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# Regimes change and exchange rate dynamics: the rand

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## **Declaration**

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This work is my own. I have not previously submitted it in whole, or in part, for the award of any degree. Each significant contribution to, and quotation in this dissertation from the works, or works of other people has been attributed, and appropriately cited and referenced, based on the American Psychological Association (APA) system.

Elvis Mtonga  
Cape Town,  
December 2008

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## **Abstract**

### **Regimes change and exchange rate dynamics: the rand**

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PhD thesis

Supervised by Prof. Melvin D. Ayogu,  
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The rand has since the mid-1980s maintained a long swing of decline that reversed in 2002 for a brief while; resuming the swing shortly thereafter. In contrast to these fairly predictable fluctuations, the rand's short run movements are increasingly volatile and seemingly unpredictable. Anchored in the *asset approach* to exchange rate determination, this study examines the two issues of the long run and short run exchange rate dynamics of the rand.

Using a systems approach that combines Johansen's (1995) multivariate cointegration technique with the long run structural modeling techniques of Persaran, Shin, and Smith (2002), the study finds that economic fundamentals anchor the rand's long swings. However, the anchorage is regime dependent – the regime-switch to Inflation Targeting (IT) in 2000 appears to have significantly altered the role and importance of fundamentals in pricing the rand. South Africa's IT regime so far has been characterized by an absence of obvious intervention by the monetary authority even though the rand has become more volatile.

Tests for return predictability of short run movements of the rand, conversely, suggest “weak-form” market inefficiency, although it is unclear how much of the increased volatility is due to this short-run inefficiency. Nonetheless, using Generalized Autoregressive Conditional Heteroskedasticity (GARCH) technique, there is evidence of volatility clustering that is asymmetrically distributed; periods of rand depreciation induce more volatility than episodes of rand appreciation. This suggests that

short and long positions on the rand have been unevenly distributed and thereby the market's overall view of the rand has tended to be unidirectional. It is speculated that this behavior may be rooted more in the psychology of financial market participants than can be uncovered by econometric techniques. Thus in the quest to better understand asset price movements over time, advances in behavioral finance continue to hold strong promise as the ideal complement to the economist's traditional toolkit.

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# Chapter 1

## 1 Introduction: background and motivation

### *In context*

Until 2000, when South Africa changed its monetary regime to an Inflation Targeting framework, managing the rand has been at the heart of the country's efforts at achieving economic stabilization. From inception early on in the 1960s and through to late 1970s, stability of the rand was itself a policy objective (Van der Merwe, 1996). This was sustained by a policy of maintaining the rand at fixed parity with the major currencies - *the US dollar and the British pound sterling* – under the Bretton Woods Agreement that bound all countries to fixed currency peg regimes. In the beginning, the authorities used the policy to sustain the rand at overvalued rates in order bring in cheap capital imports to support an industrialization program that the government had embarked upon (Jones & Muller, 1992).

Later, when commodity prices became overly volatile in early 1970s, the policy action targeted maintaining profitability of the gold mining industry. At that stage in South Africa's history, the gold mining industry was pivotal to the economy. Not only was it a driver of growth, but it also provided the much needed foreign exchange revenues to support the industrialization program, offered substantial tax revenues to the Government as well as huge employment opportunities (Jones & Muller, 1992). Other industries also relied on gold mining for their future expansion.

Especially with regard to export earnings, gold was the major export commodity. Gold exports contributed the bulk of the country's export revenues (table 1-1), although this is now significantly reduced. Erratic fluctuations in the price of gold thus posed problems because their adverse impact on export revenues threatened the overall expansion of the economy, given the inter linkages with other sectors.

Table 1-1: South Africa's merchandise exports: 1960 to 2004

Year	Merchandise exports (millions of rand)	Net gold exports (millions of rand)	Share of gold exports in merchandise exports (%)
1960	892	530	59.4
1965	1,075	775	72.1
1970	1,542	837	54.3
1975	3,967	2,540	64.3
1980	10,141	10,140	100.0
1985	20,874	15,370	73.6
1990	44,740	16,703	37.3
1995	86,580	21,484	24.8
2000	194,223	27,838	14.3
2004	278,932	32,830	12.0

Source: South African Reserve Bank, *Online data download facility*, available at [www.reservebank.co.za](http://www.reservebank.co.za) (accessed: October 2005)

To put the significance of the gold price to South Africa into context, consider that prior to 1970, the world market price of gold was held fixed, tied to the US dollar at a fixed parity (Kahn, 1991). This ensured a stable price and, in turn, the gold mining industry boomed (Jones & Muller, 1992). Post 1970, however, the world market gold price became variable and highly volatile. Although the initial rise in the gold price temporally bolstered gold output, its subsequent erratic changes lead to a series of booms and busts. Export revenues correspondingly fluctuated unpredictably, thereby threatening the profitability of the industry. These uncertainties to export revenues also affected the country's external sector position; to the extent that it frequently required corrective measures (Kahn, 1991).

Wanting therefore to preserve stability and profitability of gold mining, the authorities resorted to discrete adjustments to the rand in response to changes in the price of gold. Whenever there was a sustained fall in world market price of gold, the authorities acted to devalue the rand, which made it possible to raise the rand price of gold, thereby making gold mining profitable. Likewise, measures to revalue the rand were instituted once a prolonged rise in the world price of gold occurred, which reduced the corresponding rand price. This ensured a stable rand gold price and

helped to stabilize profitability of the gold mining industry (Kahn, 1991). To that extent, one can say that the fluctuations in the gold price determined exchange rate policy during that time.

This changed in the 1980s and early 1990s, with the thrust of policy shifting to preventing economic instability and resolving balance of payments problems. Starting in the early 1980s, political unrest against Apartheid, coupled with adverse macroeconomic developments, had pushed the economy into recession. Then in 1985, severe balance of payments deficits developed when a major foreign debt crisis ensued in the country.

The foreign debt crisis followed a massive international campaign for economic sanctions against South Africa in protest of its Apartheid policy. The sanctions called for immediate disinvestment and forbade further lending to the country (Gelb, 1991). Lead by Chase Manhattan, an American bank, foreign creditors withdrew all credit lines and existing loans (US Library of Congress, 1997). As a result, capital outflows occurred on a massive scale (Mohr & Fourie, 2004) and sizeable external payments arrears developed (Kahn, 1992). Unable to repay the debt at short notice, and added to the country's inability to access new capital, South Africa defaulted on the debt and declared a moratorium on further repayments (US Library of Congress, 1997). This precipitated the debt crisis

In response, the authorities opted to implementing policies that targeted at generating current account surpluses. This led to the establishment of a dual currency system of managing the rand, which comprised of a commercial rand and financial rand. The dual rand system was first been introduced in 1979 but later discontinued in 1983 when the rand was temporary designated a free-float. The idea was to value transactions by residents at the commercial rand rate and those of non-residents at

the financial rand rate. In this way, the authorities hoped the financial rand would insulate the country from non-resident capital transactions, which had become very volatile. This made the financial rand a form of exchange control. However, both political unrest and sanctions did not abate until early in the 1990s.

Post 1994, after the country had transformed to democracy and Apartheid ended, South Africa faced major challenges of high unemployment levels, widespread poverty, and entrenched socioeconomic inequalities that had become prevalent among most of the population (Lewis, 2001). The authorities introduced the Growth, Employment, and Redistribution (GEAR) as the macroeconomic policy framework for resolving these challenges. The GEAR called for attainment of a high and sustainable economic growth rate as the basis for creating more jobs, and, in turn, alleviating the problem of high unemployment and poverty (Republic of South Africa, 1996). Two processes underpinned this. One was to attain macroeconomic stability, through fiscal prudence and monetary discipline. The other was a program of financial and trade liberalization aimed at reinserting the economy into the global economy (Lewis, 2001).

As part of a broader effort to liberalize financial markets, therefore, the dual rand system was in March 1995 discontinued and the exchange rate regime thereby reverted to a unitary rate. There was nonetheless continued use of the rand as policy instrument for stabilizing domestic prices and correcting balance of payments imbalances. This was reflected in the foreign exchange market interventions aimed at stabilizing the rand that became commonplace. It was not until after adoption of inflation targeting as a framework for conducting monetary policy in February 2000 that the authorities left determination of the value for the rand to the dictates of the

market. To succeed, inflation targeting requires a policy regime of not targeting the exchange rate.

### *A dwindling and volatile rand*

In view of the historically significant attention devoted to stabilization measures in the domestic foreign exchange market, one would have expected a stable rand. However, the reality has been different. From the mid 1980s, the rand has sustained a long swing of depreciation that reversed in 2002 only for a short while, but resuming the swing in 2006 (figure 1-1). In contrast to these fairly predictable fluctuations, the rand's short run fluctuations are increasingly volatile and seemingly unpredictable. Indeed, variations in the rand by as much as four percent in a single day or week are common, especially since the mid 1990s (figure 1-2).

This increase in volatility as well as both the size and persistence of its periodic fluctuations has concerned the Government, out of fear that it may pervasively affect the tradable goods sector. Indeed, through these tradable sectors, the cost to the economy that follows from exchange rate volatility can be enormous, with devastating consequences (Lewis, 2001). This is especially true when these tradable goods sectors are large relative to the overall size of the economy. Besides its more apparent effect of affecting the level of uncertainty, and thus investment decisions, exchange rate volatility is known to lead the collapse of existing policies and weaken financial institutions when it becomes excessive (Ayogu & Dezhbakhsh, 2008). Persistently excessive exchange rate volatility can thus be inimical to both the design and effectiveness of macroeconomic stabilization policies.

Figure 1-1: Long swings in the rand: February 1979 to April 2007

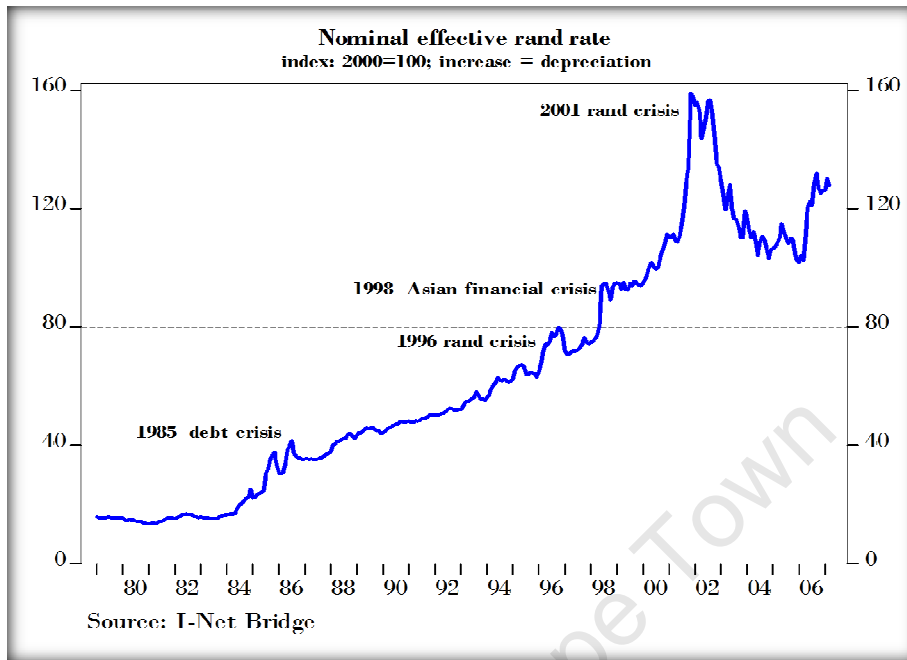
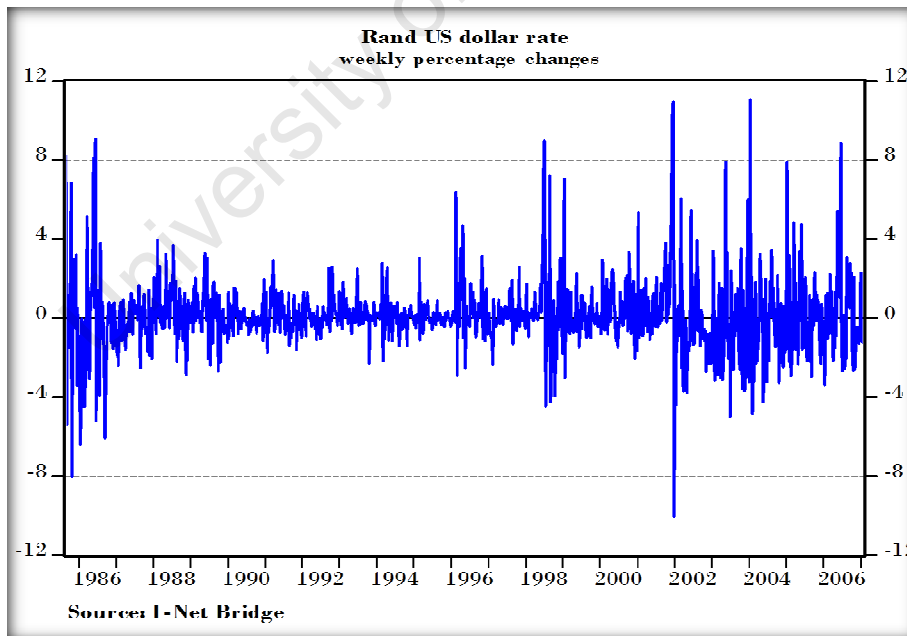


Figure 1-2: The volatility of the rand: 25 August to 3 February 2007



Specially during the 2001-rand crisis, concerns over the overall impact on the economy of the unexpectedly large depreciation of the rand by more than 40 percent over a relatively short period of six months, from June to December, prompted the President, Thabo Mbeki, to appoint the Myburg Commission (2002), on 8 January 2002, to investigate the factors behind its rapid collapse. Even though the Commission largely failed to pinpoint responsible factors, its constitution serves to highlight the level of concern that the rand has continued to generate from policy makers<sup>1</sup>.

Another case in point that bears testimony to this is the policy responses of the South African Reserve. For many years, from 1985 to 2000, the Reserve bank actively attempted to prevent what it considered unwarranted depreciations of the rand through its policy of foreign exchange market intervention using the forward book mechanisms. These foreign exchange intervention activities came at a high cost to the economy, given the limited stocks of foreign reserves at the country's disposal. Between 1993 and 1999, for example, the cost to the economy of these rand defenses was an average US \$20 billion each year, measured by the increase in the negative value of the country's net open foreign exchange position (figure 1-3).

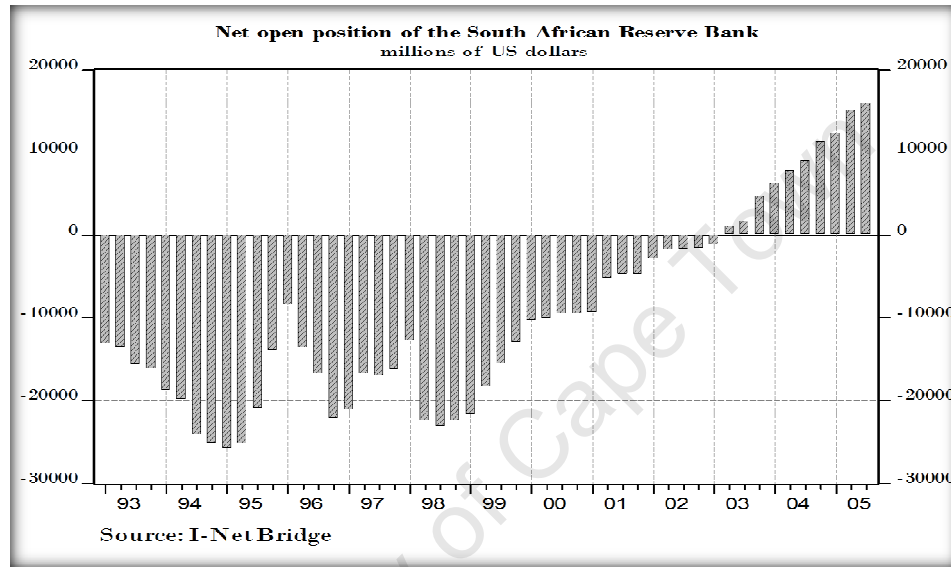
The major wide swings in short run fluctuations easily map to episodes when unusual events adversely affected South Africa's financial markets, and which at times precipitated a currency crisis. The 1985 foreign debt crisis is one case in point. As stated earlier, the United States of America led the international community in imposing economic sanctions on South Africa against the country's policy of

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<sup>1</sup> Some of the factors cited were the strength of the US dollar vis-à-vis other major currencies and higher inflation in South Africa relative to that of its major trading partners. Others included negative sentiments against South Africa's financial markets due to contagion effects that arose from the Argentinean crisis, economic problems in neighbouring Zimbabwe, and a host of factors related to the performance of the economy. For a detailed discussion, see the Myburg Commission (2002) report.

Apartheid. The economic sanctions forced US banks to recall not only their loans from South Africa, but also to refuse rollover of outstanding loan balances. The sanctions also barred international financial markets from lending to South Africa, which resources the country needed to refinance its international debt obligations.

Figure 1-3: South Africa: Foreign exchange market interventions and the forward book: Jan 1993-November 2005



The resultant financing limitation forced South Africa, in the now infamous Rubicon speech, to declare a debt repayment moratorium. Because of the massive capital flight that took place during this time, the rand plummeted by fifty three percent over a six months period, starting in July through to December 1985 (figure 1-1). Though the rand recovered moderately after this, an equally large depreciation of thirty-six percent began in April 1986 through to August 1986; thereafter the rand started to depreciate steadily.

During 1996, a series of aftershocks occurred, attributed to the uncertainty surrounding the post-Apartheid transition process, which influenced South Africa's financial markets negatively. These included the appointment of Trevor Manuel as Minister of Finance, who had come from the labour movement. As well, Nelson

Mandela, then state President, was rumored ill, which, together with the political violence in the Kwazulu Natal province (Wakeford, 2002), unnerved investors. Owing to these aftershocks, a large capital outflow resulted and caused a thirty percent depreciation of the rand during January through to December that year.

In 1998, the rand depreciated sharply by twenty six percent within four months. The rand's collapse this time around was due to contagion effect of financial crises of other emerging market countries, namely in Russia and the South Asian countries - *the Asian crisis* (Wakeford, 2002; Mohr & Fourie, 2004). In those countries, beginning in the 1990s, large capital inflows, mainly short-term flows, enabled them to sustain managed pegs of their currencies of different kinds. However, because of unsound investments and banking practices, several bank failures in Thailand caused a major crush of its currency, the baht. The wave of negative sentiments that ensued quickly spread to other South Asian countries and to those classified as emerging markets worldwide. Those negative perceptions also affected South Africa, itself classified as an emerging market, leading to large capital flight.

In 2001, the rand depreciated on trade-weighted basis by more than fifty percent in a space of just six months, from June to December – being the most severe of rand's crises. The rapidity of the collapse and concerns over its overall impact on the economy lead to the appointment of the Myburg Commission (2002), to investigate the factors that may have accounted for such a huge loss in the value of the currency. Although it identified a variety of potential factors, the Commission's findings proved inconclusive<sup>2</sup>. Nevertheless, by the end of 2004, the rand had recovered by sixty two percent of its 2001 value.

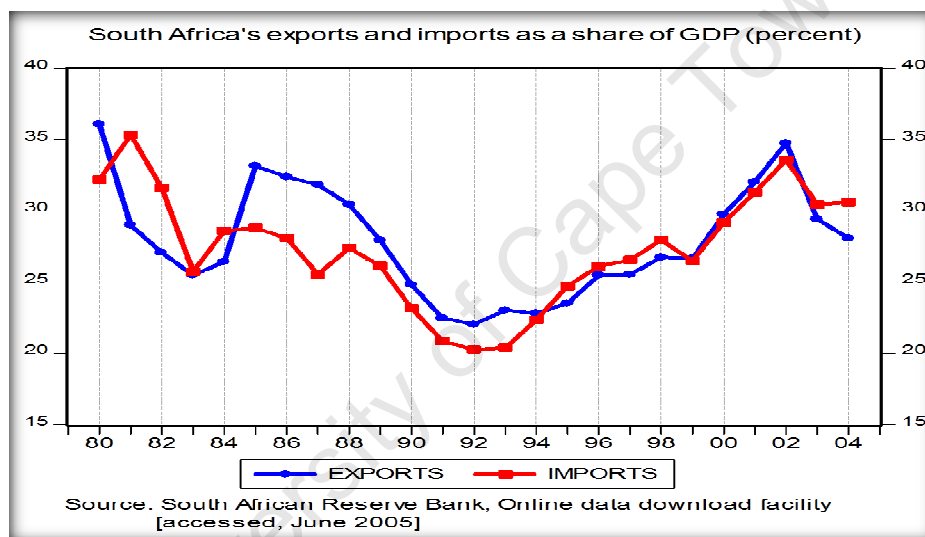
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<sup>2</sup> Some of these included the economy's vulnerability to global uncertainties in the wake of the September 11 terrorist attack on the USA and the impact of the economic crisis in neighboring Zimbabwe. The Commission also cited the strength of currencies of the major trading partners,

## Research questions

All this begs the question of what explains, on the one hand, the long swing of collapse of the rand—its *roller coaster ride* – and, on the other hand, its volatility – its *short run bumpy ride*? Is there something in the South African economy that can help us understand this behavior? More to the point, are these fluctuations an equilibrium phenomenon, reflecting linkages of the rand to its fundamental determinants, or do they simply reflect the influence of random shocks to the economy?

Figure 1-4: South Africa: Share of exports and imports in GDP



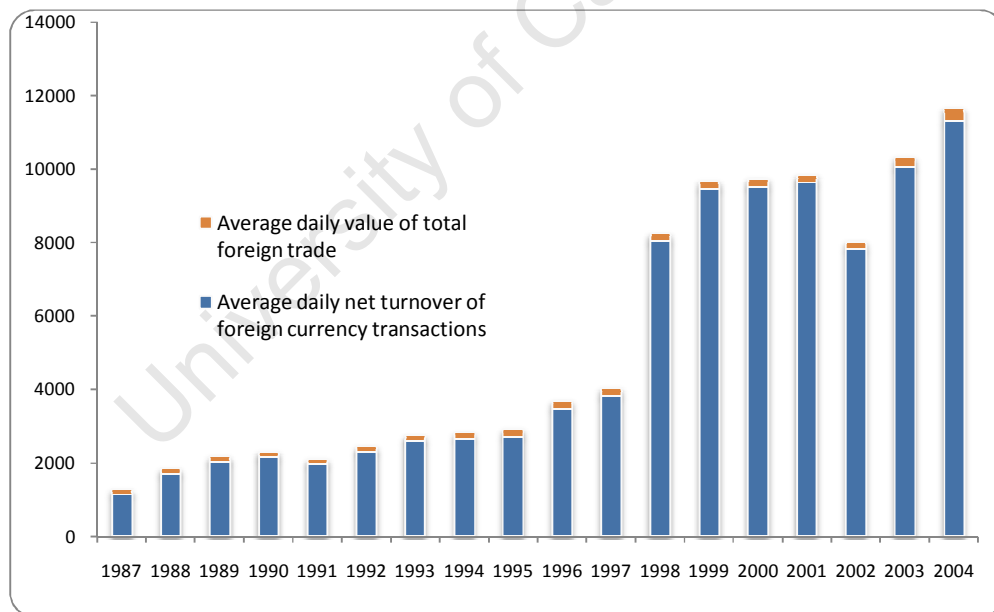
Answers to these questions are pertinent because they can inform effective policy making directed at stabilizing the economy and also condition agents' expectations about future movements in asset prices, including the rand itself. As the rand's exchange rate is a highly visible economic indicator and a key policy variable, its volatility can interact pervasively with the domestic political economy and international relation. This issue is more prominent now that the government has launched the Accelerated and Shared Growth Initiative for South Africa

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particularly the US dollar, coupled with general weaknesses of the South African economy as other factors that may have played a significant role.

(ASGISA)<sup>3</sup>, which aims to accelerate sustainable economic growth rate from 4.5 percent in 2004-09 to at least 6 percent per annum in 2010-14 (Republic of South Africa National Treasury, 2006) in order to create employment as an anti-poverty strategy. ASIGISA singles out currency volatility as one of the key impediments to attaining the country's growth objectives. Moreover, South Africa is highly trade-dependent with highly concentrated export and import sectors, by as much as thirty percent of Gross Domestic Product (figure 1-4). Also, its domestic financial markets strongly anchors with global markets. Especially the domestic foreign exchange market boasts large trades in financial assets in volumes that are much greater than merchandise trade, akin to those of industrial countries (figure 1-5).

Figure 1-5: Average daily volume of turnover on the South African foreign exchange market and the value of foreign trade (in million US dollars)



Source: South African Reserve Bank, *online data download facility*, available at [www.reservebank.co.za](http://www.reservebank.co.za), [accessed: June 2005], and author's own calculations.

<sup>3</sup> Frankel, Smit, and Sturzenegger (2006) is an interesting perspective into the risks and challenges this brings to the country's overall development strategy, particularly its fiscal implications, given the need to sustain macroeconomic stability

Indeed, the fear is that these circumstances may attract considerations that may trigger positions that could culminate into market interventions to smoothen the exchange rate, but doing so without a clear understanding of underlying drivers of the currency's volatility. In that regard, if, for example, it were known that the rand's exchange rates anchored on their fundamental determinants, the solution to the problem of their volatility may lie at stabilizing or enhancing the speed of adjustment in those fundamentals. On the other hand, if the rand's exchange rates are divergent from fundamentals and instead their fluctuations merely reflect diverging cyclical positions, such as random speculative behaviors by the foreign exchange market, the strong likelihood is that their influences, on balance, will be harmful to the economy. To the extent that the source of such random behaviors were known, as for example, imperfections in the flow of information to the market, then an interventionist policy that seeks to illuminate the quantity and quality of information to market participants would be the ideal. The policy maker's challenge, and that of the researcher, is to seek to understand how this all interfaces, to make an informed decision – this is where the results of the present study can help.

### ***Purpose***

The study thus has the following objectives:

- a) To ascertain the linkages of the rand to the South African economy by seeking to unearth a set of factors that aid explaining long run trends in the rand; and
- b) To establish the extent to which unpredictable arrival of information to which the South African currency market may or may not quickly adjust helps understand short run fluctuations in the rand.

## ***Structure***

The thesis provides three areas of analysis. The first is an analytic narrative of exchange rate policy since the 1960s, which is covered in a single chapter - chapter two. The aim is to offer an understanding on how policy objectives have driven the choice of exchange rate regimes and the extent to which the different regimes were successful in achieving their desired policy goals. This portion of the analysis is necessary because an understanding of currency movements requires an appreciation of the context in which such movements are occurring – that is, of the institutions that condition the market. Such context also helps to inform the resolution of several empirical questions such as *the exchange rate horizon choice* and the effect of *regimes change*.

In the second area, the analysis examines the long run movements of the rand by seeking to uncover a set of factors that help to map the long run trends of the rand. This starts with chapter three, which is a summary of the literature that seeks to explain long run trends in currency movements, and thereafter, in chapter four, provides an empirical analysis.

The third area considers the short run movements of the rand as an asset traded in markets with unpredictable arrival of information to which the market may or may not quickly adjust. After examining the relevant literature in chapter five, chapter six offers an empirical analysis on this.

The final chapter, chapter seven, provides concluding perspectives by way of synthesizing the main findings of the study.

## Chapter 2

### 2 Economic policy and the rand

This chapter examines South Africa's exchange rate policies since the 1960s. The objective is to understand how Government's policy objectives have influenced the choice of exchange rate regimes and in turn how successful the regimes were in achieving the policy goals. The examination is necessary to aid the resolutions of the empirical questions of the *exchange rate horizon choice* and the *impact of regime change* that the study subsequently makes.

#### Exchange rate policy since the 1960s

Several changes to the exchange rate regime characterize South Africa's exchange rate policy; rooted in a myriad of causes, of which the most important is the Apartheid and political instabilities and international isolation that it induced<sup>4</sup>. Table 2-1 illustrates how the exchange rate regime has changed since the 1960s and figure 2-1 maps the rand's movements onto these regime's change.

#### ***Fixed rates with exchange control: the 1960s and 1970s***

In the 1960s and most of the 1970s, the rand was held fixed at adjustable parities either to the US dollar or British pound sterling at different times. At that point, stability of the rand was itself an objective, in part because of South Africa's signatory to the Breton Woods Agreement to manage fixed exchange rates (Wakeford, 2002; Van der Merwe, 1996; De Kock Commission, 1985), as did the rest of the world. However, the government sought also to maintain an overvalued rand, to aid importation of cheap capital goods to support a rapid industrialization program that had been embarked upon (Jones & Muller, 1992).

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<sup>4</sup> Further elaboration is given in Aron, Elbadawi and Kahn (2000; 1997); Kahn (1992) and Van der Merwe, (1996)

Along with the fixed exchange rate regime, the authorities placed strict foreign exchange control regulations on capital account transactions by both residents and non-residents. Consider for instance that the regulations barred non-residents from repatriating proceeds from their investments until after a five-year period (Jonsson, 2001). This was made much more restrictive particularly with regard to non-residents' transactions in early 1960s when a series of political unrests, triggered by the Sharpeville massacres<sup>5</sup>, resulted in massive capital outflows (Van der Merwe, 1996).

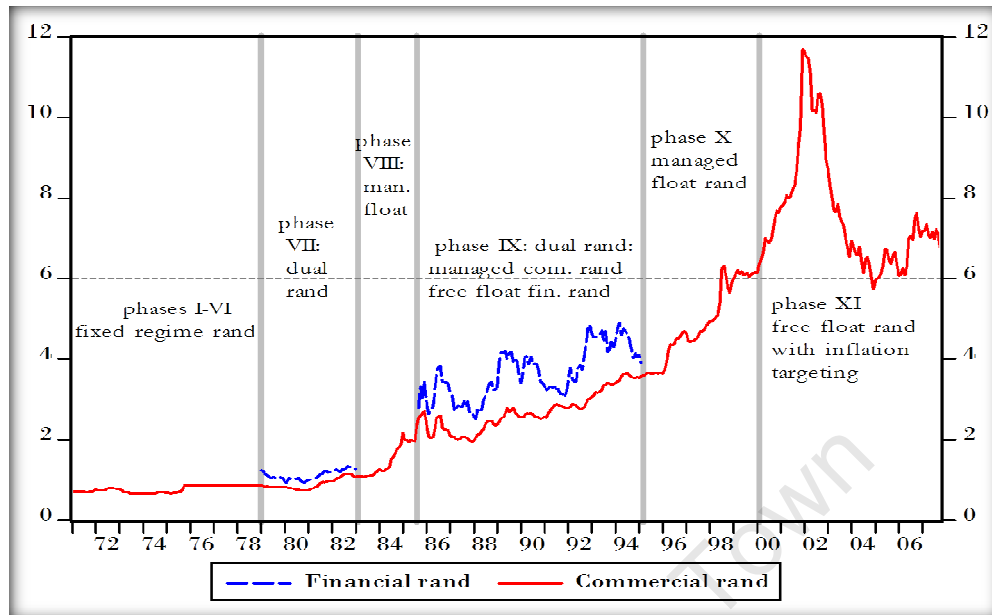
Table 2-1: South Africa: Exchange rate regime changes

Episode	Date	Exchange rate regime
I	Feb 1961 - July 1971	Fixed exchange rate regime: rand pegged to the British pound
II	Aug 1971 - Nov 1971	Fixed exchange rate regime: rand pegged to the US dollar
III	Dec 1971 - Sept 1972	Fixed exchange rate regime: rand pegged to the British pound
IV	Oct 1972 - May 1974)	Fixed exchange rate regime: rand pegged to the US dollar
V	June 1974 - May 1975	Crawling peg rand: rand pegged to a basket of currencies
VI	June 1975 - May 1979	Fixed exchange rate regime: rand pegged to the US dollar
VII	June 1979 - Jan 1983	Dual exchange rate regime: Crawling peg commercial rand and free floating financial rand
VIII	Feb 1983 - Aug 1985	Unitary exchange rate: Managed float rand
IX	Sept 1985-Feb 1995	Dual exchange rate regime: managed float commercial and free float financial rand
X	Mar 1995 - Jan 2000	Unitary exchange rate : Managed float rand
XI	Feb 2000- present	Unitary exchange rate: free floating rand, with inflation-targeting framework of monetary policy

Source: Aron, Elbadawi and Kahn (2000), De Kock Commission (1985); Author's compilation.

<sup>5</sup> The Sharpeville massacre relates to an incident on March 21, 1960 at which police killed 69 and injured 180 of the people that had gathered in Sharpeville to demonstrate against the stipulations of the Pass Law that had required Africans [black people] to carry identity cards.

Figure 2-1: Exchange rate regimes change and the rand



With the collapse of the Bretton Woods system of fixed rates in 1973 and subsequent shift of the international monetary system towards flexible rates, the rand temporarily became a crawling peg of a basket of currencies in June 1974. This policy framework allowed for relatively more frequent but smaller adjustments to the rand's exchange rates, to increase the role of market forces in pricing the rand while ensuring its stability. Nonetheless, surmountable speculative pressures mounted against the rand that forced a returning in 1975 to a fixed peg to the US dollar (De Kock Commission, 1985).

### ***Dual rates: crawling pegging and managed floating, 1979-1983***

The returning to fixed pegging of the rand however coincided with intensified political unrest against Apartheid, notably the 1976 Soweto riots<sup>6</sup>. In turn, these

<sup>6</sup> The Soweto riots had its genesis in the 1974 government's issued decree that had required all schools to use the Afrikaans language when teaching black children. Beginning first with the children at Orland West Junior School on 30 April 1976, several schools in Soweto protested against this policy. Their protests resulted in a mass rally on 16 June 1976, which turned violent. In response, the police shot and killed more than 500 schoolchildren, triggering widespread violence across South Africa that also claimed more lives.

attracted a series of economic sanctions by the international community. Both the tumultuous political environment at home and international economic sanctions exerted severe pressures on the economy and caused a massive capital out flow, especially non-resident capital. The country also endured the influence of adverse global markets developments, particularly the dollar's weakness - the US dollar plummeted during 1978 (De Kock Commission, 1985).

Facing these turbulent political and economic events, the authorities set up the *De Kock Commission* of inquiry on 16 August 1977 to study and give advice on changes to the country's monetary system and monetary policy. In an interim report published in November 1978, the Commission found that the policy of pegging the rand was unable to evolve as an appropriate mechanisms for pricing the currency in consonance with the then government's objectives of achieving sustainable economic growth, balance on the external payments accounts, and low inflation (De Kock Commission, 1985; Van der Merwe, 1996). Instead, a managed floating of the rand was found fitting. Unfortunately, the foreign exchange market lacked sufficient depth to sustain a managed float. This led to the recommendation for a dual exchange rate mechanism, which the authorities implemented in June 1979.

The dual exchange rate regime comprised of two rates; the commercial rand and financial rand. On the one hand, the financial rand, a secondary rate, applied only to non-resident capital transactions and functioned mainly as a form of exchange control on those transactions, particularly equity capital. The idea was that this way would insulate the economy from volatility in non-resident capital transactions, given the tumultuous political environment and economic sanctions. Accordingly, the pricing of the financial rand was permitted under a relatively free fully market

conditions. However, the market thinly traded the financial rand and thereby generated a large spread between bids and asks rates, which made it overly volatility.

The commercial rand, on the other hand, was a principal rate and applied to all resident transactions. Although it had been designated a floating rate, it was subject to an official intervention policy, according to which the Reserve Bank made frequent market purchases and sales in support of desired rates. Exchange control over all resident transactions was also continued.

### ***Controlled floating and unitary rand, 1983-1985***

In 1983, seeking to enlarge the scope of the foreign exchange market, a forward market was introduced, albeit heavily regulated by the Reserve Bank (Van der Merwe, 1996; Aron, Elbadawi, & Kahn, 2000; 1997). This decision satisfied the authorities as to the sufficiency of the foreign exchange market to support a managed float. Thus, the financial rand was discontinued in February 1983 and the exchange rate regime reunited to a managed float. Along with the cessation of the financial rand, exchange control over both resident and non-resident transactions was abolished. Official intervention policy was nonetheless continued (Aron, Elbadawi, & Kahn, 2000; Aron, Elbadawi, & Kahn, 1997; Mboweni, 2002).

### ***Return to dual rates but with managed floating, 1985-1995***

In May 1985, the United States of America placed economic sanctions against South Africa that included cessation of new lending and freezing of existing credit lines. This was problematic for South Africa because American banks, particularly Chase Manhattan Bank, held the bulk of its foreign debt, mostly short term. When therefore the American banks withdrew all their lending and refused to roll over maturing debt liabilities, South Africa defaulted in its foreign debt obligations by declaring moratorium on its repayments (Ayogu & Dezhbakhsh, 2008). This resulted

in a foreign debt crisis, and, in turn, impeded external financing of current account deficits, which the debt crisis induced. This problem had to be resolved by implementing absorption-reducing measures to generate and sustain current account surpluses.

Therefore, as part of a package of measures designed to achieve this goal, the exchange rate regime made way to a dual rand mechanism by way of reconstitution of the financial rand in September 1985. Furthermore, exchange control over both resident and non-resident transactions was reinstated. The intention of reintroducing the financial rand remained much the same as had been set out when it was first instituted early on in 1979, namely to forestall further outflows of non-resident capital. The commercial rand on the other hand was maintained as a managed float, supported by interventions policy.

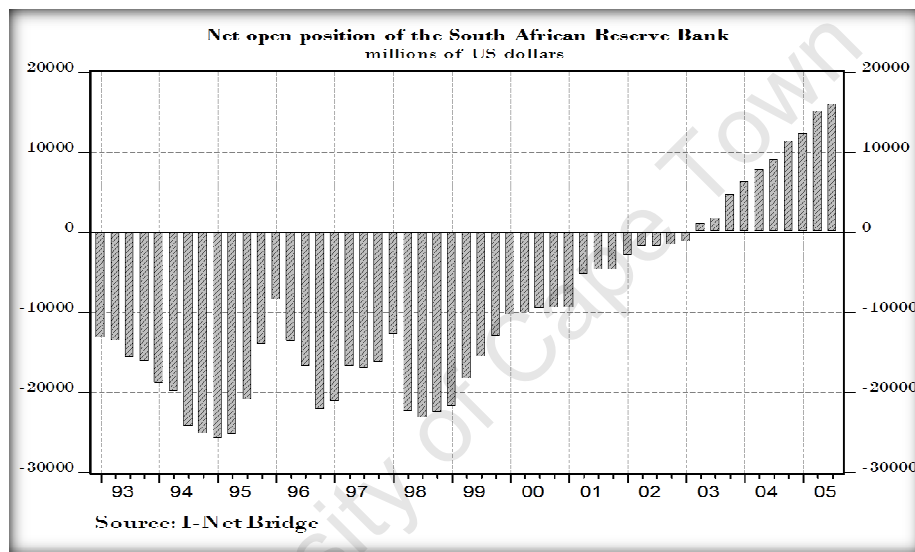
While often one can cite the debt crisis as the prime reason for reintroducing the dual rate regime, we argue here, based on the above, that political developments were a major contributor. Unfortunately, this turbulent political environment did not subside until the early 1990s when the authorities took steps towards political reconciliation.

