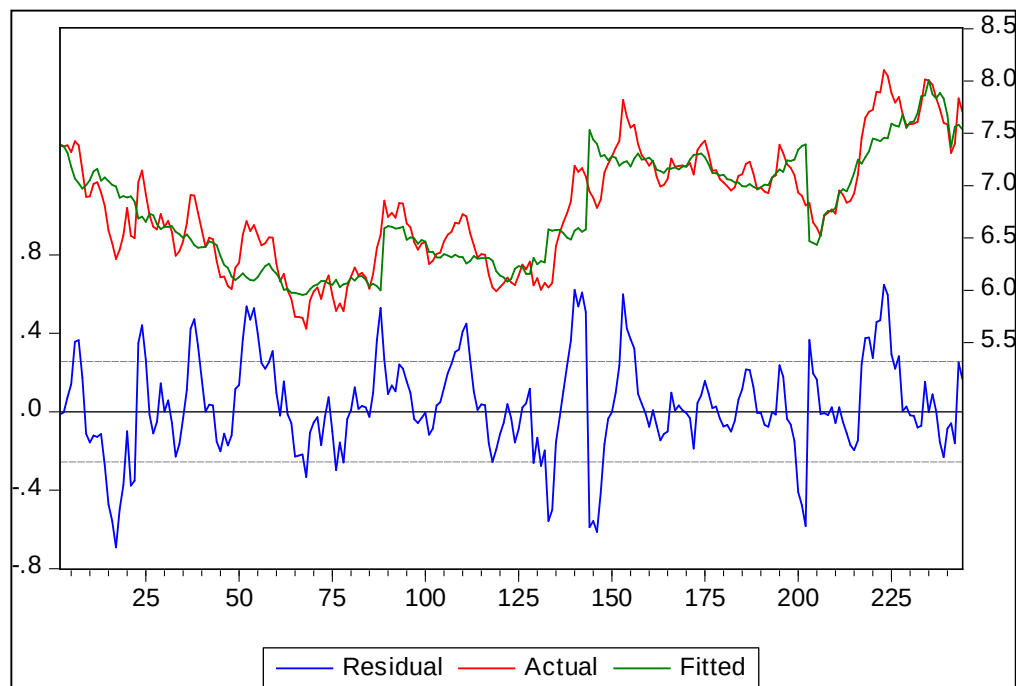
Although Table 6.65 was considered the best exchange rate model of this study, the Theil's inequality coefficient (U) must also be estimated to determine the model's forecasting ability. A Theil estimate of almost zero implied that the model has a good, but not perfect, ability to forecast the realized spot exchange rate. Figure 6.4 illustrates the actual/fitted values and

¹²⁴ See Table 17 in the appendix.

¹²⁵ See Table 18 in the appendix.

residuals of the model reported in Table 6.65. This figure illustrates that the fitted values have the same trend tendencies of the actual values, providing further confirmation of the exchange rate model's ability to estimate the realized future spot exchange rate with accuracy.

Figure 6.4: Actual/fitted and residual values



Source: Compiled by author.

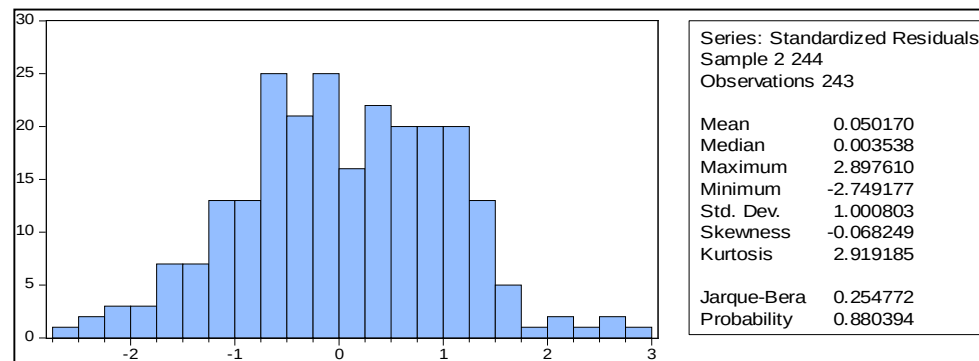
Furthermore, the figure illustrates that there is a small fluctuation in residuals present, following a white noise trend. Figure 6.5, derived from the results reported in Table 6.65¹²⁶, shows that the model's distribution has a long left tail (negative skewness) and is relatively flat to the normal (but almost 3, which indicates a normal distribution). Also, the Jarque-Bera probability was greater than 0.05, thus the null hypothesis of a normal distribution was not rejected.

To summarise, by using current non-stationary, level economic fundamental time series data, an improved ability to estimate the realized future spot exchange rate more accurately was established. These results also emphasised the superior ability of non-stationary, level time series data to estimate exchange rate models. The following section will further validate the

¹²⁶ Only the best ARCH model's normality test is reported in the text, the other models' normality tests are reported in the appendix.

results from Table 6.64 and Table 6.65 and the use of non-stationary, level time series data instead of stationary time series data to model the realized future spot exchange rate.

Figure 6.5: Normality test of the best model

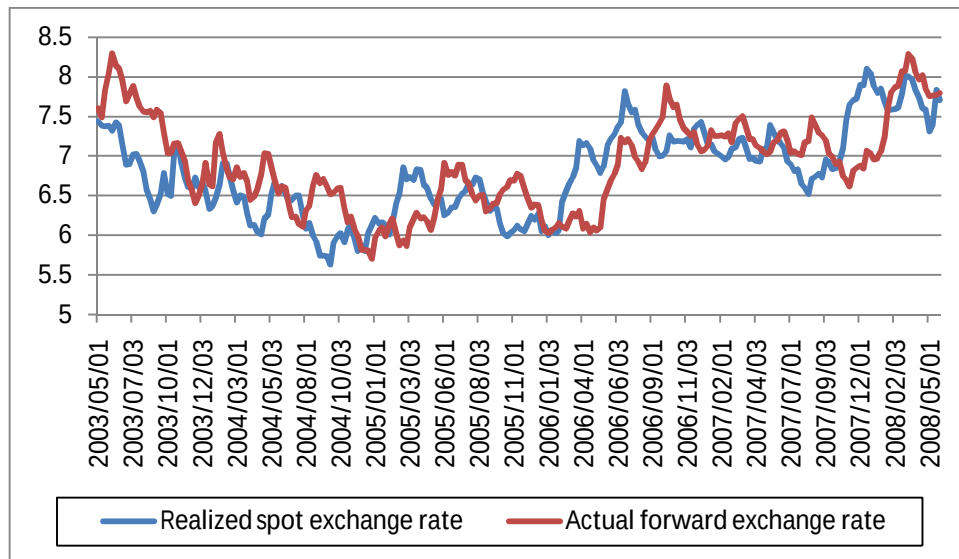


Source: Compiled by author.

6.3.2.3 Providing comprehensive validation

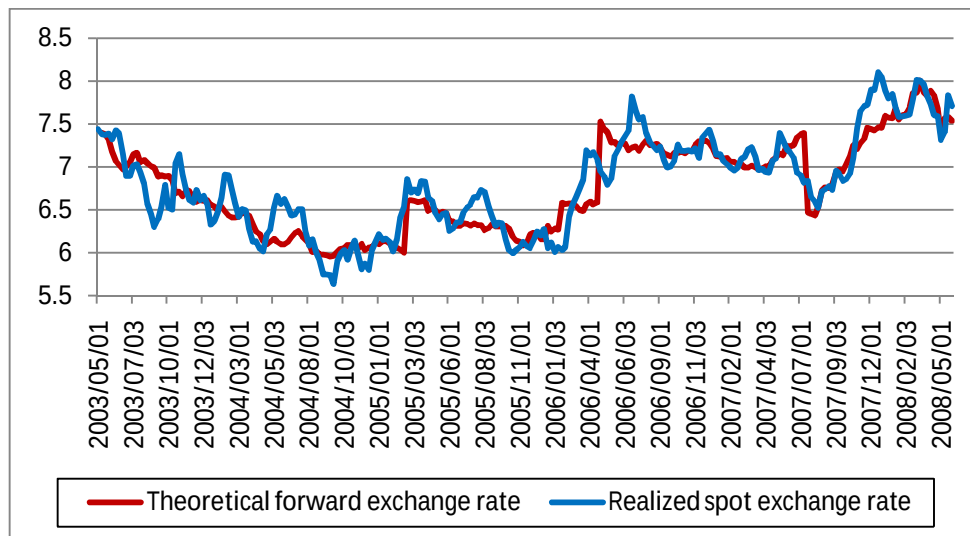
By means of a graphically illustration and by applying an alternative stationary empirical approach, will this section provide a validation regarding the results found in Table 6.64 and Table 6.65. Figure 6.6 emphasised the results reported in Section 6.3.2, which justified the biasedness of the forward exchange rate as an estimate of the realized future spot exchange rate, where the forward exchange rate does not follow the trend of the realized future spot exchange rate. In Section 1.2, it was stated that the forward exchange rate would more likely follow the movements of the current spot exchange rate, with the small carry cost as the only difference between the current spot exchange rate and the forward exchange rate (Figure 6.6). Also, by comparing the theoretical forward exchange rate (generated from Table 6.65) with the realized future spot exchange rate (Figure 6.7), the visual illustration demonstrates that the theoretical forward exchange rate, which is only based on economic fundamentals, showed improved similarities regarding the trend of the realized future spot exchange rate.

