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“A TIME SERIES ANALYSIS OF THE ZAR/USD EXCHANGE RATE”

of

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ABSTRACT

Exchange rates have significant effects on production, trade, employment and many other areas of both a domestic and world economy, so it is very important to understand the factors responsible for their variations.

This paper aims to analyze the relationship between the exchange rate of the South African rand / U.S. dollar and the changes of the macroeconomic fundamentals of the two countries, but also to consider whether and how these changes are sufficient for the interpretation and prediction of the exchange rate in the future. It tries to find out the main determinants of the nominal exchange rate and the dynamic adjustment of the nominal exchange rate covering a time span after the country's financial liberalization and, especially the last decade with the starting point to be the early 2002. Then a planned military coup by a white supremacist movement known as the Boeremag (Boer Force) was foiled by the South African police. With two dozen conspirators including senior South African Army officers arrested and the extremist organization dismantled, South African police proved to be so effective that strengthened public perceptions that the democratic order was irreversible.

The study begins with an updated background on the economy and the exchange rate system in South Africa and provides a brief review of literature on the determinants of the exchange rate. An empirical model linking the exchange rate to its theoretical determinants is then specified to provide robust long run effects and short run dynamic effects on the exchange rate.

To undertake an econometric investigation, quarterly data of the period from the first quarter of 2002 to the fourth quarter of 2012 from the database of the International Statistical Yearbook (ISY) / International Monetary Fund (IMF) Statistics are used through Gretl econometric analysis program, facing the South African rand as the domestic currency and the U.S. dollar as the foreign currency.

The paper, first, tries to verify the applicability of the theory of Purchasing Power Parity, according to which the evolution of the exchange rate is positive and

proportional to the difference in the evolution of the price level. Then, it examines whether the differential of the yield curve, which is a measure of the difference between the interest rates on short-term loans (or bonds) and those on long-term loans (or bonds), has additional power for the exchange rate determination. Subsequently, it estimates the speed at which the exchange rate converges toward its equilibrium level and, correspondingly, the gap between the actual and the equilibrium levels.

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1. INTRODUCTION

In the last 10 years since South Africa transformed into a democracy, the rand has seen an increase in volatility of its exchange rate. These fluctuations in the rand's exchange rate have raised questions as to whether they signify significant misalignment of the currency and thereby undermine competitiveness of South Africa's exports abroad. This is a pertinent question in the South African context because foreign trade has been critical to the growth of the economy. Efforts to address current high levels of unemployment and widespread poverty among the majority of the population have depended upon this growth. This study investigates the extent to which fluctuations in the rand's exchange rate have impacted on the competitiveness of South African trade flows by determining whether, at some point, the rand had been misaligned, and the likely consequences of such a misalignment. Therefore, it investigates the hypothesis that the purchase power parity theory is valid, because if so, then the exchange rate misalignment would not be observed.

1.1 ECONOMY OF SOUTH AFRICA

The economy of South Africa is the largest in Africa, accounts for 24% of its gross domestic product in terms of purchasing power parity and is ranked as an upper-middle income economy by the World Bank. This makes the country one of only four countries in Africa in this category (the others being Botswana, Gabon and Mauritius). Since 1996, at the end of over twelve years of international sanctions, South Africa's Gross Domestic Product has since almost tripled to $400 billion and foreign exchange reserves have increased from $3 billion to nearly $50 billion, creating a growing and sizable African middle class, within two decades of establishing democracy and ending apartheid.

South Africa has a comparative advantage in the production of agriculture, mining and manufacturing products relating to these sectors. South Africa has shifted from a primary and secondary economy in the mid-twentieth century to an economy driven primarily by the tertiary sector in the present day which accounts for an estimated 65% of GDP or $230 billion in nominal GDP terms. The country's economy is reasonably diversified with key economic sectors including mining, agriculture and fisheries, vehicle manufacturing and assembly, food processing, clothing and textiles, telecommunication, energy, financial and business services, real estate, tourism, transportation, and wholesale and retail trade.

Mining has been the main driving force behind the history and development of Africa's most advanced and richest economy. Large-scale and profitable mining started in 1867, but South Africa is even now one of the world's leading mining and mineral-processing countries. Though mining's contribution to the national GDP has fallen from 21% in 1970 to 6% in 2011, it still represents almost 60% of exports.

Principal international trading partners of South Africa, besides other African countries, include Germany, the United States, China, Japan, the United Kingdom and Spain. Chief exports include corn, diamonds, fruits, gold, metals and minerals, sugar, and wool. Machinery and transportation equipment make up

more than one-third of the value of the country's imports. Other imports include chemicals, manufactured goods, and petroleum.

According to official estimates, a quarter of the population is unemployed and, according to a 2013 Goldman Sachs report, that number increases to 35% when including people who have given up looking for work. Moreover, a quarter of South Africans live on less than US $1.25 a day. Poverty also remains a major problem. The high levels of unemployment and inequality are considered by the government and most South Africans to be the most salient economic problems facing the country. These issues and others linked to them, such as crime and social unrest, have in turn hurt investment and growth, consequently having a negative feedback effect on employment. Crime is considered a major or very severe constraint on investment by 30% of enterprises in South Africa, putting crime among the four most frequently mentioned constraints.

South Africa, unlike other emerging markets, has struggled through the late 2000s recession, and the recovery has been largely led by private and public consumption growth, while export volumes and private investment have yet to fully recover. The long-term potential growth rate of South Africa under the current policy environment has been estimated at 3.5%. Per capita GDP growth has proved mediocre, though improving, growing by 1.6% a year from 1994 to 2009, and by 2.2% over the 2000–09 decade, compared to world growth of 3.1% over the same period.

1.2 ECONOMIC HISTORY OF SOUTH AFRICA

The formal economy of South Africa has its beginnings in the arrival of Dutch settlers in 1652, originally sent by the Dutch East India Company to establish a provisioning station for passing ships. As the colony increased in size, with the arrival of French Huguenots and German citizens, some of the colonists were set free to pursue commercial farming, leading to the dominance of agriculture in the economy.

At the end of the 18th century, the British gained control of the colony. This led to the Great Trek, spreading farming deeper into the mainland, as well as the establishment of the independent Boer Republics of Transvaal and the Orange Free State.

In 1870 diamonds were discovered in Kimberley, while in 1886 some of the world's largest gold deposits were discovered in the Witwatersrand region of Transvaal, quickly transforming the economy into a resource-dominated one. The British gained control as a result of the Boer War. The country also entered a period of industrialization during this time, including the organization of the first South African trade unions.

The country soon started putting laws distinguishing between different races in place. In 1948 the National Party won the national elections and immediately started implementing an even stricter race-based policy named Apartheid, effectively dividing the economy into a privileged white one, and an impoverished black one. The policy was widely criticized and led to crippling sanctions being placed against the country in the 1980s.

South Africa held its first multi-racial elections in 1994, leaving the newly elected African National Congress (ANC) government the daunting task of trying to restore order to an economy harmed by sanctions, while also integrating the previously disadvantaged segment of the population into it. The 1994 government inherited an economy wracked by long years of internal conflict and external sanctions.

The government refrained from resorting to economic populism. Inflation was brought down, public finances were stabilized, and some foreign capital was attracted. However, growth was still subpar. At the start of 2000, then President Thabo Mbeki vowed to promote economic growth and foreign investment by relaxing restrictive labor laws, stepping up the pace of privatization and cutting unneeded governmental spending. His policies face strong opposition from organized labor. From 2004 onward economic growth picked up significantly, both employment and capital formation increased.

South Africa's success in reforming its economic policies is probably best reflected by its GDP figures, which reflected an unprecedented 62 quarters of uninterrupted economic growth between 1993 and 2007, when GDP rose by 5.1%. With South Africa's increased integration into the global market, there was no escaping from the impact of the 2008-09 global economic crisis, and GDP contracted to 3.1%. While the economy continues to grow - driven largely by domestic consumption – growth is at a slower rate than previously forecast. It is projected to grow at 2.7% in 2013, 3.5% in 2014 and 3.8% in 2015.

1.3 COMPARISON WITH OTHER EMERGING MARKETS

South Africa compares well to other emerging markets on affordability and availability of capital, financial market sophistication, business tax rates and infrastructure, but fares poorly on the cost and availability of labor, education, and the use of technology and innovation.

In a 2010 survey, South Africa was found to have the second most sophisticated financial market and the second-lowest effective business tax rate (business taxes as a percentage of company profits), out of 14 surveyed countries. The country was also ranked fourth for ease of accessing capital, fourth for cost of capital, sixth for its transport infrastructure (considered better than that of China, India, Mexico, Brazil and Poland, but behind that of Korea and Chile), and seventh for foreign direct investment as a percentage of GDP: in 2008 it was over 3% of the GDP.

However, for availability of manual labor, South Africa is ranked last, and is also the only country of the 14 whose labor force shrunk in 2008 (by over 3%, compared to India, where the workforce grew by almost 3%). The cost of manual labor is ranked fifth out of 11 countries, at about the same level as South Korea, but more expensive than Brazil, India and China. South African factory workers are also better paid than those of Brazil, China, India, Poland and Mexico. South African workers are more productive than workers in Russia, Colombia, Brazil, China and India, but less productive than workers in Korea, Chile and Mexico.

South Africa ranks poorly when it comes to education; only India fares worse when it comes to the percentage of matriculants moving onto higher education in 2007: in Brazil, 30% of matriculants graduated to tertiary institutions in 2007, and the figure was over 50% in Chile and over 90% in Korea, compared with just 15% in South Africa. This is despite the report ranking South Africa fourth for the percentage of GDP it spends on education (more than 4% in 2007). The report ranks South Africa 11th out of 14 countries when it comes to the country's use of technology and innovation, putting the African country behind

Korea as well as the BRIC countries, but ahead of Colombia, Mexico and Argentina.

Nevertheless, South Africa is falling behind other emerging markets, such as India and China, owing to several factors. The country is relatively small, without the advantage of a huge domestic customer base. It has had for decades an unusually low rate of saving and investment, partly because of political uncertainties. An inadequate education system results in an acute shortage of skilled manpower and a strong and volatile currency deters investors and makes its exports less competitive.