### ***Attempts at financial liberalization, 1995-2000***

This political reconciliation took place in 1994 when the political regime made the transition from Apartheid to an all-inclusive participation. Desirous of reinserting the country into the global economy, the new Government embarked upon a process of gradually liberalizing the financial markets. As a first step, both the financial rand and exchange control on non-residents were abolished effective March 1995. The exchange rate regime thereby reverted to a managed float, but with official interventions to stabilize the rand continuing. Particularly during 1996 and 1998, the

Reserve Bank fought hard to prevent rapid depreciations of the rand by growing its open position on its forward book in the forward foreign exchange market (Mboweni, 2004). Unfortunately, this practice culminated into a large net open position against the Reserve Bank (figure 2-2), with a negative effect on foreign investments into South Africa and the markets' assessment of domestic economic conditions (Ayogu & Dezhbakhsh, 2008)

Figure 2-2: Net open position of the South African Reserve Bank



Exchange control on resident transactions was initially retained but has since been progressively slackened. The major changes that have occurred so far include the decision to allow resident institutional investors (i.e. pension funds, insurers, unit trusts as well as other institutional investors) to undertake foreign investments by way of the foreign exchange asset swap mechanism (Vittas, 2003; Farrell & Todani, 2004; Bruce-Brand, 2002)<sup>7</sup>. This allowed resident institutional investors to obtain foreign investments by exchanging part of their existing asset portfolios with assets

<sup>7</sup> A foreign exchange swap is defined in Fourie et al (1999) as a transaction that involve a contract to purchase or sell an amount of foreign currency on a specific date, at an agreed rate of exchange, and simultaneously to resell or repurchase the same amount of foreign currency for a date further in the future, also at an agreed rate of exchange. In other words, one currency is swapped for another currency for a given period, and later swapped back, thus creating an exchange and re-exchange of the currency.

of foreign investors. Although the swap mechanism was discontinued in February 2001, outright acquisition of foreign investment is still permitted.

For residential companies, a similar allowance has been granted for direct investments abroad and acquisition of foreign funding against their domestic balance sheets. However, this was initially given an overall limit of three billion rand investment, with at least two billion rand invested in Africa and the remaining one billion for the rest of the world. In addition, dividends repatriation from foreign subsidiaries became eligible for exchange control credit.

As for changes relating to private individuals, it had been made possible for individuals above the age of 18 years to undertake limited foreign investments from July 1994. Initially, this was limited to R200, 000 per individual, but later by February 2000, the limit was increased to R750, 000 per individual. Apart from these changes, foreign exchange tax amnesty was also been introduced during 2003.

Thus far, there has been substantial progress towards eliminating exchange control restrictions since the installation of democracy in 1994. However, as at the writing of this thesis, during 2007, equally significant levels of exchange control restrictions remain enforceable<sup>8</sup>. These include restrictions on foreign investments and acquisition of foreign loans by corporate organizations, acquisition of foreign portfolio assets by institutional investors, and limits on the amount of local assistance that South African companies with a large foreign interest can acquire. In the case of private individuals, a wide range of transactions still requires approval of the exchange control authorities. Notably, transactions relating to foreign investments, acquisition of foreign loans, travel allowances, foreign study allowances, holidays, gifts, and payments to non-residents. A number of restrictions apply also to

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<sup>8</sup> Exchange controls regulations are available at the website of the South Africa Reserve Bank; [www.reservebank.co.za](http://www.reservebank.co.za)

authorized dealers in foreign exchange. Examples are transactions related to import and exports of goods and services, forward exchange contracts with both residents and non-residents, and management of customer foreign currency accounts.

### ***Free floating in a new monetary policy regime, post 2000***

In February 2000, inflation targeting was adopted as the operating framework for monetary policy. Under this framework, monetary policy is focused on announced inflation rate benchmarks to be met over a specified time frame, explicit inflation forecast as the intermediate variable, and interest rate as the policy instrument. For policy efficacy and thereby credibility, the regime of inflation targeting requires no pre-commitment to an exchange rate target (Masson, Savastano, & Sharma, 1998)<sup>9</sup>. Accordingly, the Reserve Bank took the step to cease its foreign exchange market interventions policy to stabilize the value of the rand except for reserve accumulation. A major milestone in this pursuit was reached with the closure of the Reserve Bank's negative net open position in May 2003 and cessation of its forward book in the foreign exchange market in February 2004 (International Monetary Fund, 2004; Mboweni, 2004). The inflation-targeting regime so far has continued to be implemented successfully and obvious interventions in the foreign exchange market in support of the rand have been absent.

With adoption of the inflation-targeting framework, therefore, the exchange rate regime has become consistent with a free float. However, the continuous use of exchange controls implies that the liberalization of the foreign exchange market is yet to be completed. Nevertheless, given ongoing debate about the appropriate financial architecture in the context of globalization and increased macroeconomic volatility, it is not clear that complete liberalization for an emerging market is the ideal.

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<sup>9</sup> With a targeted exchange rate, there is no independent monetary policy – the goal of monetary policy becomes that of defending the exchange rate.

## Summary and transition

What South Africa's experience therefore reflects is an exchange rate regime that has been overly sensitive to political developments. For the most part, the many changes to the exchange rate regime were a consequence of political forces. Although overall macroeconomic stability was achieved when political reconciliation was reached in 1994, an unstable political environment prevailed soon thereafter, which necessitated continuing exchange control regulations and conducting regular intervention of the domestic foreign exchange market to control the rand. It is only with concomitant dismantling of exchange controls and the regime switch to an inflation-targeting monetary policy framework in 2000 that one can recognize rand pricing with economic forces, at least in the "*de jure*" sense. Admittedly, since implementation of inflation targeting, economic policy is doing well, as was, for example, the handling of the 2001-rand crisis when the Reserve Bank resiliently relied on its interest rate policy as the operating tool<sup>10</sup>.

The lesson from all this is that empirically modeling South Africa's experience presents a challenge in the choice of an empirical horizon because of a short history that is dominated by frequent changes to the exchange rate regime. Tests in the exchange rate literature that can be applied to explain the rand's experience require examining a longer period and apply to market generated data. Unfortunately, there is a relatively shorter period of floating, where the data are market generated. Rather, the longer span of data available pertains to a period of very controlled floating and where they are affected by exchange regime changes. Therefore, a proper account of factors mostly likely to explain fluctuations of the rand must address the likely impact of exchange rate regimes change. To that end, the analysis first provides a review of

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<sup>10</sup> Initially, this came at a cost of high interest rates but favorable realizations of inflation targeting have led to their subsequent decline gradually.

relevant literature in the next chapter, and thereafter, reports on results from an empirical analysis that accounts for regimes change.

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## Chapter 3

### 3 Literature review: explaining long-run exchange rate behavior

#### 3.1 Overview

Explaining currency movements is notoriously difficult. This difficulty is reflected in the myriad of approaches that have overtime yielded a rich literature on exchange rate determination. Williamson (2008), De Grauwe (2005), and Sarno and Taylor (2002a) are among the more recent reviews on these approaches. Some earlier reviews are Isard (1995) and Taylor (1995). These approaches include, not least, models based on trade flows such as the Mundell-Fleming model [Mundell (1960; 1968), Fleming (1962)] which is based on the notion that exchange rates arise from international trade in goods and services. Similarly, purchasing power parity theory (Cassel, 1921) attributes exchange rates to arbitrage in internationally traded goods across countries. Liquidity or cash-in-advance constrained models (Lucas, 1982; Obstfeld & Stockman, 1985), conversely, are asset models couched in the optimization paradigm and are capable of accommodating commodity and productivity shocks. Particularly Lucas's (1982) model shows success in explaining risk premia, although not necessarily levels of the spot rate.

Krugman (1991) pioneered the target zone models, which seek to explain exchange determination within permitted margins of fluctuations around a specified central parity. The new open economy macroeconomics literature (Obstfeld & Rogoff, 1995; 1996), by contrast, addresses currency pricing in the context of dynamic general equilibrium models with nominal rigidities and market imperfections, alongside well-specified micro foundations. Lane (2001) provides a survey. Unfortunately, no integrated framework exists at present that synthesizes

these approaches. Rather, each adds an important insight but by itself without providing a definitive answer.

Nonetheless, since the post Bretton Woods period of floating rates, the asset approach has become the conceptual and methodological workhorse for the empirical examination of exchange rate behavior. Its appeal has stemmed from its emphasis on the importance of capital markets and financial flows in determining exchange rates. The lessons from the experiences since the post Bretton Woods era suggest that in comparison to merchandise trade, financial flows are the key drivers of the foreign exchange market activities. This is reflected in the fact that global trading volumes on foreign exchange markets now dwarf merchandise trade (Bank for International Settlements, 2007). Similarly for South Africa, average daily trading volume on the domestic foreign exchange market has since 1998 increased to more than US dollar 10 billion, with a mere 2.4 percent of this reflecting merchandise trade (South African Reserve Bank, 2007).

The thesis therefore focuses on the asset approach to exchange rate determination as a framework for modeling movements of the rand. To that end, the review first discriminates and comments on the elements that define this approach, explicating their respective channels through which exchange rate behavior is influenced. Then, there is an assessment of the empirical literature on it.

### 3.2 The asset approach: *exchange rates as asset prices*

Structurally, the asset approach is founded on the monetary approach to the Balance of payments, which Polak (1957) and Johnson (1961)<sup>11</sup>, *inter alia*, brought to prominence. It emerged as a theory of exchange rate determination only in the late

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<sup>11</sup> Early contributions date back to works of David Hume in the eighteenth century but Johnson (1972, 1976, 1977), among others, stands out as its major pioneers [cited in (Isard, 1995)]

1970s<sup>12</sup>, though its structure has changed little since then. While critiqued as ad hoc in its formulation, many of its predictions nonetheless easily follow from models based on micro foundations, such as those of Lucas's (1982) and Stockman's (1987; 1980).

Two distinguishable strands of the literature constitute the approach; the *monetary* and the *portfolio balance* models (MacDonald, 1988; Frankel, 1983). The novelty of both is that national currencies are cast as financial assets which investors may hold profitably and that exchange rates are thus asset prices<sup>13</sup> (Hallwood & MacDonald, 2000). Accordingly, exchange rates are viewed as being established by portfolio considerations; as the price that equilibrates the relative international supplies of and demands for stocks of various currency denominated financial assets (Cross, 1998), similar to determination of any other asset price such as a stock or bond price (Levich, 1981).

This portrayal of exchange rates as asset prices carries three further implications (MacDonald, 1988). First, real factors matter only if they influence the supplies and demands of financial assets. Second, current exchange rates are expected to depend in large measure on the market's expectations about their future values<sup>14</sup>. Thus, sudden changes in today's rates may just as well be a manifestation of the market's sudden revision of those exchange rate expectations. Third, in a free floating exchange rate regime, foreign exchange markets are expected to function efficiently in the sense of currency values fully reflecting publicly available market information; akin to other financial markets in which assets are traded in auction markets (Levich, 1981).

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<sup>12</sup> At the height of the recent float; the post Bretton Woods era

<sup>13</sup> Since by definition they represent relative prices of two financial assets - *one country's currency in terms of another's*

<sup>14</sup> This follows from the argument that current holdings of financial assets usually depend on expectations of their future worth.

Another attribute that the asset models share is the assumption of free capital mobility between countries. This carries the suggestion that asset market equilibrium should instantaneously occur; to which exchange rates continuously respond (Frankel, 1983). In fact, it is argued persuasively that exchange rate volatility is the result to be expected in such an environment (Cross, 1998; Humpage, 1998). Clearly, this has relevance for understanding short run movements in the rand; *the “bumpy ride”*.

However, outside of these common threads, the monetary and portfolio balance models contrast with regard to their assumptions about which financial assets are traded internationally; the risk characteristics of those assets; and the attitude towards risks of international investors. There are thus differences not only on predictions of which set of factors matter for understating exchange rate determination, but also how those factors interface with the foreign exchange market in influencing the pricing of currencies.

### 3.2.1 The monetary models

The monetary models develop in works of Frenkel (1976), Mussa (1976; 1979), and Kouri (1976). Their distinguishing feature is that they portray non-money assets such as bonds as perfect substitutes in asset holders’ portfolios<sup>15</sup>. However, national moneys are not. In other words, asset holders are presumed risk neutral. Thus, although a menu of domestic and foreign non-money assets is available, the presumption is that asset holders view them as riskless; which then render them irrelevant to determination of currency values. There is in effect only one non-money asset worldwide. Therefore, money is the only asset whose demand and supply play a

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<sup>15</sup> There are assumed to be no risk premia or portfolio preferences, and therefore the expected returns are always equalised regardless of asset supplies

role. Monetary models accordingly have a focus on money supplies and demands in each nation as the key to understanding determinants of exchange rates.

Typically, monetary models then take as their setting a financial market in which the supply of money is exogenous; controlled through the Government's monetary policy operations<sup>16</sup>. The demand for money, conversely, is assumed to be stable - positively linked to real income and the price level and inversely related to the interest rate (an opportunity cost variable). Continuous stock equilibrium is assumed, with the result that correspondences of money demand with money supply establish monetary equilibrium. Furthermore, money supply neutrality is assumed— its increases or decreases overtime lead to proportionate changes in the price level, with only temporary effects on output or the interest rate (Cross, 1998). The effects that relative changes in money supplies and demands have on the exchange rate thus work through influencing relative price levels, via goods market adjustment. Here, the monetary models take two directions.

### Models with flexible prices

One strand of the models, labeled *flexible-price monetary models*, following a suggestion in Frenkel (1976) and Mussa (1976; 1979), assumes that all prices are sufficiently flexible both in the short run and long run; responding instantaneously to excess demand and supply in the goods markets. The consequence is of this is that continually holding purchasing power parity (PPP) governs the evolution of international relative pricing relationships.

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<sup>16</sup> In practice, however, the extent to which the monetary authorities control the money supply is hotly debatable. Goodhart (1989), for instance, forcefully argues that the many factors that affect components of the money supply, currency and bank deposits, lie outside the Governments sphere of influence. Similarly for the money demand, wealth considerations as well as foreign interest rates also play a role.

Attributable to Cassel (1921; 1918), purchasing power parity (PPP) holds that exchange rates between currencies adjust primarily to equalise relative prices across countries, and therefore keep real exchange rates unchanged overtime. The idea of PPP is rooted into the law of one price. This asserts that provided markets are competitive, free trade equalizes prices of similarly traded goods worldwide, when valued in a common currency. The law of one price applies to an individual good. Its generalization on the one hand is absolute PPP, the statement that exchange rates adjust to equate nations' overall price levels. On the other hand, relative PPP hypotheses only that changes in exchanges should be proportional to changes in relative national price levels, and therefore has a focus on changes in prices rather than on absolute price levels. In either variant, nonetheless, the implication is that if, starting from equilibrium, goods prices rise in one country relative to those of another, then its exchange rate must depreciate and vice versa.

However, experience has shown significant violations of PPP, particularly over shorter periods. Indeed, it has been pointed out that there exist trade barriers of various kinds, transportation costs, non-traded goods, and imperfect information about prices in different countries, all of which prevent prices from fully equalizing (Johnson A. , 2005; Salvatore, 2004). Moreover, on both causal empiricism (Taylor & Taylor, 2004; Lindert & Pugel, 1996; Isard, 1995)<sup>17</sup> and formal empirical tests in a variety of data settings (Sarno & Taylor, 2002b; Froot & Rogoff, 1995), data rejects short run PPP, flatly<sup>18</sup>. In contrast, over long periods, empirical evidence suggests tendencies for exchange rates to mean revert towards PPP, although scholars such as Rogoff (1996) and Froot and Rogoff (1995) have found such mean reversions to be

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<sup>17</sup> This relates to the fact that real and nominal exchange rates have been overly volatile since the float, both in terms of their historical values and relative to their fundamental determinants

<sup>18</sup> Both time series and panel data have been used, spanning more than 100 years in some instances [Frankel (1995), Lothian & Taylor (1996), Taylor (2002)] and across a spectrum of methodologies

very weak. Their work finds that deviations from PPP take at best an average of three to five years to damp out by half. This has generated consensus that PPP approximates long run exchange rate behavior well, but is not a valid explanation of why short run fluctuations occur.

Nonetheless, accepting PPP as the relationship deciding the evolution of relative prices leads to the prediction that *relative excess money supplies* and factors determining relative money demands (*relative real income* and the *interest rate differential*) anchor the exchange rate<sup>19</sup>. In the model, the effects that these factors have on the exchange rate are propagated primarily through influencing relative prices. On one hand, the money supply has a direct influence, due to its neutrality property. Rapidly expanding the domestic money supply relative to its foreign counterpart leads to a matching increase in prices. Via PPP, this thereby depreciates the home currency proportionately.

Changes in the other factors, by contrast, affect relative prices and the exchange rate indirectly; through their effect on the demand for money. An increase in home real income increases money demand, causing monetary disequilibrium. Given that the money supply is premised exogenous, equilibrium can only be restored via a fall in prices, and thus, through PPP, the home currency appreciates<sup>20</sup>. In contrast, a higher home interest rate means a smaller demand for money, which requires a corresponding fall of the money supply to maintain equilibrium. Again, with an exogenous money supply, this occurs only through a rise in prices, and via PPP, leads to depreciated home currency. Therefore, according to the model, a country will have

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<sup>19</sup> This obtains from the fact that, given monetary equilibrium in the home and foreign markets, the national price levels can be solved for relative prices by equating real money supply to real money demand in each country.

<sup>20</sup> Notice that this contrasts with the standard Keynesian IS/LM/BP model in which an increase in domestic incomes causes imports to rise, worsening the balance of payments and producing a depreciation of the currency. In the monetary models, the assumption is that real incomes are exogenously determined by supply side factors, which eliminates this possibility.

an appreciating currency if, relative to foreign countries, it has a combination of *strong economic growth, slower money supply growth, and falling interest rates.*

The positive correspondence between the interest rate and the exchange rate arises in this kind of the models primarily due to the flexible-price assumption. Hallwood and MacDonald (2000) describe an alternative mechanism of how this occurs, using the Fisher Parity relationship. Fisher's parity depicts nominal interest rates as encompassing a real and expected inflation rate component. Given PPP, the real interest rate must also equalize across countries<sup>21</sup>. It follows then that increases in interest rates imply increases in inflationary expectations and this causes agents to reduce their demand for money and increase their expenditures. Prices then rise in line with expectations and PPP ensures that the currency depreciates. Therefore, other formulations of monetary models have the expected inflation rate differential replacing the nominal interest rate differential, as, for instance, in Frenkel (1976).

### Expectations and the equilibrium exchange rate

A further pillar of monetary models is that, jointly, the assumptions they make of perfect substitutability of home for foreign assets and of perfect capital mobility, imply that international asset equilibrium must satisfy the principle of uncovered interest rate parity (UIP). Uncovered interest rate parity posits that efficient arbitrage should assure that identical financial assets earn the same rate of return worldwide, provided there are no impediments to the free flow of capital (IMF Institute, 1998). This suggests that international interest rate differentials reflect the market's expected rate of change in the exchange rate, and therefore currency values ought to depend in large part on expectations of their future values (H M Treasury, 2003). In particular, the interest rate differential on home and foreign assets can be regarded as a

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<sup>21</sup> Since the real exchange rate remains unchanged under PPP

predictor of the future change in the spot rate (Froot & Thaler, 1990; Isard, 1995), whereby the fact that home interest rates are above foreign interest rates today should be taken to imply the home currency will depreciate tomorrow by an offsetting amount (Wadhvani, 1997).

Unfortunately, in common with PPP, reality is unresponsive of UIP. On one hand, Froot and Thaler (1990), Lewis (1995), Engel (1996) show that many a paper has found that the interest rate differential is not a good predictor of the subsequent change in the exchange rate, particularly as regards short run exchange rate behaviour. What is more, its correspondence with that subsequent change is actually perverse, suggesting that higher interest rate currencies tend to appreciate rather than depreciate. On the other hand, some studies (Meredith & Chinn, 1998; Chinn & Meredith, 2004; Chinn & Meredith, 2005) do report evidence of UIP for longer interest rate maturities of more than five years and using longer horizon exchange rate data, while others (Thornton, 2007; Sarno, 2005; Nikolaou & Sarno, 2005; Bacchetta & van Wincoop, 2007) claim to rationalise the adverse short run findings. However, as Chaboud and Wright (2003) argue, there is still controversy around those findings. Many scholars therefore do not regard strict uncovered interest rate parity as valid.

Nonetheless, in the context of the flexible price assumption, imposing uncovered interest rate parity ensures that the interest rate differential is replaceable in the model by the expected change in the exchange rate. The result is that the current exchange rate depends not only on relative money supplies and demands, but also on the market's expectations of its future value (Frenkel & Mussa, 1980). This linkage to exchange rate expectations illustrates the general implication of the asset view; namely, current currency values encompass their future expected changes

(Frenkel & Mussa, 1985). To that extent, present changes in currency values may for the most part be a manifestation of the fact that expectations are being revised due to news arrival or surprises (Haache, 1983), hence a cause of volatility<sup>22</sup>.

However, much depends on how expectations are formed. Monetary models make the assumption that expectations are generated rationally, whereby agents make correct guesses, conditioned on full market information in the present. It then turns out that both the exchange rate in the present period as well as current expectations of its future value depends on expectations pertaining to the future values of economic fundamentals. Mussa (1976) was the first to illustrate this insight. It draws attention to the important result that exchange rates will also change because of arrival of new information or news that alters the future course of those fundamentals (Frenkel & Mussa, 1980). It follows then that if, on the one hand, this news arrival is stable, so too is the exchange rate. On the other hand, if such news arrival is unexpected, this allows the exchange rate to be excessively volatile relative to its fundamental determinants (Meese, 1990). This illustrates the possibility that rational bubbles may be present in foreign exchange markets, driving exchange rates away from fundamental determinants (Neely & Sarno, 2002). Seen from this perspective, monetary models thus claim to rationalize exchange rate volatility as being attributable to volatility in expectations pertaining to exchange rate fundamentals.

### Sticky-prices and exchange rate overshooting

However, the reality is that nominal rigidities are typical of both goods and labour markets and therefore the expectation of continually adjusting prices is unlikely to be fulfilled. Admitting these realities, another genre of the monetary

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<sup>22</sup> Indeed, casual empiricism appears to support this conjecture; short run exchange rates have been overly volatile relative to the main suggested fundamental determinants discussed here

models, dubbed the *disequilibrium or sticky-price* models, allows modelling prices as sticky but permitting for their gradual response to excess demand and supply in goods markets (Frankel & Rose, 1995; Haache, 1983). Dornbusch (1976) is the canonical paper. The novelty of Dornbusch's model is in the fact that, by allowing interaction of continuously equilibrating asset markets with sticky prices, it is able to show that short-term changes in exchange rates can "overshoot" or exceed their long term values needed by corresponding changes in relevant fundamentals. The lessons to be drawn are that currencies may exhibit misalignment relative to their equilibrium values, with implications for competitiveness in ways that are unjustified by changes in, for instance, comparative advantage (Shapiro & Sarin, 2008). Although Dornbusch's work has been extended in different directions (Wilson, 1979; Mussa, 1982; Buiters & Miller, 1982; Eastwood & Venables, 1982) the overshooting result is what characterizes this type of the models.

Exchange rate overshooting arises in this type of models primarily due to the asymmetry of adjustment between goods and asset markets. On one hand, asset markets instantaneously clear, in response to new information or changes in expectations (Shapiro & Sarin, 2008). Owing to price stickiness, goods markets on the other hand, sluggishly adjust, clearing only in the long run. Consequently, PPP will govern the long run equilibrium but not the short run adjustment period to such equilibrium. Monetary fundamentals thus determine the long run exchange rate only, through PPP. Expectations, by contrast, drive the rate in the present. However, those expectations are for the exchange rate to vary at a speed proportional to the gap between its current and long run value (Copeland, 2005). Precisely, a mean-reverting expectations mechanism is posited whereby when the current rate is below or above its long run value, it is expected to revert towards rather than away from it (Hallwood & MacDonald, 2000).

Thus, if, for instance, there is an unanticipated money supply increase, prices will eventually rise proportionately and cause matched exchange rate depreciation. In the short run, price stickiness prevents an immediate adjustment of prices to the new equilibrium. With prices initially fixed, the increase in the money supply now means an increase in the real money stock. There must then be a corresponding increase in the real demand for money, to clear the money market. But sluggishly adjusting output and prices prevent this. Instead, a fall in the domestic interest rate brings about the required rise in money demand. This, in turn, leads to an incipient capital flight, causing instantaneous exchange rate depreciation.

With a capital market equilibrium sustained by uncovered interest rate parity, the new lower interest rate will be equilibrium only if the public must expect a currency appreciation, to offset lower interest rate payments with capital gains (Shapiro & Sarin, 2008). In turn, future expected domestic currency appreciation requires that the extent of the current depreciation be larger than its eventual long run depreciation.<sup>23</sup> Hence, the initial effect of a money supply increase is to cause the exchange rate to “overshoot” its long run value; since only under these conditions will the public expect an appreciation (Were, Geda, Karingi, & Ndung'u, 2001).

At the initial level of prices, however, the exchange rate overshoot now translates into a real depreciation, and this improves competitiveness of home goods. Added to a fallen domestic interest rate, the result is a boosted aggregate demand. Therefore, over the medium run, the risen aggregate demand in turn sets in motion an incipient rise in prices, pushing the economy towards the new long run equilibrium. With rising prices, the real money supply begins to fall, driving up

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<sup>23</sup> Note that this follows because under uncovered interest rate parity, domestic interest rates can only lie below their foreign counterparts if the market expects the home currency to appreciate and this can happen only if the current rate changes by more than the long run rate (Hallwood & MacDonald, 2000)

interest rates to sustain monetary equilibrium. The exchange rate then starts to appreciate towards its new long run equilibrium<sup>24</sup>, reversing the initial overshooting and ending with the exchange rate at its new long run equilibrium level, which reflects the proportionate change in the money supply increase (Copeland, 2005). Sticky-price models are thus said to rationalise the observed regularity whereby relatively high interest rate currencies tend to appreciate (Neely & Sarno, 2002). Nonetheless, they ultimately imply the same set of fundamental determinants as their flexible price form; *relative money supplies, real incomes, and inflation rate and interest rate differentials*.

It must be noted, however, that their predictions for interest rate influences on the exchange rate importantly contrast. Haache (1983) explains this dissimilarity from noting that under the flexible price assumption, continuous price adjustment is what holds money market equilibrium. Changes in interest rates simply reflect changes in expectations about future price changes. Their increases then lead to a relative reduction in money demand and, hence, currency depreciation. By contrast with sticky prices, it is interest rate changes that preserve monetary equilibrium over the short term; that is, their changes arise from liquidity effects. Therefore, when, for example, the domestic interest rate has risen, it is because there is excess money demand relative to its supply. With no corresponding fall in prices, the risen nominal rate encompasses a rise in its real rate, which in turn encourages capital inflows and appreciates the currency. Monetary models thus predict both a positive and a converse linkage of the interest rate to the exchange rate.

An important genre of the models that allows for empirical tests of these contrasting predictions is Frankel's (1979) *real interest rate differential model*. In this

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<sup>24</sup> Notice that the assumption of regressive expectations drives this; since the initial depreciation has pushed the exchange rate above its long run value, the belief is that the direction of the market's expectation will now be to appreciate the currency.

model, Frankel starts from introducing an expectations mechanism that accommodates both short run and long run adjustments. On one hand, in the short run, the exchange rate is expected to grow by the gap between its current and equilibrium value, where the ordinary monetary fundamentals determine the equilibrium rate. Conversely, in the long run, differences in expected inflation rate differentials drive the exchange rate.

On imposing uncovered interest rate parity, the real interest rate differential between the home and foreign country is shown to be proportional to the gap between the current exchange rate and its long run equilibrium value. Thus, for assets of both countries to be held willingly, their real interest rate differential must be matched by an expectation of a real depreciation (Frankel & Rose, 1995). Frankel interprets this as capturing price stickiness and the reason why exchange rate overshooting occurs. Finally, by allowing for PPP to determine the equilibrium (long run) exchange rate, Frankel is able to produce a model that captures both flexible price and sticky price elements – that is, both the positive and negative influences of the interest rate are testable.

Summing up the monetary models, these lay emphasis on changes to relative money supplies and demands in different countries as the relevant economic fundamentals for understanding exchange rate behavior. Exchange rate expectations also matter, but these are formed with reference to “news” or expected future changes in those monetary fundamentals. As far as those expectations are unstable, speculative bubbles can exist in foreign exchange markets, with the consequence of driving exchange rates away from their fundamental values and causing volatility. Exchange rate volatility is as well explained in terms of the differential speeds of adjustment between asset and goods markets, leading to overshooting.

Undeniably, monetary models make an important contribution to understanding of exchange rates. They draw attention to significance of monetary policies in influencing exchange rates and rightly warn that unnecessary money growth causes currency depreciations (Cross, 1998). Particularly in their sticky-price form, they offer a basis for understanding exchange rate overshooting and misalignment – a stylized fact of foreign exchange markets whereby exchange rates appear to seemingly exceed their eventual long run values (Levich, 1981).

However, their disregard of other non-money assets such as bonds is a severe limitation; portfolio diversification is ignored – non-money assets are assumed away from the analysis (Cross, 1998). Furthermore, no role is given to the current account for exchange rate determination. Yet, as Hallwood and MacDonald (2000) explain, experience suggests that linkages do exist between exchange rates and current account balances and, in turn, the flow of savings and wealth. What is more, several factors, for example, differential tax risk, liquidity considerations, political risk, default risk, and exchange risk, all cast doubt on the extent to which non-money assets issued by different countries are viewed as perfect substitutes. Indeed, attesting to these facts, there is now extensive trading of a wide range of financial assets as indicated by the currently large trade volumes in currency markets (Bank for International Settlements, 2007).

### 3.2.2 The portfolio balance models

The portfolio balance models, in contrast to monetary models, consider asset holders as risk-averse and consequently view domestic and foreign currency assets as imperfect substitutes. Exchange risk thus matters. Desirous of diversifying this risk, asset holders then seek to hold a portfolio of financial assets, in proportions based on each asset's expected yield rates and risk configurations (Frankel, 1983;

Haache, 1983), which they modify once these underlying conditions change. The consequence is that portfolio balance models attribute exchange rate determination to changes in the supplies of and demands for a menu of interest bearing financial assets, including money.

Furthermore, arising from the imperfect substitutability of home and foreign non-money assets assumption, equalization of expected yields alone is insufficient for portfolio equilibrium. Rather, the interest rate on riskier assets must encompass a risk premium, required by asset holders to hold them. That is, the interest rate on them will be higher, to reflect the difference in the degree of risk. Thus, unlike the monetary models, the principle of uncovered interest rate parity is not maintained as an international asset market equilibrium condition, except with a risk premium.

Though originally conceived in the 1960s from research by, for instance, McKinnon and Oates (1966), Branson (1968), and McKinnon (1969), application of portfolio balance models to analysis of exchange rates became established only in the 1970s in papers by *inter alia* Kouri (1976) and Branson (1977)<sup>25</sup>. Their structural specifications exist in various forms of complexity, as, for instance, in Branson and Henderson (1985). Taylor (1995) and Hallwood and MacDonald (2000) use a simple three-asset market variant of the models to explain the main results that emerge from them. In that model, it is assumed residents divide their wealth among domestic money, domestic bonds and foreign currency bonds. Domestic and foreign currency bonds bear interest but domestic money does not. Furthermore, domestic residents can hold all the three assets, but foreign residents may hold only foreign bonds.

The desired share of wealth held in each asset is dependent upon their relative expected yields, which are the domestic interest rate for domestic bonds, and the

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<sup>25</sup> Frankel and Rose (1995), Hallwood and MacDonald (2000)

sum of the foreign interest rate and the expected rate of depreciation of the home currency, for foreign bonds. For each asset, more of it is held in response to rising own expected yield rate and less of it when faced with a risen yield rate on the alternative asset. The exception is domestic money, where increases in yields rates on both domestic and foreign bonds induces residents to hold less of it, since, in the model, no interest accrues on money balances.

The supplies of the assets, conversely, are determined exogenously by such government policy actions as fiscal, monetary or exchange rate policy, and therefore fall outside the domain of the private sector. Thus, domestic residents may build up the stock of foreign bonds only by running a surplus on the balance of payments current account. Hence, on the real sector side, the relationship of interest is the balance of payments, wherein equilibrium is attained by equality of its current and capital account balances. On one hand, the current account depends on the trade balance and interest earnings on foreign bonds, where, in turn, the trade balance is proportional to the gap between consumption and income receipts on traded goods. The capital account, on the other hand, grows overtime through accumulation foreign assets, that is, the foreign bond.

Accordingly, if starting from a position of portfolio equilibrium in the model, there is a sudden increase in the domestic money supply, there would emerge an excess of money and demand for both domestic and foreign bonds. As residents purchase domestic bonds, the domestic interest rate falls, and, in consequence, more of foreign bonds are held. Resulting from this switch into foreign bonds, the currency depreciates. With goods prices initially unchanged at the new equilibrium, the initial currency depreciation makes traded goods more attractive and, over the medium term, leads to growth in exports and decline in imports; the country runs a

current account surplus and foreign assets begin to grow. There thus ensues an excess supply of foreign bonds, and needing a currency appreciating to re-establish portfolio equilibrium. The current account surplus thus has the consequence of appreciation the currency, which reverses part of the initial depreciation. The exchange rate in this equilibrium is however higher than the initial equilibrium; in essence, the currency overshoots. Hallwood and MacDonald (2000) produce similar results for portfolio disturbances due to either an increase in domestic bond supplies or a rise in supply of foreign bonds, though, in these two cases, the exchange rate can negatively or positively relate to the interest rate.

Therefore, compared to the monetary models, the portfolio balance models allow for a much richer examination of a range of forces driving exchange rates. The economics profession thus regard them as much more satisfactory asset models for understanding exchange rate behavior, given that casual empiricism point to a variety of factors underpinning currency movements. Particularly, the models provide justification for modeling exchange rates as functions of supplies of bonds and other non-monetary assets, fiscal and current account balances, as well as risk premiums or asset preferences. In this regard, the models have proved useful in analyzing possible effects of sterilized intervention, as, for example, in Dominguez (1998), Dominguez and Frankel (1995), and Edison et al (2003); the literature is surveyed by Humpage (2003) and Sarno and Taylor (2001). Likewise, following observations in Dooley and Isard (1982), another line of research has sought to study the determinants of and significant of the risk premium for exchange rate determination, notably Hooper and Morton (1982), Frankel (1983; 1982b), Fama (1984). Lewis (1995) has surveyed the relevant literature.

In sum, the foregoing discussion has looked at the theoretical literature on the asset approach in terms of its two main strands; the *monetary* and *portfolio balance* models. Monetary models put emphasis on money as the asset whose trading play a role in exchange rate determination, arguing that non-monetary assets are perfect substitutes. Accordingly, only domestic and foreign money supplies, and factors determining money demands in different countries – real incomes, interest rates, and inflation rates - are the relevant economic fundamentals for understanding exchange rate behavior. In contrast, portfolio balance models maintain a focus on a wider range of assets, on the ground of imperfect substitution between non-monetary assets. The outcome is an exchange rate equation that encompasses, as its arguments, non-money asset supplies such as bonds, factors which may underlay their changes such as current account and fiscal imbalances, alongside money supplies. In addition, exchange rates can be modeled as functions of risk premiums and asset preferences.

Structurally, however, these models have since their emergence in the 1970s changed little. It is in their empirical literature where there has been a significant advance in knowledge both in the scope of its coverage and in the range of empirical techniques that have been brought to bear on this; to which the thesis now turns. To maintain a focus since much has been published on the subject, the review is organized according to methodologies applied in studying these relationships.

### 3.3 Estimating and testing asset models

As to be expected, the empirical literature has concentrated on testing the predictions of both strands of the asset approach to exchange rate determination, overtime yielding a wealthy empirical literature. Frankel and Rose (1995), Taylor (1995) and Hallwood, MacDonald (2000) offer comprehensive reviews of much of this literature. Recent updates are rather fragmented but include Williamson (2008),

De Grauwe (2005), Sarno and Taylor (2002a), Neely and Sarno (2002), and the papers in the 2003 special issue of *Journal of International Economics*<sup>26</sup>. Developed economies are the focus of the bulk of existing studies. But with developing countries having had adopted freer regimes starting with varying efforts at economic liberalization in the 1990s, evidence is beginning to become available for their economies as well, notably Chen, Rogoff, and Rossi (2008) and Chen and Rogoff (2003).

### Testing the monetary models

The predictions of the monetary models are more amendable to data and, not surprisingly, it is here where much of the research effort has concentrated. Both reduced-forms and forward-looking or present-value structures of the models have been tested. But it is the former which has attracted the attention of researchers. Keeping this focus here of their reduced-form structures, the canonical empirical model typically examined is of the form of (3-1) below; estimated on the assumption of agents forming rational expectations (Meese, 1990)

$$s_t = g(\Gamma, f_t) + \epsilon_t \quad (3-1)$$

Where  $s_t$  denotes the exchange rate,  $g(\Gamma, f_t)$  is a linear combination of fundamental determinants  $f_t$ , with  $\Gamma$  denoting a matrix of reduced form parameters to be estimated, and  $\epsilon_t$  an error term. Composition of  $f_t$ , the set of fundamental determinants tested, differs with each model. On the one hand, as noted, in flexible-price models, the relevant fundamentals are relative money supplies, relative real incomes and the expected inflation differential. But the interest rate differential may replace the expected inflation rate differential, because, with flexible prices, it is argued that interest rates will change only if expected inflation has changed. On the

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<sup>26</sup> Journal of International Economics, vol. 60, 2003

other hand, when testing the sticky-price model, both influences of the expected inflation differential and interest rate differential are interrogated. However, the interest rate differential appreciates the exchange rate in this genre of the models, since monetary disturbances have real consequences.

### *Early literature: limited cause for optimism*

The early empirical literature, prior to the mid-1980s, rely on ordinary least squares (OLS) estimations of the models and focus on judging their validity based on their in-sample fit, as given by signs of coefficients, their statistical significance, plus overall fit measured by, say,  $R^2$ . In the review articles of Frankel and Rose (1995) and Taylor (1995), it is shown, on one hand, that tests based on pre-1978 free-float data supported the models. Frenkel (1976) is cited as one of the influential studies, which gave strongly corroborative evidence for the German mark-dollar exchange rate based on data for the German hyperinflation period of the 1920's. Others are Bilson (1978), for mark-pound rate during 1972 to 1976, Hodrick (1978), for the mark-dollar and pound-mark rates from 1972-1975, and Dornbusch (1980) for the mark-dollar rate on 1973-1978 data.

When, on the other hand, post-1978 data are used, empirical tests prove unsuccessful. Estimated relationships collapse; displaying poor fit and generally failing conventional diagnostic tests (Taylor M. P., 1995). Meese (1990) explains further that the models explain only dismal variation in exchange rates. Worse, in some cases, estimated parameters become incorrectly signed. Much talked about cases in point are the estimates on the mark-dollar rate, which gave results suggesting that growth in the German money supply during that period resulted in an appreciation of the mark, contrary to expected predictions of a depreciation (MacDonald & Taylor, 1992; Hallwood & MacDonald, 2000; Salvatore, 2004).