Figure 6.6: Comparison of the actual forward with the realized future spot exchange rate



Source: Compiled by author.

Figure 6.7: Comparison of the theoretical forward with the realized future spot exchange rate



Source: Compiled by author.

Figure 6.7, therefore, illustrates an improved model, which possesses an enhanced ability of illustrating future exchange rate movements (the realized future spot exchange rate), compared to the traditional exchange rate methodology, as illustrated in Figure 6.6. To further justify the results found in Table 6.65, an alternative stationary approach was followed.

Instead of applying a first difference approach as reported in Section 6.2, a fractionally differencing¹²⁷ approach will be applied. A process is fractionally integrated to order d , if its d 'th difference is $I(0)$. Thus, a fractionally integrated process can be illustrated as $I(d)$ (Christensen & Nielsen, 2004:2). By applying an ARFIMA model (Section 5.3.2.1.1) the fractionally differenced parameter, d , could be estimated for each explanatory variable that will be incorporated in the exchange rate model. These d -parameters, as reported in Table 35 in the appendix, is used to transform each non-stationary, level time series into a stationary time series. Each fractionally differenced explanatory variable is then incorporated in the exchange rate model to determine if fractionally differenced time series are able to generate an enhanced estimation of the realized future spot exchange rate, compared to using first differenced or non-stationary current, level time series data.

The econometric analyses that will be reported, which will be estimated with fractionally differenced explanatory variables, include the exchange rate puzzle¹²⁸ (Table 6.66), a comparison of the multi-variable model¹²⁹ from the Chiang and Yang (2007) methodology (Table 6.67), and a comparison of the estimation from Table 6.64 and 6.65 (Table 6.68 and 6.69). The results reported in Table 6.66 emphasise earlier results found in Section 6.2.5, which reported that there is an exchange rate puzzle present in the ZAR/USD exchange rate. Table 6.66 reported that the present premium ($f_t - s_t$) could only explain 26% of the future premium ($s_{t+3} - f_t$), compared to the 16% that was reported in Section 6.2.3, where first difference time series data was applied. The Durbin Watson statistic and the Ramsey Reset¹³⁰ test also indicated that the model was mis-specified. These results, therefore, emphasised that the forward exchange rate was indeed a biased estimate of the future spot exchange rate and the need for additional explanatory variables to improve the estimation abilities of the forward points.

¹²⁷ See also Section 2.3.4.2.1.

¹²⁸ See also Section 6.2.3.

¹²⁹ See also Section 6.2.4.3.3.

¹³⁰ The results from the Ramsey Reset test are reported in Table 22 in the appendix.

Table 6.66: 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*
Intercept (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 author.

Due to the presence of the exchange rate puzzle additional explanatory variables was identified and incorporated into the exchange rate model, as already reported in Section 6.2.3 and 6.2.4. Table 6.67 illustrates a comparison of the multi-variable model¹³¹ from the Chiang and Yang (2007) methodology. These results provide a comparative illustration of the effect of applying a fractionally differencing approach, instead of applying first differenced time series data that was used in Section 6.2.4.3.3. The Breusch-Godfrey serial correlation LM test indicated that there is serial correlation amongst the variables and the White test indicated the possibility of heteroskedasticity¹³². These results implied that an ARCH model is required to eliminate the presence of serial correlation and heteroskedasticity. The ARCH(1,0) model, as reported in Table 6.67, illustrates that all the variables are statistically significant at the 5% level. However, all these variables were only able to explain 14% of the future premium ($s_{t+3} - f_t$), compared to the 12% that was reported in Section 6.2.4.3.3. The real-interest rate differential provided a significant contribution to the model, compared to the requirement needed in Section 6.2.4.3.3 to use the inverse counterpart instead. The Sappi Limited stock return differential also provided more significant results than the AngloGold Ashanti stock return that was used in Section 6.2.4.3.3. The sign of each coefficient was also aligned with economic theory and the variance residual was below 1, which justify that the model is stable.

The results reported in Table 6.67 illustrated that the model consists of a relatively low AIC statistic and SIC statistic. Also, a relatively high log likelihood estimate emphasised the goodness-of-fit of the model. Evidence also indicated that there were no remaining ARCH

¹³¹ See also Section 6.2.4.3.3.

¹³² The White test and the Breusch–Godfrey serial correlation LM test results are reported in Table 23 and Table 24, respectively in the appendix.

effects present in the model and the residuals were normally distributed, as reported by the Jarque-Bera probability statistic¹³³. The results from Table 6.67, therefore, demonstrate that the economic variables proposed by the Chiang and Yang (2007) methodology were unable to estimate the realized future spot exchange rate. The exchange rate model had to be reconstructed, using individual explanatory variables, in order to enhance the estimation of the realized future spot exchange rate. The use of first differenced stationary time series were also unable to provide a significant contribution in explaining the realized future spot exchange rate. This led to the use of level time series data, where the best model was already reported in Table 6.64 and Table 6.65. Table 6.68 will provide a comparison of Table 6.64, to illustrate the effect of the fractionally differenced approach, in order to justify the significance of considering the order of integration when estimating exchange rate theories.

Table 6.67: 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.

Source: Compiled by author.

The Breusch-Godfrey serial correlation LM test and the White test reported that there is serial correlation and heteroskedasticity amongst the variables in the model¹³⁴. An ARCH(1,0) model will, therefore, be applied in Table 6.68 to eliminate the presence of serial correlation and heteroskedasticity. The results reported in Table 6.68 illustrate that the fractionally differenced explanatory variables were able to explain 67% of the realized future spot exchange rate. However, these results are still worse than the 71% reported in Table 6.64, with the use of non-

¹³³ The normality test and the ARCH LM test results are reported in Table 25 and Table 26, respectively in the appendix.

¹³⁴ The White test and the Breusch–Godfrey serial correlation LM test results are reported in Table 27 and Table 28, respectively in the appendix.

stationary, level time series data. Nevertheless, Table 6.68 reports that all the explanatory variables were statistically significant and provided a relative low AIC and SIC statistic. The relatively high log likelihood estimate also emphasised the goodness-of-fit of the model. By lagging the U.S.A. expected inflation variable with 1 period, the South African T-Bill rate variable with 4 periods, and the AngloGold Ashanti price difference variable with 1 period provided the most significant contribution to the model¹³⁵.

Table 6.68: The ARCH(1,0) comparison for level format – fractionally differenced approach

Dependent: Fractionally differenced S_{t+3}				Coefficient	Std. error	t-prob.
U.S.A. 91-day T-Bill rate				0.195	0.045	0.000*
U.S.A. expected inflation rate(-1)				-0.046	0.023	0.048*
U.S.A. 10-year government bond yield rate				0.135	0.065	0.038*
South African actual inflation rate				-0.067	0.020	0.001*
South African 91-day T-Bill rate(-4)				0.083	0.026	0.001*
South African 10-year government bond yield rate				0.252	0.042	0.000*
AngloGold Ashanti price difference in USD terms(-1)				0.034	0.014	0.014*
Sappi Limited ICAPM				-0.051	0.024	0.038*
Euro/USD exchange rate in ZAR terms				0.784	0.083	0.000*
Pound/USD exchange rate in ZAR terms				-0.440	0.057	0.000*
Brent oil price(-1)				-0.010	0.002	0.000*
Gold price				0.002	0.001	0.003*
Intercept				-0.006	0.152	0.968
Variance equation						
Intercept				0.008	0.002	0.000*
Residual(-1)^2				1.025 ¹³⁶	0.223	0.000*
R-squared	0.671	AIC	-0.562	Log likelihood		82.181
Adjusted R-squared	0.654	SIC	-0.344	Sum squared residuals		11.473

* Statistically significant at the 5% level.