In 2011, after a year of observer status, South Africa officially joined the BRICS group of now-five emerging-market nations at the summit held in Sanya, Hainan, China.

1.4 A BRIEF HISTORY OF THE RAND

The rand (sign "R", code "ZAR") is the currency of South Africa. The rand has the symbol "R" and is subdivided into 100 cents, symbol "c". The ISO 4217 code is ZAR, from Dutch Zuid-Afrikaanse Rand (South African rand). Before 1984, the Dutch language was one of the official languages of South Africa.

The rand is the currency of the Common Monetary Area between South Africa, Swaziland and Lesotho (both landlocked by South Africa). Although Namibia withdrew from the Common Monetary Area, the rand is still legal tender there. Historic users of the South African Rand were Bophuthatswana, Ciskei, South-West Africa, Transkei and Venda.

The rand was introduced on 14 February 1961 and its name was derived from the area of land where the majority of South Africa's gold deposits are located. This area, located in Johannesburg, was named Witwatersrand, which was the Afrikaner word for "white waters ridge".

A Decimal Coinage Commission had been set up in 1956 to consider a move away from the denominations of pounds, shillings and pence, submitting its recommendation on 8 August 1958. This was at a time when many former British colonies were making moves to move away from the British currency. So, rand replaced the South African pound as legal tender, at the rate of 2 rand = 1 pound or 10 shillings to the rand. The government introduced a mascot, Decimal Dan, "the rand-cent man" to familiarize the populace with the new currency. This took place in the same year that the Republic of South Africa was established.

A rand was worth US $1.40 from the time of its inception in 1961 until 1982, when mounting political pressure combined with increasing international isolation and sanctions placed against the country due to apartheid started to erode its value. The currency broke above parity with the dollar for the first time in March 1982, and continued to trade between R 1–R 1,30 to the dollar until June 1984, when depreciation of the currency gained momentum. By February 1985, it was trading at over R 2 per dollar, and, in July that year, all foreign exchange trading was suspended for 3 days to try to stop the devaluation.

By the time that State President PW Botha made his Rubicon speech on 15 August 1985, it had weakened to R 2,40 per dollar. The currency recovered somewhat between 1986–88, trading near the R 2 level most of the time and even breaking beneath it sporadically. The recovery was short-lived however, and by the end of 1989 the rand was trading at levels of more than R 2,50 per dollar.

As it became clear in the early 1990s that the country was destined for black majority rule and one reform after the other was announced, uncertainty about the future of the country hastened the depreciation until the level of R 3 to the dollar was breached in November 1992. A host of local and international events influenced the currency after that, most notably the 1994 democratic election which saw it weaken to over R 3,60 to the dollar, the election of Tito Mboweni as the new governor of the South African Reserve Bank, and the inauguration of President Thabo Mbeki in 1999 which saw it quickly slide to over R 6 to the dollar. The controversial land reform program that was kicked off in Zimbabwe, followed by the September 11, 2001 attacks, propelled it to its weakest historical level of R 13,84 to the dollar in December 2001.

` **`This sudden depreciation in 2001 led to a formal investigation, which in turn led to a dramatic recovery. By the end of 2002, the currency was trading at under R 9 to the dollar again, and by the end of 2004 was trading at under R 5,70 to the dollar. The currency softened somewhat in 2005, and was trading at around R 6,35 to the dollar at the end of the year. At the start of 2006 however, the currency resumed its rally, and, as of 19 January 2006, was trading at under R 6 to the dollar again. However, during the second and third quarters of 2006 the rand weakened significantly.**

In sterling terms, it fell from around 9.5p to just over 7p, losing some 25% of its international trade-weighted value in just six months. Late in 2007, the rand rallied modestly to just over 8p, only to experience a precipitous slide during the first quarter of 2008.

This downward slide could be attributed to a range of factors: South Africa's worsening current account deficit, which widened to a 36-year high of 7.3% of gross domestic product (GDP) in 2007, inflation at a five-year high of just under 9%, escalating global risk aversion as investors' concerns over the spreading impact of the sub-prime crisis grew, and a general flight to "safe havens", away

from the perceived risks of emerging markets. The rand depreciation was exacerbated by the Eskom electricity crisis, which arose from the utility being unable to meet the country's rapidly growing energy demands.

In particular, major mines were shut down, with Eskom warning that major new industrial projects could not be powered until additional power generation capacity could be brought on stream, something unlikely to be achieved for at least another 5 years. This would have a significant impact on production and exports by South Africa's mining industry, and would thus worsen an already worrisome current account deficit. It is particularly unfortunate that this should have happened at a time of record high prices for hard and soft commodities. The situation has since stabilized, though currently South Africa is still battling to control its two-digit inflation levels.

Table 1. Historical South African Rand Rate (ZAR)

Year	ZAR/USD	Year	ZAR/USD	Year	ZAR/USD	Year	ZAR/USD
1971	0.71	1983	1.12	1995	3.63	2007	7.05
1972	0.77	1984	1.48	1996	4.30	2008	8.26
1973	0.70	1985	2.24	1997	4.61	2009	8.42
1974	0.68	1986	2.29	1998	5.53	2010	7.32
1975	0.74	1987	2.04	1999	6.12	2011	7.26
1976	0.87	1988	2.28	2000	6.95	2012	8.20
1977	0.87	1989	2.62	2001	8.63		
1978	0.87	1990	2.59	2002	10.52		
1979	0.84	1991	2.76	2003	7.56		
1980	0.78	1992	2.85	2004	6.45		
1981	0.88	1993	3.27	2005	6.36		
1982	1.09	1994	3.55	2006	6.76		
Average annual currency exchange rate for the South African Rand (Rands per U.S. Dollar) is shown in this table: 1971 to present.							

1.5 THE ZAR IN THE FOREX MARKET

The ZAR belongs to the class of currencies known as the emerging market currencies in the forex market, such as the Dollars of Hong Kong and Singapore, the Chinese Yuan, the Mexican Peso, the Brazilian Real, etc and is considered an exotic currency.

It is usually paired against the USD, EUR and GBP, since U.S.A., Eurozone and Great Britain are South Africa's traditionally bigger trade partners. Of these three pairs however, the USD/ZAR is the most commonly traded ZAR pair.

Due to the fact that inflation control is now a challenge to the Reserve Bank of South Africa, fundamental news items such as interest rate decisions are a very key component of ZAR trading. Being an emerging market currency, the ZAR is not often on the radar of currency traders. The wide spread of the USD/ZAR behooves traders interested in trading this currency to possess large margins on trading accounts. However, the wide daily ranges provide good trading opportunities for the seasoned trader.

As a trading center, multiple currencies circulated throughout South Africa. The first official currency used was the Guilder. During the late 17th century, the Rixdollar was used and was the first South African currency to include paper notes. During British occupation, in 1826, the Cape Colony was put on a sterling basis, though other currencies, including Spanish Dollars, US Dollars, French Francs, and Indian Rupees continued to circulate until 1961, when the rand was introduced.

2. LITERATURE REVIEW

Forecasting exchange rate movements is always an attractive subject in the international finance literature. So, there is an extensive literature, both theoretical and empirical, regarding the determination of exchange rates, mostly for the developed economies and to a less extent for developing economies. In case of South Africa, however, there is a clear dearth of studies.

2.1 THEORETICAL LITERATURE

There is a wide set of studies that investigate the determinants of real and nominal exchange rates, either bilateral or effective. They can be divided into two main groups. The first group belongs to the chartists and the second, to the fundamentalists. Argy (1994:345) states that the chartists consist of those studies whose models base their expectations of exchange rate fluctuations on its past movements while the fundamentalists consist of those studies whose models are based on the fundamentals, so that when the exchange rate is driven away from fundamentals they form expectations that it will return in due course to the levels projected by fundamentals. Most of the studies that have already been conducted up to this stage regarding floating exchange rates tend to concentrate more on the fundamentals. Floating exchange rate models based on the fundamentals are classified into two categories, namely, monetary exchange rate models and portfolio balance models. As from Neely and Sarno (2002:2-8), the monetary models of exchange rates can also be subdivided into two groups: the flexible-price model, due originally to Frankel (1976), Bilson (1978) and Mussa (1976, 1979), and the sticky-price model, due originally to Dornbusch (1976) and Frankel (1979).

In the flexible price model, the monetary approach starts from the definition of the exchange rate as the relative price of two monies and attempts to

model the relative price in terms of the relative supply and demand for those monies. As Neely and Sarno (2002) describe, the starting point of the monetary model is the purchasing power parity (PPP), which is also called "the inflation theory of exchange rate" and holds that goods-market arbitrage will tend to move the exchange rate to equalize prices in two countries.

Also as per Jeffrey A. Frankel (1979) who called the flexible price model as "Chicago" theory, when the domestic interest rate rises relative to the foreign interest rate, it is because the domestic currency is expected to lose value through inflation and depreciation. Demand for the domestic currency falls relative to the foreign currency, which causes it to depreciate instantly. This is a rise in the exchange rate, defined as the price of foreign currency.

The sticky-price monetary model, originally expressed by Dornbusch (1976), allows short-term overshooting of exchange rates above their long-run equilibrium levels. In this model, it is assumed that some variables (exchange rates and interest rates for instance) compensate for stickiness in other variables, notably goods prices. The sticky-price monetary model as per Jeffrey A. Frankel (1979) is also called "Keynesian" theory.

Nevertheless, as stated by MacDonald and Taylor (1992), as long as the expected foreign exchange loss (the expected rate of depreciation of the domestic currency) is less than the known capital market gain (the interest rate differential), risk-neutral investors will continue to borrow abroad to buy domestic assets.

From this model countries with relatively high interest rates tend to have currencies whose exchange rate is expected to depreciate. Sichei et al., (2005), use the Johansen cointegration procedure for the rand-dollar nominal exchange rate during the period 1994-2004 and also find signs and magnitudes that are conformable with the sticky-price monetary model.

Moreover, the UIP hypothesis states that when the no-arbitrage condition is satisfied without the use of a forward contract to hedge against exposure to exchange rate risk, interest rate parity is said to be uncovered. Risk-neutral investors will be indifferent among the available interest rates in two countries because the exchange rate between those countries is expected to adjust such that

the dollar return on dollar deposits is equal to the dollar return on foreign deposits, thereby eliminating the potential for uncovered interest arbitrage profits. Uncovered interest rate parity helps explain the determination of the spot exchange rate.