Frankel (1982a) dubbed this finding “the mystery of the multiplying marks.” Therefore, despite initial success, the main lesson from OLS-based empirical literature was that the monetary models do not fit the facts - the predicted fundamentals simply fail to explain free float exchange rates.

Nonetheless, these OLS-based tests are fundamentally flawed in their failure to resolve the non-stationarity problem that use of time series data introduces. Presently, the consensus view is that time series data such as the exchange rate and the many macroeconomic series are essentially unit root processes (Nelson & Plosser, 1982), and therefore will not revert to their mean values overtime. Indeed, it is conventional wisdom today that use of such data in OLS-type regressions invalidates standard statistical inferences about the soundness of the model.

#### *Monetary models as equilibrium relationships: room for optimism*

Therefore, admitting this flawed methodology, the literature post mid-1980s uses cointegration methods (Engle & Granger, 1987), which addresses the non-stationarity problem of data. Cointegration tests seek for equilibrium relationships among variables, while allowing for dynamic adjustment to such equilibrium. They ask whether for any group of non-stationary data series, a linear combination of them can be found that exhibits stationarity. If so, such connection among them means equilibrium relationships. Hence, in the context of exchange rates, they apply to long horizon rather than short horizon movements. In cointegration tests of the monetary models, the central question has been whether, in their reduced forms, they hold as equilibrium relationships. If so, the models have validity as a description of long run exchange rate behavior; to which exchange rates gravitate towards.

Even use of cointegration tests has not led to consensus either. The results have tended to be sensitive to the type of cointegration test employed. The early batch of

these tests relies on univariate techniques, commonly couched in form of Engle and Granger's (1987) two-step techniques. Cointegration is said to exist by these methods if the residuals from an OLS estimated exchange rate equation are stationary. Applying these methods, cointegrating relationships between the exchange rate and asset fundamentals are often not found. In the majority of cases, residual series recovered from reduced form estimations of the models exhibit non-stationarity, for example, Meese and Rogoff (1988), Baillie and Selover (1987), Boothe and Glassman (1987), Kearney and MacDonald (1986), and Meese (1986). Therefore, this body of evidence too seems to endorse the results of the OLS-based tests.

Still, these univariate type cointegration tests have a number of deficiencies that cast serious doubts on their reliability. Harris (1995) explains these as mainly low power in small samples and reliant of their asymptotic distributions on presence of deterministic parameters in test regressions. Further, Froot and Rogoff (1995) have noted that the tests require choosing rather arbitrarily a single right-handed variable. This introduces inefficiency in the analysis. Hence, evidence from this type of test is at best regarded as largely inconclusive.

The more recent literature, post 1990s, therefore applies multivariate system cointegration, particularly the techniques of Johansen (1988; 1991; 1995) and other genres such as those of Pesaran, Shin, and Smith's (2000) and Pesaran and Shin's (2002) long run structural modeling techniques. These have the advantage over univariate tests of allowing for full information maximum likelihood estimations, whereby all parameters are simultaneously estimated. As such, validation is possible of more than one combination of variables that may represent equilibrium relationship governing the evolution of the variables (Harris, 1995). Their parameter

estimates are thus reliably efficient, and the cointegration test much more powerful than, for instance, Engle and Granger's method.

Not surprisingly, studies utilizing tests of this sort are the ones that have shown success. Frequently, cointegration is detected between exchange rate and at least a combination of some of the fundamental factors of the monetary models, both for data across different currencies and varying periods in history. A few that merit mention here are MacDonald and Taylor (1991; 1993; 1994), MacDonald and Marsh (1997; 1999), and MacDonald (1999) who find evidence of such relationships for the US dollar, the German mark, the British pound and the Japanese yen. McNown and Wallace (1994) report similar findings for currencies of Chile and Argentina, as did Miyakoshi (2000) for the Korean won. Other more recent additions include Frenkel and Koske (2004) on the euro, Islam and Hasan (2006) for the Japanese yen, and Zhang, Lowinger, and Tang (2007) on the US dollar, the Canadian dollar, the yen, and the British pound.

Other authors such as Otero and Smith (2000), however, criticize the use of multivariate cointegration tests to country specific data. They contend that such tests have low power to reject the null in small samples, given the relatively shorter period thus far of free-floating. Following the lead of Hakkio (1984) and Koedijk and Schotman (1990), another strand of the literature has accordingly re-examined the models in the context of panel cointegration tests - testing pooled data for a group of currencies. Generally, this shows that pooling the data across currencies strengthens the evidence in favour of the models.

Groen (2000), for instance, applies an Engel-Granger type panel cointegration test on pooled data for eighteen countries and finds stationary residuals<sup>27</sup>. Similarly, on a panel dataset for six Central and Eastern European countries, Crespo-

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<sup>27</sup> Note the contrast with single country regressions where this result does not generally obtain

Cuaresma, Fidrmuc, and MacDonald (2005) found that the reduced forms of monetary model accords very well as long run exchange rate relations for these countries. They then use these estimates to compute equilibrium exchange rates. For eighteen OECD countries, Westerlund and Basher (2007) on the other hand find that the evidence is reinforced when structural breaks in the data are accounted for. Other evidence from studies using this approach is found in Groen (2005), Mark and Sul (2001), and Rapach and Wohar (2004; 2002). Sarno and Taylor (2002b) summaries some of the earlier studies in the context of the real exchange rate.

Overall, the cointegration evidence is therefore heavily weighted in favor of the reduced-forms of the monetary models holding as equilibrium relationships. These encouraging results have generated strong consensus that their main predicted fundamental factors offer valuable information to understand exchange rate behavior at the long horizon - *at least over a period of several years*. Nonetheless, the short run behavior of is left unexplained by the models.

### Testing the portfolio balance models

Concerning testing of the portfolio balance models, data limitations on asset supplies in the form needed has unfortunately made testing them a near impossible task. Therefore, there is not much empirical interest. Nonetheless, the few available studies have consisted of two approaches. One has been to solve the models as reduced forms and use cumulated current balances, bond supplies, and fiscal deficit data as proxies for assets stocks (Sarno & Taylor, 2002a). A typical form of the equation examined is;

$$s_t = g(m, m^*, b, b^*, fb, fb^*)_t + \epsilon_t$$

Where  $m, b, fb$  denote the supplies of money, domestic bonds, and foreign bonds, respectively. The asterisk (\*) indicate a foreign variable.

As with the monetary models, the early literature of such reduced-form tests supported the models (MacDonald & Taylor, 1992), for example Branson, Haltunen, & Masson, (1977; 1979). However, from the 1980s, results turned negative, as in the case of Frankel (1984). In the more recent literature, where the cointegration methodology is used to address the non-stationarity problem in data, results are much more positive, as Sarno and Taylor (2002a) reports. This outcome is found to be robust in the data. The success story for the models thus comes at the long horizon movements. Therefore, as with the monetary models, reduced-from evidence supports the portfolio balance models as being helpful to understanding exchange rate movements in the long run.

Another set of tests - the so-called inverted asset demand tests (Sarno & Taylor, 2002a) - has sought to model the exchange risk premium in terms of factors that determine the supplies of non-money assets and examining the significance of this for exchange rate determination, as, for example, in Frankel (1983) and Hooper and Morton (1982). This is ground in the fact that portfolio balance models rest on the assumption of imperfect substitutability of home for foreign non-money assets, and therefore a risk premium must separate their rates of return. The idea is to examine if the risk premium accords to  $\rho_t \equiv B_t(S_t F_t)^{-1} = \sigma(i_t - i_t^* - \Delta s_{t+k}^e)$  and then test for its validity in an empirical model of the form below (Hallwood & MacDonald, 2000); assuming the expected change in the exchange rate is formed rationally<sup>28</sup>

$$i_t - i_t^* - \Delta s_{t+k} = \gamma^{-1}(B_t(S_t F_t)^{-1}) + \varphi_{t+k}$$

Where  $B_t$  is the domestic non-money assets,  $F_t$  is the comparable foreign non-money asset,  $S_t$  is the exchange rate,  $\gamma^{-1}$  is a measure of relative risk aversion,

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<sup>28</sup> This is that  $\Delta s_{t+k} = \Delta s_{t+k}^e + \epsilon_{t+k}$ , where  $\epsilon_{t+k}$  denotes an error term fulfilling with white noise properties

$i_t - i_t^* - \Delta s_{t+k}$  is the expected excess return from holding the domestic asset over the foreign asset, and  $\varphi_{t+k}$  is the error term.

Early tests of this type generally met with limited success, as was with Frankel (1982b; 1983) and Rogoff (1984). In the more recent literature, as already noted, there is a shift in focus to using the framework to address questions of whether sterilized intervention is effective; finding evidence in favor of the models. Indeed, studies such as Dominguez and Frankel (1995), Dominguez (1998), and Edison et al (2003) have found evidence that show that an effect of sterilized intervention is established through the portfolio balance conduit. Hutchison (2003) and Guimarães and Karacadag (2004) advance the literature with developing countries' experiences. This literature too lends credence to the validity of portfolio balance models as long run relationships.

#### Testing predictive ability: *Short horizon results -failure strikes*

Acknowledging the noticeable value of the asset models at the long horizon, the question of interest then is whether they contain information to accurately forecast or predict future changes in exchange rates. The classic work on this is by Meese and Rogoff (1983a; 1983b). These scholars contrasted the out-of-sample forecasting performance of various asset exchange rate models with forecasts produced by a wide range of time series models, including a simple random walk model. The latter entails a *naïve* strategy of using today's currency value as a predictor of all future values. The scholars found that the asset models consistently failed to provide better forecasts than the random walk model at horizons of one month to a year. Interestingly, Meese and Rogoff established this result even when ex-post values of the asset fundamentals were employed in the analysis.

This empirical failure of asset models to forecast short horizon exchange rates has been shown to be quite robust. As Rogoff (2008) recently noted, the numerous successor studies that have attempted to understand this empirical regularity using a plethora of techniques have remarkably found it to be true for wide grid of currencies and varying periods in history. In fact, beating the random walk model's forecasts has become something of a benchmark for assessing the success of empirical exchange rate modeling in the literature. A recent paper in this spirit is Engel, Mark, & West (2007). These authors reconfirm the result of no predictability at short horizons but not at longer horizons. On the other hand, Cheung, Chinn, & Pascual (2005a; 2005b) examine the out-of-sample fit of an assortment of the asset vintage models and find that none consistently outperforms a random walk model at any horizon. Neely and Sarno (2002) and Frankel and Rose (1995) survey several of the earlier studies.

Some studies claim to have generated forecast based on the assets models that outperform those of the random walk model. Molodtsova and Papell (2008) and Gourinchas and Rey (2007) provide most recent evidence of this. Other earlier works include Clark and West (2006), Engel and West (2006; 2005), Sarantis (2006), and Clarida et al (2003). In Molodtsova and Papell (2008), the novelty of the analysis is that the authors incorporate Taylor rule models<sup>29</sup> into the investigation and find that encompassing this feature strengthens predictability compared to the conventional asset models. However, Rogoff and Stavrageva (2008) and Rogoff (2008) contend that these studies fail to overturn convincingly the Meese-Rogoff findings of no out-of-sample predictability of exchange rates at the short horizon, arguing that such findings are hardly replicable for either wide range of currencies or even different

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<sup>29</sup> For details on this, see Engel and West (2005; 2006)

times. Other authors such as Neely and Sarno (2002) and Frankel and Rose (1995) concur.

The finding consistently of no short horizon out-of-sample predictability of exchange rates has thereby become somewhat a stylized fact of data. This poor out-of-sample performance of asset models has produced a concurrence in the economics profession that explaining or predicting exchange rates in the short run based on fundamental determinants is infeasible. Rather, at the short horizon, it seemingly appears that changes in exchange rates are at best largely unpredictable (Frankel & Rose, 1995); there appears are no systematic economic forces determining short run exchange rates.

#### Testing predictive ability: Long horizon results -*resurrection*

Against the backdrop of this empirical failure to predict short run exchange rates, other successor studies have sought to see if the asset models may then have long horizon predictability. Mark (1995) is the canonical study. In it, Mark repeated Meese and Rogoff's tests for a number of US dollar exchange rates at horizons of three months, one year, and three years, but using data from 1981 through to 1991. The author found that the asset models outperformed the random walk at least at the three-year horizon. A parallel study by Chinn and Meese (1995) re-confirmed Mark's work in finding the asset fundamentals helpful in predicting US dollar rates at longer horizons beyond three years, using data for the period 1983 to 1990.

Applying somewhat different methodologies, several succeeding works has collaborated these findings for long horizon predictability. A strand of this literature draws on cointegration methods. An example is MacDonald and Marsh (2004; 1999; 1997), who use a dynamic multivariate error correction model to study the yen-dollar and mark-dollar exchanges rates and finds that the forecasts of asset models strongly dominate the random walk at longer horizons. Other studies have used panel error-

correction estimations of asset models, corroborating the superiority of the models over the random walk model at horizons beyond at least sixteen quarters. Engel, Mark, & West (2007), Groen (2005), Rapach and Wohar (2002), and Mark and Sul (2001) are in this group. Killian and Taylor (2003), on the other hand, estimate an exponential smooth transition autoregressive (ESTAR) model (Granger & Terasvirta, 1993), amendable to nonlinearities in data. They find predictability at horizons of two to three years, but as expected, short horizon predictability tests fail. Overall, the key finding in this literature is that data robustly substantiates such results. This has led to consensus that the asset models have predictability at longer horizon – at the very least, beyond twelve months.

What the literature then establishes is that the asset exchange rate models can be expected to explain and predict long run exchange rate behavior only. The models however fail to explain exchange rates at the short run horizon. Obstfeld and Rogoff (2000) have labeled this empirical regularity the “*determination puzzle*,” given the widely held belief that exchange rates must be jointly determined with other economic variables.

#### Why do the models fail?

Two interpretations for the dismal short run forecasting ability of the asset models are common in the literature. One and probably most important (Meese, 1990; Lindert & Pugel, 1996; Neely & Sarno, 2002) is the fact that foreign exchange markets are buffeted with immense new information, which exchange rates strongly and instantly respond to. The point is that because such news is unanticipated, it cannot be incorporated into any predictions. Evidence indeed sustains this explanation. Various studies (Chaboud, Chernenko, & Wright, 2008; Clarida & Waldman, 2007; Fausta, Rogers, Wang, & Wright, 2007; 2003; Engel & Frankel,

1984) have acknowledged the instantaneous effects of news of different kinds<sup>30</sup> on exchange rates and casual empiricism indicates that responses to such news have often entailed large movements in currency values.

The other interpretation stresses the likelihood of failure to model adequately exchange rate expectations. The asset models discussed here lay emphasis on exchange rate expectations as a major force in determining currency values. However, these are unobservable to the econometrician. But in testing the models, the economic agents are assumed rational in forming those expectations. This has the effect of thinking of those expectations as being homogenous and that the agents make them with reference to news about economic fundamentals. The difficulty that emerges with this however is that in studies that have used survey data (Jongen, Verschoor, & Wolff, 2008; Chinn & Frankel, 2002; Cheung & Chinn, 2001)<sup>31</sup> the rationality assumption is strongly refuted. Predominantly, what emerges is that foreign exchange market participants are extrapolative and often self-confirming in their actions at short horizons<sup>32</sup>, with recent trends in exchange rates tending to be reinforced and persistence for a while. The survey data are also confirmatory of manifestation of heterogeneity in forming expectations and that such expectations are made not with reference to economic fundamentals but private information sets (Isard, 1995). Thus, in such an environment where the rules of the game keep changing, the argument is that serious misspecifications are likely to contaminate any efforts to capture expectations using a statistical model.

Additional sources of misspecifications are elaborated upon by Meese (1990). They include nonlinearities in the underlying data generating mechanism, omitted

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<sup>30</sup> It has not been uncommon for exchange rates to change on account of not only news about current and future changes in economic variables, but also to those of non-economic ones such as politics (elections), wars, or international tensions

<sup>31</sup> Hallwood and MacDonald (2000) and Sarno and Taylor (2001a) review some earlier studies.

<sup>32</sup> That is to say, if, for example, the exchange rate has risen recently, market participants expect it to continue to rise in the near future

variables or failure to account for regime shifts. The gist being that a nonlinear data generating mechanism may be improperly modeled using linear techniques, leading to poor empirical predictability. Indeed, an empirical regularity of distributions of high frequency exchange rate returns data is that they are generally fat-tailed than normal distributions, which is indication of nonlinearities. There is also serial correlation in return volatility (Meese, 1990). Research into these issues generally succeeds in modeling nonlinearities of this sort using an assortment of techniques<sup>33</sup>. However, the picture changes little; studies generally fail to improve upon the random walk's forecast, for example Killian and Taylor (2003)

### 3.4 Summary: what lessons then?

In wrapping up this review, attention is directed once more to the hallmark of the asset approach to understanding of exchange rate behavior. This is that national money (foreign exchange) is a financial asset and the exchange rate is an asset price. Therefore, in an asset-pricing framework, exchange rates arise from portfolio considerations. Accordingly, their current values encapsulate not only exogenous factors that induce changes in financial asset supplies and demands but also the expected values of those factors in the future.

However, between its core elements – *the monetary and portfolio balance models* – there is debate regarding which financial assets are tradable and hence on predictions of factors on which exchange rate determination depend on. In the monetary

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<sup>33</sup>. Commonly used techniques include, Stock's (1987) model, Hamilton's (1988) regime-switching model, and Engle's (1982) autoregressive conditional heteroskedasticity (ARCH) model. Details of how these methodologies have been applied to exchange rate analysis appear on pages 129 to 130 of Meese's (1990) paper. Stock's model is essentially a time deformation model, which allows modelling economic events to arise on a time frame that differs from observable time. For example, a series can be allowed to exhibit say a different characteristic at a different time than another over the same sample period. Similarly, Hamilton's model allows for changes in a variable's characteristics over a given period, but the procedure utilise a latent variable signalling the probability of a change in characteristic or regime change. The ARCH is a procedure for modelling persistence in the conditional variance or more generally of serial correlation in volatility of a data series; illuminating episodes of turbulence (high variance) and quiescence (low variance). Further discussion of this is made in chapter 5 in this thesis.

models, only national moneys are relevant. This is founded on the assumption that asset holders are neutral, wherein domestic non-money assets such as bonds substitute perfectly for foreign ones. The exchange rate then comes to depend only on factors determining the relative demands for and supplies of money; posited as relative money supplies, relative real incomes or outputs, interest rate and inflation rate differentials.

Portfolio balance models, by contrast, portray asset holders as risk averse and therefore explicitly incorporate exchange risk. In consequence, asset holders regard non-money assets as imperfect substitutes in their portfolios. Portfolio diversification thereby occurs among a wide range of assets and in proportions that depend on each respective asset's expected yield rate and risk configurations. The result is that portfolio balance models assign a role for a richer menu of potential fundamental determinants, including risk premiums, portfolio preferences, sterilized interventions, current account and fiscal positions, as well as wealth variables. This makes them appealing over their monetary counterparts in making an empirical distinction between models in terms of their explanatory power.

How useful are asset models in explaining exchange rate behavior? The body of empirical evidence, a selected few of which this review has examined, is rather mixed. On the one hand, the models fail to predict and explain exchange rates at the short run horizon – exchange rates are neither explainable nor predictable with asset fundamentals at the short horizon of less than a month. At this horizon, exchange rates are seemingly unpredictable: *a simple random walk model consistently and robustly fits data better than a structural model with asset fundamentals*. The models, however, do appear to have explanatory and predictive validity at the long horizon - over a long span.

Hence, the weight of the evidence leans towards consensus of asset models as long run relations.

Therefore, on balance, the empirical regularity that has emerged from the literature is that asset fundamentals are helpful to explicating long run exchange rate behavior. Clearly, this has applicability to understanding the rand's long swing decline – *the roller coaster ride*. Accordingly, the next chapter draws on this literature in providing a structural model that the study uses to account empirically for the rand's long swings.

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## Chapter 4

### 4 Empirical tests and evidence: explaining rand's long swings

Drawing on the preceding review of the asset approach literature, this chapter presents a structural exchange rate model that can account for the rand's long swings. A hybrid *monetary* and *portfolio balance* model of exchange rate determination is thereby tested, which allows for testing for a wider range of potential determinants. The analysis considers only *in-sample* prediction tests to compare the statistical significance of the variables tested and does not attempt to offer *out-of-sample* predictions.

The study is however not the first effort at understanding long trends in exchange rates of the rand. Using monthly data, Chinn (1999) sought to explain movements in the rand-US dollar exchange rate during the period 1980 to 1998. The study uses a specification consisting of money supplies, manufacturing output, consumer price inflation, and the nominal short-term interest rate of South Africa relative to those of the USA. Applying the vector error-correction model and Johansen's cointegration techniques, all the explanatory variables except the nominal interest rate differential are found to be statistically significant. The author uses the interbank rate to proxy for the nominal interest rate differential.

Brink and Koekemoer (2000) also attempt to explain movements in the rand-US dollar exchange rate using variables similar to Chinn (1999), but employ a quarterly data set spanning the period from 1979 to 1995. These authors adopt the Engle and Yoo's (1991) three-step cointegration technique. As with Chinn (1999), the authors report evidence of a strong correspondence between the rand dollar rate and all the explanatory variables, but with the lack of significance of interest rate variable

continuing. In their case, the three months Treasury bill rate is used to proxy for the interest rate differential.

Gebreselaise, Akanbi, and Sichei (2005a; 2005b) also try to explain movements in the rand dollar rate using the same variables and quarterly data as Brink and Koekemoer (2000). However, the period covered in their study is both different and shorter in time span; from 1994 to 2004. Their findings nonetheless improve upon earlier studies in finding that the nominal short-term interest rate matters for pricing of the rand.

This study differs from these previous studies in two fundamental ways. Firstly, it covers a much longer data span of thirty-one years, beginning 1984 through to 2005<sup>34</sup>, and tests for the possible impact of short-term and long-term interest rates - these existing South African literatures only look at short-term interest rates. It is indeed plausible to think in this direction, because though according to the expectations hypothesis nominal interest rates should move in sync at all maturities (Thornton, 2004), the reality, as Sarantis (1995) has observed, is that nominal interest rates have generally behaved differently at the short and long term spectrum of maturities. The same can be said for South Africa. This seems to suggest that investors have tended to substitute for assets of different maturities at varying degrees, and implies that asset maturities may convey separate information. Moreover, it is theoretically ambiguous whether the short term or long-term interest rate is what matters for exchange rate determination, as has been pointed out in chapter three. It is therefore of interest to model together the two horizons of asset maturities to see if they convey the same information for understanding exchange rate behavior. Besides, some studies such as Meese and Rogoff (1988), Sarantis (1995), Kim and Mo (1995), and Nadal-De Simone and Razzak (1999) have studied

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<sup>34</sup> Reliable data on the variables of interest and their frequencies are available only from 1983

jointly the influence of both short-term and long-term interest rates in an exchange rate model.

Second, regimes change is explicitly incorporated in the model. Addressing the impact of regimes change in exploring rand movements has been emphasized earlier in chapter two. Frequent regimes change within a relatively short history pose empirical challenges that have not been addressed clearly in the literature on empirical modeling of the South African market. This gap is understandable. The traditional technique for analyzing exchange rate changes requires market generated data over a large number of observations. However, in South Africa's case, the exchange rate regimes have not been stable. Moreover, a free market in exchange rates is a relatively new phenomenon, having been in existence since February 2000. This leaves a longer span of data that is obviously affected by multiple exchange rate regimes change.

Empirically modeling the rand in the face of this instability of the exchange rate regime encounters the difficulty that, as the institutional setup in which currency movements are occurring, the exchange rate regime itself induces agents' expectations about the evolution of those movements in the future. Those expectations in turn influence currency movements in the present. Thus, an exchange rate regime change would generally be expected to alter the information set on which exchange rate expectations are formed. To the extent then that regimes change matters and agents take this into account, as Lucas (1976) argued, the process driving currencies would differ across the spectrum of regimes.

Clearly, this is to be expected in South Africa's case where the exchange rate regime has kept changing. The set of relevant fundamentals that prevails under the current regime of free floating likely differs from those that existed in previous

regimes of very controlled floating. To adequately account for rand's linkages to fundamental determinants over the period that we examine, it is necessary therefore to also explore whether such relationships have altered due to regime changes.

The rest of the chapter presents the theoretical motivation for the model that we use, the methodological framework for testing the predictions of the model, and finally, the inferences from the results.

#### 4.1 The model

The model that we propose falls in the class of asset-pricing models in which the exchange rate is treated as a freely fluctuating asset price that depends on expectations of its future value and exogenous factors that affect asset supplies and demands. It thereby combines characteristics of both the monetary and portfolio balance approaches to exchange rate determination. By combining both features, the model acquires the advantage of allowing for specification and testing for a wider range of potential determinants of the exchange rate.

##### *Asset market equilibrium*

The monetary features of our model draw on Frankel's (1979) *real interest rate differential model*, which is based on the notion that the exchange rate is a relative price of domestic and foreign moneys and thus depends on supplies and demands for those moneys. In particular, that the exchange rate arises from equilibrium conditions in domestic money markets. This in turn requires assuming a stable money demand that depends positively on real incomes and the price level but inversely related to the nominal interest rate, since this represents the opportunity cost of holding money. However, the money supply arises exogenously, through government policy actions. Money supply is also assumed to equal money demand

continuously and therefore the condition for equilibrium in domestic money markets can be specified as

$$m_t - p_t = \delta y_t - \lambda i_t \quad (4-1)$$

Where  $m$ ,  $p$ ,  $y$ , and  $i$  are the log of the nominal money supply, national price level, real income, and the level of the nominal interest rate;  $\delta$  and  $\lambda$  are the income elasticity and interest rate semi-elasticity of demand for money, respectively.

The monetary equilibrium condition is assumed identical<sup>35</sup> between countries and, accordingly, equilibrium in foreign money markets can be stated as

$$m_t^* - p_t^* = \delta^* y_t^* - \lambda^* i_t^* \quad (4-2)$$

where the asterisks (\*) indicates the variables pertain to a foreign country.

### *International goods market equilibrium*

A second monetarist feature of our model is that we assume that purchasing power parity ties together relative prices of domestic and foreign goods. This relates the exchange rate to relative prices of domestic and foreign goods, wherein the exchange rate is required to adjust to maintain parity of international goods prices due to goods arbitrage. However, we model prices in both domestic and foreign goods markets as sticky; allowing their sluggish responses to market disequilibrium but permitting full adjusting in the long run. Consequently, purchasing power parity applies as a long run phenomenon and, accordingly, provides the long run exchange rate

$$\bar{s}_t = p_t - p_t^* \quad (4-3)$$

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<sup>35</sup> Use of this assumption here is not to deny its implausibility in the light of obvious differences between economies of South Africa and other countries. Even the question of to what extent the money supply can be regarded exogenous is still a matter of debate, as Goodhart (1989) argued; given the many factors believed to impact the supply of money practically lie outside the influence of the monetary authorities. However, it is the model's predictions that are important and imposing these assumptions is necessary in showing how those predictions come about.

where  $\bar{s}_t$  denotes the log of the nominal exchange defined as the domestic price of foreign currency and the bar over the variable indicates the relationship pertains to the long run.

Since goods' prices are sticky, short run violations from purchasing power parity occur and, in consequence, deviations of the current exchange rate from its long run value arise routinely. The model thus allows for long run behavior of the exchange rate and its short run transition dynamics onto the path to long run equilibrium.

In terms of long run behavior, we return to the monetary equilibrium conditions and solve the domestic and foreign money market equilibrium conditions (equations 4-1 and 4-2) for the relative price level by taking their difference:

$$p_t - p_t^* = m_t - m_t^* - \delta(y_t - y_t^*) + \lambda(i_t - i_t^*) \quad (4-4)$$

where it is assumed for simplicity's sake that the cross country money demand parameters match, that is  $\delta = \delta^*$  and  $\lambda = \lambda^*$ . Thus, we have the result that relative prices of home versus foreign goods depend on relative money supplies and demands between the domestic and foreign countries

We then combine this resulting relative price relationship (equation 4-4) with the purchasing power parity relation (equation 4-3) to obtain a prediction equation for the exchange rate in the long-run as follows:

$$\bar{s}_t = m_t - m_t^* - \delta(y_t - y_t^*) + \lambda(i_t - i_t^*) \quad (4-5)$$

This anchors the exchange rate on the ratio of the domestic and foreign money supply ( $m_t - m_t^*$ ), the ratio domestic and foreign real incomes ( $y_t - y_t^*$ ), and the nominal interest rate differential on domestic and foreign assets ( $i_t - i_t^*$ ).

In terms of this prediction, these variables determine pricing of exchange rates through changing the price differential on domestic goods prices and through

purchasing power parity. The money supply affects prices directly; growth in the money supply at home relative to money demand yields an equiproportionate increase of the price level, which, via purchasing power parity, depreciates the home currency. In contrast to the money supply, the other variables affect prices via their effect on money demand. On the one hand, because growth in domestic real incomes raises the demand for money relative to its supply, it leads to a fall in the price level and thereby induces an offsetting currency appreciation. Relatively higher domestic interest rates, on the other hand, mean a smaller demand for real money relative to money supply, which requires a rise in the price level to sustain monetary equilibrium and therefore brings about home currency depreciations.

However, nominal interest rates are modeled here as obeying the Fisher hypothesis. This hypothesizes that nominal interest rates embody a real interest rate and an expected inflation rate component, and therefore the interest rate on domestic assets can be stated as

$$i_t = r_t + \pi_{t+1}^e \quad (4-6)$$

And analogously, on foreign assets

$$i_t^* = r_t^* + \pi_{t+1}^{e*} \quad (4-7)$$

where  $r_t$ ,  $r_t^*$ ,  $\pi_{t+1}^e$ ,  $\pi_{t+1}^{e*}$  are, correspondingly, the home and foreign real interest rates and expected inflation rates over a  $k$  maturity horizon of an underlying financial asset ( $k = 1$ , for simplicity).

Our assumption of long run purchasing power parity implies that real interest rates must converge internationally (Frankel, 1979). Thus, in long run equilibrium, nominal cross-country interest rates differ only because of differences in expected

rates of inflation and, consequently, nominal interest rate differentials can be viewed as representing expected inflation differentials;

$$i_t - i_t^* = \pi_{t+1}^e - \pi_{t+1}^{e*} \quad (4-8)$$

This allows restatement of the prediction equation (4-5) for the long run exchange as (4-9) below, wherein expected inflation differential replaces the nominal interest differential;

$$\bar{s}_t = m_t - m_t^* - \delta(y_t - y_t^*) + \lambda(\pi_{t+1}^e - \pi_{t+1}^{e*}) \quad (4-9)$$

Here the role of expected inflation rate differential is equivalent to that of the interest rate differential. Namely, an increase in the expected inflation differential at home induces agents to reduce their demand for real money balances, increases prices, and in so doing depreciates the home currency.

With regard to short run deviations of the current exchange rate from its long run values, because our assumption of price stickiness means gradual price adjustment in the model, this causes the exchange rate to initially “overshoots” its long run value in response to fundamental determinants but returning to this long run value overtime. We thereby adopt a ‘regressive’ or mean reverting expectations mechanism (Frankel, 1979), according to which short run deviations of the current rate from its long run value are expected to damp out at a constant rate. Furthermore, when the exchange rate falls onto its equilibrium path, instead of being constant, it is expected to change by the expected inflation rate differential - reflecting the loss in value due to inflation. Thus, the path for short run transitional dynamics for the exchange rate can be stated as;

$$\Delta s_{t+1}^e = \phi(\bar{s}_t - s_t) + (\pi_{t+1}^e - \pi_{t+1}^{e*}) \quad (4-10)$$

Where  $\Delta s_{t+1}^e$  is the change in the exchange rate expected in period  $t + 1$ ,  $(\bar{s}_t - s_t)$  is the short run disequilibrium gap that the exchange rate experiences relative to its long run value  $\bar{s}_t$ ,  $\phi$  is the parameter that captures the speed of adjustment, and  $\pi_{t+1}^e - \pi_{t+1}^{e*}$  is the inflation rate differential expected in period  $t + 1$ .

We rewrite equation (4-10) as equation (4-11) below to show overtly how the short run gap depends on changes in expectations about inflation and the exchange rate in the future;

$$s_t = \bar{s}_t + \frac{1}{\phi} (\pi_{t+1}^e - \pi_{t+1}^{e*}) - \frac{1}{\phi} \Delta s_{t+1}^e \quad (4-11)$$

Obviously, there is dynamic dependence here, particularly via the expected exchange rate term  $\Delta s_{t+1}^e$ , but for now we sidestep the question of how agents are forming those expectations.

### *International capital markets equilibrium*

We next describe here features of the portfolio balance model that our model acquires (Frankel, 1983), which can be summarized as follows. Portfolio balance models, which explain the existence of a risk premium, argue that agents allocate wealth among asset menu per expected relative returns internationally. Investors are assumed to view assets of identical default risk as imperfect substitutes due to the different currency denominations. This imperfect substitutability produces a risk premium as differential rates of return on the foreign denominated and domestic bonds. Combined with the assumption of cross-country perfect capital mobility, this allows representing international capital markets equilibrium by an uncovered interest rate parity condition adjusted for a risk premium;

$$\Delta s_{t+1}^e = (i_t - i_t^*) - \rho_t \quad (4-12)$$

Where  $i_t - i_t^*$  is the interest rate differential;  $\rho_t$  is a risk premium; and  $\Delta s_{t+1}^e$  is the change in the home currency expected in the future, where  $\Delta s_{t+1}^e = E_t s_{t+1} - s_t$  and  $E_t s_{t+1} = E(s_{t+1} | \Omega_t)$  is the expectation of the future exchange rate conditioned on information set  $\Omega_t$  available to economic agents at time  $t$ .

Our contribution is in how we exploit the argument (Frankel, 1983; Dooley & Isard, 1982) that the risk premium can be solved in terms of factors that determine the supplies and demands of domestic and foreign currency denominated assets. In particular, an investor desirous of spreading the risk due to exchange rate variability will allocate his domestic and foreign currency portfolio holdings in response to expected returns on each as;

$$\frac{B_j}{S F_j} = \sigma_j(i_t - i_t^* - \Delta s_{t+1}^e) \quad (4-13)$$

where  $B_j$  is the stock of domestic currency denominated asset held by investor  $j$ ;  $F_j$ , the stock of foreign currency denominated asset held;  $S$  is the nominal exchange rate; and  $\sigma_j$  is a positive valued function (Frankel, 1983) with the property that

$$\sigma_j(i_t - i_t^* - \Delta s_{t+1}^e) = e^{[\alpha + \theta(i_t - i_t^* - \Delta s_{t+1}^e)]} \quad (4-14)$$

We assume same portfolio preferences for all investors, thus allowing for addition of the individual demand functions into an aggregated asset demand equation;

$$\frac{B_t}{F_t S_t} = \sigma(i_t - i_t^* - \Delta s_{t+1}^e) \quad (4-15)$$

where  $B = \sum_{j=1}^n B_j$ ,  $F = \sum_{j=1}^n F_j$  are now net supplies of assets, and the function  $\sigma$  captures similarity of preferences.

Now the term in brackets on the left hand side of equation (4-15) is the risk premium, from the capital markets equilibrium condition internationally (equation 4-12). Therefore, the risk premium can be equivalently stated as;

$$\rho_t = \frac{1}{\sigma} \frac{B_t}{F_t S_t} \quad (4-16)$$

This illustrates more clearly the linkage of the risk premium to determinants of supplies and demands for domestic and foreign assets.

We sidestep that for the moment and focus, instead, on equation (4-15), which we re-express in log form, given (4-14), to yield;

$$b_t - s_t - f_t = \alpha + \theta(i_t - i_t^* - \Delta s_{t+1}^e) \quad (4-17)$$

This captures the idea that investors seeking diversify the resultant risk of exchange rate variability will balance their holdings of domestic and foreign asset holdings in portions that depend on a risk premium. Particularly, an increase in the relative supply of domestic assets, for example, will require an increased risk premium for these assets to be willingly held in international portfolios. The opposite would apply in domestic markets in the case of foreign currency denominated assets. Changes in the risk premium thereby accommodate underlying shifts of the supplies of domestic currency assets relative to foreign currency assets that are held in private portfolios.

#### *The equation for exchange rate determination*

We now synthesize the monetary and portfolio balance features elaborated above to form our model. This we do by first combining the equation for short run transition dynamics (equation 4-10) with the condition for international capital markets equilibrium (equation 4-12), but where equation (4-16) is used to describe the risk premium;

$$s_t - \bar{s}_t = -\frac{1}{\phi} [(i_t - \pi_{t+1}^e) - (i_t^* - \pi_{t+1}^{e*})] + \frac{1}{\phi} (i_t - i_t^* - \Delta s_{t+1}^e) \quad (4-18)$$

Notice that the expression in square brackets is now interpretable as the real interest rate differential and we have  $(i_t - i_t^* - \Delta s_{t+1}^e)$  as the risk premium.

This shows that the exchange rate deviates from or ‘overshoots’ its long run value for two reasons; firstly sluggish price responses create a real interest rate differential, and, secondly, imperfect asset substitutability produce a risk premium. Note that the interest rate differential appears here with a negative coefficient. This is because existence of price stickiness allows changes in monetary equilibrium to have liquidity effects, wherein changes in nominal interest rate also imply changes in real interest rates. Therefore, when the nominal interest rate rises, it is because the real interest has risen, which attracts incipient capital inflows, thereby bidding up demand for the home currency and causing it to appreciate. By contrast, the risk premium encapsulates a positive coefficient because imperfect asset substitutability means that investors will require a higher rate of return to hold home assets if they perceived to be relatively risk. Otherwise, they will attempt to switch to holding more of foreign assets. The resulting rise in the risk premium will thereby weaken the home currency. Consequently, if the interest rate differential is high, the exchange rate will lie below its equilibrium value. Conversely, if the risk premium is high, the exchange rate will lie above its equilibrium value.

We next use equation (4-9) to substitute for the long run exchange rate in the equation for short run transition dynamics (4-18), and solve for the current spot rate. On denoting the real interest rate as  $i_t - \pi_{t+1}^e$  and thereby the resulting real interest rate differential as  $r_t - r_t^*$ , we obtain;

$$s_t = (m_t - m_t^*) - \delta(y_t - y_t^*) + \lambda(\pi_{t+1}^e - \pi_{t+1}^{e*}) - \frac{1}{\phi}(r_t - r_t^*) + \frac{1}{\phi}(i_t - i_t^* - \Delta s_{t+1}^e) \quad (4-19)$$

Thus, our model yields an equation in which the spot rate comes to depend on the relative money supply, the level of real income, the expected rate of inflation, the real interest rate differential, and a risk premium. This is the prediction that we use for the in-sample tests to account for the long swings in the rand.