Source: Compiled by author.

In comparison with the model from Table 6.64, the South African 10-year government bond yield rate is included in the model, because it provided a statistically significant contribution. The South African 10-year government bond yield rate was statistically insignificant in Table 6.64 and was, therefore, eliminated from that model. Further evidence also indicates that there were no remaining ARCH effects present in the model and the residuals were normally distributed, as

¹³⁵ Note that upcoming models consist of lagged variables. Although the lags vary from each model, each specific lag was carefully considered in order to make sense in economic theory. For example, some lags illustrate the cyclical nature of that specific variable. These lagged variables also provided the most statistically significant results.

¹³⁶ Although the variance residuals in the following two 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.

reported by the Jarque-Bera probability statistic¹³⁷. The conclusion can be made that using non-stationary, level data may incorporate more vital information of explanatory variables, which can be lost by fractionally differencing or by first differencing the variables. Nevertheless, fractional differencing provided more enhanced estimations of the realized future spot exchange rate than the use of first differenced time series data. These findings justify the importance of considering the appropriate order of integration before modelling exchange rate theories.

In order to conclude the fractionally differenced approach, Table 6.69 attempts to incorporate an alternative approach regarding preventing the inclusion a number of dummy variables that can be regarded as a cumbersome approach, as already reported in Table 6.65. In order to prevent this possible cumbersome approach, a slope dummy and an intercept dummy, based on the date where the model illustrated a change in trend, was incorporated in the model. The slope dummy provided insignificant results and was, therefore, eliminated from the model. On the other hand, the intercept dummy, which is based on the point in time when the trend in the model changed, provided a statistically significant contribution to the model. The intercept dummy (Dummy 1) spanned from the first week in September 2004 to the fourth week in May 2008, which can also be linked to some of the economic events as discussed in Section 6.3.2.2. Evidence from a White test and from a Breusch-Godfrey serial correlation LM test indicated that heteroskedasticity and serial correlation are present amongst the variables in the model¹³⁸. These findings required the implementation of a ARCH(1,0) model in order to eliminate the presence of heteroskedasticity and serial correlation.

The results reported in Table 6.69 illustrate that all the variables in the ARCH(1,0) model provided a statistically significant contribution to the model, explaining 68% of the realized future spot exchange rate. The sign of each of the variables' coefficients collaborated with economic theory. By lagging the South African T-Bill rate variable with 4 periods and the AngloGold

¹³⁷ The normality test and the ARCH LM test results are reported in Table 29 and Table 30, respectively in the appendix.

¹³⁸ The White test and the Breusch–Godfrey serial correlation LM test results are reported in Table 31 and Table 32, respectively in the appendix.

Ashanti price difference variable with 1 period contributed in enhancing the explanation of the realized future spot exchange rate. The U.S.A. expected inflation rate variable was, however, eliminated from the model, due to a lack of providing a statistically significant contribution to the model.

Table 6.69: The ARCH (1,0) comparison with a dummy – fractionally differenced approach

Dependent: Fractionally differenced S_{t+3}				Coefficient	Std. error	t-prob.
U.S.A. 91-day T-Bill rate				0.263	0.036	0.000*
U.S.A. 10-year government bond yield rate				0.095	0.059	0.110***
South African actual inflation rate				-0.092	0.018	0.000*
South African 91-day T-Bill rate(-4)				0.080	0.025	0.001*
South African 10-year government bond yield rate				0.209	0.043	0.000*
AngloGold Ashanti price difference in USD terms(-1)				0.034	0.015	0.026*
Sappi Limited ICAPM				-0.055	0.024	0.019*
Euro/USD exchange rate in ZAR terms				0.860	0.081	0.000*
Pound/USD exchange rate in ZAR terms				-0.475	0.058	0.000*
Brent oil price(-1)				-0.009	0.001	0.000*
Gold price				0.011	0.001	0.040*
Dummy 1				-0.137	0.063	0.030*
Intercept				0.046	0.148	0.755
Variance equation						
Intercept				0.008	0.002	0.000*
Residual(-1)^2				1.044	0.216	0.000*
R-squared	0.678	AIC	-0.574	Log likelihood		83.595
Adjusted R-squared	0.661	SIC	-0.356	Sum squared residuals		11.228

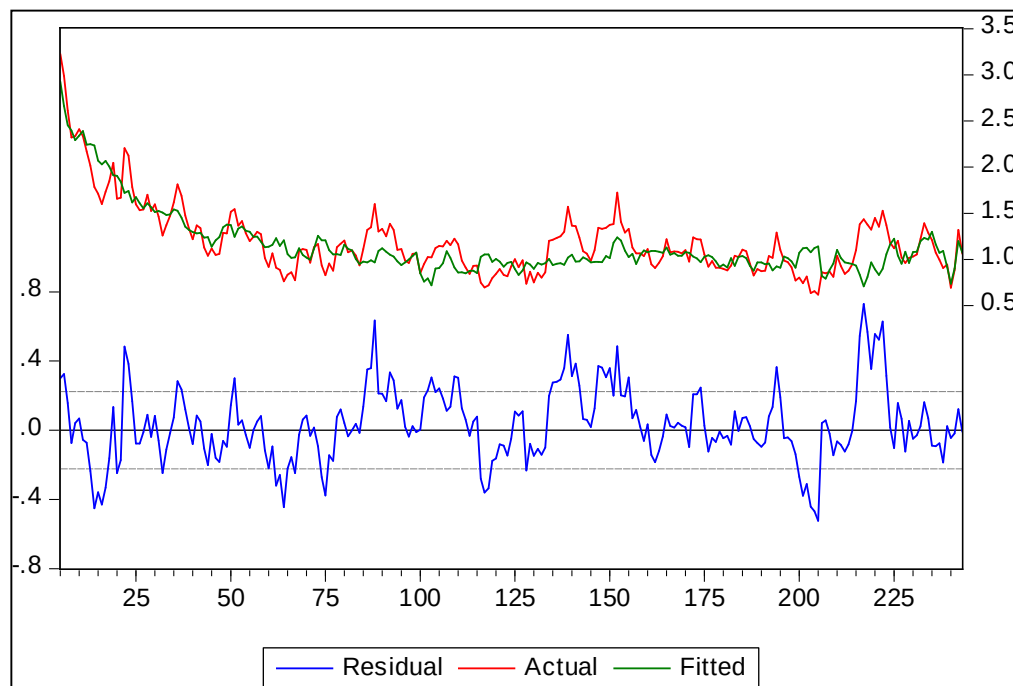
* Statistically significant at the 5% level.

*** Statistically significant at the 15% level.

Source: Compiled by author.

Although the model (Table 6.69) provided a weaker explanation of the realized future spot exchange rate compared to the 81% found in Table 6.65, has the fractionally differenced approach provided more dominant results than the first differenced approach (Section 6.2). From Figure 6.8 it is also evident that this model still has the ability to provide an illustration of when changes in the exchange rate will occur. The results reported in Table 6.69 also illustrate that the model consists of a relatively low AIC statistic and SIC statistic. A relatively high log likelihood estimate was also reported that emphasised the goodness-of-fit of the model. Evidence also indicated that there were no remaining ARCH effects present in the model and the residuals were normally distributed, as reported by the Jarque-Bera probability statistic¹³⁹.

¹³⁹ The normality test and the ARCH LM test results are reported in Table 33 and Table 34, respectively in the appendix.

Figure 6.8: Actual/fitted and residual values of the fractionally differenced approach

Source: Compiled by author.