Many studies, however, emphasize the violation of UIP like Fama (1984) who shows that on average the target currency appreciates. This anomaly of the foreign exchange market makes carry trade profitable on average. “Carry trade”, as it is called, refers to the situation in which investors borrow low-yielding currencies and lend (invest in) high-yielding currencies.

Clarida et al. (2009) investigate such strategies to conclude that a strong relationship exists between their excess returns and exchange rate volatility. Nevertheless, they show that the failure of the UIP is present only in low-volatility environments. Chaboud and Wright (2005) also find support for UIP. Chinn and Meredith (2004) have strong evidence that UIP holds much better at long horizons instead of less than 12 months frequencies. Froot and Thaler (1990) argue that short-term deviations may occur while long-horizon UIP holds if inefficient markets or short-term market frictions prevent an immediate complete response of the exchange rate to an interest rate change. When using longer horizon data, the standard test of UIP yields remarkably different output, with slope parameters that are positive and insignificantly different from the value of unity.

2.2 EMPIRICAL LITERATURE

In August 1971, when the United States unilaterally terminated convertibility of the U.S. dollar to gold, the Bretton Woods system of monetary management collapsed and the fixed currency relationships started to move to more fluctuating currency systems. Then extended research with substantial contribution to the empirical understanding, of exchange rate determination were carried out. However, many times the results of these researches were in conflict or questions still remain unanswered. One of the most widely studied and still unanswered questions involves why monetary models of exchange rate determination, which emerged as the dominant exchange rate models at the outset of the float in the early 1970s, cannot forecast much of the variation in exchange rates. Also, the developed models can explain part of the exchange rate movements and to this significantly contributes the specialties of each country currency that is under investigation. This is the reason why this paper addresses with two different categories of empirical literature: the developing and other emerging market economies and, of course, South Africa.

2.2.1 EMPIRICAL LITERATURE FROM DEVELOPING AND OTHER EMERGING MARKET ECONOMIES

The importance of the exchange rate, particularly in developing countries, has led to several studies investigating its determinants and behaviour. These studies include the pioneer work of Edwards (1989), Ghura and Grennes (1993), Elbadawi (1994), Obadan (1994), Mkenda (2001), Miyakoshi (2003), Joyce and Kamas (2003) and Coricelli and Jazbec (2004), among others.

The main finding of Edwards' study is that, in the long run, only real variables affect long run equilibrium real exchange rates of a panel of 12 developing countries, including South Africa, while in the short run the real exchange rate is driven by both real and nominal factors. However, since the study employed panel methods, it did not provide a specific result for South Africa.

Ghura and Grennes investigated the determinants of the real exchange rate using a panel of Sub-Saharan countries, excluding South Africa to find that there are several factors that affect the real exchange rate.

2.2.2 EMPIRICAL LITERATURE FROM SOUTH AFRICA

Though, there exist a sufficient number of studies that have looked into forecasting nominal exchange rates (primarily with respect to the US dollar) for South Africa, the literature on analyzing the determination of the real exchange rate and its behavior is sparse, to say the least, especially for the last decade. The period after the transformation of the South African economy remains largely neglected. Most of the studies dealing with real exchange rate in South Africa essentially look at in-sample linear and at times non-linear (Markov-switching) modeling of the real exchange rate based on a wide variety of fundamentals such as interest rate differentials, suitable productivity measures, commodity prices, openness, and fiscal balance and capital flows (see for example, Chinn, 1999; Aron et al., 2000; MacDonald and Ricci, 2004; Mtonga, 2006; Frankel, 2007; Kaufmann et al., 2011; de Jager, 2012; Egert, 2012; Fattouh et al., 2008). From the above, in our opinion, the work of Aron et al. (2000) and MacDonald and Ricci (2003) stand out.

Aron et al. (2000) employ a cointegration framework with single equation equilibrium error correction models to investigate the short and long run determinants of the quarterly real effective exchange rate for South Africa, over the period 1970:1-1995:1. They find a cointegrated equilibrium from a theoretical model characterizing equilibrium as the attainment of both internal and external balance for sustainable capital flows and trade tax regimes, given terms of trade (including the price of gold) and technology. Specifically, they estimate an equation based on the following explanatory variables: RER = F(terms of trade, price of gold, tariffs, capital, official reserves, openness, nominal depreciation, government share in GDP, domestic credit, technological progress). An increase in the terms of trade, price of gold, tariffs, capital inflows, official reserves, government share in GDP, domestic credit and technological progress, all lead to an appreciation of the real exchange rate in South Africa, while an increase in openness and nominal

depreciation depreciates the real exchange rate. Their finding that an increase in the terms of trade leads to an appreciation of the real exchange rate suggests that the income effect dominates the substitution effect in South Africa. However, the remaining variables (nominal depreciation and domestic credit) show only a short term impact on the real exchange rate.

Finally, MacDonald and Ricci (2003) also estimate the equilibrium real exchange rate for South Africa using the Johansen cointegration estimation procedure and data spanning from 1970:1 - 2002:1. The explanatory variables included in their model include real interest rate differential, real GDP per capita relative to trading partners (productivity), real commodity prices, openness, the ratio of fiscal balance to GDP and the ratio of net foreign assets of the banking system to GDP. Based on their cointegration estimation results, much of the long run behavior of the real effective exchange rate of South Africa can be explained by real interest rate differentials, relative GDP per capita (productivity), real commodity prices (terms of trade), trade openness, the fiscal balance and the extent of net foreign assets. As in other empirical studies, they find that an increase in the real interest rate differential, productivity, terms of trade, fiscal balance and net foreign assets appreciate the real exchange rate in South Africa, while an increase in openness depreciates it. They further find that if the real exchange rate deviates from its equilibrium level owing to temporary factors, it can be expected to revert to equilibrium fairly quickly, in the absence of further shocks. Their study partly covers the post-apartheid period, but excludes some variables which other researchers have used in analyzing other emerging market economies, such as monetary variables.

It can be noted from the foregoing empirical literature review that there is a myriad of factors that affect the exchange rate.

2.3 CONCLUDING REMARKS

It is very difficult to summarize literature on the determinants of the exchange rate. Previous researchers have empirically estimated these fundamentals models, but only selecting variables that suit their different situations. However, it is self-defeating to come away from the literature covered in this chapter without more than a feeling that the main determinants of the long run exchange rate in developing countries include changes in ppp and real interest rate differentials vis-à-vis trading partner countries.

However, shocks to nominal variables, such as changes in monetary and nominal exchange rate policies, may cause the real exchange rate to deviate from its long run path, but their effects will only be transitory. Thus, the real exchange rate is determined by both real and nominal variables in the short run, while only real variables influence the real exchange rate in the long run.

3. EMPIRICAL ANALYSIS

3.1 INTRODUCTION

The preceding review of the literature on the determinants of the exchange rate and a background on the exchange rate system in South Africa, have both shed some light on the linkage between the exchange rate and its potential determinants. This chapter which builds on that background is divided into two sections and each of them into six subsections.

The first defines the variables and the data sources, while the second consolidates the literature on the determinants of the exchange rate and the background of the exchange rate system in South Africa, covered previously, to develop a model that links the exchange rate to its potential determinants, the ppp differential and the yield curve differential. The third presents the results of stationarity/unit root tests, the fourth presents and discusses the cointegration test results and discusses the long run relationship, the fifth presents the short run dynamics of the selected exchange rate model, while the sixth presents the results of the stability tests.

3.2 THE RELATIONSHIP BETWEEN THE ZAR/USD EXCHANGE RATE AND THE PPP DIFFERENTIAL

3.2.1 DATA

The first step is the determination of the variables of the model, which we import into the software. All the time series that we use are quarterly average data collected from International Monetary Fund and the sampling period begins at 1st quarter of 2002 and ends on the last quarter of 2012.

We define the variables and present their figures (figures 1 and 2) as follows:

- **199 RF: Principal Rate, Period Average/ Rand, per US dollar/ averages/ Cnt: South Africa/ Source: IMF, Wash → xr, for the ZAR/USD exchange rate,**
- **199 63: Ppi/ Wpi/ Index Number/ Base year: 2005/ averages/ Cnt: South Africa/ Source: IMF, Wash → za_ppp, for South Africa's purchase power parity and**
- **111 63: Ppi/ Wpi/ Index Number/ Base year: 2005/ averages/ Cnt: United States/ Source: IMF, Wash → us_ppp, for U.S.A.'s purchase power parity.**

Figure 1. ZAR/USD exchange rate (columns)