However, the risk premium is unobservable and therefore not adaptable to empirical verification. Proxies for the risk premium are thus required. We finesse this by exploiting the insight of equation (4-17) wherein the risk premium is solved for the supplies of home versus foreign assets and solve for the current exchange rate. We thereby substitute the relative asset supplies in for the unobserved risk premium and obtain;

$$s_t = \beta_1(m_t - m_t^*) - \beta_2(y_t - y_t^*) + \beta_3(\pi_{t+1}^e - \pi_{t+1}^{e*}) - \beta_4(r_t - r_t^*) + \beta_5(b_t - f_t) \quad (4-20)$$

Where  $\beta_1 = \frac{\phi\beta}{\phi\beta+1}$ ,  $\beta_2 = \frac{\phi\beta\delta}{\phi\beta+1}$ ,  $\beta_3 = \frac{\beta(\phi\lambda+1)}{\phi\beta+1}$ ,  $\beta_4 = \frac{\beta}{\phi\beta+1}$ , and  $\beta_5 = \frac{1}{\phi\beta+1}$

The innovation in this specification is that the exchange now comes to depend on not only money supplies and demands, but it also acknowledges that expectations and exchange rate risk matters. The specification distinguishes the set of *empirically testable exchange rate fundamental determinants* as relative stocks of money supplies, relative real incomes or output levels, expected inflation rates, interest rate differentials, and risk premiums. Reflecting exchange rate overshooting due sluggish price responses and imperfect asset substitutability, rising interest rate differentials and risk premiums, respectively, cause the exchange rate to depreciate and appreciate. On the one hand, because a give increase in the money supply eventually inflates prices and a rising expected inflation rate differential reduces the value of a currency, both cause exchange rate depreciations. Rising relative incomes, on the other hand, eventually raise the demand for money and thereby appreciate the exchange rate.

Nonetheless, even with this formulation (equation 4-20), mapping the model to data requires deciding on how to estimate the expected inflation rate, which, also, is *unobservable*. Unfortunately, knowing exactly what people's inflation expectations are is near impossible. Nevertheless, the economics literature uses three methods to measure inflation expectations: (1) surveys of people's expectations, (2) use market data (nominal and real interest rates) and (3) use the hypothesis of rational expectations, which posits that expectations correspond to optimal forecasts, given available information, the optimality of which can be gauged using statistical methods. Of these three approaches, the second provides a more reliable measure of the expected inflation rate and is the most illuminating. However, available data for South Africa falls short of the period of interest of the present study. Instead, the expected inflation rate is measured following the third approach, that is, the rational expectations hypothesis. Specifically, we conjecture that the expected inflation rate equals the observed value and a stationary forecast error<sup>36</sup>, and use stationarity tests to assess the optimality of this. Clearly, this is an unsatisfactory measure, as it is unhelpful in an economic environment that is constantly changing, as has happened in South Africa. Nonetheless, it is the best option available, not to mention that it is also the most commonly applied in many empirical undertakings, as Patterson (2000) explains. One exception, however, is Frankel (1979) who proxied expected inflation by the long-term bond yield rate, on the ground that it captured future trends in inflation.

The other obstacle concerns which assets to use to measure the exchange rate risk premium to the satisfaction of the prediction equation (4-20). The risk premium can depend on many factors. Here, we have motivated it as arising from the private sector's preferences of domestic relative to foreign currency-denominated assets.

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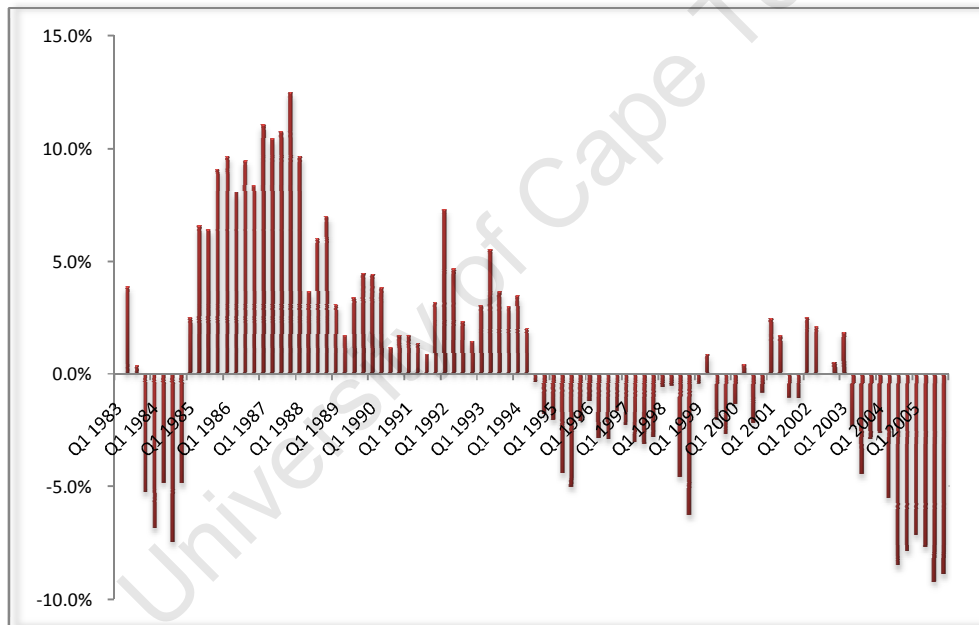
<sup>36</sup> This is that  $\pi_{t+1}^e = \pi_{t+1} + v_t$ , where  $v_t$  has white noise properties

However, a longer span of this data for South Africa is absent. We use instead the ratio of current account balance to nominal national income, measured cumulatively to capture the forward-looking nature of investment flows. This choice is justified by exploiting the argument (Sinn & Westermann, 2001; Hooper & Morton, 1982; Meese & Rogoff, 1983a; Pilbeam, 1995; Were, Geda, Karingi, & Ndung'u, 2001) that current account balances are variables that measure the net foreign indebtedness, and, thus, bring about changes in the private sector's holdings of foreign assets. The intuition is that, when a country registers a deficit on its current account, foreign residents are acquiring domestic assets. To the extent that these assets are interest bearing, and their supply is increased, then the value of the home currency can be expected to fall rather than rise when capital flows into the country increases. This contrasts a surplus on the current account balance, which is expected to create opportunities for domestic residents to hold foreign assets and, in turn, increase the value of the home currency. Of course, one can argue that this is inappropriate in South Africa's case where the current account was for a long time manipulated for political reasons, as the narrative in chapter has shown. However, investors probably used the same political events as a barometer for their risk assessment of South Africa's economy. Indeed, figure 4-1 below seems to reflect this - the current account was in surplus for the most part in the 1980s when foreign flows dried up. This changed to a deficit starting in the mid-1990s onwards, as political reconciliation built investor confidence into South Africa that attracted foreign capital to flow into the country. Therefore, we view the use of this measure as a hypothesis to be tested.

A final specification issue that we address is that both the short term and long-term interest rates are examined, in part, because, empirically, there is no consensus on the appropriate interest rate data to be employed in an exchange rate equation (Meese & Rogoff, 1988; Sarantis, 1995; Nadal-De Simone & Razzak, 1999).

Theoretically, there is discussion only of the interest rate. But, the reality, as has already been pointed out, is that there is a range of interest rates across a spectrum of differentiated assets as well as at different horizons and those interest rates have behaved differently across those maturities. This raises the empirical issue of which interest rate should be used. While, ordinarily either a short term or long term interest rate should be used, it is of interest to examine the two rates, to see if they provide the same information set for understanding the sensitivities of the exchange rate to the interest rate.

Figure 4-1: South Africa, cumulative current account balances (percentage of GDP)



Given all of the above, the empirical model that is mapped to data has the following form;

$$s_t = \beta_0 + \beta_1(m_t - m_t^*) + \beta_2(y_t - y_t^*) + \beta_3(r_t^{ST} - r_t^{ST*}) + \beta_4(r_t^{LT} - r_t^{LT*}) + \beta_5(\pi_t - \pi_t^*) + \beta_6(CA_t - CA_t^*) + \epsilon_t \quad (4-21)$$

The variables have the following interpretation:

- $s_t$  is the log of the rand spot nominal rate;

- $m - m^*$  is the log of the ratio of South Africa's money supply to the foreign money supply;
- $y - y^*$  is the log of the ratio of South African to foreign real income
- $r^{ST} - r^{ST*}$  is the short term real interest rate differential
- $r^{LT} - r^{LT*}$  is the long term real interest rate differential,
- $\pi - \pi^*$  is the inflation rate differential,
- $CA - CA^*$  is South Africa's current account relative the foreign current account balances and, stands in for the risk premium.

An asterisk (\*) denotes counterpart foreign variables and  $\epsilon_t$  is a stochastic error term satisfying white noise properties.

Some economic meanings can be given to the parameters  $\beta_2$  to  $\beta_6$ . Each is interpreted as (partial) elasticity of the exchange rate variable with respect to a unit change of that respective determinant. The signs of estimates of those coefficients for the relative money supply, current account balance and inflation rate differential are all expected to be positive because the hypothesis is that a rise in the values these variable should depreciate the rand. That for the relative money supply, however, should yield a positive unity, since relative money supply exhibits first-degree homogeneity in this model. In contrast, the signs of the parameters on the two interest rates and real income variables should be negative, as their increase is expected to lead rand appreciations. Therefore, the testable priors are that:

$$\beta_1 = 1, \beta_2 < 0, \beta_3 < 0, \beta_4 < 0, \beta_5 > 0, \text{ and } \beta_6 > 0.$$

## 4.2 Profile of data

### 4.2.1 Definitions and sources

The data set used consists of quarterly observations and is sampled for the period from the fourth quarter of 1984 through to the last quarter of 2005, yielding 85 data points. Table 4-1 profiles their interpretation and sources.

Rand exchange rate data pertains to a trade weighted nominal rate, measured as the rand price of foreign currency. The series is formed from a trade-weighted basket of currencies comprising the euro, the US dollar, the British pound, and the Japanese yen. The four currencies have been selected because most currency trading on the South African foreign exchange market is conducted in these currencies, and the Euro area, the US, the UK, and Japan are the country's major trade partners.

Moreover, until 1999, the South African Reserve Bank actually relied on these four currencies to form the currency basket used to calculate both the nominal and real exchange rate indices (Farrell, 2001; Walters, 1999; Walters & De Beer, 1999)<sup>37</sup>. Even though the currency basket for calculating the exchange rate indices is now expanded to thirteen currencies, the four currencies are still dominant, accounting for 77.65% of the total weight (South African Reserve Bank, 2007)<sup>38</sup>. For the series used in this investigation, these trade weights have been normalized to 42% for the Euro, 21% for the US dollar, 21% for the British pound sterling, and 16% for the Japanese

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<sup>37</sup> There has been a significant change, over the years, in both the structure of the currency basket and the methods for calculating the trade weights used in the construction of the effective exchange rate index. Prior to 1999, the currency basket consisted of only the US dollar, the German Mark, the British pound and the Japanese yen. After 1999, the Euro replaced the German mark with a weight of 31.6%, while the US dollar, the British pound, and the Japanese yen represented weights of 42.8%, 16.7%, and 8.9% respectively. In terms of the methodology for actual calculation of the weights, the practice, prior to 2003, was to calculate exchange rate weights as a ratio of each respective country's share to total trade in merchandise and services based on the currency denominations of commodities traded on the international market. Following international practices, this changed, from 2003, to calculation of weights based on the terms of trade in consumption of manufactured goods rather the share in the volume of trade. For a detailed discussion of this issue, see Walters (1999) and Walters and De Beers (1999).

<sup>38</sup> See page s-103

yen. These same normalized trade weights have then been used to make weighted averaged values of data series on variables of interest on the four trading partners, namely the Euro area, the USA, the UK, and Japan.

Note, however, that as the euro was introduced only in 1999, data on the euro rate series corresponds to the German mark prior to this date. While this increases the likelihood of a structural break in the euro rate series given its applicability to a much larger economic area than the German mark did, both are market-generated data. Thus, we think that it is unlikely its use may result in errors in modeling of the sort that would follow from a reconstituted series. Moreover, on inception, the euro replaced the German mark on a one to one basis in the South African Reserve bank's currency basket (Walters, 1999).

A final point is that the trade weighted rate has been preferred to bilateral rates in order to obtain an average measure of the rand's value. Multilateral rates hold the advantage of providing a much more complete picture of a currency's strength or weakness, given that bilateral rates may not necessarily move in the same direction. Bilateral rates, on the other hand, provide information only about a particular country and its currency, and thus, their relevance is confined to analysis of specific factors between two countries. Nonetheless, in South Africa's case where the US dollar and British pound sterling serve mainly as vehicle currencies, bilateral rates in these currencies can convey the same information.

Concerning the fundamental factors, narrowly defined money, M1, is proxy for the money stock. Although the specification in our model is over nominal money balances, these data enter the analysis in real terms. The reason is to avoid collinearity with the inflation rate variable, which is also part of the specified empirical model. Moreover, money market equilibrium requires that real money supply equal real

money demand. Each respective data series are therefore deflated using the consumer price index. For the rest of the fundamental determinants, the real income variable is represented by the value of GDP at 2000 constant prices. The annual (4 period change) percentage change in the consumer price index( 2000=100) stand in for the inflation rate. The three-month Treasury bill rate is used for the short-term interest rate, while the ten-year Government bond rate is proxy for the long-term interest rate. Both data are adjusted for CPI-inflation to express their values in real terms. Current account data, which, as already stated proxy the risk premium, are measured as a one period ahead cumulative balance, captured as a share of nominal GDP. The use of cumulative values here is to try to capture the forward-looking nature of investment flows, which is what is intended..

Table 4-1: The data and their sources

Variable name		Description		Source: basic data
Nominal rand rate	$s_t$	ltwr	Log of trade weighted exchange rate for the rand's nominal bilateral exchange rates with the euro (42%), the US dollar (21%), the British pound (21%), and the Japanese yen (16%), trade weights in brackets. An increase in the value denotes depreciation	InetBridge
Relative money supply	$m_t - m_t^*$	rrm1	Relative real money stock, defined as the log of M1 over CPI for South Africa minus a corresponding weighted average measure for the four trading partner countries, using the same weights from the trade weighted exchange rate	Inet-Bridge, South African Reserve Bank for South Africa, International Financial Statistics (IFS) for trading partners
Relative real income	$y_t - y_t^*$	rrgdp	Relative real gross domestic product (GDP), calculated as the log of South Africa's GDP at constant 2000 prices minus the log of a corresponding trade weighted value for the four trading partners (billions of local currency)	South African Reserve Bank for South Africa, IFS, for trading partners
Short term interest rate differential	$r_t^{ST} - r_t^{ST*}$	rrtbt3	Real short term interest rate differential, calculated as the log of the three months treasury bill rate minus annual CPI-inflation [ $\log(1+(tbt3-infl/100))*100$ ] less a corresponding weighted average for the four trading partners (% per annum)	Inet-Bridge, South African Reserve Bank for South Africa, IFS, for trading partners
Long term interest rate differential	$r_t^{LT} - r_t^{LT*}$	rrgb10	Real long term interest rate differential, calculated as the log of the 10 year government bond rate minus annual CPI-inflation [ $\log(1+(gb10-infl/100))*100$ ] less a corresponding weighted average for the four trading partners (% per annum)	South African Reserve Bank for South Africa, IFS, for trading partners
Inflation rate differential	$\pi_t - \pi_t^*$	infd	Inflation rate differential, calculated as annual percentage change of the log of South Africa's consumer price index (CPI) minus a corresponding weighted average for the four trading partners (2000=100)	IFS
Current account balance	$CA_t - CA_t^*$	rcakcm	Relative cumulative current account balance, calculated as the share of South Africa's one period ahead current account balance in GDP minus a corresponding trading weighted measure for the four trading partners (billions of local currency)	South African Reserve Bank for South Africa, IFS, for trading partners

Figure 4-2 provides a graphical profiling of data employed. Several features of data series are evident. The relative real M1 money stock falls rapidly during 1984 through to 1986 but recovered moderately thereafter up until 1994. It thereafter rises

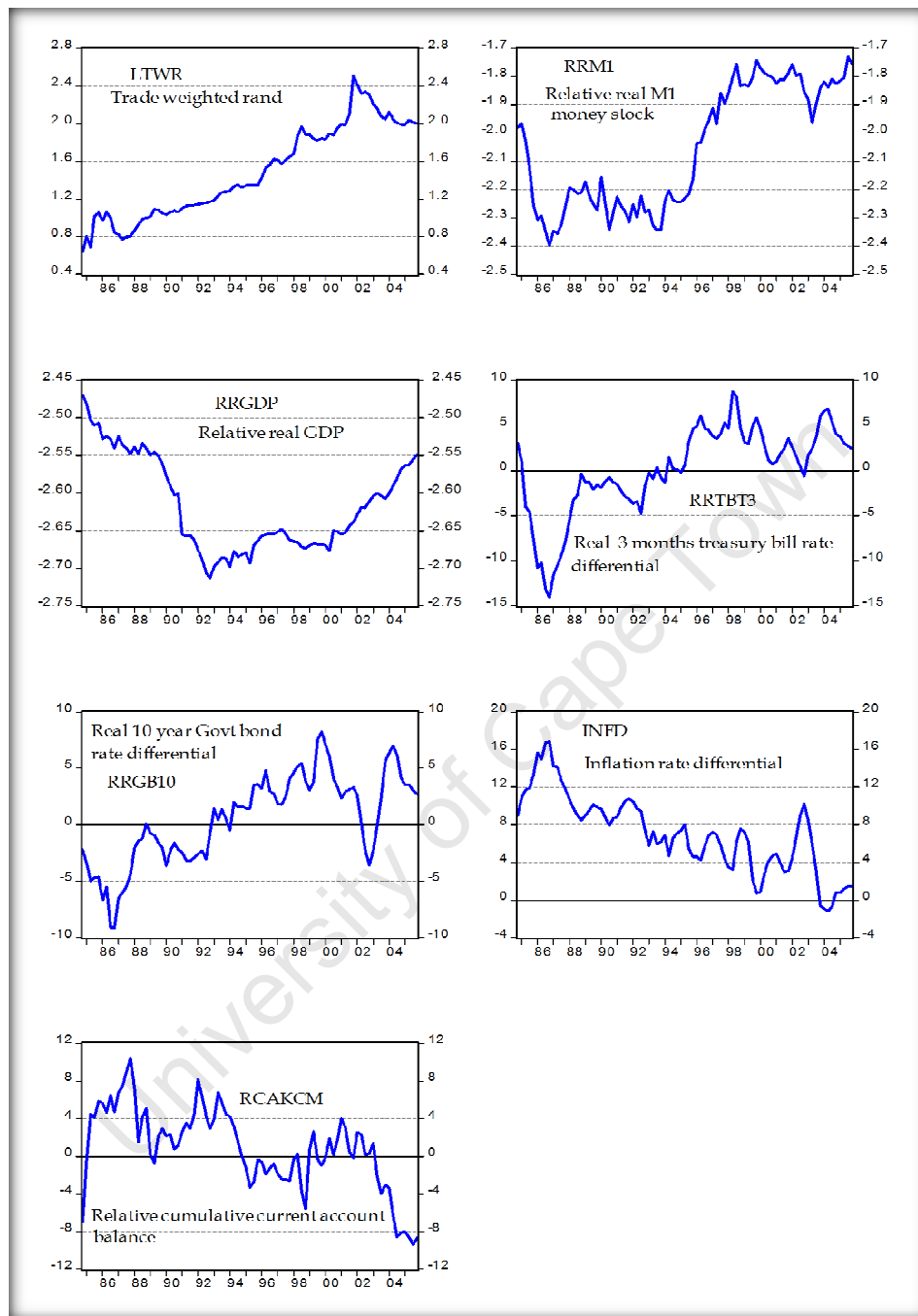
much more sharply and establishes its peak during 1998, and remains fairly stable in the remainder period.

The real GDP data series is also rapidly trended downwards from 1984, but its rate of descent is much more severe, as this persists till 1993. Nonetheless, a slow rebound begins to occur in 1994, while growth picks up strongly only after 2000.

Trends in real interest rate differential data somewhat contrast those of other data. The three months Treasury bills rises much more sharply for the most part, except during 1984 to 1986 and 2002 when sharp declines are observed, apparently reflecting accelerated inflation in these periods. There is a similar pattern is in the ten-year government bond yield rate data series, although, here, the extent of the decline during 2002 is much more extensive.

In contrast, the general pattern of developments in the inflation rate differential is a steady decline for the most part, except for occasional sharp increases observable in the mid 1985 and 2002. On the other, the relative current account balance remains significantly favorable (positive) throughout the 1980s and early 1990s, mainly underscoring the fact that, in this period, South Africa was forced to run a current account surplus due to financial sanctions (Jonsson, 2001). However, post 1994, the relative current account balance became unfavorable (negative), with the size of the deficit widening sharply after 2002, although there is a modest improvement from 1999 to 2001

Figure 4-2: The rand and its macroeconomic determinants



#### 4.2.2 *Time series properties*

Before applying the proposed empirical analysis, the statistical properties of the data that form the instrument of our study are first examined, partly to gain more knowledge of their time series characteristics. There is now considerable evidence in the literature indicating that data generating processes that underlie many time series data such as those on macroeconomic variables typically embody non-stationary *stochastic trends* or *unit roots* in level; becoming stationary only after differencing<sup>39</sup>. These induce permanency in shocks, causing variables to grow overtime with no tendency to revert to their mean values. Their presence in the data poses the challenge that standard testing procedures such as t- and F-statistics do not lead to valid inferences. Nonetheless, even if data are non-stationary, valid inferences can be made, provided they share a common stochastic trend – if they are *cointegrated*. Otherwise, data would have to be estimated in their differenced form. While some practitioners often difference the data arbitrarily in the expectation of achieving stationarity, econometricians disapprove of such practice. It is even suggested that arbitrary differencing may cause problems more serious than inappropriately assuming stationarity. Therefore, to determine whether to estimate them in their level or differenced form, and the appropriate methodology for doing this, data are first tested for their stationarity properties.

#### *Dickey and Fuller unit root tests*

For this purpose, the likelihood ratio unit root tests proposed by Dickey and Fuller (1979; 1981) are employed<sup>40</sup>. These entail examining whether an underlying

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<sup>39</sup> Nelson and Plosser (1982) were the first to make this traction. Following Meese and Singleton (1982), many authors identify exchange rates as essentially random walks, for example, Baillie and Bollerslev (1989).

<sup>40</sup> Several approaches to testing for unit roots in economic data now exist, some of which Maddala and Kim (1998) have aptly surveyed. However, the Dickey-Fuller procedure is considered the standard unit root test

data generating process follows the random walk model. That is to say, for a data series  $\{y_t\}$ , the Dickey and Fuller test is to test whether  $\rho = 1$  in an equation of the form

$$y_t = \rho y_{t-1} + \epsilon_t \quad (4-22)$$

Where the error term,  $\epsilon_t$  satisfies white noise properties, namely  $\epsilon_t \sim iid(0, \sigma^2)$

In conducting the test, the random walk model above is reformulated, by subtracting  $y_{t-1}$  from both sides, so that the model eventually tested is (4-23) below

$$\Delta y_t = \theta y_{t-1} + \epsilon_t \quad (4-23)$$

With  $\theta = \rho - 1$ . Dickey and Fuller's test is performed as a t-test on  $\theta$ . A test of the hypothesis that  $H_0: \theta = 0$  means that  $\rho = 1$  and therefore gives confirmation that  $y_t$  is a non-stationary process with a unit root (i.e. integrated of order one). If, on the other hand,  $H_a: \theta < 0$ , then  $\rho < 1$  and the evidence favours  $y_t$  as a stationary process.

The problem however is that the distribution for the t-statistic is not asymptotically normal under the null hypothesis, and therefore, the conventional t-test cannot be used to assess the statistical significance of  $\theta$ . Rather, the t-statistic follows the *Dickey-Fuller distribution*<sup>41</sup> and, accordingly, suitable critical values are those tabulated by Dickey and Fuller (1979; 1981). MacKinnon (1991; 1996) has generated a much larger set of simulations of these critical values, and has made them applicable to any sample size. The study uses these MacKinnon's critical values to assess the unit root hypothesis for the data applied in this investigation.<sup>42</sup>

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<sup>41</sup> Wooldrige (2006)

<sup>42</sup> Note that the computer software, *Eviews 5.0*, generates these automatically.

Furthermore, a simple random walk model proves an inadequate representation of the data in many practical instances, as data may exhibit correlation at higher orders and often drifts or trends overtime. When data exhibits higher serial correlation, the necessary assumption of white noise error terms cannot be sustained. Therefore, a more general autoregressive process is usually specified as the testing model, with the choice of including a constant or a trend as optional exogenous regressors, and augmenting the test regression with lagged first difference values of the series in order to correct for higher order serial correlation. The test regression model typically examined is thus equation (4-24) below, labeled the augmented Dickey-Fuller or ADF model, in which (4-23), labeled the DF model, is nested as a special case.

$$\Delta y_t = \alpha_0 + \alpha_1 t + \theta y_{t-1} + \sum_{i=1}^{p-1} \varphi_i \Delta y_{t-i} + \epsilon_t \quad (4-24)$$

Where  $\theta = (\sum_{i=1}^p \varphi_i) - 1$ ,  $\varphi_j = -\sum_{k=j+1}^p \varphi_k$ ,  $\alpha_0$  is a constant,  $t$  is a deterministic trend, and  $p$  is the number of first differenced values of data series (i.e. the order of augmentation).

Even in this formulation, the unit root test is carried out in the same fashion, namely  $H_0: \theta = 0$ , alias  $\rho = 1$ , which is ordinarily assessed by Dickey and Fuller's testing critical values. However, the inclusion of exogenous regressors and the order of augmentation affect results of the tests. Therefore, there is the additional requirement that the test regression model appropriate to the data series under consideration (i.e. whether to include a constant or trend) must be determined beforehand. The literature offers no clear-cut guidance on how to resolve this. However, Hamilton (1994)<sup>43</sup> recommends choosing a specification that is a plausible

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<sup>43</sup> See the discussion on page 501

description of the data under both the null and alternative hypotheses<sup>44</sup>. Looking at the data plot given by figure 4-1, only the exchange rate and inflation data appear trending. For these two data series, the trend stationary form of the test regression is used, whereas for the rest of the data series, a drift difference stationary model is employed.

As well, the order of augmentation P needs to be predetermined in conducting the Dickey-Fuller tests. This is addressed by applying a Schwarz Bayesian information criterion (BIC) on the data, from a maximum lag length of eleven.

Table 4-2: Dickey-Fuller tests for unit roots in data series (1984q4-2005q4)

Description	Null order series	I(1) in level			I(1) in 1 <sup>st</sup> difference	
		ADF <sub>c</sub>	ADF <sub>t</sub>	P	ADF	P
Trade weighted rand	ltwr		-2.52	1	-8.59***	0
Long term interest rate differential	rrgb10	-2.07		1	-7.17***	0
Short term interest rate differential	rrbt3	-1.53		0	-7.17***	0
Relative money supply	rrml	-0.66		0	-8.87***	0
Relative real income	rrgdp	-2.39		0	-8.38***	0
Inflation rate differential	infd		-3.78	5	-4.66***	4
Cumulative current account balance differential	rcakem	-1.63		2	-9.91***	1

Explanatory notes:

- (a) The ADF<sub>t</sub>, ADF<sub>c</sub> and ADF denote the Augmented Dickey-Fuller test statistic, including a constant and trend, a constant only, and no constant and no trend in respective order.
- (b) The asterisks (\*\*\*) denote rejection of the unit root hypothesis at the 1% critical values.
- (c) P, the order of augmentation (lag length) of the ADF test regression, is the last significance lag of the 11 employed, based on Schwartz Bayesian Information criteria (SBC) for selecting the lag length.
- (d) The critical values are the non-standard Dickey-Fuller regression as reported in Mackinnon (1991; 1996), and are provided here as part of *Eviews 5.0* output.
- (e) With a sample size of 85, the 1%, 5%, and 10% ADF test critical values are -4.07, -3.46, and -3.16, when a constant and trend are included, -3.51, -2.90, & -2.59 with constant, and -2.59, -1.94, & -1.61 when neither constant nor trend are included in the test regression.

Table 4-2 reports results from testing for a unit root in each of the data series using the Dickey-Fuller tests. These results fail to reject the unit root hypothesis for all the data series. The exception is the inflation rate differential where the evidence is less strong; the unit root hypothesis can be rejected at the five percent level of significance but is nonetheless sustained at the one percent significance level.

<sup>44</sup> See also *Eviews 5.0 Users Manual* (2004), p.507

Therefore, based on the ADF tests, we conclude that all our data series exhibit a unit root and, accordingly, it is reasonable to treat the data as non-stationary  $I(1)$  series

*Perron's tests: unit root hypothesis and structural change*

However, on inspection of data plots reported in figure 4-1, it appears structural breaks are present in the data series. The presence of structural breaks in data series renders Dickey-Fuller tests unreliable, in that such tests tend to under-reject the unit root hypothesis (Enders, 1995). The reason for this is that a permanent change in the deterministic component of a data process implies a persistent innovation to the stochastic trend, which standard ADF tests easily read as a unit root (Charemza & Deadman, 1997). Failure to account for the structural break therefore means that the standard unit root tests may lead to a false non-rejection of the null hypothesis of non-stationarity (Patterson, 2000). Thus, as a robustness check, the unit root evidence is re-examined using Perron's (1989) testing procedure, which permits examination of the unit root hypothesis when structural breaks are present in the data.

Perron's (1989) testing procedure is a generalization of the ADF tests by allowing for a one-time change in the deterministic structure of a data series occurring at time  $T_b$ , where  $1 < T_b < T$  and  $T$  is the sample size. The structural break is accounted for by including dummy variables in the deterministic component of the appropriate ADF regression. In this respect, there is a choice of three hypotheses<sup>45</sup>. One, labelled model A, is to allow for an exogenous change in the level of the series effective at time  $T_b + 1$ . Another, labelled model B, is to allow for exogenous change in the growth of the series beginning in  $T_b + 1$ . Finally, the third

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<sup>45</sup> See also the discussion in Mills (1993) and Patterson (2000)

option, model C, also labelled the innovation multiplier model (Patterson, 2000) allows for both a change in the level and growth rate of the series effective in  $T_b + 1$ .

The more general option, model C, is chosen here, since it provides the advantage of testing for the impact of both changes. In that case, the procedure is to estimate regression model of the form;

$$\Delta y_t = \mu + \beta t + \alpha DU_t + \gamma DT_t + \delta DTB_t + \theta y_{t-1} + \sum_{i=1}^p \varphi_i \Delta y_{t-i} + \epsilon_t \quad (4-25)$$

Where, given the date of the structural break as  $T_b$ , the specification of the dummy variables are such that  $DU_t = 1$  if  $t > T_b$ , and zero otherwise;  $DT_t = t - T_b$  if  $t > T_b$  and zero otherwise;  $DTB_t = 1$  if  $t = T_b + 1$  and zero elsewhere. The dummy variables are interpretable as follows. The dummy variable  $DTB_t$  corrects for an instantaneous change in the drift of the data process, while  $DU_t$  allows for change in the trend slope function. On the other hand,  $DT_t$  maintains the one-time change in the trend slope function, thus giving rise to a segmented trend process.

The null hypothesis of a unit root process corresponds to a t-test of  $H_0: \theta = 0$  given the change in the level and drift of the series, which is tested against the alternative of a trend stationary process, namely that  $H_a: \theta < 0$  and  $\beta, \alpha, \gamma, \delta \neq 0$ . In common with the standard ADF tests, however, the sample t-statistic is not t-distributed under the null hypothesis, and therefore conventional t-testing procedures inappropriate. Instead, the null hypothesis is assessed by comparing the sample t-statistic to testing critical values provided in Perron (1989)<sup>46</sup>. However, these are dependent upon the relevant breakpoint, and therefore the value of  $\lambda = \frac{T_b}{T}$ , the proportion of observations prior to the break point relative to the sample size, needs to be ascertained before hand in order to conduct the test.

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<sup>46</sup> Table VI.B, p. 1377

A major drawback of Perron's procedure, however, relates to the fact that only a single break point can be tested, and even this has to be exogenously determined. This poses a serious constraint, as the reality may be that repeated shocks to the data of various kinds may occur (Aron & Ayogu, 1997). Also, the break point may be endogenously determined, so much that attempting to pin point it exogenously may render the analysis open to criticisms of data mining. Recognizing this deficiency in Perron's tests, other approaches that allow for endogenous selection the break points are available, for example Zivot and Andrews (1992) and Perron and Vogelsang (1992). However, as the aim in applying Perron's tests is only to check robustness of Dickey-Fuller's tests, these other approaches are not pursued.

Table 4-3 reports results from testing the data for unit roots using Perron's tests. Note that implementing the procedure requires pre-dating the break period. The choice of dates for the break in each series is made by looking ex-post at the data, even though this leaves the analysis open to the criticism of data mining. As has been pointed out, this analysis lends itself as a robustness check, and the results should be viewed only as illustrative and complimentary.

With the above caveat in mind, we pick the date of the break for the exchange rate data in the first quarter of 2002, corresponding to the period of the rand's recovery. For the Government bond rate, the Treasury bill rate, and inflation rate differentials, the break is the first quarter of 1987, most likely picking up the effects on financial markets of the debt crisis. In the case of the real GDP series, the selected break point is 1993q1, whereas for the M1 money stock series, this occurs in 1993q4, both corresponding to the period of ascendance to political democracy. Finally, 1988q1 is selected as a potential break point for the current account data series.

Table 4-3: Perron's unit roots tests given structural change in the data

Testing model: $\Delta y_t = \mu + \beta t + \alpha DU_t + \gamma DT_t + \delta DBT_t + \theta y_{t-1} + \sum_{i=1}^p \varphi_i \Delta y_{t-i} + \epsilon_t$										
	series	$T_b$	$\lambda$	$P$	$\mu$	$\beta$	$\alpha$	$\gamma$	$\delta$	$t_{\theta=0}$
Trade weighted rand	.ltwr	2002q1	0.8	3	0.16 [3.00]	0.01 [3.17]	0.01 [0.22]	-0.01 [-1.22]	-0.08 [-0.79]	<b>-2.46</b>
Real 10 yr. Govt. bond rate	.rrgb10	1987q1	0.1	1	-1.34 [-1.57]	0.002 [0.01]	0.97 [1.12]	0.02 [0.11]	-1.45 [-1.09]	<b>-3.50</b>
Real 3 months TB rate	.rrtb3	1987q1	0.1	2	-1.85 [-1.82]	-0.08 [-0.40]	2.30 [2.02]	0.10 [0.48]	-1.34 [-0.89]	<b>-3.24</b>
Relative real M1	.rrm1	1993q4	0.4	0	-0.34 [-2.99]	0.00 [0.00]	0.05 [2.09]	0.001 [0.69]	0.05 [0.93]	<b>-2.83</b>
Relative Real GDP	.rrgdp	1993q1	0.4	0	-0.26 [-1.94]	-0.001 [-1.85]	0.005 [1.00]	0.001 [2.08]	0.01 [0.64]	<b>-1.90</b>
Inflation rate differential	.infd	1987q1	0.1	2	3.93 [4.51]	0.17 [1.20]	-1.43 [-1.83]	-0.21 [-1.49]	2.37 [2.04]	<b>-5.46</b>
Current account balance	.rcakcm	1988q1	0.2	3	1.85 [1.54]	0.06 [0.36]	-1.74 [-1.42]	-0.09 [-0.51]	-1.67 [-1.45]	<b>-2.73</b>

Notes: (1) the sample size,  $T$ , is 85.

(2)  $T_b$  is the time of the structural break,

(3)  $\lambda$  denotes the proportion of observations occurring before the break (i.e.  $T_b/T$ )

(4)  $P$  is the lag length (order of augmentation in the test regression), chosen based on the statistical significance of the last lag from a maximum of 6

(4) The appropriate t-statistics are in square brackets. For  $\mu, \beta, \alpha, \gamma,$  and  $\delta$ , the null hypothesis is that the coefficient is zero. In addition,  $t_{\theta=0}$  is the t-statistic for testing the unit root hypothesis that  $H_0: \theta = 0$ . Notice that this hypothesis is rejected only in the case of the inflation rate differential, based on Perron's testing critical values reported in table 4-4 below,

Comparing estimates of the statistic,  $t_{\theta=0}$  to Perron's testing critical values reported in table 4-4 below, the unit root hypothesis is sustained at the 10% level of significance in all the data series except the Government bond rate and inflation rate differential. There is, however, support of existence of a unit root in the Government bond rate at the 5% level of significance. Hence, even for this data series, the evidence appears to lean in favour of non-stationarity. However, we are able to reject the unit root hypothesis for the inflation rate differential, suggesting trend stationarity for this series, conditional on the structural break. Indeed, both the level and growth dummies prove significant for this series. There is also evidence favoring structural breaks in other data series. The intercept dummies establish significance in data series on the Treasury bill rate and M1 money stock, whereas the segmented trend dummy is supported by real GDP data.

Table 4-4: Perron's testing critical values

$\lambda =$	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1%	-4.38	-4.65	-4.78	-4.81	-4.90	-4.88	-4.75	-4.70	-4.41
5%	-3.75	-3.99	-4.17	-4.22	-4.24	-4.24	-4.18	-4.04	-3.80
10%	-3.45	-3.66	-3.87	-3.95	-3.96	-3.96	-3.86	-3.69	-3.46

Source: Perron (1989), table VI. B, pp. 1377

### 4.3 Outline of testing methodology

The methodology that we use to estimate our empirical model, equation (4-21), is described in this section. The goal of the analysis is to test how well an estimate of this model lends itself to random's long swings – that is, how well the model fits the data. A possible difficulty with model's specification is that it comprises jointly determined variables and therefore endogeneity problems are likely plague their estimations. To finesse this problem, estimations proceeds by way of a vector autoregressive (VAR) representation of the model. This circumvents the endogeneity problem by positing each variable as an endogenously determined function of past values of all variables forming the model;

$$Z_t = \sum_{i=1}^p \Psi_i Z_{t-i} + \Theta W_t + U_t \quad (4-26)$$

Where  $Z_t$  denotes a  $n$  vector of variables forming the model under investigation,  $W_t$  is a vector of deterministic variables,  $\Psi_1, \dots, \Psi_p$  and  $\Theta$  are matrices of coefficients to be estimated, and  $U_t$  is a vector of error terms satisfying white noise properties.

However, the evidence provided by unit root tests, demonstrating that the data that we use are all non-stationary series with a unit root, restricts estimation of the model on data in their first-differenced form. This is because regression one non-stationary process against another is not valid; it can lead to spurious results, wherein

conventional significance tests will tests to indicate a relationship between the variable when in fact none exists. Nonetheless, as already stated, despite their unit root property, data in their level may well form a linear combination of them that is stationary<sup>47</sup>. In that case, they are said to be *cointegrated*, following Engle and Granger (1987), and to *form a long run relationship* among them. This information needs to be accounted for in analysis; excluding it, which occurs when data is differenced, is counterproductive and misspecifies the model.

As interest of the study is in exploring the possibility that the long swings that we find in the rand can be accounted for by the set of factors posited by the model, we test the data for cointegration. This offers the benefit that sample information on both short run transitional dynamics and long run covariation among variables is preserved, despite non-stationarity of data.

## Cointegration

Originated by Engle and Granger (1987), the idea of cointegration, following Greene (2003), develops on the notion that linear combinations of non-stationary series, differences between them, should ordinarily evolve as non-stationary processes also. Thus, if given say two series  $x_t$  and  $y_t$  that are both  $I(1)$ , then  $\xi_t = y_t - \beta x_t$  is also  $I(1)$  for any value of  $\beta$ .<sup>48</sup> Accordingly, if, for example,  $x_t$  and  $y_t$  were each drifting upwards with their own trends, then the difference between them should also be growing by yet another trend.