To summarise, from these results it is evident that the use of fractionally differenced explanatory variables can have a significant impact on explaining the realized future spot exchange rate. From the concluding evidence it is clear that fractionally differenced time series data must be considered above the use of first differenced time series data, emphasising the importance of considering the appropriate order of integration. However, the conclusion can be made that non-stationary, level data still has the dominant explanatory ability, justifying the need to further examine non-stationary, level data without the fear of spurious results.

6.4 CHAPTER SUMMARY

A country's exchange rate has an influential impact on the future decisions made by investors, traders, speculators and policy-makers. Based on past empirical findings, the use of the current quoted forward exchange rate as an indicator of the realized future spot exchange rate will lead to biased results. This study has provided a solution by formulating a model that has the ability to explain the realized future spot exchange rate and the exchange rate puzzle. The study followed two different approaches in modelling the future spot exchange rate.

The first approach, which included the use of the Chiang and Yang (2007) methodology, made use of stationary time series data. The second approach made use of non-stationary, level time series data.

The first approach first determined whether the ZAR/USD exchange rate has long-memory (Section 5.3.2.1). It was found that the ZAR/USD exchange rate has long-memory, which implies that economic fundamentals could be used to estimate the realized future spot exchange rate. However, before examining suitable economic fundamentals, the ZAR/USD exchange rate was tested for the presence of an exchange rate puzzle. The presence of an exchange rate puzzle would suggest that the forward exchange rate is a biased estimate of the realized future spot exchange rate. It was found that there was an exchange rate puzzle, which emphasised the need for additional economic fundamentals to improve the accuracy of the explanation of the realized future spot exchange rate (Section 6.2.3). The economic fundamentals that were identified were the International Equity Parity theory (Section 4.1), the PPP theory (Section 3.2), the Uncovered Interest Rate Parity theory (Section 3.3.6), the Covered Interest Rate Parity theory (Section 3.3.3) and the expectations hypothesis of the domestic term structure of interest rates (Section 2.3.4.2.4).

The preliminary model used to model these economic fundamentals was the Chiang and Yang (2007) methodology (Section 5.2.2). The first approach provided results that suggested that stationary time series data was not suitable for modelling exchange rate theories. However, the use of fractionally differenced time series data (Section 6.3.2.3) did provide a more enhanced explanation of the realized future spot exchange rate. The results found, by using fractionally differenced time series data, also emphasised the importance of considering the most appropriate level of integration. The results found, by using first differenced time series data (Section 6.2), however, lack the ability of providing a superior explanation of the realized future spot exchange rate. This implies that the choice of which order of integration to use may have an effect on the explanatory abilities of exchange rate models. The results, from the first

difference stationary approach, demonstrated that economic fundamentals are unable to explain the realized future spot exchange rate completely. In addition, the results also imply that the use of composite variables, as suggested by the Chiang and Yang (2007) methodology, will only lead to statistically insignificant results.

Re-examining the economic theories, from which the Chiang and Yang (2007) methodology was derived, provided insight regarding the individual economic fundamentals to be used instead of the composited variables. From the PPP theory (Section 6.2.5.2.1), the Fisher effect (Section 6.2.5.2.2), the Covered Interest Rate Parity theory (Section 6.2.5.2.3) and the Uncovered Interest Rate Parity theory (Section 6.2.5.2.4), results demonstrated that actual inflation rates (not expected inflation rates) and the short-run interest rates (not long-run interest rates) yield the best results. In addition, it was found that the Sappi Limited stock return differential, the AngloGold Ashanti speed of adjustment series and the Sappi Limited ICAPM were the best proxies to use to incorporate the interaction between the JSE and the NYSE in an exchange rate model (Section 6.2.5.2.5). By incorporating these individual economic fundamentals in an exchange rate model, a 43% increase in the R-squared compared to the Chiang and Yang (2007) approach was achieved. However, these economic fundamentals still lacked the ability to explain the realized future spot exchange rate completely. These findings, therefore, illustrated that the use of stationary time series data to model exchange rate theories may be inappropriate and must be reconsidered.

A second approach was followed in an attempt to improve the accuracy of the explanation of the realized future spot exchange rate and of the exchange rate puzzle. The second approach modelled individual economic fundamentals in level format, which yielded more statistically significant results. Section 6.3.2.2 illustrated that using economic fundamentals in the same levels in which market participants perceive them (level format) and by incorporating economic fundamentals individually in an exchange rate model will increase the explanation of the realized future spot exchange rate (81%). These results, therefore, concluded the notion that

using non-stationary, level data provide the most superior explanation of the realized future spot exchange rate. These findings also emphasise the notion that economic analysts should not fear the use of non-stationary, level time series data, if the required precautions are in place. These findings also indicate that economic fundamentals can be used to generate a theoretical forward exchange rate that can substitute the current mechanistic calculated forward exchange rate. Furthermore, this chapter's findings suggest that the exchange rate puzzle is not due to the weak explanatory power of economic theory, but is a pseudo puzzle greatly due to the fear of using current non-stationary, level time series data to model exchange rate theories.

CHAPTER 7

Conclusion

7.1 INTRODUCTION

This study posed the following primary research question in light of the mechanistic determination of the forward exchange rate: Can current (time t) economic fundamentals explain the realized future spot exchange rate (time $t + i$)? The following secondary research question was also posed: Is the exchange rate puzzle a fallacy caused by the rigorous, unyielding practice of exclusively using stationary time series in the investigations into this puzzle.

Therefore, the primary research objective of this study was to develop an exchange rate model using current (time t) economic fundamentals (time series data) in an effort to establish a theoretical forward exchange rate that reflects the realized future (in time $t + i$) spot exchange rate to such an extent that market participants will take note of it. The secondary research objective of this study was to investigate the importance of using non-stationary, level time series data (in time t) to estimate a theoretical value of the forward exchange rate. In doing so, the realized future spot exchange rate (in time $t + i$) was to be reflected to such a level of significance that market participants would make use of it, resulting in supply and demand to enter the forward exchange market. Once a more realistic future spot exchange rate is quoted, arbitrage ought to induce a more market-related forward exchange rate being quoted.

This chapter will briefly summarise how these research objectives were achieved by providing a broad review of the literature and the results from the empirical study (Section 7.2). The review will highlight the theoretical explanations behind the difference in the forward exchange rate and the ZAR/USD realized future spot exchange rate. In addition, this study's contribution to the field of exchange rate modelling will be summarised (Section 7.2). The chapter will conclude with a

discussion of the recommendations for future studies (Section 7.3).

7.2 REVIEW OF THE LITERATURE AND EMPIRICAL RESULTS

The continuous fluctuation in the ZAR/USD exchange rate increases the difficulty of determining future exchange rate movements, which hampers the daily decision-making processes of investors, traders, and policy-makers alike. Market participants use daily quoted forward points as an indicator of future exchange rate movements, thus enabling them to estimate the forward exchange rate. However, it was found that there is a substantial difference between the current quoted forward exchange rate in the market and the realized future spot exchange rate, which came to be known as the exchange rate puzzle.

This study set out to determine the reason this difference exists for the ZAR/USD exchange rate, and whether current economic fundamentals can be used to help explain this difference. It also sought to determine whether an exchange rate model can be developed that has the ability to establish a theoretical forward exchange rate that will reflect the ZAR/USD realized future spot exchange rate to such an extent that it will attract the attention of current market participants.

The study commenced by investigating past explanations of the exchange rate puzzle (Section 2.3). Past empirical studies relied on the perception that macro-economic fundamentals possessed weak explanatory powers and have excess volatility, and that the exchange rate follows a random walk, thus exhibiting a reduced ability in explaining the FX rate premium. However, the paramount deficiency was that none of the past studies took into consideration that the actual day-to-day determination of the forward exchange rate was more mechanistic (based on the current spot exchange rate and the carry cost of transactions) rather than based on economic fundamentals. Also, most studies focused on explaining the FX rate premium rather than explaining the realized future spot exchange rate. The inadequacy of these past studies was caused by the assumption that the FX rate premium was already inconsistent

owing to the mechanistic nature of the forward exchange rate. These conclusions, as mentioned above, led to the investigation of the hypothesis that eligible basic economic fundamentals can be incorporated into an exchange rate model, which will be able to replace the current use of the forward exchange rate estimation. By formulating a theoretical forward exchange rate based on current economic fundamentals alone, the demand and supply forces in the forward exchange market can be improved, which will cause arbitrage to induce an improved market-related forward exchange rate quote.