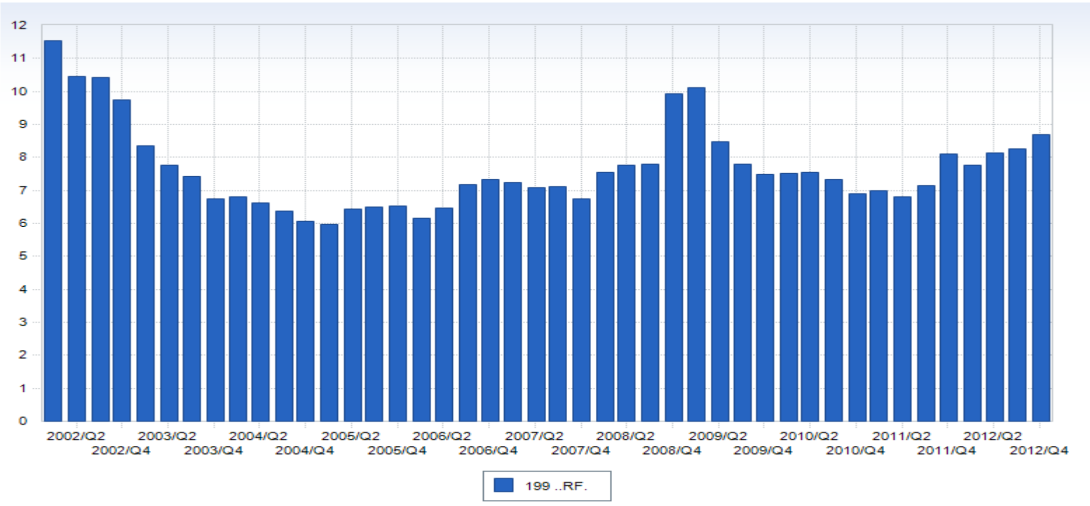
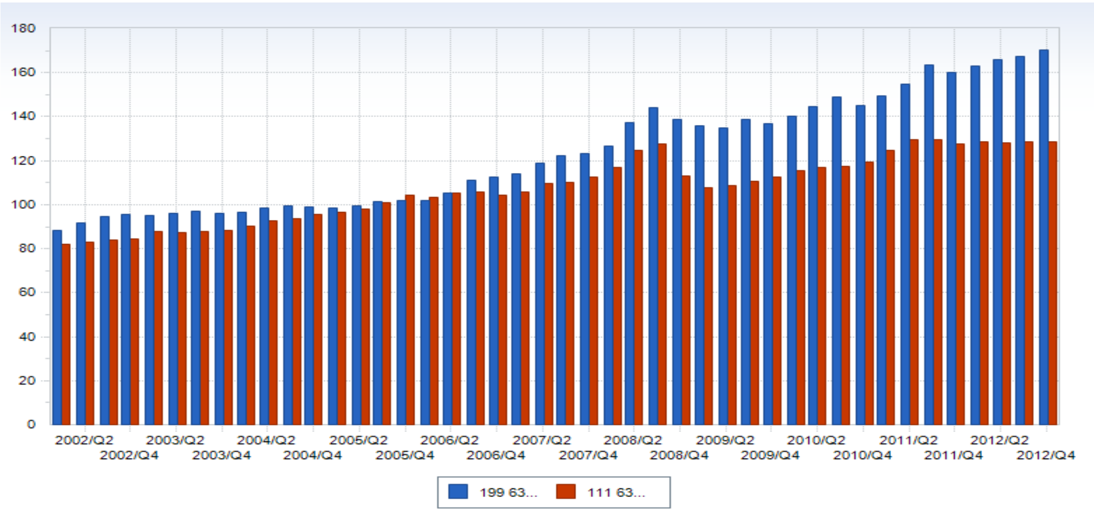


Figure 2. S. Africa and USA price levels (columns)



Then we create the logarithms and the first differences of the variables above:

- **l_xr, which is the logarithm of xr,**
- **l_za_ppp, which is the logarithm of za_ppp,**
- **l_us_ppp, which is the logarithm of us_ppp,**
- **pppDif, which is the difference between l_za_ppp και l_us_ppp,**
- **d_l_xr, which is the first difference of l_xr and**
- **d_pppDif, which is the first difference of pppDif.**

Note that all the variables are converted to logarithms for the obvious reasons of obtaining elasticity coefficients on these variables and minimizing the impact of outliers.

3.2.2 METHODOLOGY

We investigate the long-run equilibrium exchange-rate equation by adopting a co-integrating relationship between the ZAR/USD exchange rate and the ppp differential. The target of this chapter is to explore if there is a stable and robust model for the link between these two variables.

We express the relationship by defining the equation:

$$l\_xr_t = a + b*pppDif_t + u_t \qquad (1)$$

where a = constant, b = coefficient of variable pppDif and u = error term.

[The error term should satisfy the assumptions of normality, constant error variance and orthogonality (independent to the right hand variables -uncorrelated-error terms)].

Furthermore, if cointegration amongst the ZAR/USD exchange rate and the ppp differential is established, then, given the Granger representation theorem, it will be possible to explore the short-run dynamics of such a relationship by the way of standard error-correction (EC) model.

We express this relationship with the equation:

$$d\_l\_xr_t = a + b*d\_pppDif_t + u_{t-1} \qquad (2)$$

where a = constant, b = coefficient of variable d_pppDif and u = error correction term.

Therefore, if we are driven to accept the theory of Purchase Power Parity, that is that there is a positive proportional relationship between the two variables, then the constant must be equal to zero (a=0) and the pppDif coefficient equal to unity (b=1).

Because the steps of the methodology are so detailed and highly

interrelated, we prefer to discuss only some of the most relevant issues in these steps. The first issue is to determine the stationarity (order of integration) of all the variables in equation, the next is performing cointegration tests in order to identify any long run relationships in the variables, a short run error correction model is then estimated on condition of finding cointegration in the previous step and finally, residual diagnostic checks form the last step.

3.2.3 UNIT ROOT TESTS

After the determination of the variables and the methodology, it is possible to conduct the econometric analysis, which consists of a few steps. The first step of the methodology is to determine the order of integration of the series, because in regression analysis involving time series data, a critical assumption is that the time series under consideration is stationary. Broadly speaking, a time series is stationary if its mean and variance are constant over time and "the value of covariance between two time periods depends only on the distance or lag between the two time periods and not on the time at which the covariance is calculated" (Gujarati, 2003: 797). A series that is not stationary is referred to as non-stationary. In addition, a series is said to be integrated and is denoted as *I* (d), where d is the order of integration. The order of integration refers to the number of unit roots in the series, or the number of differencing operations it takes to make a variable stationary.

There are several reasons why the concept of non-stationarity is important and why it is essential that variables that are non-stationary be treated differently from those that are stationary.

First, if a time series is non-stationary, we can study its behavior only for the period under consideration. Each time series will therefore be a particular episode. As a result, it will not be possible to generalize it to other time periods. For forecasting purposes, therefore, non-stationary time series will be of little practical value.

Moreover, the use of non-stationary data can lead to spurious regressions. If two stationary variables are generated as independent random series, when one of those variables is regressed on the other, the t-ratio on the slope coefficient would be expected not to be significantly different from zero, and the value of R^2 would be expected to be very low. This seems obvious, for the variables that are not related to one another. However, if two variables are trending over time, a regression of one on the other could have a high R^2 even if the two are totally unrelated. So, if standard regression techniques are applied to

non-stationary data, the end result could be a regression that looks good under standard measures (significant estimated coefficients and a high R^2), but which is really valueless. Such a model would be termed a "spurious regression". In other words, the dependent variable will follow the trend of its explanatory variables. In such a case, the results will be meaningless. If the variables employed in a regression model are not stationary, then it can be proved that the standard assumptions for asymptotic analysis will not be valid. In other words, the usual t-ratios will not follow a t-distribution, and the F-statistic will not follow an F-distribution. Hence in cases of non-stationary time series, these tests are not reliable.

Consequently, unit root or stationarity tests should be done on all the variables before proceeding with the tests for cointegration and estimation of parameters. There are several tests for stationarity including a visual plot of the data, unit root test and those that directly test for stationarity, among others.

In this study, one informal test for stationarity and one formal test are employed. One of the most popular informal tests for stationarity is the graphical analysis of the series. A visual plot of the series is usually the first step in the analysis of any time series before pursuing any formal tests. This preliminary examination of the data is important as it allows the detection of any data capturing errors and structural breaks and gives an idea of the trends and stationarity of the data set. Figures 3 to 8 plot the variables we created against time:

Figure 3. ZAR/USD exchange rate (lines)

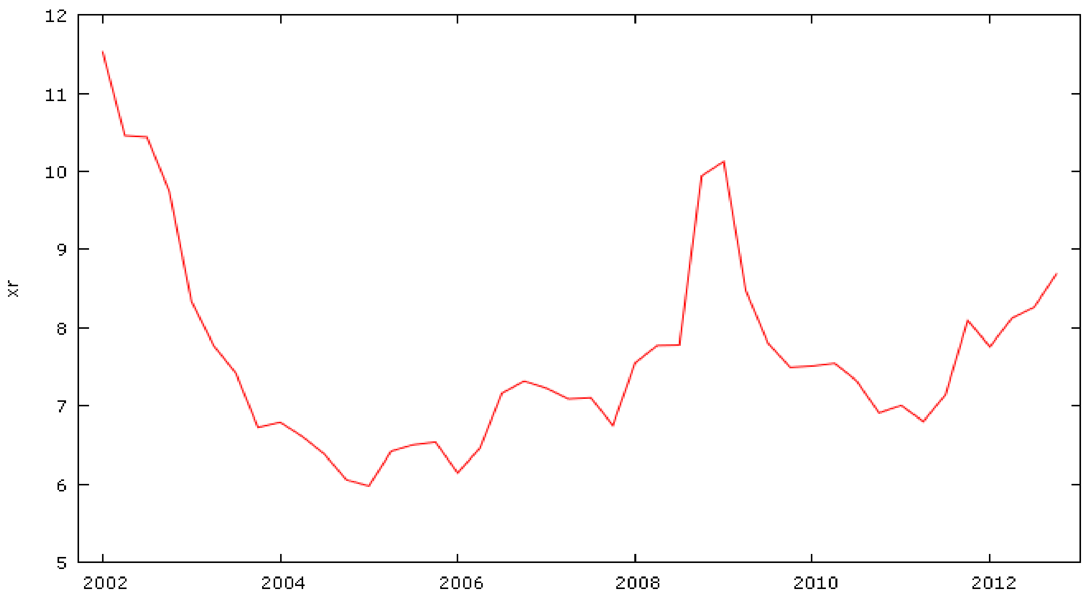


Figure 4. S. Africa and USA price levels (lines)