Conversely, there may be a value of  $\beta$  such that this partial difference between the two series (i.e. their stochastic trend difference) may be stable around a fixed

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<sup>47</sup> That is, a commonly shared stochastic trend governs their evolution overtime

<sup>48</sup> Note that the same result obtains when variables or data series exhibit different orders of integration, for example, if  $x_t \sim I(1)$  and  $y_t \sim I(0)$  then  $y_t - \beta x_t$  is in general  $I(1)$ , see, for example, Greene (2003) for a detailed discussion

mean. This would imply that the series are growing together at an approximately equal rate, which should mean  $\xi_t = y_t - \beta x_t$  is  $I(0)$ . In consequence, knowledge of one variable helps to predict the other, at least in one direction. When data series satisfy this requirement, they are said to demonstrate *cointegration*, and this is interpretable as a *long run equilibrium relationship* between them, whereby the vector  $[1 \quad -\beta]'$  corresponds to the cointegrating vector. In that case, the *long run*<sup>49</sup> relationship between variables can be distinguished from their *short run* dynamics<sup>50</sup> (Greene, 2003). Clearly, the method of cointegration is amendable to this study in enabling one not only to extract from data information about equilibrium relationships among variables, but also in discerning their adjustment to such equilibrium.

### *Johansen's methodology*

To map the VAR representation of the model onto data, we use Johansen's (1988; 1991; 1995) cointegration technique. This entails reformulating the VAR model to its stationary form; which is essentially a dynamic vector autoregressive (VEC) model;

$$\Delta Z_t = \Pi Z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Z_{t-i} + \Theta W_t + U_t \quad (4-27)$$

Where  $\Pi = \sum_{i=1}^p \Psi_i - I$  denotes a matrix of long run coefficients that produce linear combinations of the variables in  $Z_t$  and  $\Gamma_i = -\sum_{j=i+1}^p \Psi_j$  corresponds to a coefficient matrix capturing short run dynamic adjustments among the variables.

A nice feature of this way of formulating the VAR model is that it simultaneously allows for examination of long run relationships among the variables and their short run adjustment to such long run equilibrium relationships. Firstly,

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<sup>49</sup> The manner in which they covary over time in their levels

<sup>50</sup> Their deviations from their long run trends

since  $\Pi$  is a long run impact matrix, the  $\Pi Z_t$  term captures long run relationships among the variables. These relations contained in the lagged term  $\Pi Z_{t-1}$  serve as equilibrium correction devices or ‘seeds’ that ensure that the short run adjustments of variables are tied to their long run values overtime. Secondly, the terms  $\Delta Z_{t-1}$  represent the short run dynamics or deviations of the variables from their long run equilibrium, whose impact is represented by  $\Gamma_i$ . Thirdly and most important, to the extent that the variables establish cointegration, then  $\Pi Z_{t-1}$  is stationary, as is  $\Delta Z_{t-1}$ , given that  $Z_{t-1}$  is integrated of first order. The vector error-correction model thus has the useful property of mapping a non-stationary VAR model to a stationary process, which is adaptable to standard inference procedures, inspite of non-stationarity of data.

Estimation then proceeds in two steps. A first is to test data for and estimate cointegrating relations. Evidence of this is discerned from the rank of  $\Pi$ , the *cointegrating rank*, since this contains coefficients forming long run relationships of variables. If, on one hand, the non-stationary data fail to establish cointegration, no linearly independent columns exit in  $\Pi$ , and consequently its rank is zero. A VAR on first differenced data is thus the requisite model. If, on the other hand, data cointegrate, matrix  $\Pi$  is rank deficient, holding at most  $r \leq n - 1$  linearly independent columns, where  $n$  is the number of elements forming the VAR. This provides evidence of existence of  $r \leq n - 1$  cointegrating or long run relationships in  $Z_t$ . Therefore, though a stationary form of the VAR must subsist, cointegration entails a restriction on the rank of  $\Pi$ .

In this cointegrating case, the matrix  $\Pi$  is equivalent to the decomposition that  $\Pi = \alpha\beta'$ , where  $\alpha$  and  $\beta$  are both  $n \times r$  matrices of full rank  $r$ . The matrix  $\alpha$  is

interpretable as describing the speed of adjustment of the variables to their previous period's disequilibrium. Matrix  $\beta$ , conversely, contains the  $r$  linearly independent columns forming the cointegrating vector, and consequently, has the property that  $\beta'Z_t$  is stationary. Thus  $\alpha\beta'Z_{t-1}$  replaces  $\Pi Z_{t-1}$  in (4-26), yielding

$$\Delta Z_t = \alpha\beta'Z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Z_{t-i} + \Theta w_t + U_t \quad (4-28)$$

Cointegrating relationships are now formed by the term  $\beta'Z_{t-1} = \xi_t$ . This reduces the cointegrating hypothesis reduces to a hypothesis about the reduced rank of matrix  $\beta'$ . That is,

$$H_0(r): \beta' = r \leq n - 1$$

Conducting the cointegration test then first entails generating estimates  $\Pi = \alpha\beta'$ . The Johansen's procedure achieves this by relying on the method of reduced rank regression, whereby the matrix  $\Pi = \alpha\beta'$  is first estimated from the unrestricted VAR model, and then testing whether the restrictions imposed by its reduced rank property can be rejected by the data. This is tested using two alternative log likelihood ratio (LR) tests. One, the Trace statistic, tests the null hypothesis of cointegrating relationships against the alternative of  $n$  cointegrating relationships, where  $n$  is the number of variables in the VAR, and for  $r = 0, 1, \dots, n - 2, n - 1$ . This test's statistic is given by

$$LR_{trace} = -T \sum_{i=r+1}^n \log(1 - \hat{\lambda}_i) \quad (4-29)$$

Where  $\lambda_i$  is the  $i$ -th largest eigenvalue of  $\Pi$ . The other is the Maximum Eigenvalue or  $\lambda - max$  statistic. This tests the null hypothesis of  $r$  cointegrating relationships against the alternative of  $r + 1$  cointegrating relationships present among data series. The statistic for assessing this test is given by

$$LR_{max} = -T \log(1 - \hat{\lambda}_{r+1}) \quad (4-30)$$

Both tests yield asymptotically nonstandard distributed under the cointegration hypothesis. While ordinarily, testing the null hypothesis relies on critical values in Johansen (1988), other authors have also tabulated these critical values, for instance Osterwald-Lenum (1992). In the present application, the more recent critical values tabulated in MacKinnon, Haug, and Michelis (1999) are used, which also allow for calculation of p-values<sup>51</sup>.

The distribution of the two test statistics for the cointegration is also dependent upon trend characteristics of data under investigation. More often, data series not only exhibit stochastic trends, but non-zero means as well as deterministic trends. Reflecting this, the cointegrating relations among these data series most likely may also exhibit non-zero means and or deterministic trends, and this would have to be taken into account during the course of investigation. However, the two cointegration test statistics are sensitive to inclusion of the deterministic trends in the test VAR. Therefore, the form of the underlying test VAR [i.e. whether the intercept or deterministic trend are restricted], needs to be ascertained in order to conduct the test.

Conditional on the choice of the data trend assumptions underlying the test VAR, the existence of cointegrating relationships among variables is then established sequentially. The hypothesis that  $r = 0$  is first tested, and then proceeding to  $r = n - 1$  until the test fails to reject the hypothesis. Where evidence favors  $r > 1$ , an *identification* problem is encountered- the presumptive behavioral relationship among the variables cannot be uncovered unless one elects to *specific out-of-sample* information. Unfortunately, there is as yet no consensus on appropriate identification

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<sup>51</sup> Note that Eviews 5.0 computes these MacKinnon, Haug, and Michelis (1999) p-values automatically

schemes and how to interpret the cointegrating relations so detected (Granger, 1997; Pesaran, 1997). In analysis that the present study subsequently makes, this issue is resolved relying on the *long run structural modeling* approach due to Pesaran and Shin (2002) and Pesaran, Shin, and Smith (2000). Their approach advocates using information derived from economic theory to uniquely indentify the presumptive relationship sought, with option to test validity of such restrictions on data. Other out of sample information deemed relevant is also adaptable.

Conditional on the choice of  $r$  and subsequent estimates of  $\Pi$ , a final step in the estimation process is to generate estimates of the stationary form of the model, equation (4-27); exploring its implications for short run dynamics among the data and overall fit.

#### 4.4 Discussion of empirical estimates

This section discusses results from estimating the model using the methodology outlined above. We first address the issue of how the empirical question of the *choice of the exchange rate horizon* that underlies these findings is resolved. It has been stressed early on that modeling South Africa's experience requires exploring the likely impact of regimes change. Rand pricing has occurred in an environment of frequent policy changes. Most of the dramatic changes, as has been pointed out, followed a combination of political events and changes in government policies. In terms of government policies, up until 2000, multiple periods of varying degrees of very controlled floating existed, together with capital controls and restricted trade with the global economy. It was not until trade and financial market liberalization, which began in the mid-1990s, resulted into adoption of Inflation Targeting as the monetary policy framework did the exchange rate regime become a free-float. The consequence is that available data span a relatively shorter period of free floating

while there are many years of very controlled floating, and where data are influenced most likely by regimes change.

Therefore, our premise is that the rand and perhaps some of its determinants have experienced episodes in which the behavior of their time series seems to have changed dramatically. The analysis needs to uncover this from the data. In other words, the question that arises is whether regimes change is in the data and if accounting for it then improves the fit of data.

To model the likely change in the processes of the variable that we study due to regimes change, we proceed in our analysis as follows. We first take the regime switch to an Inflation Targeting monetary policy framework in 2000 as a point of reference. We argue that since its implementation until now, obvious interventions have been notably nonexistent, save for reserve build up. Furthermore, its application has permitted the Government to set monetary policy by determining interest rates based on the inflation rate as a nominal anchor, and rely instead on the market to set the rand. Thus, market forces rather than Government interventions can be expected to have a major influence on exchange rate determination since then.

We then truncate the sample period at February 2000, the date of the regime change to inflation targeting, and estimate our empirical model on both a truncated and full sample data<sup>52</sup>. We thereby implement a three step testing strategy:

- a) First, estimation of the model is made on a sub-sample data set, 1984q4 to 1999q4, which is split at February 2000 – outside the period of

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<sup>52</sup> Enders (1995) provides further discussion of this in the context of unit root testing. Studies that make similar treatments include Ott and Veugelers (1986). These authors examined whether changes in US monetary policy regimes affected forward rate forecast errors of spot rates of the dollar, finding that they did.

Inflation Targeting. Results from this sub-sample estimation are catalogued model 1A.

- b) Second, the same estimation is repeated on full sample data, from 1984q4 to 2005q4, which incorporates the regime change to Inflation Targeting. Resulting estimates are labeled model 1B.
- c) Third, the findings from the two estimations are thereby compared.

The intuition is to determine if there is a difference in the relationship of the rand and its determinants during the period that we study. That is, if the relationship has remained the same before and after the regime-switch to inflation targeting. If regime change is not binding, there should be no significant change in the relationship between the rand and fundamentals. Otherwise, we should expect to observe a breakdown in the relationship, whereby either previously insignificant variables gain their significance. Alternatively, previously significant variables should be noticed to lose their significance. Thus, our null is that regime change - the switch to Inflation Targeting - has not affected the linkage of the rand to its fundamental determinants.

However, the approach has the handicap that valuable degrees of freedom are lost due to splitting the sample period. In addition, exogenously selecting regime change dates lends itself open to criticisms of data mining. There are thus other alternatives that overcome these constraints. One that has gained popularity is the *Regimes-Switching* modeling methodology. This allows modeling time series models as processes that shift direction in each of a fixed number of states, the '*regimes*'. The stochastic process assumed to generate the regimes is then included as part of the model. Usually, the regime is unobservable and the researcher must make inference about the regime the process was in at past periods in time. Regime-switching

models are of two categories. Markov-switching models, pioneered by Hamilton (1988; 1989) and first applied to exchange rate analysis by Engel and Hamilton (1990), rely on a latent variable called a markov chain to signal the probability of a regime shift. Hamilton (2008) has provide a more recent review of this literature. In contrast, Threshold models, first suggested by Tong (1983), model regime shifts in terms of observed variables assumed to be related to the unobserved threshold. Piper (2007) offers a summary the literature of this genre. Nevertheless, even without the benefit of this modeling elegancy and rigor, we think that our approach contains a useful way of addressing the impact of regime change on the relationship examined, since the regime change that we model is exogenously given – *it is a known event*.

#### 4.4.1 Cointegration tests

We first consider results from cointegration tests. In making cointegration tests, the data trend specification choice made is to restrict the intercept in the test VAR. Two lags of each data series in their first differences are added, on the strength of the Schwartz Bayesian and Akaike information criteria for lag selection, alongside three centred seasonal dummies (sr1, sr2, & sr3) intended to account for seasonality in the data. Also included in each specification is a series of first-differenced values of the real gold price ( $\Delta\text{golpr}$ ), intended to control for the impact of changes in the terms of trade. Gold mining has a historical importance to the South African economy. Lastly, a dummy variable, D2001=1 in 2001q1-2002q1, is added to the specification estimated on full sample data, to capture the effect on the rand of its rapid collapse in that period. We thereby estimate VAR models of the form;

$$\Delta Z_t = \delta + \alpha(\beta'Z_{t-1} + \mu) + \Gamma_1\Delta Z_{t-1} + \Gamma_2\Delta Z_{t-2} + \Theta w_t + U_t \quad (4-31)$$

Where

$$(i) \quad Z_t = [ltwr, rrm1, rrgdp, rrtbt3, rrgb10, infd, rcakcm]$$

- (ii) When analysis is made on sub-sample data,  $w_t = [sr1, sr2, sr3, \Delta lgo lpr, ]'$
- (iii) When full sample data is used,  $w_t = [sr1, sr2, sr3, \Delta lgo lpr, D2001]'$

As a check on the statistical adequacy of the underlying testing VAR model, table 4-5 reports chi-square statistics from testing the null hypothesis of normality and serial correlation in estimated residuals. These indicate that the model's estimated residuals appear free of serial correlation, while the null of no skewness is also not rejected. However, both the excess kurtosis and Jarque-bera tests reject the null of normality. Fortunately, cointegration test results are not affected if normality tests fail for any reason other than skewness (MacDonald & Ricci, 2003). The model's statistical adequacy is promising, overall.

Table 4-5: Chi-square statistics for joint tests of test VAR model diagnostics

	<b>Model 1A</b> <b>1984q4-1999q4</b>	<b>Model 1B</b> <b>1984q4-2005q4</b>
<b>Normality</b>		
<i>Skewness</i> \ (1)	4.8 (0.7)	8.2 (0.3)
<i>Kurtosis</i> \ (2)	37.6 (0.0)*	30 (0.0)*
<i>Jarque-Bera</i> \ (3)	42.4 (0.0)*	38.0 (0.0)*
<b>Serial correlation</b>		
<i>LM</i> \ (4)	56.2 (0.2)	63 (0.08)

Trace and Maximum Eigenvalue statistics from sequentially conducting the Johansen's test for cointegrating relationships among the data series are reported in table 4-6. The two statistics strongly reject the null of no cointegration among data series, but indicates that at least two cointegrating relationships may be present when the model is mapped on sub-sample data, model 1A, and one cointegrating relationship on full sample data, model 1B. Consequently, the rand and the set of factors posited by our model *form a long run relationship*.

Table 4-6: Johansen's test for cointegration among data series

Tested number of CEs	Trace test				Maximum eigenvalue test			
	Model 1A (1984q4-1999q4)		Model 1B (1984q4-2005q4)		Model 1A (1984q4-1999q4)		Model 1B (1984q4-2005q4)	
	Test statistic	p-value	Test statistic	p-value	Test statistic	p-value	Test statistic	p-value
None	177.7**	0.0000	161.8**	0.0001	59.4**	0.0012	70.8**	0.0000
At most 1	118.2**	0.0006	91.0	0.1022	49.5**	0.0033	39.3	0.0606
At most 2	68.8	0.0611	51.6	0.5658	31.1	0.1024	22.9	0.5382
At most 3	37.6	0.3211	28.7	0.7809	20.4	0.3171	12.3	0.9178
At most 4	17.2	0.6250	16.4	0.6850	11	0.6493	8.3	0.8854
At most 5	6.2	0.6692	8.1	0.4550	6.2	0.5932	4.5	0.8002
At most 6	0.1	0.7982	3.6	0.0587	0.1	0.7982	3.6	0.0587
No of CEs by model	2		1		2		1	

Note: (1) the asterisks (\*\*) denote rejection of the cointegration hypothesis at the 5% level  
 (2) p-values are calculated using Eviews5.0 econometric software, based on MacKinnon, Haug & Michelis (1999)

However, the two cointegrating relationships uncovered in the first case pose the difficulty of how to identify the two relationships. This is resolved following on Pesaran, Shin, and Smith's (2000) advice who have argued that when more than one cointegrating relationships are present, the decision concerning the choice of the number of cointegrating relationships must be made in conjunction with other out of sample information available such as economic theory. Indeed, the primary concern in the present study is discriminating the linkage of the rand to the set of factors we have posited. This is achievable only if all the variables of interest are taken into account. There is also the added difficulty that the other cointegrating relationship is not interpretable as an exchange rate equation, as alluded to early on<sup>53</sup>. Therefore, a rank of  $r = 1$  is imposed on the model and the resulting cointegration relationship normalized on the exchange rate variable,  $ltwr$ . In terms of variable definitions described earlier, the relationship of interest is thus;

$$\begin{aligned} \xi_{1t} = & \beta_{11}ltwr - \beta_{12}rrm1 + \beta_{13}rrgdp + \beta_{14}rrtbt3 + \\ & \beta_{15}rrgb10 - \beta_{16}inf d - \beta_{17}rcakcm + \mu \end{aligned} \quad (4-32)$$

<sup>53</sup> See also the exposition in MacDonald and Ricci (2003) and Chinn (1999)

Where the just identifying restriction is set as  $\beta_{11} = 1$

#### 4.4.2 Long run behaviour

Table 4-5 presents estimated coefficients associated with this relationship. Broadly, these results corroborate a priori expectations, in the sense that coefficients attached to variables have hypothesized signs. Relative money supply (M1), inflation rate differential, and current account balance all have positive coefficients, though, for current account balance, this fails on full sample data. Given that upward movements in the rand data series examined here denote depreciation, this indicates that higher relative money supply leads rand depreciations. As does inflation rate differential in favour of South Africa and a widening of its current account deficit. Relative real output (real GDP), in contrast, has a negative coefficient, suggesting correctly that rising incomes or, alternatively, strong economic growth in South Africa appreciates the rand.

However, the evidence of the direction of impact of the interest rate differential conflict; the coefficients attached to the two interest rates carry contrasting signs. For both the real short-term and long-term interest differential, the hypothesized a priori is that they bear a negative coefficient. Instead, the real 3 months Treasury bill rate differential holds a positive coefficient, whereas the real 10-year Government bond rate differential correctly carries a negative coefficient. The suggestion is that a rise in the real short-term interest rate differential in favor of South Africa leads to a depreciation of the rand whereas that of the real long term interest rate differential appreciates it. Thus, from the data, it does appear South African investors have tended to sell the rand when faced with higher short-term interest rates, but buy it when long-term interest rates are relatively higher.

Table 4-7: First stage estimation of the cointegrating equation for the rand exchange rate model

Regressor	name	Dependent variable: <i>trade weighted rand</i>	
		Model 1A (1984q4-1999q4)	Model 1B (1984q4-2005q4)
Relative money supply	rrm1	1.00 [2.73]	1.56 [6.59]
Relative real income	rrgdp	-0.64 [-0.99]	-2.16 [-3.26]
Interest rate differential			
<i>Short term rate</i>	rrtbt3	0.11 [3.03]	0.07 [3.75]
<i>Long term rate</i>	rrgb10	-0.05 [-1.49]	-0.11 [-4.56]
Inflation rate differential	infd	0.03 [0.56]	0.01 [0.23]
Cumulated current account balance	rcakcm	0.04 [2.29]	-0.004 [-0.28]
Constant	c	1.47	-0.97

Note: t-statistic in square brackets

There are arguments, nonetheless, that having the two interest rates in the same equation introduces colinearity, which may be contaminating their separate influences, hence their opposite signs. To verify the validity of this assertion in the present case, table (4-8) below reports results from estimating the single cointegrating equation, where the two interest rates are introduced separately into the analysis. As the results contained therein demonstrate, both interest rates still retain their opposite signs on their coefficients. It seems therefore that the result is a property of the data.

Intuitively, this finding may be justified on the ground that, given the evidence of non-stationarity of their data, in their local domains, domestic short term and long-term interest rates are governed by a common stochastic trend, or *are cointegrated*, so that their predictability rather than their colinearity is what drives this relationship. Indeed, there are theoretical arguments to support such conjecture. From the theory of the term structure of interest rates, long-term investors should be rewarded more

than short-term investors should and, as such, yield rates on assets of shorter maturities should follow those on longer maturities. This suggests a positive relation between long term and short-term rates. Certainly, large deviations between the two rates are not expected to persist, as arbitrageurs should keep the relation in equilibrium<sup>54</sup>.

Table 4-8: Differential impact of the short term and long term real interest rate differential on the rand

Regressor		Dependent variable: <i>trade weighted rand</i>			
		Model 1A		Model 1B	
	name	1984Q4	1999Q4	1984Q4	2005Q4
Relative money supply	RRM1	1.099	1.82	1.11	3.41
		[5.25]	[6.25]	[4.54]	[5.39]
Relative real income	RRGDP	-1.14	-1.62	-2.03	-2.98
		[-2.64]	[-2.53]	[-3.73]	[-2.31]
Short term rate	RRTBT3	0.062		0.068	
		[2.48]		[3.84]	
Long term rate	RRGB10		-0.06		-0.38
			[-1.77]		[-4.78]
Inflation rate differential	INFD	0.03	-0.075	0.085	-0.26
		[0.87]	[-2.17]	[4.33]	[-3.23]
Cumulated current account balance	RCAKCM	0.03	0.003	0.009	-0.06
		[2.64]	[0.23]	[0.70]	[-2.28]
constant		0.38	1.53	-2.17	2.78

t-statistics in [ ]

Moreover, theoretically, the question of which interest rate is relevant is not even settled. As has been pointed out in Chapter three, there are conflicting predictions for the interest rate variable. Under the flexible price assumption, the presumption is that nominal interest rates represent inflationary expectations, and therefore their changes should eventually lead to depreciated exchange rates. On the other hand, if price stickiness is hypothesized, nominal interest rates embody a real and inflationary component, so that it is possible to see appreciated exchange rates from interest rate changes. This follows from the conjecture that a rising real interest

<sup>54</sup> See also the discussion in Woodridge (2006) as well as Gujarati (2003)

rate differential should call forth a capital inflow. Finally, similar results are also commonplace in demand for money studies, where the short-term interest rate is added to represent the own yield rate on money assets<sup>55</sup>.

In any case, the findings above are very preliminary at this stage. The normalization used to derive them is arbitrary, and just aids identification of the relationship. To locate uniquely robust relationships capturing interactions among the variables, a number of hypotheses relating to whether some variables can be excluded from the equation forming the long run equilibrium are tested. This is done following Pesaran, Shin, and Smith (2000) and Pesaran and Shin's (2002) long run structural modeling methodology, as previously indicated. Recall that this advocates using economic theory or any relevant out of sample information to test the validity of the estimated relationships.

We begin the analysis by noting that the model that we have tested posits that changes in relative monies will bear equal-proportionate changes in the exchange rate. The coefficient attached to the relative money stock variable should therefore equal unity in the exchange rate equation. The identification process thus starts with testing the validity of this homogeneity hypothesis. To do this, the cointegration equation is re-estimated together with the over-identifying restriction that  $\beta_{12} = -1$  in equation (4-32) shown earlier.

#### *Isolating regimes change: sub sample data estimations*

Results from sub-sample data estimations, 1984-1999 (model 1A), are examined first. The log-likelihood ratio statistic for testing the above restriction is given as  $X^2(1) = 0.00006$ , which, with a p-value of 0.99, means that the restriction is easily supported by the data. Notice also from table (4-7) that both the relative real

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<sup>55</sup> A South African perspective is Todan (2007)

GDP and inflation differential data have no statistical significance on this data sample. Consequently, the coefficients on these variables are each restricted to zero by testing the over-identifying restrictions that  $\beta_{13} = 0$  and  $\beta_{16} = 0$ , which, if accepted, implies the variables may be removed from the analysis. The test yields a log-likelihood statistic of  $X^2(3) = 0.29$ , with p-value of 0.96, which is also statistically insignificant. Data thus fits the restrictions.

Next, the coefficient on the current account variable is restricted to zero by testing the extra restriction that  $\beta_{17} = 0$ , providing a log-likelihood statistic of  $X^2(4) = 3.02$ , with a p-value of 0.55. Again, this is insignificant. All the four restrictions are not binding, and therefore real incomes, the inflation rate differential, and the current account balance do not explain the rand. Essentially this leads us to the conclusion that, for the sample period from 1984q4 through to 2005q4, it is only the relative money supply (real M1), the short term interest rate differential (real 3 months Treasury bill rate) and the long term interest rate differential (real 10 year Government bond rate) that map long trends in the rand. The identified long run relationship is thus equation (4-33) below, which is also provided in table (4-9), labeled *Coint.Eq Model 1A*.

$$ltwr = rrm1 + 0.25rrtbt3 - 0.30rrgb10 + 3.43 \quad (4-33)$$

Accordingly, if South African M1 rose in real terms by one percent, the rand would depreciate by one percent. Similarly, the rand would tend to depreciate by an average of 0.25% on account of a 100 basis points increase in the real short term interest rate differential favoring South Africa. On the other hand, the effect of an increase in the long-term interest rate differential of 100 basis points would be to appreciate the rand by an average 0.30%.

### *Accounting for regimes change: full sample data estimations*

In comparison to estimates for the full sample period (model 1B, table 4-7), the results differ markedly only in respect of the real income variable. Relative real GDP now evidence a significant coefficient based on the just indentifying restriction (i.e. setting  $\beta_{11} = 1$  in 4-31). However, as with sub-sample data, both the inflation rate differential and the current account maintain their lack of significance. The null of first degree money supply homogeneity is thus tested jointly with those that the inflation rate differential and the current account balance do not matter in this equation. This is done by imposing the over identifying restrictions  $\beta_{12} = -1, \beta_{16} = 0$ , and  $\beta_{17} = 0$ , which gives a log-likelihood statistics of  $X^2(3) = 4.36$ , with p-value of 0.22, and does not reject the joint hypothesis. Therefore, the inflation rate differential and the current account balance maintain their lack of significance in explaining the rand, but real GDP does. Consequently, from table (4-9), the relation characterizing the long run relationship that explains the rand may be written as

$$ltwr = rrm1 - 1.3rrgdp + 0.09rrtbt3 - 0.10rrgb10 + 0.24 \quad (4-34)$$

As can be seen from this equation, extending sampling data to incorporate the period of Inflation Targeting reveals an extra and very important piece of information. Particularly, there is the additional evidence of statistically significant responses of the rand to variability in relative real GDP. According to its estimated parameter, the rand would, on average, tend to appreciate by 1.3% if the South African grew by one percent relative to those of its trading partners. Therefore, it appears the regime shift to Inflation Targeting has had the effect of illuminating to the market the importance of information on the economic growth of the country, as data did not support this variable in preceding analysis. Examining figure 4-1 readily

reveals why this must be so. Having begun to rebound from mid-1992, the South African economy accelerated after 2000, which is supporting of this inference.

Table 4-9: Second stage estimation of long run relationships

Regressor	Var. name	Dependent variable: <i>trade-weighted rand</i>	
		Model 1A (1984q4-1999q4)	Model 1B (1984q4-2005q4)
Relative money supplu	rrm1	1.00	1.00
Relative real income	rrgdp	0.00	-1.27
			[- 2.51]
Interest rate differential			
<i>Short term rate</i>	rrtbt3	0.26	0.09
		[6.08]	[6.52]
<i>Long term rate</i>	rrgb10	-0.31	- 0.10
		[-5.00]	[-4.84]
Inflation rate differential	infd	0.00	0.00
Cumulated current account balance	rcakcm	0.00	0.00
Constant	c	3.43	0.24
<b>No of tested restrictions</b>		4	3
<b>Chi-sq stat (p-value)</b>		3.02 (0.55)	4.36 (0.22)
Identifying restriction		$\beta_{12} = 1$	$\beta_{12} = 1$
Included exogenous variables		$\Delta l golpr$	$\Delta l golpr, D2001$

Note: t-statistic in square brackets

Importantly, however, the parameters of the two interest rates display large movements. Although maintaining their signs and statistical significance, their magnitudes fall dramatically. Now, every 100 basis points increase in the real 3 months Treasury bill rate differential is associated with approximately 0.09% depreciation of the rand, compared to 0.26% when sub-sample data are used. Similarly for the relative 10-year government bond rate, its rise by 100 basis points appreciates the rand by an average 0.10%, whereas it was 0.30% previously. This exceptionally large decrease in the interest rate sensitivities may be explained by the fact that, with inflation targeting, the Reserve Bank has been intervening in money markets through interest rate announcements, as this policy regime has replaced money targeting with smoothing of short-term interest rates – the repo rate is the

operating target of monetary policy. In turn, this has had the unintended consequence of smoothing out the information content from interest rates for currency pricing. This also applies to long-term interest rates because those rates are the average of anticipated short-term rates that agents anticipate in future.

To sum up, data sustains evidence of a strong correspondence of the rand to a subset of fundamental factors that have been posited. However, only relative money supply, the short-term and the long-term interest rate differential form a statistically significant relationship when the model is examined on a sub-sample data set, from 1984 through to 1999. When, on the other hand, full sample data encompassing the regime switch to inflation targeting are used, there is the added statistical significance of the relative real income variable. Thus, accounting for the regime change to inflation targeting improves the fit of the data. What the study then establishes is that the linkage of the rand to fundamentals is regime-dependent. Nevertheless, data does not validate the hypothesized influences of the expected inflation rate differential and the risk premium.

#### *Accounting for regime change: the dummy variable procedure*

Although testing for regime change by way of partitioning the sample period succeeds in isolating the difference in the relationship due to a regime shift, as detailed above, it does not allow us to distinguish the source of the break in the relationship. Therefore, as a verification test of robustness of results obtained above, the evidence is re-examined by investigation whether the structural break is due to a changes in the slope coefficients. The investigation of this proceeds as follows.

- a) A regime shift dummy is created,  $D_{2000}$ , which equals unity in 2000q2-2005q4, the period of Inflation Targeting, and zero elsewhere.

- b) Each respective explanatory variable in the test VAR model is then interacted with dummy variable, D2000 (i.e. multiplied by D2000) to create another variable, a *multiplicative dummy*, labeled MD2000, which takes the value of a respective explanatory variable when D2000=1, i.e. in the period of Inflation Targeting. This means  $MD2000 = f_{it}$  only in 2000q2-2005q4 and zero otherwise, where  $f_{it}$  represents explanatory variable  $i$ , in the VAR model.
- c) Rather than truncate the sampling period, the estimation is made on full sampling data only, but with introducing the multiplicative dummy on each explanatory variable,  $MD2000$ , separately into the analysis as an additional regressor.

In brief, the intuition underpinning the testing procedure is the following. For each variable in the VAR model, we consider its correspondence with the rand as possibly driven by a process that undergoes a regime change of the form<sup>56</sup>

$$s_t = \delta_0 + \delta_{1i}f_{it} + \delta_{2i}(D_t f_{it}) + \epsilon_t \quad (4-35)$$

Where  $s_t$  represents the rand exchange rate,  $f_{it} \in Z_t$  is a fundamental determinant in the VAR model,  $D_t = D2000$  is the regime shift dummy,  $D_t f_{it} = MD2000$  is the multiplicative dummy variable, and  $\epsilon_t$  satisfies white noise properties.

The impact of regimes change is then assessed by examining the statistical significance of  $\delta_{2i}$ , the coefficient on the multiplicative dummy variable  $D_t f_{it}$ . This tells by how much the slope coefficient on an explanatory variable differs before and after the regime change. To see how, note that before the regime change, when  $D_t = 0$ , the mean value function for the model above is

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<sup>56</sup> See, for example, the discussion in Gujarati (2003) and Thomas (1997)

$$E(s_t|D_t = 0, f_{it}) = \delta_0 + \delta_{1i}f_{it} \quad (4-36)$$

But after the regime, when  $D_t = 1$ , the mean value function is now

$$E(s_t|D_t = 1, f_{it}) = \delta_0 + \vartheta_1 f_{it} \quad (4-37)$$

Where  $\vartheta_1 = \delta_{1i} + \delta_{2i}$ . As can be seen from (4-36) and (4-37), it is  $\delta_{2i}$  that distinguishes the slope coefficients from the two periods (pre and post regime). Without the regime change, the slope coefficient on the fundamental determinant is simply  $\delta_{1i}$ , whereas, with the regime change, a different coefficient exists, namely  $\vartheta_1 = \delta_{1i} + \delta_{2i}$ .

Therefore, the null hypothesis is stated as that  $\delta_{2i} \neq 0$ , which is assessed using a standard t-test for statistical significance of the estimated coefficient. Thus, the value of  $\delta_{2i}$  can be either negative or positive. A positive value of the parameter  $\delta_{2i}$  is interpretable as suggesting that the slope coefficient is larger in the post-regime change period relative to that of the pre-regime change period. This in turn is signifying the predictive power of the fundamental variable is enhanced by the regime change. A negative value of  $\delta_{2i}$ , conversely, implies the slope coefficient is smaller in the post regime-change period, which is indication that the regime change diminishes the predictive impact of the fundamental variable. In these two instances, the implication is that regime change has a binding effect on the relationship. Otherwise, (i.e. if  $\delta_{2i} = 0$ ) the relationship is invariant to the regime change.

The test result is reported in table 4-10. These fail to reject the hypothesis that the multiplicative dummy variable is statistically indistinguishable from zero in any of the data, except those on the relative real M1 and relative real GDP. In terms of this result for these two variables, we find evidence in favour of the regime change to Inflation Targeting affecting the linkage of the rand with respect to relative real M1 and relative real GDP, but not with the other variables tested. Our earlier finding of

an improvement in the fit of the data from accommodating regime change into the analysis is thus confirmed by results provided in table 4-10.

Table 4-10: Tests of regime change on the rand: 1984q4-2005q4

Dependent variable: <i>trade-weighted rand</i>						
<i>Interacted regressor</i>	<i>Money supply (RRM1)</i>	<i>Real income (RRGDP)</i>	<i>Interest rate differential</i>		<i>Inflation rate (INFD)</i>	<i>Current account balance (RCAKCM)</i>
			<i>Short term rate (RRTBT3)</i>	<i>Long term rate (RRGB10)</i>		
RRM1	1.76 [7.78]	1.75 [7.59]	1.96 [8.27]	1.97 [8.76]	2.06 [8.98]	2.06 [9.54]
RRGDP	-2.88 [-6.50]	-2.86 [-6.41]	-2.83 [-4.98]	-2.89 [-5.25]	-3.02 [-5.43]	-3.55 [-6.34]
RRTBT3	0.05 [3.78]	0.05 [3.85]	0.06 [4.16]	0.06 [3.90]	0.06 [3.95]	0.04 [3.15]
RRGB10	-0.09 [-5.14]	-0.09 [-5.16]	-0.12 [-5.70]	-0.12 [-5.52]	-0.13 [-5.73]	-0.12 [-5.83]
INFD	0.00	0.00	0.00	0.00	0.00	0.00
RCAKCM	0.00	0.00	0.00	0.00	0.00	0.00
Tests of the Multiplicative Dummy Variable						
<i>DTRRM1</i>	-0.09 [-2.03]					
<i>DTRRGDP</i>		-0.06 [-2.07]				
<i>DTRRTBT3</i>			0.00			
<i>DTRRGB10</i>				0.00		
<i>DTINFD</i>					0.00	
<i>DTRCAKC</i>						0.00
<i>M</i>						
Constant	-2.43	-2.44	-1.86	-2.00	-2.14	-3.54
Tested restrictions	2	2	3	3	3	3
Chi-sq stat (p-value)	1.13 (0.57)	1.24 (0.53)	0.81 (0.81)	0.72 (0.87)	0.85 (0.84)	5.89 (0.12)
Incl exog var.	$\Delta l golpr$	$\Delta l golpr$	$\Delta l golpr$	$\Delta l golpr$	$\Delta l golpr$	$\Delta l golpr$

t-statistic in squared brackets

In particular, the estimated multiplicative dummy coefficient for relative real M1 is 0.09, while that on the relative real GDP is 0.06. Given that relative real M1 enters the cointegrating equation with a negative sign, the above estimate means that the shift to Inflation Targeting appears to have diminished the predictive impact of relative real M1 by about 0.09. By contrast, for the relative real GDP variable, the

consequence of this has been to illuminate its predictive impact, on the average, by 0.06.

For the relative real GDP variable, this finding is assenting to earlier findings obtained from using the sample-truncation technique. However, there is now the benefit of unearthing the extra evidence indicating the regime change appears to have diminished the importance of news about money supply changes in deciding the rand's value. This finding of a regime dependent money supply impact on the rand is an advance in our analysis; the result could not be found using the sample-truncation method applied earlier on. Thus, tests of the regime change dummy also support the finding that the connection of the rand to fundamentals seems regime-dependent.

#### 4.4.3 Short run behavior

Finally, the short run transition dynamics of the relationships are examined by generating vector error correction estimations of the model for both sub-sample and full-sample data, conditioned on the respective long run relations. Results revealed no explanatory power of most of the determinants in predicting the change in the rand. Thus, table (4-11) below reports only estimates of short run dynamics that are significant. These equations for the short run transitional dynamics that result from these results are shown below labeled equations (4-38) and (4-39) respectively.

$$1A: \Delta ltwr = 0.03 - 0.05ecm(-1) + 0.61\Delta l golpr \quad (4-38)$$

$$1B: \Delta ltwr = 0.02 - 0.14ecm(-1) + 0.29\Delta ltwr(-1) + 0.69\Delta l golpr + 0.09D2001 \quad (4-39)$$

Where  $ecm(-1)$  is the lagged value of the equilibrium error correction term from the preceding period

A particular interest in these results is the sign and statistical significance of the coefficient attached to the lagged value of the equilibrium error-correction term,

since this captures the speed at which equilibrium is restored once displacement from such equilibrium is occasioned. The results show statistically significant estimates of the error coefficient, which thereby validates the long run relationships that we find. The error coefficient also carries a negative sign, showing that the rand gravitates towards its long run value governed by the set fundamental determinants examined here<sup>57</sup>. This is a valuable finding, as were the equilibrium error correction to be statistically indistinguishable from zero, the conclusion made earlier about existence of a long run relationship of the rand and fundamentals would be invalidated.