However, before economic fundamentals could be identified, it was necessary to prove that the ZAR/USD exchange rate data has long-memory. In Section 5.3.2.1, it was reported that evidence was found that the ZAR/USD exchange does have long-memory, which implies that the random walk phenomenon can be ignored (Section 2.3.3.1) and, because the exchange rate movements are greatly dependent on the current economic fundamentals that already contain exchange rate movement history, fundamentals can provide a suitable input into an exchange rate model. The basic economic fundamentals that were identified were the PPP theory (Section 3.2), the Fisher effect (Section 3.3.2.1), the Covered Interest Rate Parity theory (Section 3.3.3), the Uncovered Interest Rate Parity theory (Section 3.3.6), the expectations hypothesis of the domestic term structure of interest rates (Section 2.3.4.2.4), and the International Equity Parity theory (Sections 4.1 and 5.2.5). This study investigated each of these economic theories and concluded that, although these theories provided inconsistent results regarding their validity in developing and emerging countries, they do provide a suitable benchmark for modelling a basic exchange rate model. From these theories, inflation rates, short- and long-run interest rates, and stock returns were identified as the basic explanatory variables required to model the ZAR/USD realized future spot exchange rate.

However, incorporating all these economic theories into one exchange rate model posed its own challenges. In an attempt to combine the various existing theories, stationary data (weekly) was incorporated into the Chiang and Yang (2007) methodology (Section 5.2), which is an

appropriate preliminary exchange rate model still based on past theories, although ignoring the mechanistic nature of the forward exchange rate. Therefore, the study redirected the focus of estimating a theoretical forward exchange rate that can improve the accuracy of the estimation of the ZAR/USD realized future spot exchange rate. In the process of evaluating the Chiang and Yang (2007) methodology and the economic theories on which Chiang and Yang (2007) based their methodology, it was found that the explanatory power of the composite variables were insufficient. This implies that individual economic variables should be used instead of a composite variable methodology, as suggested by Chiang and Yang (2007). After an evaluation of the preliminary Chiang and Yang (2007) model, it became clear that there were some areas for improvement when applied to this specific problem in the South African context. The first was made by generating an expected inflation rate. In order to generate this expected inflation rate, an exponential weighted procedure and an Exponential Weighted Moving Average model (Section 5.3.2.1.3) were used. By doing this, it was possible to incorporate both historical values and future expectations (uncertainty component) into a 1-month ahead current time series.

This study also examined the use of alternative approaches of incorporating the interactions of the international financial markets into an exchange rate model as an additional economic fundamental to explain the realized future spot exchange rate. These alternative approaches, which include the use of price differences of dual-listed stocks, entail the ability to incorporate market expectations more effectively. Alternative proxies for incorporating the interaction of the international financial markets included the following (Section 5.4):

- The expected stock returns (indices) were generated from stock closing prices;
- The indices were substituted with expected stock returns generated from individual dual-listed stocks. Dual-listed stocks may have the ability to incorporate market expectations and thus the interaction of international financial markets more explicitly, since the price differences of the dual-listed stocks provide information regarding the investor's perception

of the exchange rate (market expectations). The time lag between the two exchange markets also improved the ability to predict the future exchange rate;

- The stock return variable was substituted with an ICAPM series generated with dual-listed stock data. The purpose of using the ICAPM was to incorporate the presence of the exchange rate risk of an international portfolio (Sections 4.7 and 5.4.3); and
- The stock return variable was substituted with a speed of adjustment series generated with a VEC model (Section 5.4.4). Using the speed of adjustment series as a proxy for the interaction between two international financial markets (JSE and the NYSE) may provide sufficient information regarding market expectations (the volatility spillover effect, as discussed in Section 4.8).

In order to better incorporate the interaction of the international financial markets, stock indices were first used but they failed to provide statistically significant results. Therefore, dual-listed stocks were introduced as a proxy for the interaction of international financial markets and this provided statistically significant results. Section 6.2.5.2.5 reported that the Sappi Limited stock return differential, the AngloGold Ashanti speed of adjustment series and the Sappi Limited ICAPM were the best proxies to use for incorporating the interaction between the JSE and the NYSE in an exchange rate model. However, none of the Sappi Limited proxies provided statistically significant results in the Chiang and Yang (2007) model, whereas all the AngloGold Ashanti proxies were statistically significant.

By including stationary (first differenced) individual economic variables and the stationary statistically significant financial market proxies, the Chiang and Yang (2007) model provided a weak explanation (16%) of the ZAR/USD realized future spot exchange rate and of the exchange rate puzzle (55%). These results were, however, challenged by estimating an exchange rate with fractionally differenced explanatory variables. Although the fractionally differenced economic variables were able to explain only 26% of the exchange rate puzzle and 68% of the ZAR/USD realized future spot exchange rate, the results illustrated the dominance

that fractionally differenced time series data has over first differenced time series data. The results from the fractionally differenced approach also emphasised the importance of considering the appropriate order of integration, whereas the order of integration can have an impact on the explanatory abilities of an exchange rate model. Nevertheless, the first differenced and fractionally differenced approaches still failed to provide a satisfactory explanation of the ZAR/USD realized future spot exchange rate. This led to the following questions. Why do the current economic fundamentals still lack the ability to explain the movements of the ZAR/USD realized future spot exchange rate? Can the exchange rate puzzle be a pseudo problem due to the rigorous approach of using stationary data to model exchange rate theories?

The contribution of this thesis was thus to determine the validity of this question and to develop a theoretical forward exchange rate by using non-stationary, level data to serve as a substitute forward exchange rate measure for market participants. Phillips (1998) and Ventosa-Santaulària (2009) argue that unit root processes and OLS models are limited in the modelling of non-stationary, level economic data. According to them, results could also be misperceived and falsely interpreted, with high R-squares, a low Durbin Watson statistic, and highly statistically significant coefficients as early signals of possible spurious results. However, Ventosa-Santaulària (2009) states that making data stationary will not necessarily prevent spurious results. Furthermore, the stationary adjustment may prevent current economic fundamentals from providing their authentic explanatory ability of explaining the ZAR/USD realized future spot exchange rate, which may solve the exchange rate puzzle.

During the modelling of weekly non-stationary, level time series data, the current spot exchange rate did not provide statistically significant results, thus implying the importance of only using current economic fundamentals as explanatory variables. An ARCH model provided more statistically significant results compared to the results for the GARCH model, which eliminated serial correlation and heteroskedasticity amongst the variables. It was further found that the

U.S.A. expected inflation rate, the South African actual inflation rate, the South African and U.S.A. 91-day T-Bill rates, and the U.S.A. 10-year government bond yield rates provided the best statistically significant results amongst all the individual variables.

Re-examining the impact of financial proxies on the exchange rate model, the Sappi Limited ICAPM proxy and the price difference of AngloGold Ashanti, expressed in USD, yielded the best results. Cross-exchange rates were also incorporated into the exchange rate model, which included the Euro/USD and the Pound/USD exchange rates expressed in ZAR. Also, the compensation for structural breaks was made due to economic events like the preliminary shocks of the financial crises, the Russian gas crisis, the invasion of Iraq, and the commodity crisis, during which there was a dramatic increase of metal and energy prices, resulted in the development of a more accurate theoretical forward exchange rate. Weekly gold prices, weekly Brent oil prices, and four dummy variables were also included to compensate for these structural breaks.

This new model was able to generate a theoretical forward exchange rate that could explain 81% of the ZAR/USD realized future spot exchange rate. These results confirmed that economic fundamentals could indeed provide a statistically significant explanation of the ZAR/USD realized future spot exchange rate and that the exchange rate puzzle was indeed a pseudo problem. No further evidence was found of possible spurious regression results or remaining ARCH effects, which emphasised that a better approach to follow in modelling exchange rate theories is to use non-stationary, level time series data.