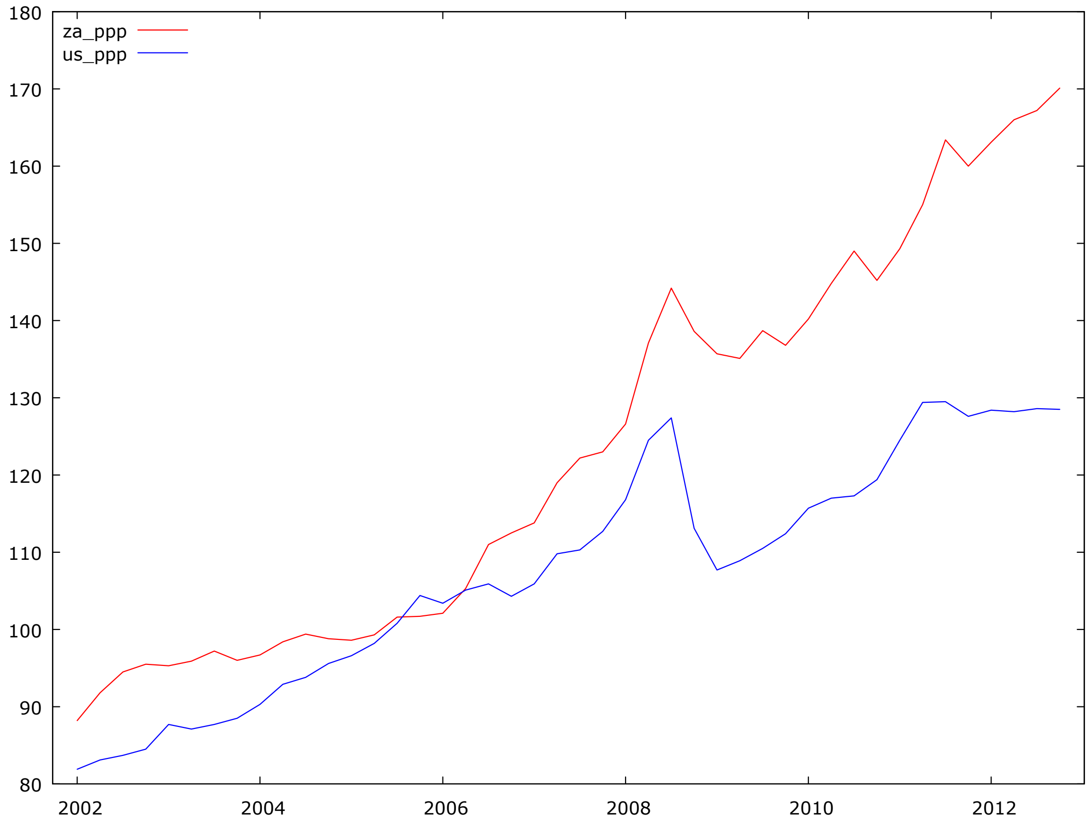


Figure 5. Logarithm of ZAR/USD exchange rate (lines)

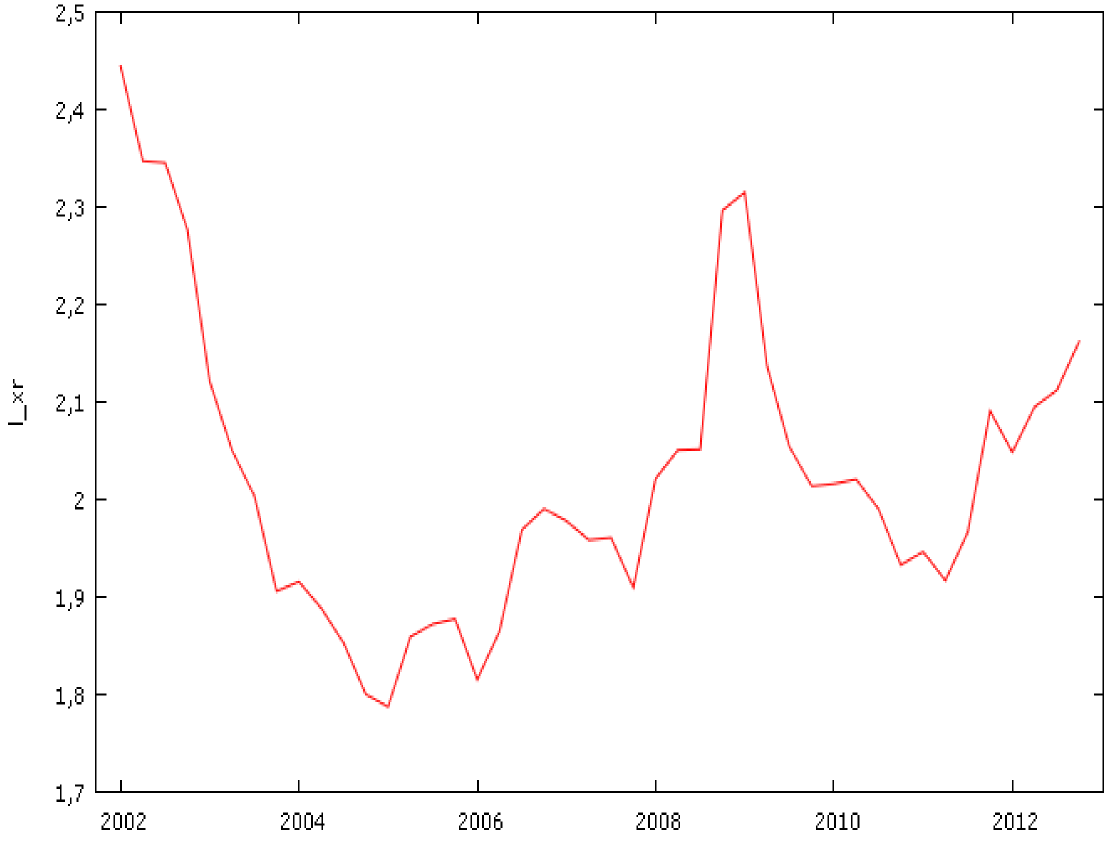


Figure 6. Logarithms of S. Africa and USA price levels (lines)

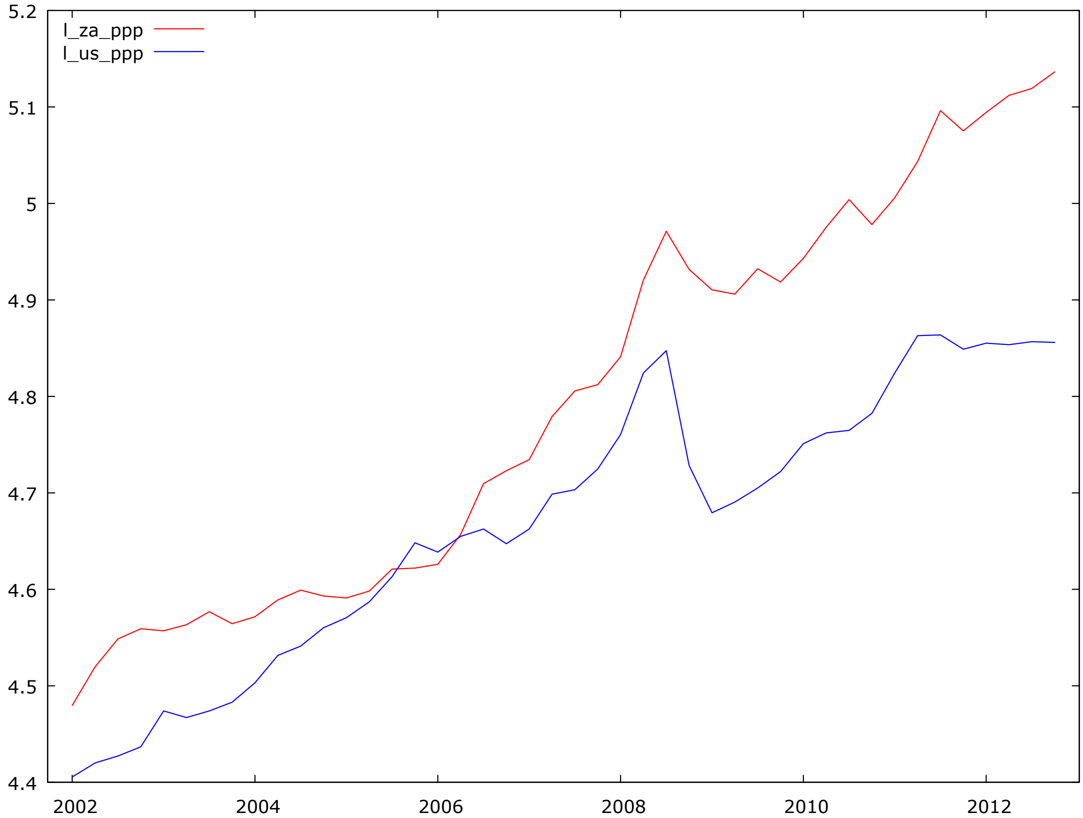


Figure 7. Logarithms of ZAR/USD xr and S. Africa and USA price level differential (lines)