Table 4-11: Estimates of the short run dynamic adjustment of the rand's model

Dependent variable: first differenced trade weighted rand ( $\Delta ltwr$ )		
Regressor	Model 1A 1984q4-1999q4	Model 1B 1984q4-2005q4
<b>Dynamic terms</b>		
<i>Long run term (ecm(-1))</i>	-0.05 [-3.04]	-0.14 [-4.54]
$\Delta ltwr(-1)$		-0.29 [-2.44]
<i>Constant</i>	0.03 [ 2.70]	0.02 [ 2.50]
<b>Exogenous conditioning variables</b>		
$\Delta l golpr$	0.61 [ 3.96]	0.69 [ 4.92]
$D2001$		0.02 [2.50]
Half life of deviation from equilibrium (years)	3.2	1.1
<b>Diagnostics</b>		
R-squared	0.57	0.55
Adj. R-squared	0.37	0.41

Note: t-statistic in square brackets

More to the point, the estimated error term coefficient is -0.05 and -0.14 from sub-sample and full-sample data estimations respectively. These estimates imply that

<sup>57</sup> To elaborate, if the rand is above its equilibrium value ( $s_t > f_t$ ), then, in the next period, the error correction works to push back the rand toward the equilibrium. And when the rand is below its equilibrium value ( $s_t < f_t$ ), the error correction similarly induces a positive change in the rand back toward equilibrium [see Woodridge (2006), pp. 653].

at least 5 % of the variations in the rand is corrected each quarter, when sub-sample data is used, suggesting a period of 3 years for the initial shock to be reduced by half. On the other hand, about 14% of the variations are corrected when full sample data is used, suggesting a mean reversion of 1.1 years. Thus, if the rand were to depreciate by say 50%, the suggestion is that such depreciation would persist for at least 14 quarters before reducing by half, based on sub-sample data, and only 5 quarters when data is stretched across the whole sample. There is accordingly speedy convergence to equilibrium when the relationship is explored on full sample data. Intuitively, this finding appear to substantiate the claim made early on the analysis that liberalization measures undertaken in the latter part of the sample period may have made the exchange much more sensitive to changes in its fundamental determinants, however fewer these fundamental determinants.

The other notable result is that the rand is also found to respond to contemporaneous changes of the real gold price. Short run changes of the gold price generate positive changes in the rand's short run dynamics. Estimates of its coefficients range from 0.61 to 0.69 between the two sample data sets examined, suggesting that short run changes in the gold price are quickly reflected in the rand's movements. This should not be a surprising finding if one takes account of the historical importance of gold mining as a foreign exchange earner for the South African foreign exchange market. However, its positive linkage implies gold price increases have been associated with depreciations of the rand. This seems a perverse result if the point has to be laboured about gold mining as foreign exchange earner. Rather, appreciations other than depreciations should be expected. Nevertheless, it is possible to offer a rationalization of this if one speculated that the market may have tended to view the gold price as a leading indicator, whereby its immediate increase creates temporary expectations of future appreciations. The

market then bids the foreign currency in the current period, causing depreciations. As the rise in the gold price persists across quarters, this trend reverses and the rand falls in line with developments in the gold price.

Furthermore, in estimations on full sample data, there are dependences of changes in the rand to their recent past history, but with a lag of one quarter. The estimated coefficient is -0.29. This implies, at a quarterly horizon, that when the rand is high today, it will tend to fall tomorrow. Similar to findings on the gold price, it can be speculated intuitively that the market may have tended to view short term changes in the exchange rate as lagging indicators, signaling appreciations in the wake of an immediate past depreciations which later dissipate once the change in the exchange rate persists.

However, given the relatively poor goodness of fit statistics (37% to 41%) of the VECMs, the results do not suggest that the variables captured for this study do provide a comprehensive depiction of long run dynamics of the rand. This is not a surprising result, given that exchange rates respond to several factors.

#### 4.5 Summing up

We have explored in chapter the prospect that fundamental factors aid rationalization of the long swing movements that the rand has shown. The exploration has used a model that draws on the asset approach to exchange rate determination, which maps long trends in the rand to money supplies, real incomes, short term and long term interest rates, expected inflation rates, and the risk premium in South Africa relative to those in its major trading partners.

Examining a trade-weighted rand, the main findings are twofold. The first is that fundamentals matter - *the data do indicate strong correspondence between the rand and the set of factors suggested by the model*. However, only subsets of those form a statistically

significant relationship that is stable. In particular, growth in money supplies and higher short-term interest rates in South Africa lead rand depreciations. Conversely, growth in real incomes or economic growth and higher long-term interest rates drive rand appreciations. The data, however, do not validate the hypothesized rand's sensitivities to the expected inflation rate and the risk premium (current account balance).

Secondly, given the numerous changes to the exchange rate regime within the sample of data tested, a further hypothesis of interest has been that the rand's linkage to underlying fundamental determinants may have altered due to *regimes change*. In particular, the regime switch in February 2000 to an inflation-targeting framework for conducting monetary policy has separated the previous years of very controlled floating from the present in which obvious foreign exchange interventions have been absent and there is reliance on the market to determine the rand. With the application of this regime, therefore, there is expectation of anchorage of the exchange rate to the market, and, as a result, changes in fundamental factors may have increasingly influenced pricing of the rand because of financial market liberalization that has occurred. For that reason, in comparison to the previous regimes, one can expect alteration of the linkage of the rand to fundamental factors, possibly with the significance of the latter being regime-dependent.

Indeed, distinguishing the regime change to inflation targeting, the analysis has shown a marked improvement in the fit of the data. On the one hand, the estimates of the real income variable become statistically significant only when the estimations use the full data that encompass the period of inflation targeting, but not when this period is isolated. On the other hand, on further interacting the variables with a regime shift dummy that measures the regime change to inflation-targeting, the

sensitivity of the real income variable is enhanced while that of the money supply is lessened.

Thus, although fundamentals anchor the rand during our sample, this evidence suggests an anchorage that is regime dependent – *it has depended on which exchange rate regime the exchange rate has been in*. In the pre-inflation targeting period, only a smaller set of the fundamentals examined matter. In the post inflation-targeting period, where the rand is a free float, an expanded set of fundamentals map its long trends. Therefore, the regime switch to inflation targeting seems not only to have expanded the set of fundamentals on which the rand now anchors, but has also strengthened its linkage to those determinants.

Hence, the present study has unearthed evidence contrasting those of previous studies (Chinn M. D., 1999; Brink & Koekemoer, 2000; Gebreselasie, Akanbi, & Sichei, 2005a; 2005b). Those studies did not explore the significance of regimes change to understanding rand dynamics. The analysis provided herein thus advances the South African literature this regard.

Nonetheless, there are other complicating factors in the exchange rate equation. Undeniably, that South Africa has since 1994 pursued a much more robust macroeconomic policy framework makes it more likely that other factors may have been at play. Besides, the exchange rate and the macroeconomic variables examined here are all endogenous to the macroeconomic policy setup of a country. Unfortunately, the analysis has not probed these other influences here and no substantiated assertions on their likely influences are possibly tenable at this stage.

Mindful of these caveats, however, the suggestion of the evidence presented here is that fundamentals have been important. Developments in money supplies,

real national incomes or national output, and both short term and long term interest rates form an important information set for understanding long trends in the rand.

What would be the policy implications of these findings? Considering that the current policy framework of inflation targeting relies on setting interest rates as the operating target, the inverse relationship found between the short-term interest rate and the rand suggests that it would be difficult to achieve the goal of stabilizing the currency through raising short-term interest rates. It is speculated that such a strategy is likely to eventually fuel additional instability in the currency. Rather, the present stance of monetary policy could be supportive only in as much as higher yields rates obtained on longer maturity assets relative to shorter maturities. This would combine very well with a strategy of maintaining inflation below levels of the main trading partners, to maintain positive real interest differentials. The current policy stance has this focus, although lately inflation began to spiral outside the targeted 3 to 6 percent range and is now above the 10 percent mark - largely because of higher than expected food and energy prices. Nonetheless, indications are that inflation has now peaked.

All the same, to the extent that short-term interest rates provide an anchor for expectations about the future path of long-term rates, the policy framework should be plausible. However, more enquiries into the issue are required to get a better understanding of how such relationships interface.

Overall, at one level, the results of the study add to accumulating literature suggesting that economic fundamentals matter for currency pricing in South Africa. At another level, it suggests that exchange rates can differ in the degree to which they are connected to these underlying determinants when the economic environment in

which they are being determined continuously change; which calls for more caution in comparing and interpreting results across a spectrum of regimes change.

Results of this study may also be seen as lending empirical support to the ongoing debate on the choice of exchange rate regimes for developing countries with access to capital flows in the light of recent financial crises- the so-called bipolar hypothesis, of which Fischer (2008; 2001) is one of its advocates. The message of this study is that regimes change matters.

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## Chapter 5

### 5 Literature review: explaining short run currency movements

#### 5.1 Overview

The focus of this chapter, and the next, is on short run fluctuations in the rand; its volatility – *the bumpy ride*. The analysis begins in this chapter with a review of relevant literature, which informs the empirical analysis that the study does.

It is well recognized that exchange rates are primarily set by foreign exchange markets through decisions of market participants. Therefore, the empirical regularity which chapter three alluded to that exchange rates within short run intervals cannot be explained based on fundamentals has sparked research into the *microstructure (mechanics)* characteristics of the foreign exchange market (Lyons, 2001), to gain insights into short run exchange rate determination. This approach is rooted in studies of centralized markets such as equity markets where it is acknowledged that market behavioral issues are fundamental to the pricing of assets at the short horizon of less than a month. It thereby deals with the impacts on currency pricing of such market characteristics as *institutional rules, and perceptions and behaviors* of markets participants of various kinds (Sarno & Taylor, 2001a). The main issue of concern has been whether foreign exchange markets are pricing currencies correctly – meaning, how well foreign exchange markets are functioning.

Focusing on the microstructure of the foreign exchange market indeed seems merited. Experience since the switch to floating exchange rates in the early 1970s (post Bretton Woods era) has shown that financial flows rather than trade flows are the main drivers of foreign exchange market activities. This is reflected in the growth in global turnover in foreign exchange market activities that is now unprecedentedly

greater in volume than trade in real goods and services (Bank for International Settlements, 2007). Mirroring these global trends, the *Survey of Reporting Dealers* ([www.reservebank.co.za](http://www.reservebank.co.za)) published by the South African Reserve Bank estimates that foreign exchange turnover in South Africa has averaged US\$10 billion or six percent of GDP per day since 1998. Of this, only a dismal average of two percent of GDP can be mapped to transactions in merchandise trade. The consensus view in environments of this sort is that short run fluctuations in exchange rates reflect asset positioning and repositioning by international investors in response to changing rates of return, expectations, and news of various kinds (Lindert & Pugel, 1996).

However, microstructure analysis of foreign exchange markets is made more difficult because foreign exchange markets, unlike organized markets such as stock markets, are largely decentralized markets. They are a quote-driven dealership of internationally electronic-media networked participants in them who are physically separated from each other but with trades occurring simultaneously (Sarno & Taylor, 2001a) – usually, transactions are made by electronic media such as telephones, telexes, and computer networks. This market segmentation means that not all information is observable. The significance of this is that market participants are unlikely to face same trading opportunities, which cannot be captured adequately by existing econometric modeling tool kits that generally assume homogeneity in the information set available to market participants.

Nonetheless, the foreign exchange market microstructure literature is potentially consistent with well-known regularities in data. One strand of this literature has a focus on institutional aspects, analyzing how the trading process may affect pricing of currency values. Evans and Lyons (2002) is an example. These authors find that

the flow of orders, *order flow*,<sup>58</sup> carries information relevant for currency pricing. Similarly, Evans (2002) finds that heterogeneity in trading decisions of dealers rationalizes much of the short run exchange rate volatility in the US dollar-German mark rate during 1996, from May to August. An analogous result is reported by Bjønnes et al (2003). Generally, this research suggests that how trades are made matters for currency pricing. Evans (2008) offers a review of some recent findings, while Lyons (2001) provides theoretical and methodological perspectives, alongside a summary of some earlier studies.

Another strand asks whether market participants and their perceptions and behaviors differ in ways that affect currency pricing. Frankel and Rose (1995) and Sarno and Taylor (2001a) provide an overview of much of the literature of this genre. Their review shows several features that emerge from this research. One is that market participants are essentially of diverse groups, face private rather than public information, and therefore interpret the same information differently. Another is that deals are held onto for no more than a day, indicating that market participants operate at very short-term horizons.

From survey data, the evidence also demonstrates heterogeneity in formation of expectations. According to this evidence, at the short run horizon, dealers just extrapolate current trends. However, at the long horizon, forecasts based on fundamentals tend to dominate, which suggests that agents believe economic fundamentals to be important. In addition, on the one hand, the “bandwagon effect” is exhibited in the formation of expectation, wherein, for example, currency depreciation leads to expectations of a further depreciation. Equally, on the other hand, there are “twist” patterns in expectations, with long horizon expectations

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<sup>58</sup>Lyons (2001) explains this as the difference between buyer-initiated and seller-initiated trades during any trading time.

tending to reverse short horizon expectations. Such a finding suggests, for example, that while currency depreciation may follow an appreciation at the short horizon, this tends to reverse at the long horizon. Surveys (Allen & Taylor, 1989; Chinn & Frankel, 2002) furthermore find that technical analysis, such as *Chartism*, is widely used in the markets. Overall, the evidence is interpreted as suggesting that heterogeneity not only of markets participants, but also in their actions and perceptions is a major force in currency pricing.

Research into microstructure has also explored the role of information structure, looking into questions of how information is transmitted in the market, whether the market is processing it efficiently, and the implication of this for currency pricing. It is on this literature that the thesis hones itself. In particular, the theory of efficient markets is exploited. As applied to foreign exchange markets, this allows interpretation of exchange rate fluctuations as the market's reactions to unpredictable information arrival. Clearly, in the case at hand where short run fluctuations in the rand are seemingly unpredictable, looking in this direction is plausible. Therefore, this review first examines the efficient markets principle and then looks at competing views of market efficiency.

## 5.2 Efficient markets: unpredictable information arrival and currency pricing

The efficient markets hypothesis, due to Fama (1970), has often formed a basis for the empirical resolution of questions of the role of the market in pricing currencies. Though originally conceived as an explanation of how capital markets operate (Fama, 1965a; 1965b; Samuelson, 1965), it has applicability to any market. The hypothesis describes an efficient market as one where prices of traded assets always fully incorporate all available relevant information about them, responding only to *unexpected* arrival of new information or news. An important implication of

this is that unusual profits cannot be made in such a market from trading on information already known to the market.

This assertion is assured, according to Fama (1965b), through competitive and profitable arbitrage, according to which prices will be driven towards intrinsic or fair values of assets. For instance, if the actual asset price were to suddenly rise for some reason, opportunities for profitable arbitrage would immediately become available. Traders would then seek to buy the asset cheap and sell it dear. This would eventually drive the asset price up until the total expected return is the same and the excess profit is eliminated. Were the market not efficient, the asset price increase could lead to quick speculative profits to be consistently earned. Therefore, in an efficient market, asset prices can depart from intrinsic value, with some individual traders overreacting or under reacting in response and the possibility of making speculative gains still exists. However, the actions of the market as a whole will cause prices to reflect intrinsic values of assets (Fama, 1965b).

Essentially, then, the efficient markets hypothesis makes a prediction firstly that prices formed in efficient markets should be *unpredictable or random*. Unexploited excess returns on assets are thus untenable in such a market. This means for example that a planned investment strategy that seeks to beat the market will end in failure, except by chance. Secondly, price volatility is a manifestation of the market's rational responses to new information arrival (French, 1988), and such price volatility is accordingly driven by unanticipated news arrival (H M Treasury, 2003). Otherwise, the opposite applies, wherein the market is setting prices incorrectly and unexploited profit opportunities exist, with the implication that traders could consistently make speculative gains.

Generally, however, formulation and interpretation of market efficiency tests poses a challenge, as Levich (1985; 1989) observes. For once, consensus has generally formed that asset pricing is dependent on market expectations and that market participants make use of available information in forming these expectations (Ayogu, 1997a). However, the question of what information is actually available to market participants and which is channeled into prices remains a matter of debate. In his review essay, Fama (1970) groups market efficiency hypotheses according to three categories of information sets, namely the *weak-form*, *semi-strong form*, and *strong-form* hypotheses. In the *weak-form*, the hypothesis requires only that historical prices should be reflected in current prices. It asks if prices correctly reflect the best prediction of value and whether then future returns are predictable from their past. This means, for example, that an investment strategy that relies on past prices such as technical analysis cannot yield excess returns or beat the market. However, a 'buy and hold' strategy would be optimal (Ayogu, 1997a).

The *semi-strong* form hypothesis maintains, conversely, that the available information set includes historical prices and all publicly available information. The concern is on how quickly prices adjust to public announcements of various kinds. Accordingly, under this hypothesis, neither technical nor fundamental analysis will yield excess returns – the latter entails relying on known information to infer an asset's intrinsic value. Lastly, the *strong-form* hypothesis requires that all available information be accounted for in current prices, including insider or private information. It asks whether some investors have private information not captured in the market price. In consequence, even when trading is occurring on information that is not yet publicly available, excess returns should not be earned.

Heeding the call for further refinement of the idea of market efficiency in the light of accumulated evidence<sup>59</sup>, Fama's (1991) second review reclassifies these conceptions of market efficiency. *Weak-form* tests now encompass the more general area of predicting returns and are labeled *tests for return predictability*. *Semi-strong-form* tests on the other hand are called *event studies* and *strong-form* tests fall under the rubric of *tests for private information*. This reclassification reflects the obstacles to inferences about market efficiency that arise due to ambiguity about what information is available to market participants.

Even if one was to sidestep the difficulty of identifying the relevant information set, market efficiency tests face the challenge that the efficient market hypothesis embodies a joint hypothesis. Levich (1989) explains, on the one part, that the requirement that prices should fully reflect all known information encapsulates a market equilibrium pricing mechanism, to which the available information set is assumed to anchor and which serve as the benchmark for assessing whether or not unusual profits are available. And on the other part, the conception that market participants speedily arbitrage away any arising profitable opportunities is a statement about how market participants form their expectations. The latter leg of the hypothesis is often thought of as equivalent to the rational expectations hypothesis, wherein expected prices are collapsed to their actual values. Therefore, any test of the market efficiency hypothesis must not only concern the kind of information reflected in prices, but also how the information comes to be reflected in those prices.

Fama (1991) thus contends that this simultaneous hypothesis poses the dilemma that market efficiency per se is not testable and therefore likely to remain irrefutable.

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<sup>59</sup> This relates to the fact that variables such as dividend yields and interest rates now tend to predict returns, as opposed to the early literature that suggested constancy in expected returns. The evidence has also acknowledged seasonal effects in returns and various anomalies are manifested in tests (Fama, 1991)

Precise inferences require testing jointly a model of equilibrium prices (i.e. whether actual prices approximate expected prices) with the hypothesis that available information is efficiently processed (i.e. the way in which expectations are formed). Market efficiency is then discernable only with respect to a benchmark pricing model. The problem this poses is that if this simultaneous test of efficiency is rejected, it may be because the market is inefficient (i.e. available information is inefficiently processed); alternatively, it may be that a wrong benchmark pricing model was inferred. Equally, if the joint test is not rejected, it can be argued that a wrong benchmark pricing model was presumed, while available information is efficiently assimilated. Therefore, as Aron and Ayogu (1997) point out, the difficulty of apportioning failure or otherwise of the joint hypothesis to efficiency or an appropriate equilibrium pricing model is far more profoundly serious than the empirical problems posed by differing quality of information sets available.

### 5.3 Testing for market efficiency: a competition of views

#### Randomness

As to be expected, this ongoing debate over interpretation of market efficiency has generated competing views of market efficiency testing. Early empirical tests up to 1965 focused on stock markets and tested for the random walk behavior in stock prices as the criterion for ascertaining market efficiency. The random walk model maintains that successive changes of a random variable are independent and identically distributed. Also, its future expected rate of growth will be zero or evolve with a constant linear growth. When applied to asset markets, the model has the interpretation that price fluctuations will be purely random, without any discernable trends or patterns, and that their future movements cannot be foretold based on their past.

Fama (1965a; 1965b; 1970) summarizes this early literature [e.g. (Kendall, 1964; Granger & Morgenstein, 1964)], which largely concludes that stock price movements are unpredictable akin to the random walk model and the stock market is efficient. However, numerous later studies such as Summers (1986), Fama and French (1988), Lo and MacKinlay (1988), and Poterba and Summers (1988) showed evidence against the random walk hypothesis of stock returns.

## Martingales

Nonetheless, it was realized that the random walk model is not a bona fide economic model of asset prices (LeRoy, 1989); in the sense of suggesting that future expected changes in prices should be zero or evolve with a constant linear growth (Levich, 1985). Samuelson (1965) remedied this when he asserted that the theoretical underpinning of market efficiency accorded with the martingale model. In contrast to the random walk model, the martingale model requires only that the difference sequence of a stochastic variable should follow a “fair game”<sup>60</sup>, which means that such difference sequences should be uncorrelated for any given information set. This implies in the context of asset markets that actual prices reflect future expected prices but changes of future expected prices should be unforecastable using the available information set. Therefore, unlike the random walk model, LeRoy (1989) explains that the martingale model does constitute an economic model of prices in that it can be linked with primitive assumptions on preferences and returns in the context of a consumer’s optimization problem. Moreover, Samuelson (1965) pointed out that a preferences scheme whereby agents have common and constant time preferences,

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<sup>60</sup> LeRoy (1989) describes a stochastic process such as  $y_t$  as a fair game with respect to a sequence of information sets  $\Phi_t$  if it satisfies the property that  $E(y_{t+1}|\Phi_t) = 0$ . In other words, the corresponding forecast of  $y_t$  should be zero for any possible value of  $\Phi_t$

have common probabilities, and are risk neutral, indentifies with the martingale model.

However, as LeRoy (1989) points out, it is the empirical work of Fama's (1970) that is widely credited with bringing adoption of the martingale characterization of market efficiency into general use. In such empirical tests, market efficiency is equated with rational expectations plus the martingale model, as the benchmarking criteria. The inference is that the market uses all relevant information to establish prices and such information is used correctly. Consequently, at least for the short horizon, the argument is that systematic changes in fundamental values should be inconsequential in an efficient market with unpredictable information arrival (Ayogu, 1997a). This contrasts with Fads models (Lehmann, 1990) that predict serial correlation in asset returns over all intervals.

Even based on the martingale criteria, the interpretative difficulty associated with empirical tests of the efficiency model does not appear to be resolved. Direct tests of the martingale specification attempt to establish whether some variables in agents' information set are a predictor of future prices or returns. The intuition is that if agents know past returns and are able to use these to predict future returns, returns cannot follow a fair game and trading rules can be drawn profitably. Finding in the affirmative thus constitutes a violation of the martingale model and is accordingly identified with market inefficiency.

In Fama's (1991) survey of several studies of this genre, the evidence shows that prices do adjust to various kinds of information, although such results cave in to ambiguities presented by the joint hypothesis problem. Similarly, empirical work that test volatility implications of efficiency using variance bounds tests such as LeRoy and Porter (1981), Shiller (1979; 1981), Mankiw et al (1985), and West (1988) find

that asset prices are much more volatile than is consistent with the efficient markets model. Shiller identifies the results not only with market inefficiency but also as favoring existence of an element of irrationality in asset prices. LeRoy and Porter, on the other hand, interpret their results as an anomaly that calls for an explanation. Also arguing against the martingale model are tests for profitability using filter rules such as Bilson and Hsieh (1983), and Hodrick and Srivastava (1984) that provide evidence that seemingly contradict market efficiency.

Generally, several plausible alternative equilibrium prices and return processes are tenable in organized markets such as the equity market, to which alternative efficiency tests can be benchmarked, as explained in Fama (1991). This is not so with the foreign exchange market where there is as yet no consensus on models for determining equilibrium exchange rates. Levich (1985) and Hallwood and MacDonald (2000) observe that much of the discussion of market efficiency has been made in the context of two equilibrium relationships: *the covered interest rate parity* (CIP) and *uncovered interest rate parity* (UIP) conditions. Covered interest parity is an implication of covered interest arbitrage and relates the forward rate to the expected future spot rate. In contrast, uncovered interest rate parity anchors the expected future spot rate to the interest rate differential, and is a consequence of uncovered interest arbitrage. Market efficiency is then assessed in terms of the unbiasedness hypothesis and orthogonality tests.

### Unbiasedness

The test for the unbiasedness hypothesis is usually motivated as a joint outcome of covered and uncovered interest rate parity (Boucher, 1991). From uncovered interest rate parity, if market participants were risk neutral, cross country interest rates are an estimate of expected exchange rate returns. Similarly, by covered interest

rate parity, the forward discount on foreign exchange should predict exchange rate returns. The efficiency hypothesis is tested by combining each of these equilibrium relationships with rational expectations; according to which regressing separately the cross country interest rate differential and the forward premium on exchange rate returns should provide a slope coefficient equal to one. Furthermore, the disturbance error term should be uncorrelated with other information - all relevant information is channeled into exchange rate returns, wherein exchange rate returns will thus only change because of the unexpected arrival of new information. In essence, both the interest rate differential and the forward premium should provide unbiased predictions of future expected exchange rate returns.

The unbiasedness hypothesis has been studied extensively, with mixed results. Froot and Thaler (1990), Hallwood and MacDonald (2000), Sarno and Taylor (2002a), and, more recently, Thornton (2007), review some of these studies in the light of varying techniques. These authors observe that data soundly rejects the unbiasedness hypothesis - both the interest rate differential and the forward premium fail as unbiased predictors of future exchange rate returns and the efficient market hypothesis is thus unfounded. According to the studies, in the bulk of cases, the estimated slope coefficient on exchange rate returns does not only differ from one, but is often negative and much closer to minus one. Froot and Thaler, for example, cite an average estimate of -0.88 across 75 studies. While a few studies yield positive estimates, those neither equal to nor exceed unity. Froot and Thaler observe that this finding of a negative slope coefficient is difficult to rationalize. It suggests that the more the foreign currency is at a premium in the forward market at certain term and the higher positive interest rate differential, the more the currency is predicted to appreciate rather than depreciate, which contradicts the unbiasedness hypothesis.

This finding is often interpreted in two ways. Firstly, since unbiasedness is predicted on the basis of risk neutrality, some authors argue that market participants might be risk averse, and the prediction bias may be due to existence of a risk premium (constant or time-varying). The crux of this argument is that if the market viewed an investment as riskier, a relatively higher rate of return would be demanded as compensation for bearing foreign exchange risk. Consequently, a risk premium would be impounded into the price of a forward contract on the investment as well as in the interest rate differential. Therefore, given rational expectations, a larger forward premium and interest rate differential would simply reflect a larger risk premium, even if an exchange rate change is not anticipated. Finding a negative slope coefficient under this circumstance should then be plausible to the extent that a much larger increase in the risk premium occurs – movements in the forward premium and interest rate differential mirror changes in the risk premium.

Hallwood and MacDonald (2000) and Froot and Thaler (1990) have elaborated on the various avenues by which the merits of this argument have been assessed. Generally, their review suggest that existence of a non-zero exchange rate risk premium is largely confirmed in the majority of studies, particularly in models of risk such as Fama (1984) and Domowitz and Hakkio (1985); and in survey data studies, such as Froot and Frankel (1989), Frankel and Froot (1989) and MacDonald and Torrance (1988; 1989). However, the estimates of the risk premium uncovered from such studies are often relatively small to completely rationalize the prediction bias. Accordingly, it is argued that the risk premium argument is just a small part of the story.

A second interpretation maintains the risk neutrality assumption but argues instead that market participants do not have rational expectations. According to this

view, the failure of the efficient markets hypothesis is due to expectational errors. Some studies such as Frankel and Froot (1986; 1987; 1989), Cavaglia et al (1994), Frankel and Chinn (1993), Taylor and Allen (1992), and Ito (1990)<sup>61</sup> use surveys of foreign exchange dealers to verify this claim and find strong heterogeneity in the way market participants make their forecasts. These authors observe that different expectations operate over different time periods; on the one hand, with the majority of market participants simply extrapolating recent trends and, on the other hand, only a few of them rely on market fundamentals. Furthermore, the foreign exchange market comprises diverse groups of agents who construe the same information in different ways. Mark and Wu (1998), Goodhart (1988) and Frankel and Froot (1990), for instance, construct models in which irrational agents operate alongside rational agents, finding that exchange rate movements can be influenced by each type of market participants consistent with dynamics from survey data. Survey data evidence thus strongly refutes the rationality assumption.

Other common explanations of expectational errors suggested are less obvious. They relate to the fact that the true process underlying the economy may be subject to irregular changes, but the market takes time to know this (Mark, 2001). Thus, in the interim period, market participants have an incomplete understanding of the economy, and thereby end up making systematic prediction errors even though they are behaving rationally. Included in this grouping of reasons are the so-called ‘peso-problem’ phenomenon, speculative bubbles, incomplete information and learning,

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<sup>61</sup> There is heterogeneity in data sets used though. For example, in the Frankel and Froot (1987) study, the authors utilise generated by the *Economist's Financial Report*, from June 1981 to December 1985, *Money Market Services* from March 1983 to October 1984, and the *American Express Banking Corporation*, from January 1976 to July 1985. On the other hand, data for the Frankel and Chinn (1993) study is drawn from the *Currency Forecasters' Digest* for the period February 1988 through February 1991, whereas Cavaglia et al (1994) base their analysis on surveys by the *Business International Corporation* for the period January 1986 to December 1990 (Mark, 2001)

and the noise-trader approach<sup>62</sup>. The significance of these for rationalizing the failure of the efficiency hypothesis stem from estimations problems encountered if no account of them is made when conducting tests on data.

Indeed, Sarno and Taylor (2002a) have observed that econometric tests that account for these biases are able to replicate a slope coefficient that is both negative and close to minus one. However, when weighed against the fact that results apply only to small samples, the evidence is deemed insufficient to completely explain the strong rejection. Moreover, it is argued, for example, that learning cannot carry on forever.

Hence, the conclusion to be drawn is that both risk aversion and departures from rational expectations are responsible for the rejection of the unbiasedness as a test of efficiency of the foreign exchange market. It is speculated that efforts that simultaneously seek to account for risk aversion and deviate from the rational expectations paradigm offer greater promise.

### Orthogonality

By contrast with unbiasedness tests, orthogonality type of tests test whether forecast errors made in predicting exchange rate returns are uncorrelated with information that would be available to market participants at the time they form their expectations. Such tests are in the terms of Fama's (1991) nomenclature labeled

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<sup>62</sup> The phrase '*peso-problem*' is generally attributed to Krasker (1980) who called attention to a period in the early 1970s during which Mexico had a fixed exchange rate regime, but the peso persistently sold at a forward premium, which suggested an immediate devaluation. However, the expected devaluation failed to materialise until much later in 1976. Generally, it is used to refer to a situation where regime changes occur for whatever reason, but the market takes time to know of their existence. To the extent that such regime changes matter to the market, then statistical inferences based on sample data that fails to account for their existence may be invalidated. In respect of speculative bubbles, this is a phenomenon whereby the market's expectations become self-fulfilling, and their existence mean market participants remain systematically biased relative to fundamentals. With the 'noise trader' paradigm, some markets participants are presumed rational while others are irrational. The outcome is that this sort of a mixture of market participants produces results that are consistent with systematic forecast errors.

predictability tests. The intuition is that if the efficiency hypothesis holds, all available and relevant information is channeled into currencies, exchange rate returns are unpredictable, and, accordingly, the forecast errors should be uncorrelated with this information set. If not, information available to market participants remains unexploited and the future expected exchange rate return is predictable based on at least some of available information, which is evidence against the efficiency hypothesis.

Typically, the orthogonality tests have been of two kinds; those that include only the history forecast errors of exchange rate returns in the conditioning set; and those that append additional information to the historical forecast errors in the information set (Hallwood & MacDonald, 2000). A distinguishing feature of these tests is the myriad of estimation techniques that they employ. Some authors such as Hansen and Hodrick (1980) employ the OLS method and use the generalized methods of moments (GMM) procedure to correct standard errors for the implied moving-average error structure, while maintaining the homoscedasticity assumption. MacDonald and Taylor (1991) also use the GMM procedure, but correct for both the implied moving-average and conditional heteroscedasticity structure of the errors. By contrast, Sarno and Thornton (2004), Hakkio (1981), Baillie et al (1983), and MacDonald and Taylor (1989) use the VAR methodology; this offers the advantage of exploiting time series properties of data. Overall, the basic finding of such studies is that the orthogonality property is violated for a cross section of currencies over different samples periods, and therefore offers a resounding rejection of the efficiency hypothesis.

Other authors use the cointegration method to test for orthogonality. The use of this method for testing for market efficiency originates with the argument first

highlighted by Granger (1986) that a pair of prices established in two efficient markets cannot be cointegrated. As Maddala and Kim (1998) point out, the theory of cointegration means that two or more variables that are covariant non-stationary fluctuate conjointly in a relationship that can be seen as an equilibrium relationship; to which short run deviations, captured by an error-correction mechanism, adjust towards. This would signify predictability of at least one of the variables based not only on its past but also on another. Therefore, if the foreign exchange market is efficient, the contention is that there should be no cointegration between exchange rate return series and variables that encompass the information set available to market participants, and between pairs of currencies established across different markets.

The methodology however has its critics. Engel (1996b) has cautioned that cointegration properties of exchange rates, or lack of it, are independent of the efficiency or inefficiency of financial markets. His argument is that exchange rates can still be forecastable under efficient markets provided all useful information is used in making their forecasts. Moreover, non-stationarity is an aspect of the underlying stochastic process, which, in this case, exchange rates may establish from their linkage with other macroeconomic variables in a manner that does not necessarily bear on capital market efficiency.

Nonetheless, in the bulk of the now burgeoning literature that use the this method, cointegration is not only found between exchange rate returns and a range of other variables but also between pairs of currencies formed in different markets. Examples that are more recent are Wickremasinghe (2008) and Kuhl (2007), who have separately examined the foreign exchange markets of Sri Lanka and the Euro area. Guttler et al (2008) on the other hand apply the methodology in the context of

the stock market and tests whether the Brazilian stock market is efficient in processing new information about macroeconomic data; finding that the stock market index fluctuates conjointly with a range of macroeconomic variables. Previous research includes Phengpis (2006), Lence and Falk (2005), Crowder (1994; 1996), MacDonald and Taylor (1989c), Baillie and Bollerslev (1989), and Hakkio and Rush (1989), to name a few. Thus, the preponderance cointegration evidence also leans towards market inefficiency.

#### 5.4 Summary and transition

In sum, short run fluctuations are notoriously difficult to explain. This chapter has looked at how economists have tried to resolve this issue in the context of the efficient markets hypothesis. The efficient markets hypothesis seeks to explain why asset price changes are difficult to predict at short intervals. Its underlying premise is that no predictable profit opportunities should be available to a risk-neutral investor to exploit based on publicly available information, as those will be arbitrated away quickly. The changes noticed in asset prices at short intervals should accordingly be driven by unexpected information arrival.

Empirically testing the efficient market hypothesis however presents the challenge that it requires simultaneously testing a joint hypothesis of an equilibrium model of asset pricing plus the efficiency hypothesis – how agents form their expectations. Hence, efficiency studies remain difficult to formulate and interpret; *market efficiency per se is not testable.*

Typically, in empirical tests, market efficiency is equated with rational expectations, according to which all available information to agents is processed in their decision-making. Generally, there have been several plausible substitute models of equilibrium pricing for stock markets, to which market efficiency tests have been

anchored. By contrast, with the stock market, there is yet no consensus on models for determining equilibrium exchange rate and most discussions of efficiency in terms of the foreign exchange market have focused on the unbiasedness and orthogonality hypotheses. The former is a consequence of interest arbitrage, according to which cross-country interest rate differentials and the forward premium on forward contract should predict exchange rate returns, and such predictions should be unbiased. In terms of the former, exchange rate returns should not be predicted based on the available information set.

The empirical literature however rejects these implications of the efficient markets hypothesis for the foreign exchange market. Econometric evidence finds both the interest differential and the forward premium biased predictors of the future expected exchange rate return series, thereby suggesting market inefficiency. This has been in part because exchange rate risk matters and expectations appear irrationally established in the real world. The two issues would need to be accounted for in the analysis. Econometric evidence also finds significant dependences not only in historical exchange rate returns themselves, but also in their relation to other variables that encompass information previously known to the market. This suggests that historical information helps to predict exchange rate returns, which is also evidence against market efficiency.

Nonetheless, the efficiency market hypothesis is still a useful yardstick for judging the relative effect of news of various kinds on exchange rates. Indeed, often exchange rates have been observed to change abruptly on account of not only economic news, but also various rumors and politics. Accordingly, the next chapter draws on this paradigm in proposing a model that can account for short run

exchange rate movements with unexpected information arrival with lots of noise, and uses it in exploring the volatility in short run fluctuations of the rand.

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## Chapter 6

### 6 Testing for short run movements of the rand

This chapter draws on the efficient markets paradigm in suggesting a model that can account for short run movements of the rand. We thereby test a model that treats unpredictable information arrival with lots of noise as an important factor in pricing currencies and use it to explore the volatility in short run fluctuations in the rand; *its bumpy ride*. We ask whether the market's reactions to unexpected information arrival relevant to pricing the rand can account for at least some of its volatility at short run intervals.

This question is not addressed directly. Instead, we link it to the market efficiency issue and inquire whether the rand is priced correctly in the market. Specifically, we test for return predictability of short run exchange rate returns, and seek to establish whether exchange rate returns are predictable based on relevant information. The intuition is that market participants trading in an efficient foreign exchange market with unpredictable information arrival will react immediately to news, which necessitates instantaneous revaluation of currency values. This has the implication that exchange rate returns (the short run currency changes) should be unpredictable based on publicly available news. Seemingly, the volatility noticed in currencies is thereby a reflection of traders' reaction to relevant news.

There have been other efforts examining fluctuations of the rand at short run intervals, which have relied on this argument. Fedderke and Flamand (2005) have used daily data for the period from June 2001 to June 2005 to see if unanticipated pronouncements on various macroeconomic events in the US and South Africa bears on pricing of the rand with respect to the dollar. Their results show statistically

significant responses of the exchange rate to news 'surprises' in the range of macroeconomic variables tested. However, news flows asymmetrically; only news about US events seems to matter for the rand, but not that on South African events. Their results further demonstrate that 'good news' appears to impact the exchange rate more strongly than 'bad news'. Also, the impact of news events is time varying, in the sense that surprise events in certain variables are important in some periods and not in others.

Aron and Ayogu (1997), on the other hand, pursue the issue of market efficiency in South African spot foreign exchange market. For varying samples of data for the period between 1970 and 1995, these authors conduct weak form and semi-strong-form efficiency tests for the rand. Weak-form efficiency tests, which test how well past prices predict future returns, are carried out on monthly data for four rates for the rand, namely, the commercial rand, the financial rand, the nominal effective commercial rand, and a parallel rate. Semi-strong form efficiency tests, on the other hand, use a quarterly single equilibrium error-correction model of the rand and a range of macroeconomic variables to forecast future returns on the rand. Overall, their results demonstrate predictability of the rand in both weak form and semi-strong form of the tests, which demonstrates market inefficiency. However, the financial rand evidences market efficiency. The authors argue that the thinness of market activities in the financial rand is the reason for the result leaning towards market efficiency because even small trades moved the market and resulted in volatility. According to their observation, the reality was that investors simply used the financial rand premium as an indicator for foreign opinion of South African macroeconomic and political credibility. They also argue that their simple model of weak form efficiency test may have failed to capture factors proxying for a time-varying risk premium, an issue which may have been at play.