7.3 CONCLUSION AND RECOMMENDATIONS

This study provided substantial clarification of the exchange rate puzzle. By using only current economic fundamentals, it was demonstrated that a theoretical forward exchange rate with the ability of explaining the ZAR/USD realized future spot exchange rate with greater accuracy can be developed. This study also found that the best approach for modelling exchange rate

theories was by means of incorporating non-stationary, level time series data. The results also demonstrated that there is no need to fear the use of non-stationary data and that the required condition, of using stationary data to model exchange rate theories, is the main source of the exchange rate puzzle.

In addition to these results, the following recommendations may provide more insight into exchange rate modelling, which can be used for future studies. Incorporating daily data may yield better results, although inflation data is mostly reported in a monthly format. If daily data is not used, alternative methods, instead of linear interpolation, must be examined as transformation techniques for reworking monthly data into daily or weekly data. Further investigation may also be required to determine a non-linear model that can provide improved results in the modelling of non-stationary, level time series data. By estimating OLS models, time series data is forced through an origin, thus providing a partial explanation for the weak results reported by some economic theories. Further investigation in additional explanatory variables, like the NEER, FEER, or a proxy that incorporates the over- and undervaluation market perception of the ZAR/USD exchange rate, may provide an even more accurate explanation of the ZAR/USD realized future spot exchange rate.

APPENDIX

Table 1: Ramsey Reset Test for the forward premium hypothesis

	Value	Probability
F-statistic	4.093	0.018*
Likelihood ratio	8.184	0.017*

Number of fitted values: 2

* Reject the null hypothesis of no mis-specification error.

Source: Compiled by author.

Table 2: White test to determine heteroskedasticity in Table 6.62

F-statistic	12.872
Obs*R-squared	65.034
Scaled explained SS	69.621
Prob. F(7,205)	0.000*
Prob. Chi-Square(7)	0.000*
Prob. Chi-Square(7)	0.000*

* Reject the null hypothesis of homoskedasticity at the 5% level.

Source: Compiled by author.

Table 3: Breusch–Godfrey Serial Correlation LM test for Table 6.62

F-statistic	Obs.* R-squared	Prob. (F-statistic)	Prob. (chi-square)
428.859	172.236	0.000*	0.000*

* Reject the null hypothesis of no serial correlation at the 5% level.

Source: Compiled by author.

Table 4: White test to determine heteroskedasticity in Table 6.63

F-statistic	6.547
Obs*R-squared	49.080
Scaled explained SS	31.887
Prob. F(9,234)	0.000*
Prob. Chi-Square(9)	0.000*
Prob. Chi-Square(9)	0.000*

* Reject the null hypothesis of homoskedasticity at the 5% level.

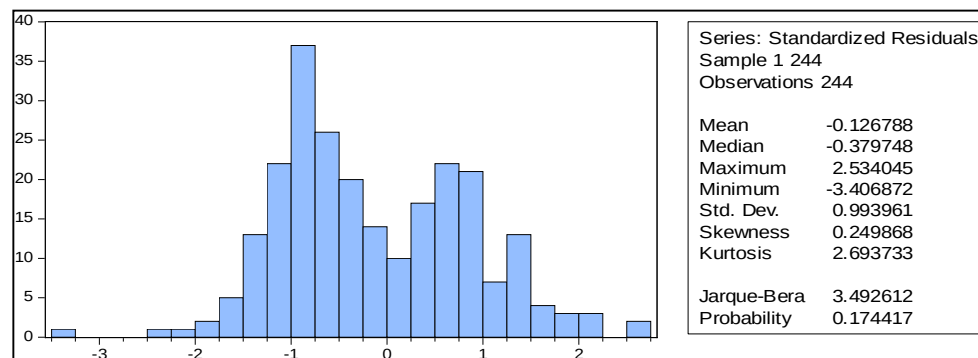
Source: Compiled by author.

Table 5: Breusch–Godfrey Serial Correlation LM test for Table 6.63

F-statistic	Obs.* R-squared	Prob. (F-statistic)	Prob. (chi-square)
428.643	192.032	0.000*	0.000*

* Reject the null hypothesis of no serial correlation at the 5% level.

Source: Compiled by author.

Table 6: Normality test for Table 6.63

Source: Compiled by author.

Table 7: ADF unit root test on the residuals of Table 6.63

	t-statistic	t-probability
ADF test statistic	-3.744	0.004*
1% level	-3.457	
5% level	-2.873	
10% level	-2.573	

*Reject null hypothesis for the presence of a unit root at the 5% level.

Source: Compiled by author.

Table 8: Testing for remaining ARCH effects in Table 6.63 with an ARCH LM test

F-statistic	0.063
Obs*R-squared	0.064
Prob. F(1,241)	0.802
Prob. Chi-Square(1)	0.801

Source: Compiled by author.

Table 9: White test to determine heteroskedasticity in Table 6.64

F-statistic	7.412
Obs*R-squared	63.447
Scaled explained SS	43.169
Prob. F(11,232)	0.000*
Prob. Chi-Square(11)	0.000*
Prob. Chi-Square(11)	0.000*

* Reject the null hypothesis of homoskedasticity at the 5% level.

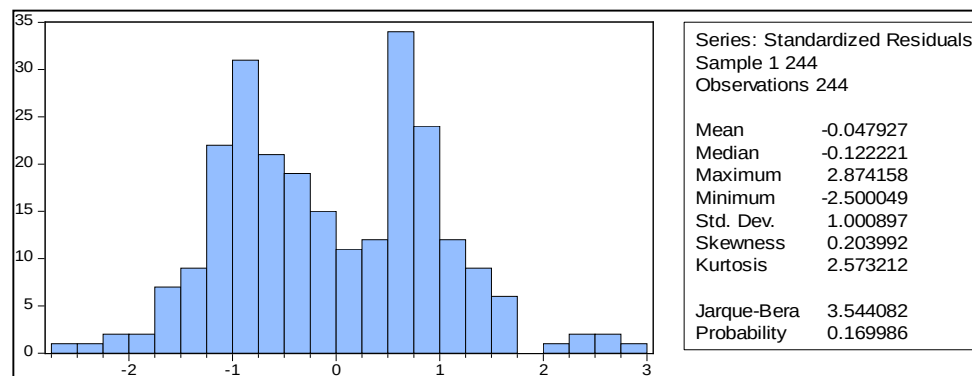
Source: Compiled by author.

Table 10: Breusch–Godfrey Serial Correlation LM test for Table 6.64

F-statistic	Obs.* R-squared	Prob. (F-statistic)	Prob. (chi-square)
410.956	190.650	0.000*	0.000*

* Reject the null hypothesis of no serial correlation at the 5% level.

Source: Compiled by author.

Table 11: Normality test for Table 6.64

Source: Compiled by author.

Table 12: ADF unit root test on the residuals of Table 6.64

	t-statistic	t-probability
ADF test statistic	-4.4659	0.000*
1% level	-3.4573	
5% level	-2.873	
10% level	-2.573	

*Reject null hypothesis for the presence of a unit root at the 5% level.

Source: Compiled by author.

Table 13: Testing for remaining ARCH effects in Table 6.64 with an ARCH LM test

F-statistic	0.486
Obs*R-squared	0.489
Prob. F(1,241)	0.486
Prob. Chi-Square(1)	0.484

Source: Compiled by author.

Table 14: White test to determine heteroskedasticity in Table 6.65

F-statistic	5.505
Obs*R-squared	64.814
Scaled explained SS	61.019
Prob. F(15,227)	0.000*
Prob. Chi-Square(15)	0.000*
Prob. Chi-Square(15)	0.000*

* Reject the null hypothesis of homoskedasticity at the 5% level.

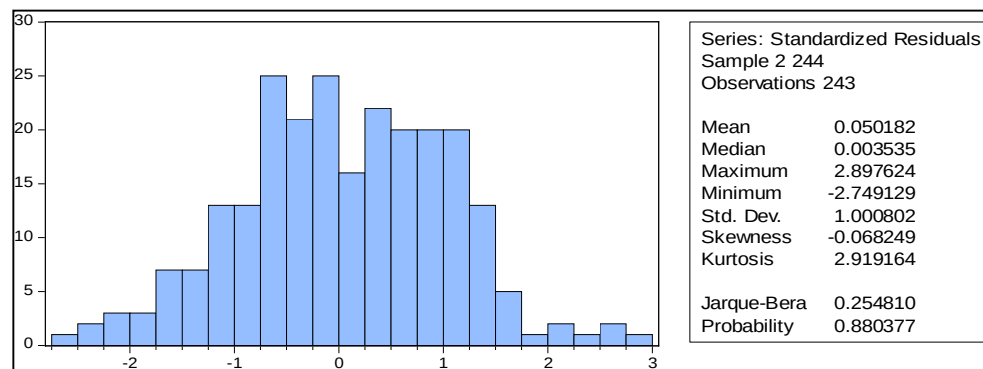
Source: Compiled by author.