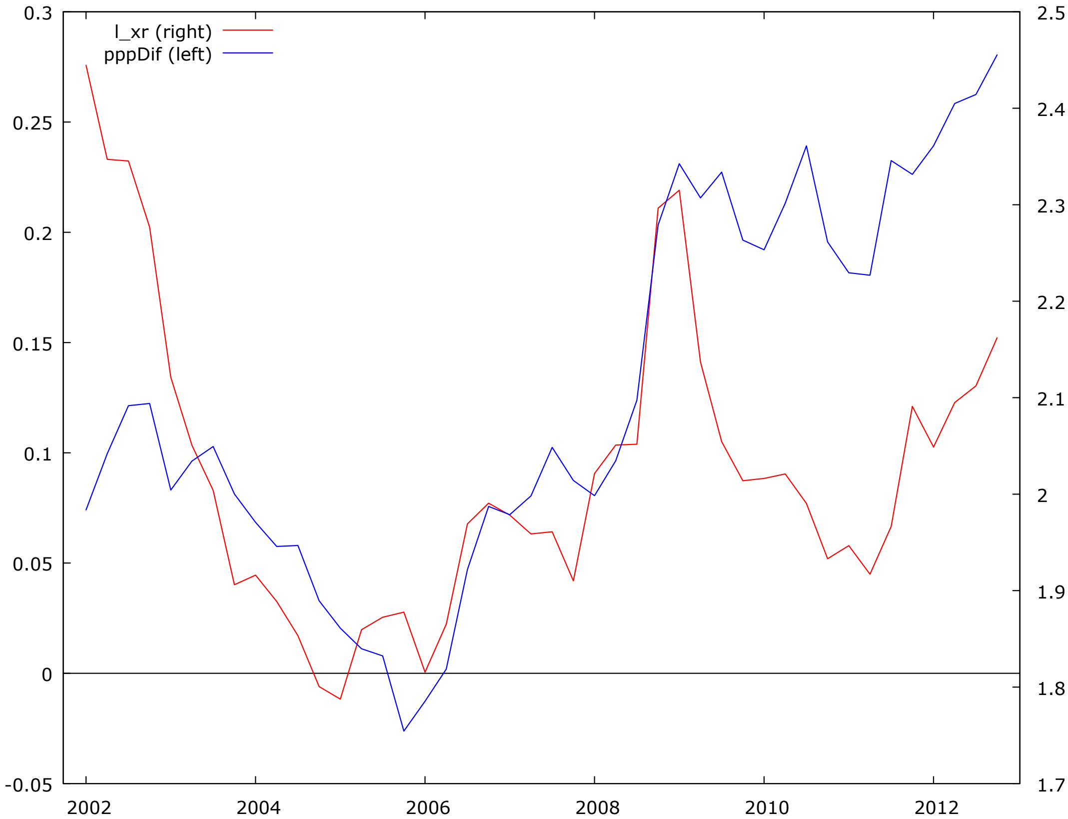
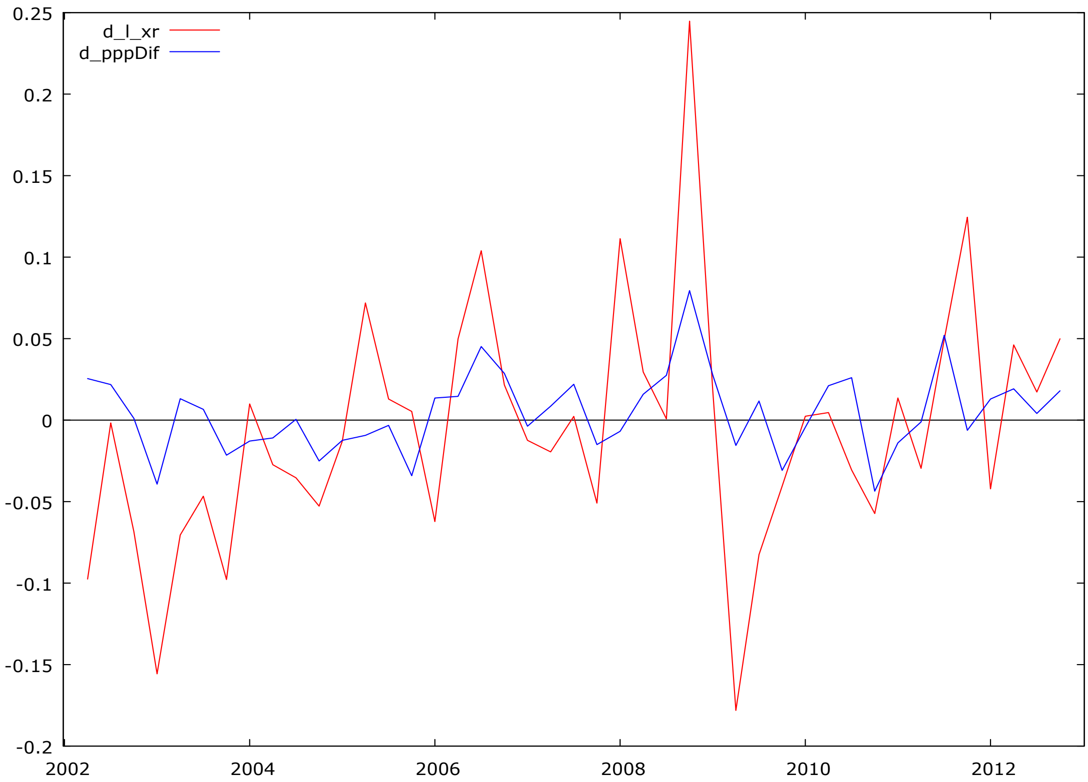


Figure 8. First differences of l_xr and pppDif (lines)



The first impression we get from the plots is that four of the variables (za_ppp, us_ppp, l_za_ppp, l_us_ppp and pppDif) have a time variant mean and variance suggesting that they are not stationary in their levels. Xr and l_xr could be stationary as they seem to be hovering around their means, but their variances are clearly not constant over time. The remaining two variables though (d_l_xr and d_pppDif) clearly follow a stationary process (white noise process), as they move closely around their mean.

However, based on this analysis alone, we cannot be completely sure about the stationarity status of the variables. Therefore, what is required here is some kind of formal hypothesis testing procedure, as the Augmented Dickey-Fuller (ADF) test. An augmented Dickey-Fuller test is a version of the Dickey-Fuller test (Dickey, 1979) for a larger and more complicated set of time series models. The augmented Dickey-Fuller (ADF) statistic, used in the test, is a negative number and the more negative it is, the stronger the rejections of the hypothesis that there is a unit root at some level of confidence. This test is conducted by "augmenting" the preceding equations by adding the lagged values of the dependent variable. In other words, it corrects for high-order serial correlation by

adding a lagged differenced term on the right-hand side in the DF equation. The results are depicted in the following tables (2 - 5):

Table 2. ADF test for l_xr

```
Dickey-Fuller test for l_xr
sample size 43
unit-root null hypothesis: a = 1

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.165
   estimated value of (a - 1): -0.177432
   test statistic: tau_ct(1) = -2.72156
   p-value 0.2335
```

Table 3. ADF test for pppDif

```
Dickey-Fuller test for pppDif
sample size 43
unit-root null hypothesis: a = 1

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.212
   estimated value of (a - 1): -0.100123
   test statistic: tau_ct(1) = -1.4967
   p-value 0.8154
```

Table 4. ADF test for d_l_xr

```
Dickey-Fuller test for d_l_xr
sample size 42
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.035
   estimated value of (a - 1): -0.772777
   test statistic: tau_c(1) = -5.08114
   p-value 0.0001402

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.042
   estimated value of (a - 1): -0.841484
   test statistic: tau_ct(1) = -5.35771
   p-value 0.0004022
```

Table 5. ADF test for d_pppDif

```
Dickey-Fuller test for d_pppDif
sample size 42
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.013
   estimated value of (a - 1): -0.783337
   test statistic: tau_c(1) = -5.10279
   p-value 0.0001312

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: -0.001
   estimated value of (a - 1): -0.813378
   test statistic: tau_ct(1) = -5.26236
   p-value 0.0005295
```

It is clear that for both l_xr and pppDif the asymptotic p-values of 0,2335 and 0,8154 respectively are higher than the 5 per cent level of significance. Thus, the unit root hypothesis cannot be rejected and these two variables are non-stationary time series, integrated of order one (I_1).

The same test applied for the first differences of the logarithms show asymptotic p-values of 0,0004022 and 0,0005295 (lower than 0,05) for d_l_xr and d_pppDif respectively, which means that there are no unit roots and these series are stationary, integrated of order zero (I_0).

3.2.4 LONG-RUN COINTEGRATION

If we regress a non-stationary time series on one or more non-stationary series, we may obtain a high adjusted R^2 value and regression coefficients that are statistically significant on the basis of the usual t and F tests. But these results are likely to be spurious or misleading because the standard linear regression procedures assume that the time series involved in the analysis are stationary. So, in the case of the l_xr and the pppDif the resulting regression may be a spurious regression. The situation in which the regression of a non-stationary time series X on one other non-stationary time series Y may not result in a spurious regression is called cointegration. This means that, although X and Y are non-stationary time series, they become stationary when differenced such that some linear combination of them is stationary. In other words, while neither X nor Y alone hovers around a constant value, if some combination of them does so, we can think of cointegration as describing a particular kind of long-run equilibrium relationship.

As Gujarati (1995: 42) puts it "the movement resembles two dancing partners, each following a random walk, whose random walks seem to be in unison". Therefore, synchrony is intuitively the idea behind cointegrated time series. Brooks further shows that "it is possible that co-integrating variables may deviate from the relationship in the short run, but their association would return in the long-run".

Since both l_xr and pppDif series are (I_1), this can be achieved by applying an ordinary least squares model (OLS). We set l_xr as the dependent variable and constant and pppDif as the regressors. This method will first estimate the regression coefficients of the equation for the time period 2002:1 - 2012:4 and the next step is to save the residuals, to name them "resids1" and to perform an ADF test to them in order to be examined for stationarity. If the residuals are stationary, then the variables are cointegrated. The results are shown in tables 6 and 7.

Table 6. OLS regression model of depended l_xr and independed pppDif

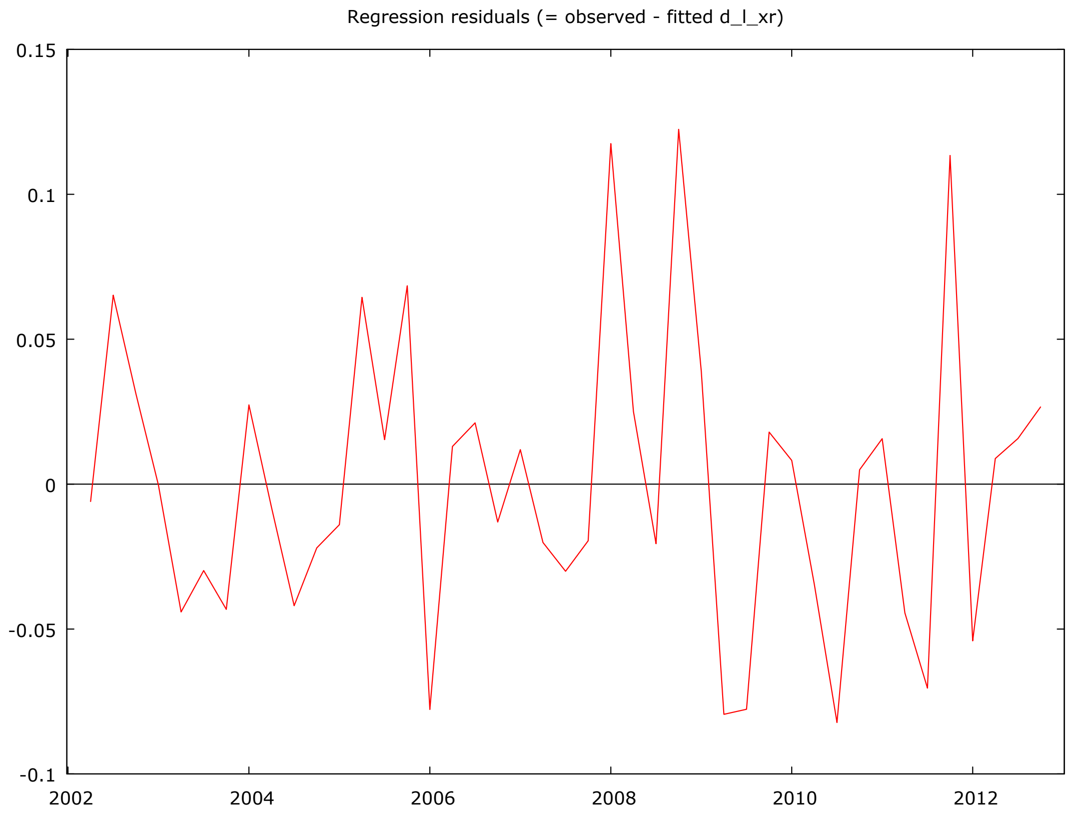
```
Model 1: OLS, using observations 2002:1-2012:4 (T = 44)
Dependent variable: l_xr
HAC standard errors, bandwidth 2 (Bartlett kernel)

             coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------
  const       1.92195      0.0491403    39.11     1.14e-034 ***
  pppDif      0.807559     0.260087      3.105    0.0034    ***

Mean dependent var   2.023660   S.D. dependent var   0.156027
Sum squared resid    0.841392   S.E. of regression   0.141538
R-squared            0.196232   Adjusted R-squared   0.177095
F(1, 42)             9.640806   P-value(F)           0.003402
Log-likelihood       24.61822   Akaike criterion    -45.23645
Schwarz criterion   -41.66807   Hannan-Quinn        -43.91312
rho                  0.762986   Durbin-Watson        0.219595

Log-likelihood for xr = -64.4228
```