Whilst applying different techniques, these previous studies uniformly yield similar outcomes in suggesting that short run rand movements are predictable. However, there are differences in coverage. Fedderke and Flamand (2005) cover the shorter and more recent period from June 2001 to June 2004 in which a significant financial liberalization program has almost completed. By contrast, the period used by Aron and Ayogu (1997), 1970 through to 1995, concludes at the dawn of financial liberalization. As emphasized earlier, a feature of the current South African macroeconomic environment is the numerous previous changes that underpin it. A complete understanding of factors that may highlight the rand movements at the short horizon needs to probe whether this is a feature of the data generating mechanism. Institutional change can have profound influences on how agents generate expectations about asset prices in the future and this in turn influences their current values. This study fills this void by accommodating the more recent period and thereby extends that result of Aron and Ayogu.

The rest of the chapter presents the model that we use, the methodology for testing its predictions, and finally, the inferences from the results.

### 6.1 The model: “news” and rand unpredictability

We begin by describing the model that we use of how exchange returns are generated – a return forecasting equation - under the maintained hypothesis that the market is efficient. As noted in LeRoy (1989), market efficiency is in the empirical literature often evaluated by equating it to the rational expectations hypothesis and benchmarking it on the martingale model. This practice is usually justified on the argument (Lehmann, 1990; Sims, 1984) that asset prices should follow a martingale process over short horizons even though there can be predictable variations in expected returns at longer horizon. Moreover, the essence of the efficient markets

hypothesis is that systematic short horizon changes in fundamental values should be negligible in an efficient market with unpredictable information arrival. We thereby adopt a martingale in the spot rate as representation of the data generating mechanism for nominal exchange rate returns.

The description of the martingale model is the following. Let the stochastic process  $y_t = \theta y_{t-1} + \epsilon_t$  denote a prediction equation for the spot exchange rate. Then, the sequence  $\{y_{t+1}\}$  is a martingale with respect to an information set,  $\Omega_t$  if the best prediction of  $y_{t+1}$  that can be made given all available information  $\Omega_t$  would simply be its currently observed value  $y_t$ , provided  $y_t$  is in  $\Omega_t$  (i.e.  $y_t \in \Omega_t$ );

$$E_t(y_{t+1}|\Omega_t) = y_t \quad (6-1)$$

Further, based on the available information set  $\Omega_t$ , the unconditional expectation of its forecast error,  $E_t(\epsilon_{t+1})$ , should equal zero;

$$E_t(\epsilon_{t+1}|\Omega_t) = E_t(y_{t+1}|\Omega_t) - y_t = 0 \quad (6-2)$$

Where  $t$  indexes time, and the prediction error,  $\epsilon_{t+1} = \Delta y_{t+1} = (y_{t+1} - y_t)$ , assuming  $\theta = 1$ . In other words, if the exchange rate process  $y_{t+1}$  is a martingale, the exchange rate return  $\Delta y_{t+1}$  should be unpredictable for any given set of publicly available information.

Therefore, in terms of the martingale specification, the market's forecast of the future spot rate is the current rate, and, under the maintained hypothesis of efficiency, past prices should not matter because today's prices already incorporate these. If, alternatively, past prices aid prediction of future prices and the martingale model is valid, then the implication is that all available relevant information is not fully exploited and agents are irrationally disregarding useful information for profitable trades. The point of the martingale hypothesis is to make precise the idea that, in an efficient market, new information arrival should be unpredictable and

therefore lagged or past information cannot be used to predict future prices. Furthermore, to the extent that expectations are rationally generated, forecast errors should be random.

The next issue that needs to be decided is what information in the information set that needs to be tested. As pointed out above and emphasized in the preceding chapter, the essence of the efficient markets hypothesis is that, if the foreign exchange market is efficient, all information relevant to determination of the value of a currency is impounded into the current value. It should not therefore be possible for market participants to revalue the currency based on the history of the currency's values or trends. We thus test only whether nominal exchange rate returns are predictable from past exchange rates, and our test conforms to weak-form predictability tests in terms of Fama's (1970; 1991) usage.

Defining  $y_t$  as the spot rate of the rand per unit of foreign currency, and the contents of the sequence of information sets  $\Omega_t$  to include only the history of  $y_t$  (i.e.  $\Omega_t = (y_t, y_{t-1}, y_{t-2}, y_{t-3} \dots)$ ), the testable hypothesis of unpredictability is set as;

$$E_t(y_{t+1} | \Omega_t) = y_t \quad (6-3)$$

We then specify an autoregressive alternative as the prediction and benchmarking equation under the null of market efficiency;

$$y_{t+1} = \theta y_t + \epsilon_{t+1} \quad (6-4)$$

Where the error term  $\epsilon_{t+1}$  has a zero expected value, given all past values of  $y_t$ ;

$$E_t(\epsilon_{t+1} | y_t, y_{t-1}, y_{t-2}, y_{t-3} \dots) = 0 \quad (6-5)$$

Combined, these two equations [(6-4) and (6-5)] imply that

$$E_t(y_{t+1}|y_t, y_{t-1}, \dots) = E_t(y_{t+1}|y_t) = \theta y_t \quad (6-6)$$

Then, the null hypothesis that exchange rate returns are unpredictable is stated as

$$H_0: \theta = 1 \quad (6-7)$$

If (6-7) is false, then exchange rate returns and, thus, short run currency movements, can be predicted based on the history of the returns. Nonetheless, the essence of the efficient markets hypothesis is that such investment opportunities will be noticed and will disappear almost instantaneously. Equations (6-3) through to (6-7) thus provide a valid description of the economic environment under the maintained hypothesis of market efficiency.

## 6.2 Data choice and description

A key insight of the literature on the microstructure of the foreign exchange market is that traders in this market are heterogeneous in their processing of information, beliefs, preferences and wealth (Sarno & Taylor, 2001a). Thus, they can and do hold positions that differ on each currency and thereby execute trades in their most favorable currencies. The implication is that exchange rates determined in the same market may not necessarily move in the same direction. This then means that the question of whether the market is efficient or otherwise may depend on which currency is under consideration. Indeed, this is particularly likely in South Africa's case because the US dollar is the most used in foreign exchange transactions, regardless of the origin of the trade (South African Reserve Bank, 2007).

Thus, to accommodate this likely asymmetry in the way market efficiency may locate itself, the study utilizes data on three spot rates for the rand - the *US dollar*, the *British pound sterling*, the *Euro*<sup>63</sup> - and a *trade-weighted rate*, which is constructed from a

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<sup>63</sup> Prior to January 1999, data pertains to the German mark (Walters, 1999)

currency basket of these three currencies and the Japanese yen<sup>64</sup>. Because it is a compounded measure of different bilateral currencies, the weighted rate alone may not capture agents' preferences of a particular currency, unless this is uniformly distributed in the market, hence the decision to add the bilateral rates.

The data are weekly series, each expressed in rand per unit of each foreign currency, and sampled for the period from 15 September 1985 through to 28 January 2007. The choice of this period is primarily because of data availability. The source of primary data on the four currencies – the US dollar, the pound, the euro, and the yen – is the database *I-net Bridge*.

Table 6-1: Descriptive statistics of data: nominal exchange rate returns on the rand

Data series	Mean	Max	Min	Std. Dev.	Skewness	Kurtosis	Sum	Sum Sq. Dev.	Obs
Dollar	0.09	10.50	-10.58	1.83	0.93	10.10	103.56	3750.33	1118
Trade-wgt rate	0.11	11.94	-11.38	1.70	0.92	12.84	118.71	3236.41	1118
Pound	0.12	13.50	-11.08	1.84	0.38	11.97	137.96	3792.11	1118
Euro	0.10	11.73	-12.10	1.84	0.89	10.79	111.90	3765.81	1118

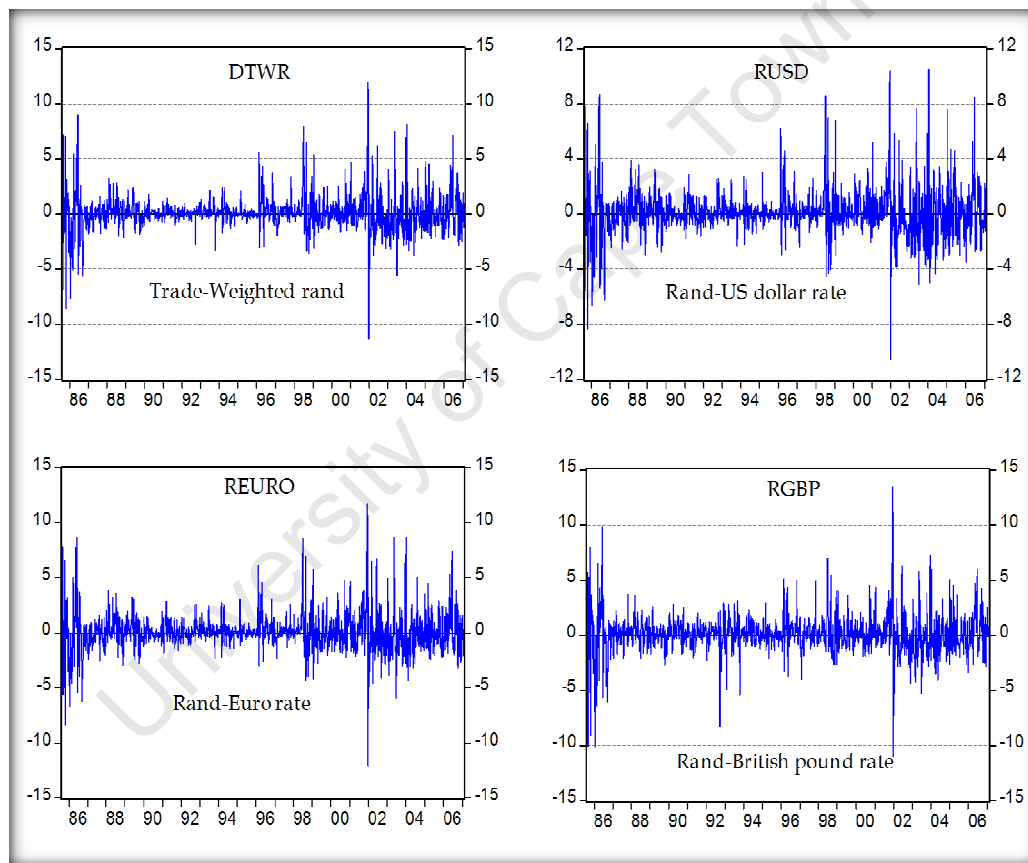
Table 6-1 presents some descriptive statistics for each of exchange rate return data series<sup>65</sup>. For the period under consideration, average weekly return is in the range of 0.10% to 0.09% across the four rates. The largest value, on the other hand, is 13.5 per cent on the pound and the smallest is – 12.10 per cent on the euro. Clearly, the series demonstrate volatility. Furthermore, data are not only highly skewed but also leptokurtic. Skewness statistics exhibit positive values whereas kurtosis values by far exceed three; the value that obtains when data are normally distributed.

<sup>64</sup> These four are the major currencies, with a total weight of 77.65% in South Africa's currency basket for computing effective exchange rates for the rand. Relative to the official currency basket reported by the South African Reserve Bank, we have revalued these weights for the purposes of this study as follows; 42% for euro rate, 21% for the dollar rate, 21% for pound rate, and 16% for the yen.

<sup>65</sup> This is the first logarithmic difference of each data series

Figure 6-1 charts movements in the exchange rate returns. In the figure, labels RUSD, RGBP, REURO, and DTWR, respectively, denote returns in terms of the US dollar rate, the British pound sterling rate, the euro rate, and the trade-weighted rate series. In all the rates, the volatility of the rand exchange rate return series is clearly manifest. A feature of this volatility is its apparent acceleration post 1994, after having exhibited a prolonged period of calm.

Figure 6-1: Weekly nominal returns for the rand: September 1985 to January 2007



### 6.3 Testing methodology

Selection of methodology to model how well past exchange rate returns predict future returns follows the principle that the methodology needs to account for possible non-stationarity of data. If the null hypothesis of unpredictability  $H_0: \theta = 1$

is true when the data sequence  $\{y_t\}$  is non-stationary, it cannot be tested as stated under standard inference procedures. The reason, as pointed out in chapter four, is that its distribution is unknown and does not converge to a Gaussian process asymptotically. Thus, our empirical model (6-4) is reparameterised by specifying a more general  $p$  th-order autoregressive representation of data that allows for a random walk model with or without drift or trend, for stationarity around trend, and uses the dynamic lag structure in returns  $\Delta y_{t-i}$  to show predictability;

$$\Delta y_t = \sum_{i=1}^p \beta_i \Delta y_{t-i} + \psi y_{t-1} + \alpha_0 + \alpha_1 t + \epsilon_t \quad (6-8)$$

Where  $\psi = \theta - 1$ ,  $p$  is the number of lags on first differences of data,  $\alpha_0$  is a constant term,  $t$  is a trend, and  $\Delta y_{t-i}$  captures serial correlation in the return series.

We thereby formulate a composite null hypothesis;

$$H_0: (\psi, \alpha_0, \alpha_1) = (0, 0, 0)$$

and

$$H_0: \beta_i = 0; \quad i = (1, \dots, p),$$

which implies the martingale property that the exchange rate return series  $\{\Delta y_t\}$  are unpredictable from their past values.

A conditional two-stage modeling strategy is then implemented, similar to Ayogu (1997a; 1997b; 1995), who studied predictability of short run currency movements in Nigeria's foreign exchange parallel market; finding that they were. We first establish the stationarity of the data by testing for the validity or otherwise of the null  $H_0: (\psi, \alpha_0, \alpha_1) = (0, 0, 0)$ . If stationarity of the data is proven, then returns are by definition predictable from their past values and the spot market will thereby not be efficient. Finding otherwise would suggest unpredictability and confirmation of market efficiency.

The stationarity tests are carried out using the log likelihood ratio tests proposed by Dickey and Fuller (1981). The null hypothesis asserts that the restricted model, (6-9) below generates the data; against the alternative that (6-8) is the data generating process.

$$\Delta y_t = \sum_{i=1}^p \beta_i \Delta y_{t-i} + \epsilon_t \quad (6-9)$$

Therefore, a standard  $F$  test statistic of this restriction is used to assess the null; where the  $F$  statistic is defined as

$$F_{\Phi_i} = \left( \frac{T-k}{\lambda} \right) \left( \frac{RSS_R - RSS_{UR}}{RSS_{UR}} \right) \quad (6-10)$$

$RSS_R$  denotes the sum of squared residuals for the restricted model (6-9),  $RSS_{UR}$  is the sum of squared residuals for the unrestricted model (6-8),  $T$  is the number of usable observations (sample size),  $k$  is number of parameters in the unrestricted model, and  $\lambda$  is the number of parameter restrictions.

The computed  $F_{\Phi_i}$  is then compared to the log likelihood ratio test statistic  $\Phi_i$  tabulated in table V in Dickey and Fuller (1981). If, based on the Dickey and Fuller F-tests, the null hypothesis fails, the testing sequence ends. We thereby conclude that the sequence of data  $\{y_t\}$  is predictable based on its past and the spot market does not obey the martingale property.

On the other hand, if having established that data supports the null, the lagged level of the spot rate,  $y_{t-i}$ , the constant  $\alpha_0$  and the trend  $t$  terms are dropped from the testing model (6-8). We next establish in the second stage of the test whether the lagged exchange rate returns terms  $\Delta y_{t-i}$  have any power in explaining the current exchange rate return  $\Delta y_t$ , by examining the statistical significance or otherwise of the coefficients,  $\beta_i$ . This is done by running a second regression using equation (6-9), the restricted model. A standard t-test is used to assess the null

hypothesis that exchange rate returns are not predictable from their past ( $H_0: \beta_i = 0$  for all  $i$ ). In this regard, the null is violated if, based on the t-test, at least one lagged differenced term,  $\Delta y_{t-i}$ , ( $i, \dots, p$ ) is statistically different from zero. This provides evidence that past exchange rate returns are predictors of future returns, and the martingale model can be rejected.

## 6.4 Empirical analysis

### *Unpredictability of rand returns*

Table 6-1 reports the result of the predictability tests for each of the data series as tabulated above. Schwarz Information Criterion tests allowed selection of an autoregressive process of order three for the data in their level, and the model thus tested for data is:

$$\Delta y_t = \psi y_{t-1} + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \alpha_0 + \alpha_1 t + \epsilon_t$$

In the table, the set of results labeled *stage one tests* pertain to the first step in the testing procedure outlined above, and obtain from tests for the null hypothesis  $H_0: (\psi, \alpha_0, \alpha_1) = (0, 0, 0)$  in the unrestricted model (equation 6-8). *Stage two test* results, conversely, relate to the second step in the testing procedure, and correspond to tests for parameter significance in the restricted model, that is,  $H_0: \beta_i = 0$  in regression of (6-9).  $F_{\phi_2}$  is the log likelihood statistic for assessing the null hypothesis  $H_0: (\psi, \alpha_0, \alpha_1) = (0, 0, 0)$  and  $P$  is the order of augmentation of the test regression. The *LM test* refers to a log likelihood statistic from testing serial correlation in residuals using the *Breusch-Godfrey* LM test.

In terms of table 6-2, the likelihood ratio test fails to reject the null  $(\psi, \alpha_0, \alpha_1) = (0, 0, 0)$  for the martingale for any of the data, although for the euro rate, the results are less strong. In that case, the null hypothesis is sustained only at

the 1% level of significance. The tabulated  $F_{\Phi_2}$  statistic is 2.05, 3.55, 4.74, and 3.50 for dollar, pound sterling, euro, and trade weighted rates, respectively. However, results from the second stage of the test overwhelmingly reject the null for martingale ( $\beta_i = 0$ ). For all data, the first lagged value of the exchange rate returns  $\Delta y_{t-1}$  has statistical significance at the one percent level, although, in terms of evidence on dollar and euro rates, there is marginal statistical significance of the second lagged return  $\Delta y_{t-2}$  at the 10% level.

Table 6-2: Unpredictability of rand returns: martingale tests

Sample data: 15 Sept 1985-28 Jan 2007 (1117 obs.)							
	Stage one tests			Stage two tests			
	$F_{\Phi_2}$	$P$	LM test	$\beta_1$	$\beta_2$	$P$	LM test
Trade weighted rand	3.50	2	2.30 (0.13)	0.18* [0.00]	0.05 [0.09]	2	0.00 (1.00)
Dollar rate	2.05	2	0.36 (0.55)	0.14* [0.00]	0.07* [0.02]	2	0.00 (1.00)
Pound rate	3.55	2	8.02* (0.01)	0.16* [0.00]	0.02 [0.60]	2	4.22* (0.04)
Euro rate	4.74	2	0.18 (0.67)	0.15* [0.00]	0.06* [0.04]	2	0.00 (1.00)

Notes:

- (1) Stage one tests are tests for  $H_0: (\psi, \alpha_0, \alpha_1) = (0, 0, 0)$  in the model  $\Delta y_t = \sum_{i=1}^p \beta_i \Delta y_{t-i} + \psi y_{t-1} + \alpha_0 + \alpha_1 t + \epsilon_t$ , while stage two tests are tests for  $H_0: \beta_i = 0$  in model  $\Delta y_t = \sum_{i=1}^p \beta_i \Delta y_{t-i} + \epsilon_t$
- (2)  $F_{\Phi_2}$  is the calculated F-statistic for assessing the  $H_0$  stated above. At the 1%, 5%, and 10% significance levels, the tabled Dickey & Fuller (1981, table IV) log likelihood  $\Phi_2$  testing critical values are 6.09, 4.68, & 4.03 for sample size  $T > 500$
- (3)  $\beta_i$   $i = (1, \dots, k)$  is the parameter of the restricted model, p-value in squared parenthesis
- (4) For each equation, the lag length,  $P$ , is selected to ensure no serial correlation, based on Schwartz information criterion
- (5) LM test is Breusch-Godfrey LM test for up to first order serial correlation, p-values in brackets

This evidence demonstrates that the weekly exchange rate return on the rand is predictable from past values of exchanges rates. Specifically, one-week ahead nominal exchange rate returns are not only predictable for the pound and trade-weighted rate, but two weeks for the dollar and the euro rates. In consequence, this leads us to the conclusion that the rand spot market is informationally not weak-

form efficient with respect to past prices for the period considered; information on past changes in the rand rate aids revaluation of the rand in future periods.

### *Regime change and rand return unpredictability*

Nonetheless, the sampling period spanned by our data encompasses phases of regimes change in the South African macroeconomic environment that chapter two has elaborated on. The problem this creates for the empirical tests is that, as implemented, the testing procedure assumes existence of sufficient interplay of market forces. In our context, this presupposes that foreign exchange market speculation occurs. However, the presence in the economy of any regime or structural changes would most likely leave little room for such speculative activity in the domestic market. A strong likelihood exists that regimes change has affected the extent to which relevant information has been used in the pricing of the currency.

While there have been many regime changes, it has been emphasized in chapter four that the regime change in February 2000 to an Inflation Targeting monetary policy framework is, as we see it, the most relevant event of reference. In the discussion in chapter two, we noted that, prior to its inception, the exchange rate regime was mainly a controlled float that combined strict capital controls with official foreign intervention policy. This means that market forces were for most part likely absent. On the other hand, since implementation of Inflation Targeting, the exchange rate regime bears the features of a free-float, at least in the de-jure sense. Not only have there been cessation the foreign intervention policy of targeting a specific value for the rand since then, but capital account transactions have also been extensively liberalized. In addition, monetary policy now relies on setting interest rates to influence inflation outcomes. This suggests that a deepened interplay of market forces can be expected in the post Inflation-Targeting period. Moreover, this

factor should contribute to increased efficiency in allocation of resources by the financial markets.

We therefore investigate the possible influence on our findings of the regime switch to Inflation Targeting. This is done by splitting our data into two sub-samples, truncated at the week beginning February 2000, the date of the regime change. Thus, in the first sub-sample, we have data spanning the period 15 September 1985 through to 30 January 2000, coincident with pre-Inflation Targeting. In the second, the data coverage starts at 6 February 2000 through 28 January 2007. The aim of the exercise is to establish if results contrast. Hence, our test of the empirical model outlined in the preceding narrative is repeated on the two sub-samples above, and we compare the results. Our a priori expectations are that the two sub-samples should generate different results if indeed the regime change matters. Otherwise, no differences in result should emerge.

Table 6-2 reports results from interrogating the data as above. Results contrast noticeably only with respect to the first stage of the test. In this respect, both data samples fail to reject convincingly the martingale hypothesis, but there are differences in the degree of failure to reject. For the first sub-period from 15 September 1985 through 30 January 2000, the evidence is very weak, as the test fails only at the 1% level of significance. An exception is the pound rate, where the result fails to reject with 5% significance level. For the dollar rate, the pound rate, the euro rate, and trade weighted rate, the calculated  $F_{\Phi_2}$  statistics are, respectively, 5.47, 4.06, 4.74, and 5.11, all of which are above the 5% testing critical value of 4.03. There thus appears preponderance towards rejection on this data sample.

On the other hand, in the post Inflation Targeting period, from 6 February 2000 to 28 January 2007, the  $F_{\Phi_2}$  statistic evidence convincingly fails to reject the null

hypothesis. All data series fail to reject the null even at the 10% level of significance. For data on the dollar rate, the pound rate, the euro rate, and trade-weighted rate, their respective  $F_{\Phi_2}$  statistics of 1.31, 2.14, 2.87, and 2.47 all fall below the 10% testing critical value of 4.05.

Table 6-3: Regime change and rand return predictability: martingale tests II

Sub sample data I: 15 Sept 1985-30 Jan 2000 (751 obs.)							
	Stage one tests			Stage two tests			
	$F_{\Phi_2}$	$P$	LM test	$\beta_1$	$\beta_2$	$P$	LM test
Trade weighted rand	5.11	2	2.30 (0.13)	0.18* [0.00]	0.05 [0.09]	2	0.00 (1.00)
Dollar rate	5.47	2	0.92 (0.34)	0.18* [0.00]	0.05 [0.19]	2	0.00 (1.00)
Pound rate	4.06	1	8.49* (0.00)	0.18* [0.00]		1	4.25* (0.04)
Euro rate	4.74	2	0.18 (0.67)	0.15* [0.00]	0.06* [0.04]	2	0.00 (1.00)
Sub-sample data II: 6 Feb 2000- 28 Jan 2007 (365 obs)							
	Stage one test results			Stage two test results			
	$F_{\Phi_2}$	$P$	LM test	$\beta_1$	$\beta_2$	$P$	LM test
Trade weighted rand	2.47	2	0.65 (0.42)	0.15* [0.00]	0.06 [0.21]	2	0.27 (0.60)
Dollar rate	1.31	2	0.54 (0.46)	0.11* [0.03]	0.09 [0.08]	2	0.44 (0.51)
Pound rate	2.14	2	0.62 (0.43)	0.16* [0.00]	0.04 [0.47]	2	0.22 (0.64)
Euro rate	2.87	2	0.22 (0.64)	0.12* [0.03]	0.07 [0.16]	2	0.00 (1.00)

Notes:

(1) Stage one tests are tests for  $H_0: (\psi, \alpha_0, \alpha_1) = (0, 0, 0)$  in the model

$$\Delta y_t = \sum_{i=1}^p \beta_i \Delta y_{t-i} + \psi y_{t-1} + \alpha_0 + \alpha_1 t + \epsilon_t, \text{ while stage two tests are tests for } H_0: \beta_i = 0 \text{ in the model}$$

$$\Delta y_t = \sum_{i=1}^p \beta_i \Delta y_{t-i} + \epsilon_t$$

(2)  $F_{\Phi_2}$  is the calculated F-statistic for assessing the  $H_0$  stated above. At the 1%, 5%, and 10% significance levels, the tabled Dickey & Fuller (1981, table IV) log likelihood  $\Phi_2$  testing critical values are 6.15, 4.71, and 4.05 for sample size  $T \in (250, 500]$  and 6.09, 4.68, & 4.03 for  $T > 500$

(3)  $\beta_i$   $i = (1, \dots, k)$  is the parameter of the restricted model, p-value in squared parenthesis

(4) For each equation, the lag length,  $P$ , is selected to ensure no serial correlation, based on Schwartz information criterion

(5) LM test is Breusch-Godfrey LM test for up to first order serial correlation, p-values in brackets

Nevertheless, in terms of stage two of the test, the result of the two sub-sample data is unanimous in strongly rejecting the null hypothesis of unpredictability of returns on the rand. In both cases, the first lagged difference for each data series is

statistically significant; thereby indicating one-week ahead return predictability. Particularly euro rate data continues to demonstrate two-week ahead predictability in the pre-inflation targeting period. Therefore, the evidence still leads to a conclusion of return predictability and market inefficiency.

However, based on stage-one test results, it appears the shift to Inflation Targeting, together with other policy changes that have accompanied the policy change have enhanced the interplay of market forces in pricing the rand. It is true that various other exogenous factors could be at play here. However, the question of interest is whether this particular policy shift is a factor. Those other factors are not explored. Even then, the evidence uncovered here is less strong and by all means unconvincing at this stage to make definitive statements. Perhaps when a longer span of data of post Inflation Targeting becomes available, one could interrogate this issue further.

To summarize, we find return predictability in rand exchange rate returns; past values of exchange rates matter for predicting future short-term changes of the rand. This is corroborated by the fact that lagged returns on the rand carry information relevant to predicting their values in future periods. The degree of such dependencies of rand returns on their historical values stretches up to one to two weeks. It seems therefore that agents are able to improve their forecasts of the future evolution of the rand using past values of exchange rates up to one to two weeks ahead. This finding applies even after allowing for the possible impact of the regime change to inflation targeting. Given that our testing methods relied exclusively on time series data on the rand series themselves, it is suggested that these findings offer a rationalization of the rand's volatility, at least in part. Thus, even with financial liberalization that has come with the regime switch to an inflation-targeting regime, the finding of this study

collaborates Aron and Ayogu (1997) in suggesting market inefficient in the rand market.

## 6.5 Stochastic volatility structure

Nonetheless, all that the analysis has so far established econometrically is that the rand market is not weak form efficient and therefore the weekly return on the rand is predictable from past values of the currency. The ramifications of this are that currency traders can draw up profitable trading strategies based on weekly movements in the rand. However, the extent to which this may be prevalent in the market is still an empirical avenue open to further inquiry.

The present section therefore extends the analysis to investigating whether market characteristics can shed some light on the kind of market inefficiency that we have found here by examining the data for forms of the stochastic process that underpin the volatility in returns on the rand. From looking at the plot of our data in the discussion above (figure 6-1), it seemingly appears the volatility of the rand may have changed significantly after 1994. Accordingly, the interest in this line of inquiry is threefold. One is to see if the volatility is time varying. Another is to ascertain whether such volatility has increased across the period studied. The final one is to look into the possibility of asymmetry in volatility dynamics, meaning, the volatility process responds asymmetrically to positive and negative shocks to the rand.

Below, the methodology used to address these issues is explained. Before that, however, a previous effort by Farrel (2001) on understanding volatility dynamics of the rand is discussed. In that study, the author uses a suite of variants of the autoregressive conditional heteroscedasticity (ARCH) methodology to examine the extent to which the financial rand system of capital controls that existed during 1985 to 1995 was successful in insulating the commercial rand rate. The analysis found

that the controls did indeed help dampen volatility of the commercial rand. However, the volatility process did not exhibit commonality between the dual rates. As well, the volatility in the financial rand market seemed not to spill over the commercial rand rate.

### 6.5.1 Testing methodology: ARCH/GARCH modeling

In this study too, the methodology used to seek out the volatility in the rand is the ARCH method. Indeed, the ARCH methodology has become widespread as a tool for examining the volatility structure of data time series, especially financial data time series. It is designed to model volatility as conditionally heteroscedastic and serially correlated variance of errors of the regression of a time series process. The technique is, however, of limited use in cases where one needs to uncover structural drivers of volatility other than modeling to improve forecasts. Nevertheless, because the interest of this study is on uncovering the volatility characteristics that the error term of our model captures, this methodology is appropriate for the analysis.

#### *ARCH process*

As a methodology for the modeling of volatility, the ARCH approach was pioneered by Engle (1982) when he introduced the ARCH process. This characterizes the variance of a regression model's error term (the volatility) as a linear function of lagged values of the squared regression disturbances. More precisely, suppose the data generating process for the exchange rate return sequence  $\{R_t \equiv \Delta \log y_t\}$  is given by an autoregressive process (6-11) below, where  $y_t$  is the spot rate, and such that  $R_t$  is stationary (i.e.  $\vartheta < 1$ );

$$R_t = \vartheta R_{t-1} + \xi_t \quad (6-11)$$

However, the forecast error process ( $\xi_t$ ), though normally distributed, is conditionally heteroscedastic with respect to an information set  $\Omega_{t-1}$ ;

$$\xi_t | \Omega_{t-1} \sim N(0, \sigma_t^2) \quad (6-12)$$

The challenge is to model the way in which this heteroscedasticity evolves overtime. The ARCH model resolves this by modeling the heteroscedasticity as an autoregressive process, where the variance series  $\{\sigma_t^2\}$  comes to dependent on serially correlated past squared errors terms  $\{\xi_t^2\}$ . The representation for the ARCH (q) variance can be written as;

$$\text{var}(\xi_t | \Omega_{t-1}) \equiv \sigma_t^2 = \omega + \sum_{i=1}^q \alpha_i \xi_{t-i}^2 \quad (6-13)$$

Here,  $\xi_{t-i}^2$  is the ARCH term, and q is the order of the ARCH. The restrictions are also made that  $\omega \geq 0$  and  $\alpha_i \geq 0$  (for all  $i = 0, 1, \dots, q$ ) to ensure that the predicted variance is always positive. Equation (6-11), conversely, stands for the mean equation that represents a prediction equation of the how the time series process under study evolves. Put together, equations (6-11) through to (6-13) form the ARCH regression model.

The basic premise of the ARCH model is that volatility of a time series depends on news about volatility of prior periods, which lagged squared errors  $\xi_{t-i}^2$  capture. This generates periods of persistence in low or high volatility, and resonates with the phenomenon of volatility clustering, whereby periods of high volatilities follow periods of higher volatilities and vice versa. The degree of such persistence in volatility depends on the quantity  $\sum \alpha_i$  - there is increased volatility the larger the value of  $\sum \alpha_i$  and vice versa. Furthermore, the ARCH model is founded on the assumption that the volatility process mean reverts, and this necessitates the requirement that the parameters,  $\alpha_i$ , must sum to less than unity (i.e.  $\sum \alpha_i < 1$ ).

Fulfilling this requirement, average or long run volatility may thereby be estimated by the unconditional variance,  $var(\xi_t) = \sigma^2$ , based on (6-13),<sup>66</sup>

$$\sigma^2 = \frac{\omega}{1 - \sum_{i=1}^q \alpha_i} \quad (6-14)$$

Consequently, long run or average volatility may be uncovered from the ARCH parameters, whose magnitude will generally govern the size of estimated long run volatility. If the sum of  $\alpha_i$ s is larger, average volatility will tend to rise. Otherwise, average volatility will tend to decrease with declining values of the sum of the  $\alpha_i$ s.

Accepting (6-13) as the process governing the stochastic volatility process, Engle (1982) has proposed a two-step procedure to testing for the ARCH (q) effect in a data series. The first is to obtain from the regression of the mean equation, (6 – 11), the residual series  $\{\hat{\xi}_t\}$ . An auxiliary regression of squared residuals  $\{\hat{\xi}_t^2\}$  is then constructed on a constant plus  $q$  own lagged values and an error term;

$$\hat{\xi}_t^2 = \varphi + \sum_{i=1}^q \pi_{t-i} \hat{\xi}_{t-i}^2 + v_t \quad (6-15)$$

where  $v_t$  denotes an error term. The null hypothesis is stated as  $H_0: \pi_1 = \dots \pi_q = 0$ , which, if true, means there are no ARCH effects in the data up to lag  $q$ . Engle's (1982) Lagrange Multiplier (LM) test statistic is used to assess the significance or otherwise of the null hypothesis. This is computed as  $nR^2$ , where  $R^2$  is the coefficient of determination from the auxiliary regression (6-15) and  $n$  denotes the sample size. Under the null hypothesis, the test statistic  $nR^2$  is asymptotically chi – squared distributed, with degrees of freedom corresponding to the number of autoregressive terms included in the auxiliary regression;  $nR^2 \sim X^2(q)$ . Values of the test statistic smaller than the critical table values provide evidence of no ARCH effects in the data. Otherwise, one rejects the null hypothesis.

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<sup>66</sup> Since variance of  $\epsilon_t$  is now  $\sigma^2 = \omega + \sigma^2 \sum_{i=1}^q \alpha_i$

### *GARCH process*

While a useful tool for uncovering volatility clustering often seen in high frequency financial and macroeconomic data, the ARCH model has the drawback that empirical application of its parameterization requires indentifying a relatively long lag structure and large set of parameters (Engle, 2001). This feature makes it difficult to identify and estimate the model (Bollerslev & Engle, 1994), especially on small samples, which is what most data sets offer. Bollerslev's (1986) remedied this by extending the ARCH process to a generalized autoregressive conditional heteroscedastic (GARCH) process, through introducing lagged values of conditional variances in the volatility equation. The resultant specification of the GARCH (q, p) variance (volatility) process is represented as

$$\text{var}(\xi_t | \Omega_{t-1}) \equiv \sigma_t^2 = \omega + \sum_{i=1}^q \alpha_i \xi_{t-i}^2 + \sum_{j=1}^p \beta_j \sigma_{t-j}^2 \quad (6-16)$$

The  $\alpha_i$ s here are the ARCH parameters – a moving average (MA) term; and the  $\beta_j$ s represent the GARCH parameters – an autoregressive (AR) term.

The distinguishing feature of the GARCH specification is that today's estimate of volatility in a data series comes to depend not only on news about volatility in previous periods, as measured by lagged squared errors  $\xi_{t-i}^2$  (the ARCH effect), but also on forecasts of volatility in previous periods, captured by  $\sigma_{t-j}^2$  (the GARCH effect). The sum  $\sum \alpha_i + \sum \beta_j$  now governs the degree of persistence of shocks to volatility. However, as with the ARCH model, it is required that  $\sum \alpha_i + \sum \beta_j < 1$ , so that the process mean reverts. It thereby becomes possible to compute a long run or average value of volatility according to (6-17) below, which can be used as a criterion for judging whether volatility can be construed as relatively higher or low in a given period.

$$\sigma^2 = \frac{\omega}{1 - \sum \alpha_i + \sum \beta_j} \quad (6-17)$$

When, conversely,  $\sum \alpha_i + \sum \beta_j = 1$ , the shocks to the volatility process will not dissipate, and the model becomes an integrated GARCH or IGARCH process (Engle & Bollerslev, 1986).

Overall, a primary benefit of the GARCH over the ARCH specification is in its parsimony in identifying the conditional variance. The specification in the GARCH specification allows for modeling the conditional variance with far fewer parameters than with an ARCH specification alone. In particular, Bollerslev and Engle (1994) show that the GARCH (p, q) model is equivalent to a restricted infinite-ordered ARCH model – an ARMA process in the squared innovations;

$$\sigma_t^2 = \frac{\omega}{1 - \sum \beta_j} + \sum_{i=1}^{\infty} \alpha_i \xi_{t-i}^2$$

Moreover, the empirical literature has found that a simple GARCH (1, 1) adequately models conditional heteroscedasticity than a much richer ARCH or GARCH process (Neely & Weller, 2002). Hence, the GARCH (1, 1) specification is typically the most applied. For this reason, it is worthwhile here to elaborate more on this. The representation of the conditional variance in this model is;

$$\sigma_t^2 = \omega + \alpha \xi_{t-1}^2 + \beta \sigma_{t-1}^2 \quad (6-18)$$

Where, as with the GARCH (p, q) model, the sum of parameters,  $\alpha + \beta$  governs the persistence of volatility dynamics. In addition, to guarantee positive values of volatility, it is required that  $\omega \geq 0, \alpha > 0, \beta > 0$ . The process is an integrated GARCH (IGARCH) when  $\alpha + \beta = 1$ , with the implication that shocks to the volatility will die out very slowly. Otherwise, there is mean reversion when  $\alpha + \beta < 1$ , and long run or average volatility may be recovered from the estimated parameters

as  $\sigma^2 = \omega/(1 - \alpha - \beta)$ . Testing whether  $\alpha + \beta = 1$  is therefore a key step to the application of the model, which is typically done by a Wald test.