Table 15: Breusch–Godfrey Serial Correlation LM test for Table 6.65

F-statistic	Obs.* R-squared	Prob. (F-statistic)	Prob. (chi-square)
177.444	149.070	0.000*	0.000*

* Reject the null hypothesis of no serial correlation at the 5% level.

Source: Compiled by author.

Table 16: Normality test for Table 6.65

Source: Compiled by author.

Table 17: ADF unit root test on the residuals of Table 6.65

	t-statistic	t-probability
ADF test statistic	-6.433	0.000*
1% level	-3.457	
5% level	-2.873	
10% level	-2.573	

*Reject null hypothesis for the presence of a unit root at the 5% level.

Source: Compiled by author.

Table 18: Testing for remaining ARCH effects in Table 6.65 with an ARCH LM test

F-statistic	0.352
Obs*R-squared	0.354
Prob. F(1,240)	0.554
Prob. Chi-Square(1)	0.552

Source: Compiled by author.

Table 19: First set of additional ADF unit root test results

		t-statistic	t-probability
Future premium, $(s_{t+3} - f_t)$	ADF test statistic	-3.636	0.006*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
Forward exchange rate	ADF test statistic	-2.152	0.225
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
Present premium, $(f_t - s_t)$	ADF test statistic	-1.881	0.341
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
Real-interest rate differential	ADF test statistic	-1.538	0.513
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
Long-short spread	ADF test statistic	-2.383	0.148
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
Inverse of the real-interest rate differential	ADF test statistic	-8.287	0.000*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
AngloGold Ashanti stock return differential	ADF test statistic	-8.992	0.000*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
Sappi Limited stock return differential	ADF test statistic	-7.548	0.000*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	

*Reject null hypothesis for the presence of a unit root at the 5% level.

Source: Compiled by author.

Table 20: Second additional ADF unit root test results

		t-statistic	t-probability
Expected inflation rate differential	ADF test statistic	-1.781	0.390
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
Actual inflation rate differential	ADF test statistic	-1.851	0.355
	1% level	-3.458	
	5% level	-2.874	
	10% level	-2.573	
Short-run interest rate differential	ADF test statistic	-2.379	0.149
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
Long-run interest rate differential	ADF test statistic	-1.828	0.367
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
$(S_{t+3} - S_t)$	ADF test statistic	-3.757	0.004*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
AngloGold Ashanti ICAPM	ADF test statistic	-9.503	0.000*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
Sappi Limited ICAPM	ADF test statistic	-7.995	0.000*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
AngloGold Ashanti speed of adjustment series	ADF test statistic	-13.406	0.000*
	1% level	-3.461	
	5% level	-2.875	
	10% level	-2.574	
Sappi Limited speed of adjustment series	ADF test statistic	-7.621	0.000*
	1% level	-3.459	
	5% level	-2.874	
	10% level	-2.573	
AngloGold Ashanti principal component	ADF test statistic	-8.996	0.000*
	1% level	-3.461	
	5% level	-2.875	
	10% level	-2.574	

*Reject null hypothesis for the presence of a unit root at the 5% level.

Source: Compiled by author.

Table 21: Third additional ADF unit root test results

		t-statistic	t-probability
AngloGold Ashanti expected stock return differential $(R_{t+k}^e - R_{t+k}^{*e})$	ADF test statistic	-10.480	0.000*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	
Sappi Limited expected stock return differential $(R_{t+k}^e - R_{t+k}^{*e})$	ADF test statistic	-8.615	0.000*
	1% level	-3.457	
	5% level	-2.873	
	10% level	-2.573	

*Reject null hypothesis for the presence of a unit root at the 5% level.

Source: Compiled by author.

Table 22: Ramsey Reset Test – fractionally differenced approach

	Value	Probability
F-statistic	4.150	0.042*
Likelihood ratio	4.166	0.041*

Number of fitted values: 1

* Reject the null hypothesis of no mis-specification error.

Source: Compiled by author.

Table 23: White test to determine heteroskedasticity in Table 6.67

F-statistic	1.831
Obs*R-squared	5.458
Scaled explained SS	5.584
Prob. F(3,239)	0.142***
Prob. Chi-Square(3)	0.141***
Prob. Chi-Square(3)	0.134***

*** Reject the null hypothesis of homoskedasticity at the 15% level.

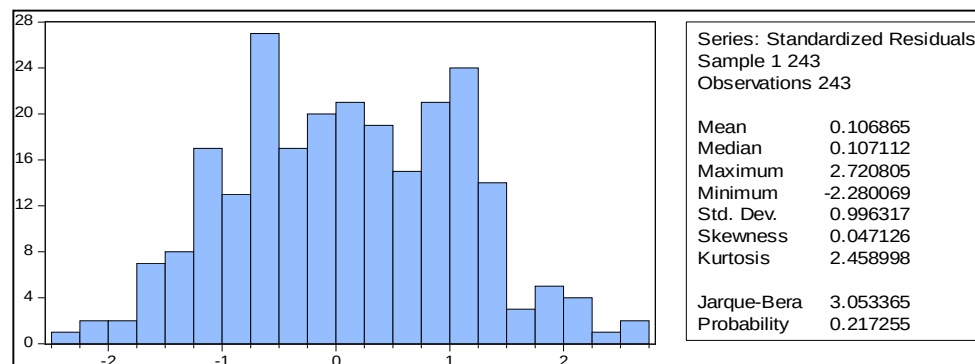
Source: Compiled by author.

Table 24: Breusch–Godfrey Serial Correlation LM test for Table 6.67

F-statistic	Obs.* R-squared	Prob. (F-statistic)	Prob. (chi-square)
296.300	173.580	0.000*	0.000*

* Reject the null hypothesis of no serial correlation at the 5% level.

Source: Compiled by author.

Table 25: Normality test for Table 6.67

Source: Compiled by author.

Table 26: Testing for remaining ARCH effects in Table 6.67 with an ARCH LM test

F-statistic	0.061
Obs*R-squared	0.061
Prob. F(1,240)	0.805
Prob. Chi-Square(1)	0.805

Source: Compiled by author.

Table 27: White test to determine heteroskedasticity in Table 6.68

F-statistic	2.268
Obs*R-squared	25.684
Scaled explained SS	21.012
Prob. F(12,226)	0.010*
Prob. Chi-Square(12)	0.012*
Prob. Chi-Square(12)	0.050*

* Reject the null hypothesis of homoskedasticity at the 5% level.

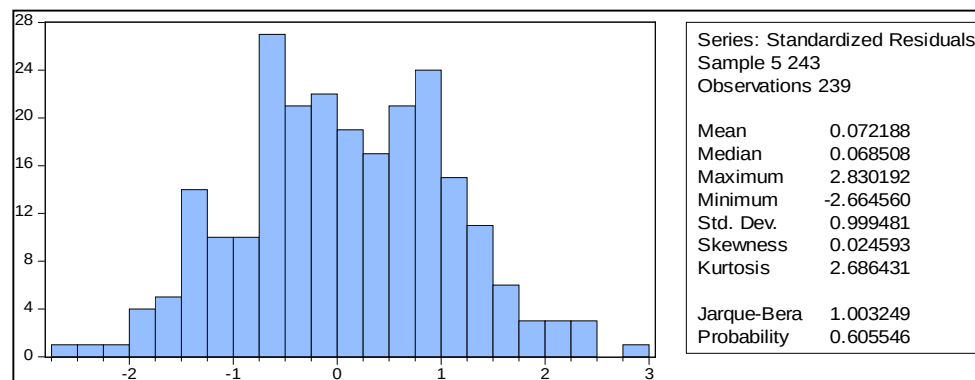
Source: Compiled by author.