Table 7. ADF test for resids1

```
Dickey-Fuller test for resids1
sample size 43
unit-root null hypothesis: a = 1

   test without constant
   model: (1-L)y = (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.177
   estimated value of (a - 1): -0.237014
   test statistic: tau_nc(1) = -3.79911
   p-value 0.0003321
```

The estimated from OLS model residuals are stationary, as the asymptotic p-value of 0,0003321 is lower than 0,05. Thus, the unit root hypothesis is rejected and resids1 is integrated of order zero (I_0). The same conclusion can be made also by the graphical analysis of the time series as depicted in figure 9.

Figure 9. Regression Residuals (observed - fitted d_l_xr)



It is obvious that the mean and the variance are constant over time and the value of covariance between two time periods depends only on the distance or gap between the two periods and not the actual time at which the covariance is computed. Thus, the time series "resids1" is cointegrated and there is a long-term equilibrium relationship between the exchange rate and the ppp differential of South Africa and the U.S.A.

By looking the figure 7 we can make some assumptions, too. We observe that at the beginning (2002) l_xr and pppDif do not proceed together, but from years 2003 to 2009 they appear to have a common trend and a similar volatility. From 2009 to 2nd quarter of 2011 the trend remains the same, but the fluctuations are not of the same proportion. At the last range (mid 2011 to 2012) the two variables seem to have a more robust relationship. This is also confirmed by the correlation matrix, as we see that with a p-value of 0.0026, lower than the critical value of 0.05, the null hypothesis of no correlation is rejected. Moreover, the positive sign (+0.44) indicates that there is a positive correlation, which means that, if the ppp differential rises, the exchange rate will appreciate.

Table 8. Corr l_xr to pppDif

```
corr(l_xr, pppDif) = 0.44298105
Under the null hypothesis of no correlation:
 t(42) = 3.20217, with two-tailed p-value 0.0026
```

At last, but not least, we have to examine the results of our model as depicted on table 6. At first glance, reaching the statistically significance of 1% level for both our variables is very satisfactory, as * indicate, as well as their p-values (1.14e-034 and 0.0034), both well lower than 0.05. This conclusion also derives from the omission tests in which both const and pppDif are proved to be essential for the model, as presented at tables 9 and 10.**

Table 9. Const omission test result

```
Test on Model 1:

  Null hypothesis: the regression parameter is zero for const
  Test statistic: Robust F(1, 42) = 1529.71, p-value 1.14226e-034
  Omitting variables improved 0 of 3 model selection statistics.
```

Table 10. PppDif omission test result

```
Test on Model 1:

  Null hypothesis: the regression parameter is zero for pppDif
  Test statistic: Robust F(1, 42) = 9.64081, p-value 0.00340237
  Omitting variables improved 0 of 3 model selection statistics.
```

In contrary to the theory, the coefficient of the constant is 1.92195 (not zero), but the coefficient of the pppDif is 0.807559, relatively close to unity. Hence, to be certain, we should investigate whether these values are such that we can accept that equal 0 and 1 respectively, applying the linear restriction tests. Setting b [const] = 0 and b [pppDif] = 1 result as follows:

Table 11. Restriction of const (b=0)

```
Restriction:
 b[const] = 0

Test statistic: Robust F(1, 42) = 1529.71, with p-value = 1.14226e-034

Restricted estimates:

             coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------
  const        0.00000      0.00000      NA        NA
  pppDif      11.3223       1.08612      10.42      2.41e-013 ***

  Standard error of the regression = 1.09313
```

Table 12. Restriction of pppDif (b=1)

```
Restriction:
 b[pppDif] = 1

Test statistic: Robust F(1, 42) = 0.547466, with p-value = 0.463471

Restricted estimates:

             coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------
  const        1.89771     0.0212338     89.37     1.78e-050 ***
  pppDif       1.00000     0.00000       NA        NA

  Standard error of the regression = 0.140849
```

The possibility that b=0 for the constant is 1.14226e-034 (< 0.05). This value means that we should reject the linear restriction and that the theory is here not confirmed.

For pppDif though, the possibility that b=1 is 0,463 (> 0.05). This value means that we should accept the linear restriction and that the theory is confirmed.

Nevertheless, the sign of the coefficient of pppDif is positive (+0.807559), in compliance to the PPP theory.

However, the adjusted R-squared indicates that only 17,71% of the actual observations of l_xr are interpreted by the model, which is a percentage that is far away from our expectations of the model.

3.2.5 ERROR CORRECTION MODEL

We have shown that l_xr and pppDif time series are cointegrated, which means that they have a long-term, or equilibrium, relationship. We will now examine how this equilibrium is achieved and if there may be a disequilibrium in the short-run.

According to the Granger Representation Theorem, if two variables are cointegrated, the relationship between them can be expressed as an ECM. In this chapter, we will see how VECM ties short-run dynamics to long-run relations via the error correction term. If we re-write the equation (1) as

$$u_t = l\_xr_t - a - b * pppDif_t \tag{3}$$

or

$$u_t = l\_xr_t - 1.92195 - 0.807559 * pppDif_t \tag{4}$$

we obtain the error term u which can be treated as the term which corrects the ZAR/USD exchange rate deviations from its equilibrium.

A crucial parameter to note in the estimation of ECM is the coefficient of adjustment which, in this study, measures the speed of adjustment in the exchange rate following a shock in the system. It can also be seen as a measure of the degree of adjustment of the actual exchange rate with regard to its equilibrium level.

The next step is to apply again the OLS method, setting d_l_xr as the dependent variable and constant, d_pppDif and resids1_1 as the regressors. We note that after some trials the residuals of lag order one were proved to be more statistically significant than those of every other lag order tested and this is the reason why this variable was chosen in our model instead of the resids1 that were saved from model (1). The results are depicted in table 13.

Table 13. OLS regression model of depended d_l_xr and independed d_pppDif

```
Model 2: OLS, using observations 2002:2-2012:4 (T = 43)
Dependent variable: d_l_xr
HAC standard errors, bandwidth 2 (Bartlett kernel)

              coefficient   std. error   t-ratio   p-value
  ---------------------------------------------------------
  const       -0.0154517    0.00645331   -2.394    0.0214    **
  d_pppDif     1.83333      0.491292      3.732    0.0006    ***
  resids1_1   -0.265224     0.0471727    -5.622    1.60e-06  ***

Mean dependent var   -0.006570   S.D. dependent var   0.073691
Sum squared resid     0.107050   S.E. of regression   0.051732
R-squared             0.530636   Adjusted R-squared   0.507168
F(2, 40)              19.03278   P-value(F)           1.56e-06
Log-likelihood        67.89242   Akaike criterion    -129.7848
Schwarz criterion    -124.5012   Hannan-Quinn        -127.8364
rho                  -0.048136   Durbin-Watson        2.088679
```

The 3 stars (***) we see next to the residuals' p-value indicate significance at the 1 percent level. Moreover, based on resids1_1 coefficient, about 26.5 per cent of the gap between the actual exchange rate and its equilibrium value is eliminated every next quarter. This suggests a rather high rate of adjustment to equilibrium.

Furthermore, both d_pppDif and const are statistically significant (p-values lower than 0.05, 0.0006 and 0.0214 respectively), even at 5% the latter. This conclusion also derives from the omission tests in which both const and pppDif are proved to be essential for the model, as presented at tables 14, 15 and 16.

Table 14. Const omission test result

```
Test on Model 2:

  Null hypothesis: the regression parameter is zero for const
  Test statistic: Robust F(1, 40) = 5.7331, p-value 0.0214247
  Omitting variables improved 0 of 3 model selection statistics.
```

Table 15. D_pppDif omission test result

```
Test on Model 2:

  Null hypothesis: the regression parameter is zero for d_pppDif
  Test statistic: Robust F(1, 40) = 13.9252, p-value 0.00059102
  Omitting variables improved 0 of 3 model selection statistics.
```

Table 16. Resids1_1 omission test result

```
Test on Model 2:

  Null hypothesis: the regression parameter is zero for resids1_1
  Test statistic: Robust F(1, 40) = 31.6115, p-value 1.60344e-006
  Omitting variables improved 0 of 3 model selection statistics.
```

The value of the coefficient of the constant, although not exactly zero as the p-value of 0.0214247 of table 14 indicates, dropped to almost zero (-0.0154517) which agrees to the theory and even the value of the coefficient of d_pppDif (1.83333) is considered to be unity, again in compliance to the PPP theory, as the linear restriction is accepted with a p-value of 0.0976184, higher than the critical value of 0.05 (table 18). Nevertheless, the sign of the coefficient of d_pppDif is positive (+1.83333), as the PPP theory argues.