### 6.5.2 Empirical estimations<sup>67</sup>

Empirical estimations proceed with testing a GARCH specification on random exchange rate returns data. Before elaborating on the specific form of the model estimated (i.e. the order of the GARCH model), we first establish the specific form of the conditional mean equation that describes the data generating process of our data. The choice of this is informed by the need to avoid serial correlation in residuals, as, when such serial correlation is present, data may falsely exhibit ARCH effects when in fact none exists. When data were initially tested for serial correlation using Breusch-Godfrey's LM serial correlation test<sup>68</sup>, results suggested an AR (2) process for the dollar rate, the euro rate, and the trade weighted rate. However, for the pound rate, an ARMA (3, 2) process fitted the data better. Accordingly, analysis of data on the dollar, the euro, and the trade-weighted rate proceeds is based on a mean equation of the form

$$R_t = \eta_0 + \sum_{i=1}^2 \varphi_i R_{t-i} + \xi_t \quad (6-19)$$

And that of the pound rate data:

$$R_t = \eta_0 + \sum_{i=1}^3 \varphi_i R_{t-i} + \xi_t + \sum_{j=1}^2 \theta_j \xi_{t-j} \quad (6-20)$$

### Time-varying volatility dynamics

Next, the data are tested for ARCH effects using Engle's LM test to establish if the volatility structure is indeed time varying. Table 6-4 reports the results. These demonstrate substantial evidence of ARCH terms in the data, as the null hypothesis of no ARCH effects in the data is soundly rejected for all data series.

<sup>67</sup> All estimations are done with the Eviews software programme

<sup>68</sup> These results are not reported

The presence of ARCH effects in the data now necessitates testing for time – varying volatility characteristics in them. The GARCH model is used for this purpose. Aiding identification of the lag specification of the GARCH model to map to data, table 6-5 presents autocorrelations of the squared residuals in estimates of the mean equations pertaining to each of the four rand-exchange rate series under study. Although not large, these autocorrelations are very significant as judged by the test p-values, which are all zero to four places. The first order autocorrelations range from 0.34 to 0.37 across the data series, and, after 15 lags, they gradually decline to a range of 0.04 to 0.07. The autocorrelations are also positive. This characteristic of the autocorrelations of the squared returns suggests a one (1, 1) lag structure as the suitable GARCH process for the data at hand (Engle, 2001). Indeed, after application of the GARCH (1, 1) specification, the ARCH test showed that no ARCH effects remained present in the residuals for every single series of the data.

Tables 6-6 and 6-7 summarize the results of the GARCH (1, 1) estimations, where the mean equations are specified as (6-19) and (6-20) above. In initial estimations, however, the GARCH (1, 1) model yielded standardized residuals that were highly leptokurtic, and this caused Jarque-bera tests to reject the normal distribution overwhelmingly. To accommodate this leptokurtosis in residuals, the error term is modeled on the student's t-distribution, with the degrees of freedom parameter fixed at 10.

In these results, the tables (6-6 and 6-7) report estimates of coefficients for both the conditional mean and variance equations, together with their corresponding Z-statistics and p-values, and cover the full sampling periods plus the two sub-sample periods. As a check of how well the GARCH (1, 1) model fits the data, there is at the bottom of each table chi-square statistics from tests for additional ARCH (1) to

ARCH (4) effects. These show no further ARCH errors present in all the data series, as already indicated. Thus, the weight of the evidence supports the GARCH (1, 1) specification.

The interest in these results is on the estimated values for  $\alpha$  and  $\beta$ , which are the determinants of both the magnitude and persistence of the volatility process. In all instances, the estimated values for these coefficients are positive and statistically significant. Moreover, although the sum of the two coefficients is very close to unity, wald tests reject the null hypothesis that their sum is unity, with the exception of the dollar rate in the full sampling period. However, this latter result holds up well when the test is conducted at the 10% level of significance. There is thus strong indication of mean reversion of the GARCH (1, 1) process for the most part, although, since their sum is very close to unity, this process only mean reverts slowly. Even so, the estimated average volatilities derived from these estimates are meaningfully interpretable as average long run volatilities, to which their short run clustering anchor.

Focusing on the size of these estimates, full sample data yield a value for  $\alpha$  of 0.16 for the dollar and 0.13 each for the pound, the Euro, and the trade-weighted rate. On the other hand, the value of  $\beta$  is 0.85 for the trade weighted rand and the euro, and 0.82 for both the pound and the dollar. Furthermore,  $\beta$  is in all cases substantially higher than that of  $\alpha$ . While less uniform, results from the sub-sample periods do not change markedly. The sub-sample period from 15 September 1985 to 30 June 2000 sustains a value of  $\alpha$  of 0.20 for the dollar, 0.09 for the pound, 0.16 for the Euro, and 0.14 for the trade weighted rate. The  $\beta$  value, on the other hand is, respectively, 0.82, 0.75, 0.83, and 0.80 in respect of the trade weighted rand, the dollar, the pound, and the Euro. Similarly, the sub-sample period from 6 February

2000 to 28 January 2007 yields, respectively,  $\alpha$  values of 0.11, 0.10, 0.09, and 0.09 for the dollar, the pound, the euro, and the trade-weighted rand. And the  $\beta$  value equals 0.84 on the trade weighted rate, 0.83 on both the dollar and the pound, and 0.79 on the Euro. In consequence, we find strong evidence of volatility clustering. In particular, the high statistical significant of the  $\alpha$  parameter is an indication that more recent shocks [depreciations or appreciations] have a strong effect on current volatility. Particularly the large values for  $\beta$  are indication of very strong persistence of this effect.

### Rise in volatility

The finding that the data permits a mean reverting variance process now allows here for exploration of the question of whether the volatility process may have shifted direction overtime. To test this hypothesis, the values for the average rate of volatility ( $\sigma^2 = \hat{\omega}/1 - \hat{\alpha} - \hat{\beta}$ ) are generated for each data series from the estimated GARCH (1, 1) model. Estimates of this on each of the three samples of the data are then compared. Tables 6-6 and 6-7 summarizes the results of this exercise. On the one hand, looking to the full sample period, the evidence shows that the dollar rate is relatively more volatile, with average volatility per week of 2.13%. This compares with 1.18% pertaining to the pound, 1.72% to the Euro, and 0.8% to the trade weighted rand. On the other hand, looking to results of the two sub-samples, there is remarkable difference in the progression of volatility. The rate of progression of volatility is very low in the period from 15 September 1985 to 30 January 2000, but this rises across the board by more than threefold in the period from 6 February 2000 to 28 January 2007. In fact, the increase in volatility is greater on the dollar rate (4.13% per week) than on any of the other three exchange rates. This points us to the conclusion that that there has been a shift in the underlying process governing the

volatility of the rand, with the volatility seemingly increasing in the more recent period.

### Asymmetries in the volatility structure

However, GARCH modeling is not well suited to determination of questions of asymmetries in volatility. This is because GARCH models ignore information on the direction of shocks to the volatility, as they treat positive and negative shocks of the same magnitude similarly; only the size of the shock matters. The implication is that good news (i.e. positive errors  $\xi_{t-1} > 0$ ) and bad news (i.e. negative errors  $\xi_{t-1} < 0$ ) all affect the volatility to the same degree. However, the reality, as Engle (2001) cautions, is that the direction of news is critical to understanding the volatility dynamics, as for example, a decline in one asset market may lead it to experience higher future volatility than a comparable market would. Therefore, there is now a variety of parameterizations of the ARCH and GARCH models to address this asymmetry, which they do by making the conditional variance a function of both the size of past errors and the direction of them. These include the exponential GARCH (EGARCH) model of Nelson (1991), the Power ARCH (PARCH) model suggested separately by Taylor (1986) and Schwert (1989), the Threshold ARCH (TARCH) and Threshold GARCH attributed to Rabemananjara and Zakoian (1993) and Glosten, Jaganathan, and Runkle (1993), and the Component GARCH (CGARCH) proposed by Engle and Lee (1993), just to list a few. Engle and Ng (1993) discusses and compares a collection of many of these in detail.

Against this background, the study employs the exponential GARCH (EGARCH) model of Nelson (1991) to resolve the question posed earlier of whether there may be asymmetries in the underlying structure of the volatility process underpinning the rand. Undoubtedly, as already noted, a feature of the foreign

exchange market that makes it a candidate for exploring this question is that it is decentralized. In it, market makers are physically separated from each other, communicate, and execute deals remotely and in private meetings. This decentralization means that not all market information is observable to all and therefore market participants may not face the same trading opportunities. In turn, given that trader behavior lies at the heart of price determination in any market (Flood, 1991), this should manifest asymmetries in the distribution of exchange rates.

For the purpose at hand, the EGARCH model offers the benefit over those above-mentioned approaches of treating the volatility asymmetry, the *leverage effect*, as exponential and employing a logarithmically transformed equation for the conditional variance thereof<sup>69</sup>. This logarithmically transformed variance equation presents the advantage that it guarantees a positive forecasted variance always, while allowing the model's coefficients to become negative. Importantly, a series of lagged standardized residuals ( $\xi_{t-i}/\sigma_{t-i}$ ) enter the volatility equation in their level as an additional regressor, which captures the volatility asymmetry – the differential effects of positive (good news) and negative (bad news) shocks. Hence, the volatility in the model explicitly comes to depend on both the *size* and *sign* (direction) of shocks to volatility. The specification for the EGARCH variance is:

$$\log(\sigma_t^2) = \omega + \sum_{i=1}^p \alpha_i \left| \frac{\xi_{t-i}}{\sigma_{t-i}} \right| + \sum_{k=1}^r \gamma_k \frac{\xi_{t-k}}{\sigma_{t-k}} + \sum_{j=1}^q \beta_j \log(\sigma_{t-j}^2) \quad (6-21)$$

In this model, the series  $\xi_{t-k}/\sigma_{t-k}$  is the asymmetry variable and the parameters  $\gamma_k$  capture the leverage effects (the differential impact to volatility of “news”). The null hypothesis for testing for the presence of volatility asymmetries is that  $H_0: \gamma_k = 0$ . The impact of shocks to volatility is asymmetric if it is found

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<sup>69</sup> In many of those above-mention approaches, such as the TARCH model, the *leverage effect* is quadratic, which necessitates introducing non-negativity restrictions to ensure a positive variance

that  $\gamma_k \neq 0$ , and this provides evidence of a *leverage effect* – meaning, there are asymmetries in volatility. Particularly, if  $\gamma_k > 0$ , “good news” (positive innovations,  $\xi_{t-1} > 0$ ) increases volatility much more than “bad news” (negative innovations,  $\xi_{t-1} < 0$ ). Given the definition of the exchange rate data series used here as units of the domestic per foreign currency, this implies that episodes of the rand’s depreciations lead much more increases in volatility than those of its appreciations. If, conversely,  $\gamma_k < 0$ , the opposite applies – the volatility increases more following an appreciation.

The general procedure followed in choosing the lag specification of the EGARCH model tested is to check the squared residual from estimates of the mean equations for linear dependencies. Looking to table 6-5, as noted earlier, the squared residuals exhibit significant autocorrelations, but these gradually decline. This is supporting of a lag specification of (1, 1). As a check for the robustness of this, ARCH tests conducted after application of the (1, 1) lag specification indicated no further ARCH terms remained in the data. The analysis is therefore carried out using an EGARCH (1, 1) process in the conditional variance. The structure of this is shown below:

$$\log(\sigma_t^2) = \omega + \alpha \left| \frac{\xi_{t-1}}{\sigma_{t-1}} \right| + \gamma \frac{\xi_{t-1}}{\sigma_{t-1}} + \beta \log(\sigma_{t-1}^2)$$

Where the test for asymmetry in volatility if  $\gamma \neq 0$ , and the episodes of positive shocks have a larger impact on volatility than negative ones if  $\gamma > 0$ . The opposite applies if  $\gamma < 0$ .

Tables 6-8 and 6-9 show the results of fitting an EGARCH (1, 1) model onto data and the resultant tests for asymmetries in volatility. Note that the mean equation in the estimations is equation (6-19) when the dollar, the euro, or the trade weighted

rate data are used, and it is equation (6-20) when the analysis pertains to the pound rate data. However, only the set of results of conditional variances estimates are reported because the interest is on the parameter  $\gamma$ .

For all the data series, and between the sub-sample periods, the parameter  $\gamma$ , which measures the asymmetric impact of shocks to the volatility process, is positive and generally statistically significant. The exception is in the period from 6 February 2000 to 28 January 2007 for the dollar and the pound data, where this is not statistically significant. Thus, in the period studied, positive shocks induced higher volatilities than negative disturbances of the same magnitude. Given that the exchange rate data are defined in terms of rands per unit of foreign currency, this finding indicates that volatility has tended to increase much more following periods of rand depreciations (positive changes) rather than in periods following appreciations (negative changes). We interpret this as suggesting that the market's overall view of the rand has tended to be unidirectional, presumably reflecting a skewed distribution of short and long positions in the rand.

Indeed, other authors have reported similar findings, for instance, Pramor and Tamirisa (2006) on the Eastern European currencies, Byrne and Davis (2005) on the Canadian dollar and the Japanese yen, and Guimarães and Karacadag (2004) on the Mexican peso and the Turkish lira. The findings of this study, however, contrasts with Farrel's (2001) who found the opposite result on the rand, although this pertained only to the nominal effective exchange rate and when estimations used monthly data. In any case, low frequency data are not well suited to capturing short run foreign exchange market characteristics simply because investors in this market are known to hold onto trades for only a short while. It would therefore not be

surprising if re-estimation of the same equation using high frequency data generated results similar to those of this study.

In sum, the evidence shows highly persistent time-varying volatility in the weekly returns on the rand that is highly dependent on the more recent past depreciation and appreciations in the rand. However, the volatility process reacts more strongly to depreciations than it does with appreciations. We interpret this as indicating that unexpected depreciations [bad news] rather appreciations [good news] have tended to give rise to higher volatilities. There is also a strong indication from the evidence that the volatility process has undergone a major shift, with the rand exhibiting relatively higher volatility in the more recent period encompassing the regime change to inflation targeting.

## 6.6 Summary

Short run fluctuations in the rand have been overly volatile. This chapter has considered the question of whether the market's reaction to unexpected arrival of relevant news accounts for some of this short run volatility in the rand by examining exchange rate return predictability. Those predictability tests asked only whether nominal exchange rate returns on the rand are predictable based on past exchange rates. The intuition that underpinned this is that traders in an efficient foreign exchange market with unpredictable news arrival with noise react immediately to relevant news. Thus, changes in currency values over short term intervals should be unpredictable based on delayed news because such news are deemed imputed into current values.

Using a martingale specification and a methodology that exploits statistical properties of the data, the empirical evidence showed that nominal exchange rate returns on the rand are predictable from their past and the spot rand market is

informationally weak-form inefficient. Previous changes in the rand carry information that is helpful in revaluing the rand up to two weeks forward. Thus, agents are able to improve their forecast of future movements in the rand up to two weeks ahead. This finding is robust to regimes change, especially the shift in the monetary policy regime to Inflation Targeting in February 2000.

As tested, the predictability tests are only able to shed light on the presence or otherwise of weak-form market inefficiency and thereby the presence or otherwise of profitable trading opportunities. Therefore, to establish how much of the increased volatility may be due to this short run inefficiency, the analysis extended to investigating the form of the stochastic volatility process underpinning the volatility in rand nominal returns. The underlying premise is that the stochastic volatility process underpinning exchange rate returns formed in an efficient market should be unsystematic.

Using a generalized autoregressive conditional heteroscedasticity (GARCH) methodology, the evidence shows volatility clustering that is asymmetrically distributed. Periods of rand depreciations lead increases in volatility than periods of rand appreciations. This is indication that long and short positions in the rand have been unevenly distributed and, accordingly, the market as a whole has tended to take a unidirectional view on the rand.

How much of the increased volatility can be attributed to this apparent short run market inefficiency is nonetheless unclear from econometric tests undertaken herein. It is conjectured that this behavior may be entrenched more in the psychology of financial market participants than can be uncovered from econometric tests. The behavioral finance literature (Sewell, 2008; Barberis & Thaler, 2003; Shleifer, 2000) uses interesting insights from psychology and sociology to shed light on behaviors of

financial market participants, the subsequent effect of this on markets, and on why and how markets might be inefficient. This literature has found that psychological, sociological, and emotional biases of various kinds influence the manner by which investors undertake their trades. Therefore, in the pursuit of a better understanding of asset price fluctuations overtime, advances in behavioral finance continue to hold strong promise as the ideal complement to the economist's traditional toolkit.

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Table 6-4: Test for ARCH effect in rand returns

Specification	ARCH(1)	ARCH(4)
Testing statistic	[ $X^2(1)$ ]	[ $X^2(4)$ ]
Data series		
<b>Period I: 15 Sept 1985 to 28 Jan 2007</b>		
Trade weighted rate	151.6* (0.000)	218.6* (0.000)
Dollar	129.3* (0.000)	166.6* (0.000)
Pound	132.6* (0.000)	221.4* (0.000)
Euro	148.9* (0.000)	202.4* (0.000)
<b>Period II: 15 Sept 1985 to 30 Jan 2000</b>		
Trade weighted rate	130.1* (0.000)	136.8* (0.000)
Dollar	120.2* (0.000)	131.6* (0.000)
Pound	109.7* (0.000)	117.4* (0.000)
Euro	123.7* (0.000)	130.6* (0.000)
<b>Period III: 6 February 2000 to 28 Jan 2007</b>		
Trade weighted rate	39.0* (0.000)	77.1* (0.000)
Dollar	28.2* (0.000)	43.2* (0.000)
Pound	39.1* (0.000)	97.1* (0.000)
Euro	39.9* (0.000)	67.3* (0.000)
Ho: no ARCH effects in residuals		
P-value in parenthesis (...)		
* denote statistical significance evaluated at the five percent critical value		

Table 6-5: Autocorrelations of squared returns of rand exchange rates

<b>Dollar rate</b>				<b>Euro rate</b>			
lag	AC	Q-Stat	Prob	lag	AC	Q-Stat	Prob
1	0.341	129.76	0.000	1	0.365	149.39	0.000
2	0.288	222.93	0.000	2	0.337	276.66	0.000
3	0.159	251.21	0.000	3	0.157	304.40	0.000
4	0.097	261.85	0.000	4	0.123	321.37	0.000
5	0.072	267.68	0.000	5	0.070	326.81	0.000
6	0.062	271.99	0.000	6	0.050	329.61	0.000
7	0.074	278.11	0.000	7	0.067	334.71	0.000
8	0.073	284.04	0.000	8	0.057	338.34	0.000
9	0.064	288.69	0.000	9	0.054	341.64	0.000
10	0.108	301.89	0.000	10	0.121	358.16	0.000
11	0.104	314.03	0.000	11	0.077	364.77	0.000
12	0.103	325.92	0.000	12	0.112	378.99	0.000
13	0.133	345.87	0.000	13	0.125	396.58	0.000
14	0.071	351.65	0.000	14	0.077	403.22	0.000
15	0.037	353.20	0.000	15	0.059	407.14	0.000

<b>Pound rate</b>				<b>Trade weighted rate</b>			
lag	AC	Q-Stat	Prob	lag	AC	Q-Stat	Prob
1	0.379	160.72		1	0.369	152.09	0.000
2	0.338	288.57		2	0.356	293.77	0.000
3	0.121	305.01	0.000	3	0.135	314.12	0.000
4	0.068	310.21	0.000	4	0.087	322.64	0.000
5	0.035	311.58	0.000	5	0.048	325.20	0.000
6	0.052	314.62	0.000	6	0.041	327.08	0.000
7	0.009	314.72	0.000	7	0.044	329.30	0.000
8	0.029	315.67	0.000	8	0.049	331.96	0.000
9	0.037	317.24	0.000	9	0.052	335.03	0.000
10	0.051	320.23	0.000	10	0.097	345.73	0.000
11	0.063	324.64	0.000	11	0.085	353.87	0.000
12	0.133	344.62	0.000	12	0.135	374.44	0.000
13	0.103	356.70	0.000	13	0.127	392.68	0.000
14	0.064	361.30	0.000	14	0.067	397.75	0.000
15	0.074	367.49	0.000	15	0.047	400.30	0.000

The sample is from September 15, 1985 to January 28, 2007  
AC is the autocorrelation coefficient for each lag  
Q-stat is the Ljung-Box Q-statistic testing the null hypothesis that there is no autocorrelation up to a specified lag, k  
If there is no ARCH in the residuals, the Q-statistics should not be significant

Table 6-6: GARCH (1, 1) estimates of volatility of rand returns

Sample (Sample size) Data series name	15 Sept 1985 to 28 Jan 2007 (1116)				15 Sept 1985 to 30 Jan 2000 (751)			
	Wgtd. rate	Dollar	Pound	Euro	Wgtd. rate	Dollar	Pound	Euro
<i>Mean Equation</i>								
$\eta_0$	0.06* [2.57]	0.05 [1.52]	0.23* [2.69]	0.04 [1.21]	0.07* [2.57]	0.05 [1.42]	0.01* [2.04]	0.04 [1.18]
$\varphi_1$	0.14* [4.52]	0.14* [4.36]	-0.32* [-6.10]	0.13* [4.18]	0.15* [4.01]	0.14* [3.49]	0.73* [5.10]	0.15* [3.96]
$\varphi_2$	0.056 [1.69]	0.06 [1.82]	-0.77* [-14.2]	0.04 [1.43]	0.05 [1.25]	0.05 [1.20]	0.29 [1.92]	0.05 [1.31]
$\varphi_3$			0.11* [3.55]				-0.07* [-1.60]	
$\theta_1$			0.48* [12.0]				-0.56* [-3.87]	
$\theta_2$			0.86* [16.7]				-0.42* [-3.13]	
<i>Variance Equation</i>								
$\omega$	0.02* [4.54] (0.00)	0.035* [4.883] (0.000)	0.09* [4.71] (0.000)	0.026* [4.481] (0.000)	0.023* [4.64] (0.00)	0.058* [5.26] (0.000)	0.089* [4.70] (0.000)	0.042* [4.62] (0.000)
$\alpha$	<b>0.13*</b> [8.50] (0.00)	<b>0.16*</b> [7.86] (0.000)	<b>0.13*</b> [7.06] (0.000)	<b>0.13*</b> [7.836] (0.000)	<b>0.14*</b> [6.742] (0.000)	<b>0.20*</b> [6.200] (0.000)	<b>0.09*</b> [5.43] (0.000)	<b>0.16*</b> [6.17] (0.000)
$\beta$	<b>0.85*</b> [61.4] (0.00)	<b>0.82*</b> [43.82] (0.000)	<b>0.82*</b> [41.4] (0.000)	<b>0.85*</b> [55.3] (0.000)	<b>0.82*</b> [38.35] (0.000)	<b>0.75*</b> [25.06] (0.000)	<b>0.83*</b> [35.21] (0.000)	<b>0.80*</b> [30.4] (0.000)
Average estimated Volatility (%) [ $\hat{\sigma}^2 = \hat{\omega} / (1 - \hat{\alpha} - \hat{\beta})$ ]								
	0.8%	2.13%	1.84%	1.72%	0.52%	1.12%	1.17%	1.08%
Wald coefficient restriction test [ $H_0: \alpha + \beta = 1$ ](a)/								
$X^2(1)$	5.21* (0.02)	2.79 (0.09)	16.7* (0.000)	3.88* (0.05)	14.28* (0.000)	8.96* (0.003)	25.9* (0.000)	7.79* (0.005)
Diagnostics: ARCH test (b)/								
ARCH(1) [ $X^2(1)$ ]	0.11 (0.74)	0.02 (0.88)	12.28* (0.000)	0.13 (0.72)	0.10 (0.75)	0.02 (0.89)	17.77* (0.000)	0.06 (0.80)
ARCH(4) [ $X^2(4)$ ]	0.41 (0.98)	0.71 (0.95)	13.42* (0.009)	0.61 (0.96)	0.47 (0.97)	0.72 (0.95)	18.69* (0.000)	0.61 (0.96)
Z-statistic in square brackets [...]								
P-value in parenthesis (...)								
* denote statistical significance evaluated at the five percent critical value								
(a)/ tests for persistence of volatility shocks								
(b)/ tests for presence of additional autoregressive conditional heteroskedasticity in residuals, based on Engle (1982)								

Table 6-7: GARCH (1, 1) estimates of volatility of rand returns

Sample (sample size) Data series name	6 February 2000 to 28 Jan 2007 (365)			
	Trade weighted rate	Dollar	Pound	Euro
<i>Mean Equation</i>				
$\eta_0$	0.01 [0.12]	0.02 [0.23]	0.002 [0.011]	-0.02 [-0.18]
$\varphi_1$	0.13* [2.22]	0.15* [2.54]	-0.55 [-0.21]	0.11 [1.85]
$\varphi_2$	0.07 [1.19]	0.09 [1.56]	0.22 [0.12]	0.03 [0.56]
$\varphi_3$			-0.03 [-0.06]	
$\theta_1$			0.68 [0.26]	
$\theta_2$			-0.09 [-0.04]	
<i>Variance Equation</i>				
$\omega$	0.206* [2.42] (0.02)	0.271* [2.17] (0.03)	0.217* [2.29] (0.02)	0.0465* [2.37] (0.02)
$\alpha$	0.09* [3.90] (0.000)	0.11* [3.45] (0.001)	0.10* [3.62] (0.000)	0.09* [3.31] (0.001)
$\beta$	0.84* [22.51] (0.000)	0.83* [18.62] (0.000)	0.83* [20.8] (0.000)	0.79* [12.85] (0.000)
<i>Average estimated Volatility (%) [<math>\hat{\sigma}^2 = \hat{\omega}/(1 - \hat{\alpha} - \hat{\beta})</math>]</i>				
	3.18%	4.17%	3.42%	3.92%
<i>Wald coefficient restriction test [<math>H_0: \alpha + \beta = 1</math>](a)/</i>				
$X^2(1)$	5.29* (0.02)	4.03* (0.04)	4.42* (0.04)	5.77* (0.02)
<i>Diagnostics: ARCH test</i>				
(b)/				
ARCH(1) [ $X^2(1)$ ]	0.86 (0.35)	0.00 (0.99)	2.68 (0.10)	0.39 (0.53)
ARCH(4) [ $X^2(4)$ ]	2.14 (0.71)	0.52 (0.97)	3.36 (0.50)	2.67 (0.61)
Z-statistic in square brackets [...]				
P-value in parenthesis (...)				
(*) denote statistical significance evaluated at the five critical value				
(a)/ tests for persistence of volatility shocks				
(b)/ tests for presence of additional autoregressive conditional heteroskedasticity in residuals, based on Engle (1982)				

Table 6-8: Asymmetric impact of shocks to volatility of rand returns

Sample (Sample size) Data series name	15 Sept 1985 to 28 Jan 2007 (1116)				15 Sept 1985 to 30 Jan 2000 (751)			
	Wgtd rate	Dollar	Pound	Euro	Wgtd rate	Dollar	Pound	Euro
<i>Variance Equation</i>								
$\omega$	-0.15* [-9.02] (0.000)	-0.20* [-9.40] (0.000)	-0.18* [-8.23] (0.000)	-0.16* [-8.37] (0.000)	-0.13* [-7.3] (0.000)	-0.22* [-7.85] (0.000)	-0.22* [-7.36] (0.000)	-0.20* [-7.63] (0.000)
$\alpha$	0.18* [8.44] (0.000)	0.27* [8.89] (0.000)	0.26* [9.14] (0.000)	0.22* [7.82] (0.000)	0.15* [6.44] (0.000)	0.29* [7.21] (0.000)	0.32* [8.14] (0.000)	0.26* [7.07] (0.000)
$\gamma$	<b>0.07*</b> <b>[5.67]</b> <b>(0.000)</b>	<b>0.04*</b> <b>[2.62]</b> <b>(0.009)</b>	<b>0.04*</b> <b>[2.42]</b> <b>(0.02)</b>	<b>0.07*</b> <b>[4.37]</b> <b>(0.00)</b>	<b>0.09*</b> <b>[6.20]</b> <b>(0.000)</b>	<b>0.07*</b> <b>[3.14]</b> <b>(0.002)</b>	<b>0.05*</b> <b>[2.29]</b> <b>(0.022)</b>	<b>0.08*</b> <b>[3.44]</b> <b>(0.001)</b>
$\beta$	0.98* [289.5] (0.000)	0.97* [160.4] (0.000)	0.96* [109.9] (0.000)	0.98* [187.1] (0.000)	0.98* [242.8] (0.000)	0.95* [97.5] (0.000)	0.92* [63.76] (0.000)	0.96* [111.1] (0.000)
<i>Diagnostics: ARCH test (a)/</i>								
ARCH(1) [ $X^2(1)$ ]	0.00 (0.99)	0.001 (0.97)	22.73* (0.00)	0.01 (0.91)	0.00 (0.97)	0.00 (0.98)	11.76* (0.00)	0.00 (0.96)
ARCH(4) [ $X^2(4)$ ]	0.08 (0.99)	0.26 (0.99)	24.6* (0.00)	0.22 (0.99)	0.06 (0.99)	0.30 (0.99)	13.99* (0.01)	0.24 (0.99)
Z-statistic in square brackets [...] P-value in parenthesis (...) * denote statistical significance evaluated at the one and five critical value (a)/ tests for presence of additional autoregressive conditional heteroskedasticity in residuals, based on Engle (1982)								

Table 6-9: Asymmetric impact of shocks to volatility of rand returns

Sample (sample size) Data series name	6 February 2000 to 28 Jan 2007 (365)			
	Weighted rate	Dollar	Pound	Euro
<i>Variance Equation</i>				
$\omega$	-0.2 [-0.53] (0.59)	-0.08 [-1.31] (0.20)	-0.04 [-0.73] (0.47)	0.09 [1.35] (0.17)
$\alpha$	0.14* [2.56] (0.01)	0.22* [3.09] (0.002)	0.20* [2.98] (0.003)	0.08 [1.29] (0.19)
$\gamma$	<b>0.096*</b> <b>[3.00]</b> <b>(0.003)</b>	<b>0.03</b> <b>[0.99]</b> <b>(0.32)</b>	<b>0.06</b> <b>[1.62]</b> <b>(0.11)</b>	<b>0.16*</b> <b>[3.44]</b> <b>(0.001)</b>
$\beta$	0.93* [32.8] (0.000)	0.94* [30.2] (0.000)	0.90* [26.4] (0.000)	0.88* [19.8] (0.000)
<i>Diagnostics ARCH test (a)/</i>				
ARCH(1) [ $X^2(1)$ ]	0.02 (0.89)	0.02 (0.89)	0.88 (0.35)	0.00 (0.98)
ARCH(4) [ $X^2(4)$ ]	0.82 (0.94)	0.44 (0.98)	1.31 (0.86)	0.87 (0.93)
Z-statistic in square brackets [...] P-value in parenthesis (...) (* denote statistical significance at the five percent critical value (a)/ tests for presence of additional autoregressive conditional heteroskedasticity in residuals, based on Engle (1982)				

## Chapter 7

### 7 Conclusion

Wanting to achieve economic stabilization, South Africa has historically devoted significant attention to stabilizing measures in the domestic foreign exchange market. Yet, the rand has since the early 1980s sustained a long swing decline in its value that reversed in 2002 for a short while, but resuming the swing in 2006. Contrasting these fairly predictable fluctuations, the rand's short run movements are increasingly volatile. Indeed, it has not been unusual for the rand to change by as much as four percent in a single day, especially since the 1990s. This study has sought to explain these two issues of the *long swings and short run volatility* of exchange rates of the rand.

The key question asked is what explains these movements? On the one hand, are these fluctuations mirroring linkages of the rand to the state of the South African economy, and on the other, do they simply reflect the influence of random shocks to the economy? As with any other currency, the exchange rate of the rand is both a key policy variable, and one whose volatility can also bear pervasively important consequences on the domestic political economy and international relation. The explanation for what underpins its behavior is thus pertinent because it can inform effective policymaking targeted at not only stabilizing the economy, but also conditioning economic agents' expectations about other asset price movements in the economy, in addition to the exchange rate itself. Indeed, the recent experiences of financial crises in the mid-1990s for a number of emerging market countries<sup>70</sup> have emphasized the large costs to an economy that exchange rate volatility and its aftermath can bring to bear.

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<sup>70</sup> For example, a number of East Asian countries in 1997, Russia in 1998, Mexico in 1994 and Argentina during 2000-2001

Certainly, South Africa can ill afford the cost of perverse effects of exchange rate volatility. Currently, the thrust of government policy is to accelerate sustainable economic growth in order to create employment as an anti-poverty strategy. Yet, the country's large exposure to international capital markets and its dependence on international trade in both financial assets and merchandise highlights its vulnerability to unwarranted exchange rate volatility.

Nonetheless, if linkages existed between the rand and fundamentals, then its changes are in line with the underlying state of the economy, and thus do not pose a threat to the economy. In that case, the solution to the problem of its volatility may lie at stabilizing or enhancing the pace of adjustment in those fundamental determinants. If conversely the rand exchange rate is divergent from the state of the economy and instead its fluctuations simply encapsulate diverging cyclical positions, such as random speculative behaviors of the foreign exchange market, the strong possibility is that this will be inimical to achieving the growth and employment objectives in the medium term. To the extent that the source of such random behaviors were known, as for instance, imperfections in the flow of information to the market, it can be argued that an interventionist policy that desires to elucidate the quantity and quality of information to market participants would be the ideal.

Therefore, on the question of the *long swing movement*, the study has sought to establish whether the rand's past experience is explainable based on fundamental determinants. Explaining currency movements is nonetheless notoriously difficult. This difficulty is reflected in the myriad of approaches that have over time yielded a rich literature on exchange rate determination, but without as yet reaching consensus on the appropriate set of fundamentals to add in an exchange rate equation. Thus, the empirical analysis has relied upon a model drawn on the asset approach to

exchange rate determination, which indentifies the factors thought to explain long trends in exchange rates as relative money supplies, real incomes, short term and long-term interest rate differential, expected inflation rate differentials, and the risk premiums.

Using a combination of the systems approaches of Johansen's (1995) multivariate cointegration technique and Pesaran, Shin, and Smith's (2002) long run structural modeling method, the analysis provides evidence that fundamentals indeed anchor the rand. On the one hand, money supply growth and rising short-term interest rates in South Africa lead to rand depreciations. Growth of the South African economy and rising interest rates on long-term maturities, on the other hand, appreciate the rand. This result is hardly surprising, as it conforms to existing literature on both South Africa and elsewhere. Nonetheless, the influence of the long-term interest on the rand has not been explored in previous studies and therefore our finding constitutes an extension of the literature in this regard.

Most importantly, however, the South African exchange rate regime has not been stable. Other dramatic changes to the macroeconomic environment have occurred within a relatively short history. Most of the dramatic changes followed from a combination of political events and changes in government policies. Empirically exploring rand movements in the face of frequent regimes change pose the challenge that such regimes change alter the information set on which agents form their expectorations, and thereby the relationship with its determinants. The existing literature on modeling the South African market has not clearly addressed this empirical challenge. Thus, it has been premised that the rand and perhaps some of its determinants have experienced episodes in which the behavior of their time series may have changed dramatically due regimes change. Regimes change has

thereby been explicitly incorporated, testing whether or otherwise the linkage of the rand to fundamental has altered due to regimes change.

The switch in 2000 to an inflation-targeting regime for conducting monetary policy isolates the previous years of very controlled floating from the current in which obvious foreign exchange interventions are absent and there is substantial liberalization of financial markets. In comparison to the previous period, one would thus expect the rand-fundamentals relationship to have altered.

Accounting for the regime change to inflation targeting into the analysis, the study finds that the rand-fundamentals linkage not only alters, but also is significantly enhanced. On the one hand, in the period pre-inflation targeting period, a smaller set of fundamentals explain the rand. In the post-inflation targeting era, on the other hand, the set of fundamental anchoring the rand is not only expanded but their impact is also enhanced. Thus, although fundamental tie the rand during the period covered by the study, the anchorage seems regime-dependent - *it has depended on the regime in which the exchange rate is in*. In short, the relationship differs on both sides of the regimes break.

It is here where the present study contributes to and thereby extends the South African literature. Existing literature has not explored the significance of regimes change on rand pricing. The findings also have a much wider implication. At one level, the evidence uncovered here suggests that exchanges can differ in the degree to which they are connected to underlying determinants when the environments in which they are determined continuously change. This calls for more caution in comparing and interpreting results across spectrum of regimes change. At another level, results lend empirical support to the ongoing debate - the bi-polar view - on the choice of exchange rate regimes for developing countries with large exposures to

international capital in the light of recent financial crises that rocked emerging market economies. The message of this study is that regime change, or more generally institutional change, matters for currency pricing. Likewise, this can pose policy challenges.

Equally, the evidence provided on the direction of causation between the rand and the fundamentals that we examined has policy implications. Of significance is the positive impact of the short-term interest rate of the rand. Given that current monetary policy relies on setting short term interest rates, this suggests that it would be difficult to achieve exchange rate stabilization through raising short term interest rates, as is often suggested by a number of commentators. It is speculated that such a strategy would add to currency instability, especially if the currency is already unstable. Rather, it would appear that the only circumstance in which monetary policy would be more supportive is if interest rates rose faster at the longer maturity end of the yield curve.

Considering the other issue of the *volatility in the short run movements* in the rand, the study sought to establish whether foreign exchange markets participants' reaction to relevant news account for some of its volatility. The study pursued this enquiry through testing for predictability of nominal exchange rate returns for the rand. These tests ask only whether nominal exchange rate returns on the rand are predictable based on past exchange rates. The underlying intuition is that, in an efficient foreign exchange market with unpredictable news arrival with noise, traders react immediately to relevant news. Changes in currency values over short term intervals should therefore be unpredictable based on delayed news because current values presumably already factor in such news.

A martingale specification of the data and a conditional two-stage likelihood ratio test drawn on Dickey and Fuller (1981)- a methodology that exploits statistical properties of the data- was used to address this question. The empirical evidence has shown that nominal exchange rate returns on the rand are predictable from their past and the spot rand market is informationally weak-form inefficient. Previous changes in the rand carry information that is helpful in revaluing the rand up to two weeks forward. Thus, agents are able to improve their forecast of future movements in the rand up to two weeks ahead. This finding is robust to regime change to inflation targeting in February 2000.

However, as tested, the predictability tests are only able to shed light on the presence or otherwise of weak-form market inefficiency and thereby the presence or otherwise of profitable trading opportunities. Therefore, to establish how much of the increased volatility may be due to this short run inefficiency, the analysis extended to investigating the form of the stochastic volatility process underpinning the volatility in rand nominal returns.

The empirical analysis of this question utilized a generalized autoregressive conditional heteroscedasticity (GARCH) methodology. The evidence has shown volatility clustering that is asymmetrically distributed, whereby volatility has tended to be higher in episodes following rand depreciations than in those of rand appreciations. We have viewed this as suggesting that long and short positions in the rand have been unevenly distributed and, accordingly, the market as a whole has tended to take a unidirectional on the rand.

How much of the increased volatility can be attributed to this apparent short run market inefficiency is nonetheless unclear from econometric tests undertaken herein. It is conjectured that this behavior may be entrenched more in the psychology of

financial market participants than can be uncovered from econometric tests. The behavioral finance literature (Sewell, 2008; Barberis & Thaler, 2003; Shleifer, 2000) uses interesting insights from psychology and sociology to shed light on behaviors of financial market participants, the subsequent effect of this on markets, and on why and how markets might be inefficient. This literature has found that psychological, sociological, and emotional biases of various kinds influence the manner by which investors undertake their trades. Therefore, in the pursuit of a better understanding of asset price fluctuations overtime, advances in behavioral finance continue to hold strong promise as the ideal complement to the economist's traditional toolkit.

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