Table 28: Breusch–Godfrey Serial Correlation LM test for Table 6.68

F-statistic	Obs.* R-squared	Prob. (F-statistic)	Prob. (chi-square)
155.670	138.996	0.000*	0.000*

* Reject the null hypothesis of no serial correlation at the 5% level.

Source: Compiled by author.

Table 29: Normality test for Table 6.68

Source: Compiled by author.

Table 30: Testing for remaining ARCH effects in Table 6.68 with an ARCH LM test

F-statistic	0.006
Obs*R-squared	0.006
Prob. F(1,236)	0.938
Prob. Chi-Square(1)	0.937

Source: Compiled by author.

Table 31: White test to determine heteroskedasticity in Table 6.69

F-statistic	2.103
Obs*R-squared	24.006
Scaled explained SS	20.441
Prob. F(12,226)	0.018*
Prob. Chi-Square(12)	0.020*
Prob. Chi-Square(12)	0.059**

* Reject the null hypothesis of homoskedasticity at the 5% level.

** Reject the null hypothesis of homoskedasticity at the 10% level.

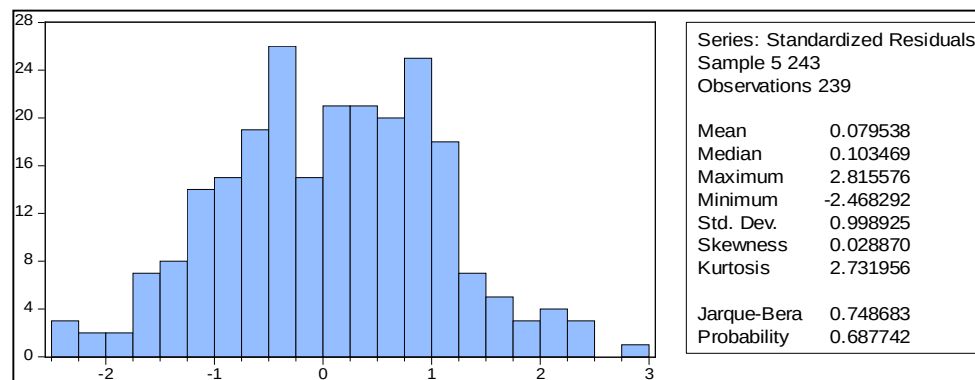
Source: Compiled by author.

Table 32: Breusch–Godfrey Serial Correlation LM test for Table 6.69

<u>F-statistic</u>	<u>Obs.* R-squared</u>	<u>Prob. (F-statistic)</u>	<u>Prob. (chi-square)</u>
152.658	137.858	0.000*	0.000*

* Reject the null hypothesis of no serial correlation at the 5% level.

Source: Compiled by author.

Table 33: Normality test for Table 6.69

Source: Compiled by author.

Table 34: Testing for remaining ARCH effects in Table 6.69 with an ARCH LM test

F-statistic	0.163
Obs*R-squared	0.164
Prob. F(1,236)	0.687
Prob. Chi-Square(1)	0.686

Source: Compiled by author.

Table 35: Estimating the fractionally differenced parameters

Variable	Type ARFIMA estimation	Statistics
S_{t+3}	AR(1) – EML estimation	$d = 0.328$ t-prob. = 0.058**
Forward exchange rate	AR(1) – EML estimation	$d = 0.296$ t-prob. = 0.026*
South African 10-year government bond yield rate	AR(1) – EML estimation	$d = 0.248$ t-prob. = 0.012*
South African AngloGold Ashanti Limited expected stock returns (R_{t+k}^e)	AR(2), MA(2) – EML estimation	$d = 0.463$ t-prob. = 0.000*
South African Sappi Limited expected stock returns (R_{t+k}^e)	AR(3), MA(1) – EML estimation	$d = 0.477$ t-prob. = 0.000*
South African 91-day T-Bill rate	AR(1) – EML estimation	$d = 0.303$ t-prob. = 0.000*
U.S.A. 10-year government bond yield rate	AR(1) – EML estimation	$d = 0.354$ t-prob. = 0.000*
U.S.A. AngloGold Ashanti Limited expected stock returns (R_{t+k}^e)	AR(3), MA(1) – EML estimation	$d = 0.225$ t-prob. = 0.005*
U.S.A. Sappi Limited expected stock returns (R_{t+k}^e)	AR(2), MA(2) – EML estimation	$d = 0.477$ t-prob. = 0.000*
U.S.A. 91-day T-Bill rate	AR(1) – EML estimation	$d = 0.174$ t-prob. = 0.003*
South African actual inflation rate	AR(1) – EML estimation	$d = 0.496$ t-prob. = 0.000*
Sappi Limited ICAPM series	AR(1) – EML estimation	$d = 0.194$ t-prob. = 0.036*
Euro/USD exchange rate in ZAR terms	AR(1) – EML estimation	$d = 0.182$ t-prob. = 0.019*
Pond/USD exchange rate in ZAR terms	AR(1) – EML estimation	$d = 0.171$ t-prob. = 0.045*
Gold price	AR(2), MA(2) – EML estimation	$d = 0.495$ t-prob. = 0.000*
Brent oil price	AR(1) – EML estimation	$d = 0.092$ t-prob. = 0.071**

* Statistically significant at the 5% level.

** Statistically significant at the 10% level.

EML denotes Exact Maximum Likelihood (Section 5.3.2.1.1).

See also Section 6.2.2.1 for already reported d -parameter estimates.

Source: Compiled by author.

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LIST OF ACRONYMS

ADF	Augmented Dicky-Fuller
ADR	American Depository Receipt
AIC	Akaike Information
ANN	Artificial Neural Network
ARFIMA	Autoregressive Fractionally Integrated Moving Average
ARCH	Autoregressive Conditional Heteroskedasticity
APT	Arbitrage Pricing Theory
AR	Autoregressive
ARMA	Autoregressive Moving Average
ARIMA	Autoregressive Integrated Moving Average
BEER	Behavioural Equilibrium Exchange Rate
BIC	Bayes Information Criterion
CAPM	Capital Asset Pricing Model
CML	Capital Market Line
CPI	Consumer Price Index
DEER	Desired Equilibrium Exchange Rate
ECM	Error Correction Model
EGARCH	Exponential Generalized Autoregressive Conditional Heteroskedasticity
EMH	Efficient Market Hypothesis
EML	Exact Maximum Likelihood
EMS	European Monetary System
EMU	European Monetary Union

EREER	Equilibrium Real Effective Exchange Rate
ESTAR	Exponential Smooth Transition Autoregressive
EWMA	Exponential Weighted Moving Average
FD	Forward Discount
FEER	Fundamental Equilibrium Exchange Rate
FX	Foreign Exchange
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GDP	Gross Domestic Product
G6 countries	Germany, France, United Kingdom, Italy, Spain, Poland
ICAPM	International Capital Asset Pricing Model
ICP	International Comparisons Project
IRP	Interest Rate Parity
JSE	Johannesburg Stock Exchange
L-max	maximum Eigenvalue
MA	Moving Average
MGARCH	Multivariate Generalized Autoregressive Heteroscedasticity
MPL	Modified Profile Likelihood
MSFE	Mean Square Forecast Error
MS-VAR	Markov Switching Vector Autoregressive
NATREX	Natural Real Exchange Rate
NCSTAR	Neuro-Coefficient Smooth Transition Autoregression
NEER	Nominal Effective Exchange Rate
NLS	Non-linear Least Squares
NYSE	New York Stock Exchange

OECD	Organization for Economic Cooperation and Development
OLS	Ordinary Least Squares
PBH	Productivity Bias Hypothesis
PEER	Permanent Equilibrium Exchange Rate
PPI	Producer Price Index
PPP	Purchasing Power Parity
RBOC	Regional Bell Operating Companies
REER	Real Effective Exchange Rate
RESI 20	JSE's top 20 resource companies ranked by their full market value
RWH	Random Walk Hypothesis
SIC	Schartz Information Criterion
SML	Security Market Line
STAR	Smooth Transition Autoregressive
TAR	Threshold Autoregressive
T-Bill	Treasury Bill
Tr	Trace
U.K.	United Kingdom
U.S.A.	United States of America
USD	United States Dollar
VAR	Vector Autoregressive
VEC	Vector Error Correction
WACC	Weighted Average Cost of Capital
ZAR	South African Rand