Table 17. Restriction of const (b=0)

```
Restriction:
 b[const] = 0

Test statistic: Robust F(1, 40) = 5.7331, with p-value = 0.0214247

Restricted estimates:

               coefficient   std. error   t-ratio    p-value
  -----------------------------------------------------------
  const         0.00000      0.00000      NA         NA
  d_pppDif      1.70767      0.334929      5.099      8.16e-06 ***
  resids1_1    -0.261548     0.0589339    -4.438      6.69e-05 ***

  Standard error of the regression = 0.0534001
```

Table 18. Restriction of d_ pppDif (b=1)

```
Restriction:
 b[d_pppDif] = 1

Test statistic: Robust F(1, 40) = 2.8771, with p-value = 0.0976184

Restricted estimates:

               coefficient   std. error   t-ratio   p-value
  ----------------------------------------------------------
  const        -0.0114455    0.00838701   -1.365     0.1798
  d_pppDif      1.00000      0.00000      NA        NA
  resids1_1    -0.242445     0.0599640    -4.043     0.0002 ***

  Standard error of the regression = 0.0549972
```

3.2.6 STABILITY TESTS

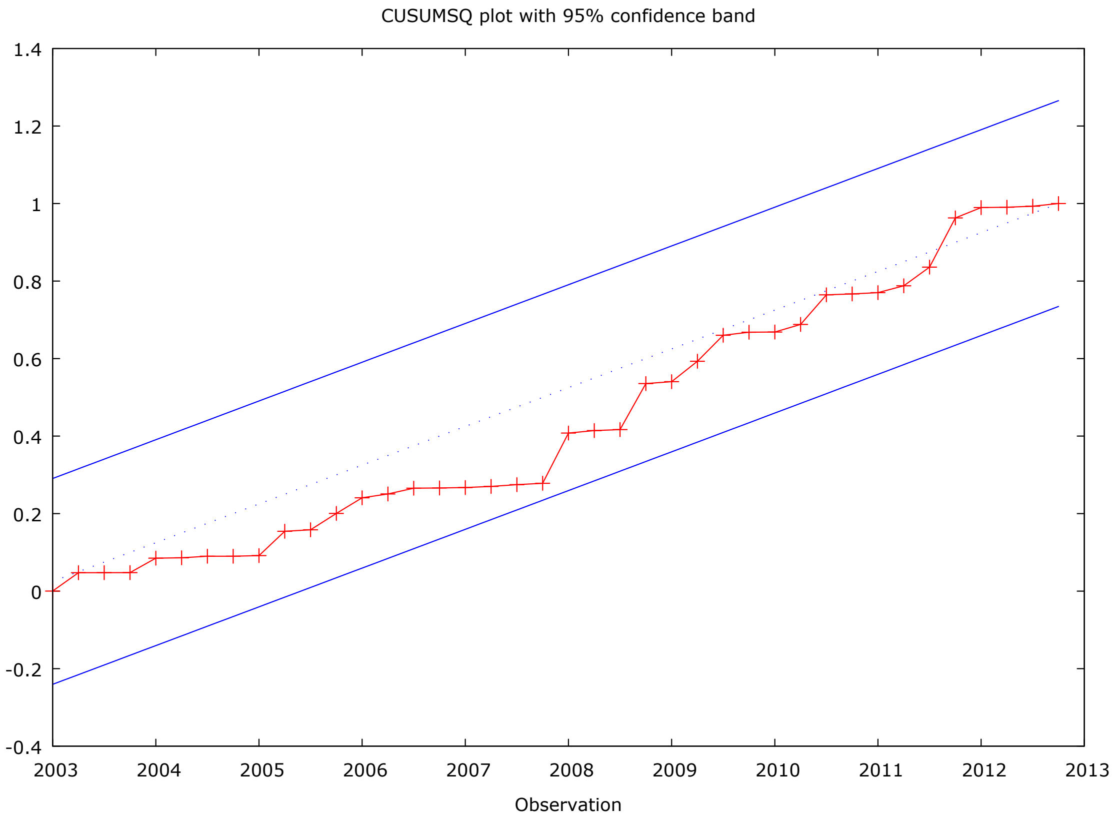
We need to confirm that the results from the ECM we have just reported are deriving from efficient models with well-behaved residuals. Thus, the next step is to perform diagnostic tests on the residuals from the alternative model specifications. Diagnostic checks are crucial in this analysis, because if there is a problem in the residuals from the estimation of a model, it is an indication that the model is not efficient, such that parameter estimates from such a model may be biased.

Two important stability tests, known as the CUSUM and CUSUMSQ tests, are derived from the residuals of the recursive estimation.

The CUSUM statistic is based on a normalized version of the cumulative sums of the residuals. Under the null hypothesis of perfect parameter stability, the CUSUM statistic is zero however many residuals are included in the sum (because the expected value of a disturbance is always zero). A set of ±2 standard error bands is usually plotted around zero and any statistic lying outside the bands is taken as evidence of parameter instability. In addition, the CUSUMSQ test is based on a normalized version of the cumulative sums of squared residuals. The scaling is such that under the null hypothesis of parameter stability, the CUSUMSQ statistic will start at zero and end the sample with a value of 1. Again, a set of ±2 standard error bands is usually plotted around zero and any statistic lying outside these is taken as evidence of parameter instability.

By performing the CUSUMSQ test, the results are depicted in figure 10.

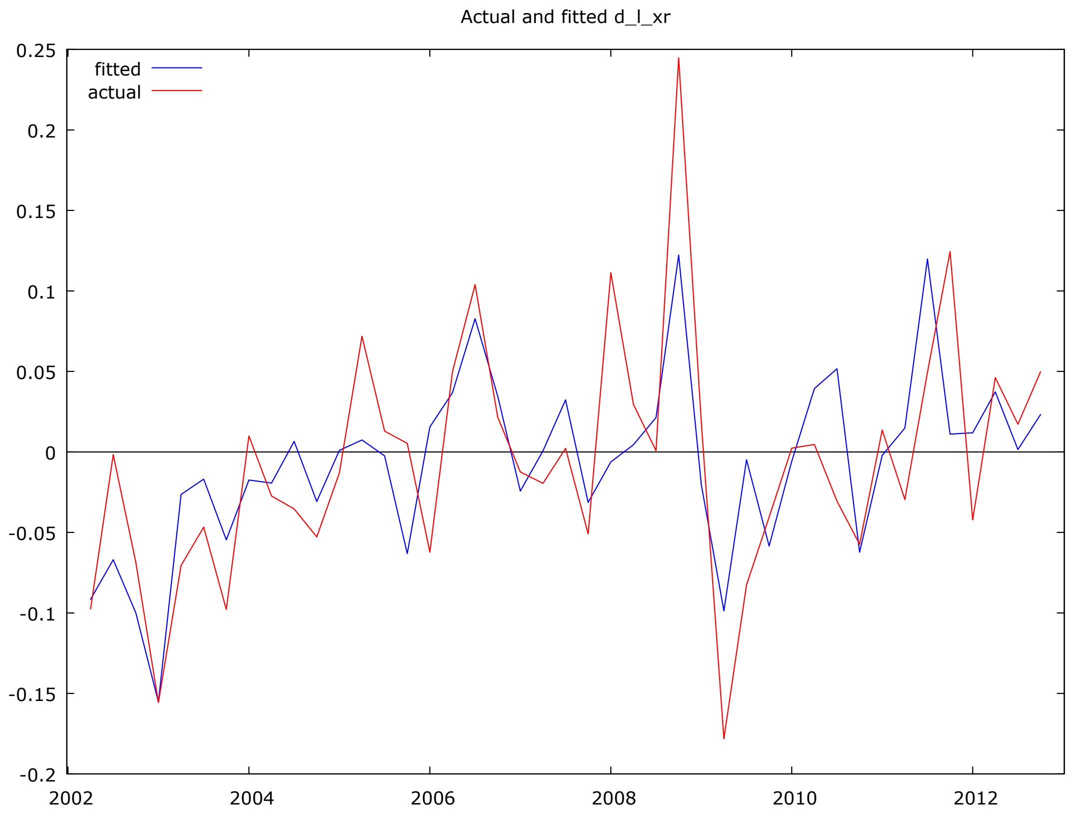
Figure 10. CUSUMSQ plot for the residuals of OLS regression model



According to figure 10, the red line is well within the confidence bands and at no point the confidence band is exceeded. As a consequence, the conclusion of parameter stability should not be rejected, since the null hypothesis of the tests is that the stability of the parameters.

Nevertheless, a plot of the actual and the fitted values of d_l_xr as the one presented below (figure 11) shows that the values calculated by the Error Correction Model are well fitted to the actual ones:

Figure 11. Actual and fitted d_l_xr prices



Summarizing the conclusions mentioned in this chapter, we conclude that the current model may not be adequate for the interpretation of the movements of the ZAR/USD exchange rate. Therefore, we will import one more independent variable in order to obtain a better adjustment. For this purpose, the yield curve differential between the South Africa and the U.S.A. is chosen.

3.3 THE RELATIONSHIP BETWEEN THE ZAR/USD EXCHANGE RATE AND PPP AND YIELD CURVE DIFFERENTIALS

3.3.1 DATA

The first step would be again to determinate the variables of the model, which we import into the software. The time series that we use are quarterly average data collected from the International Statistical Yearbook of International Monetary Fund and the sampling period begins at 1st quarter of 2002 and ends on the last quarter of 2012.

We define the variables and present their figures (figures 12 and 13) as follows:

- **199 60B: Money Market Rate/ percent per annum/ averages/ Cnt: South Africa/ Source: IMF, Wash → za_rates, for South Africa's interest rates,**
- **111 60LDD: 3-month U.s Dep. Libor/ percent per annum/ averages/ US$/ Cnt: United States/ Source: IMF, Wash → us_rates, for the U.S.A.'s interest rates,**
- **199 61: Government Bond Yield/ percent per annum/ averages/ Cnt: South Africa/ Source: IMF, Wash → za_bonds, for South Africa's government bonds and**
- **111 61: Govt Bond Yield: 10 Year/ percent per annum/ averages/ Cnt: United States/ Source: IMF, Wash → us_bonds, for the U.S.A.'s government bonds.**

Figure 12. S. Africa and USA interest rates (columns)

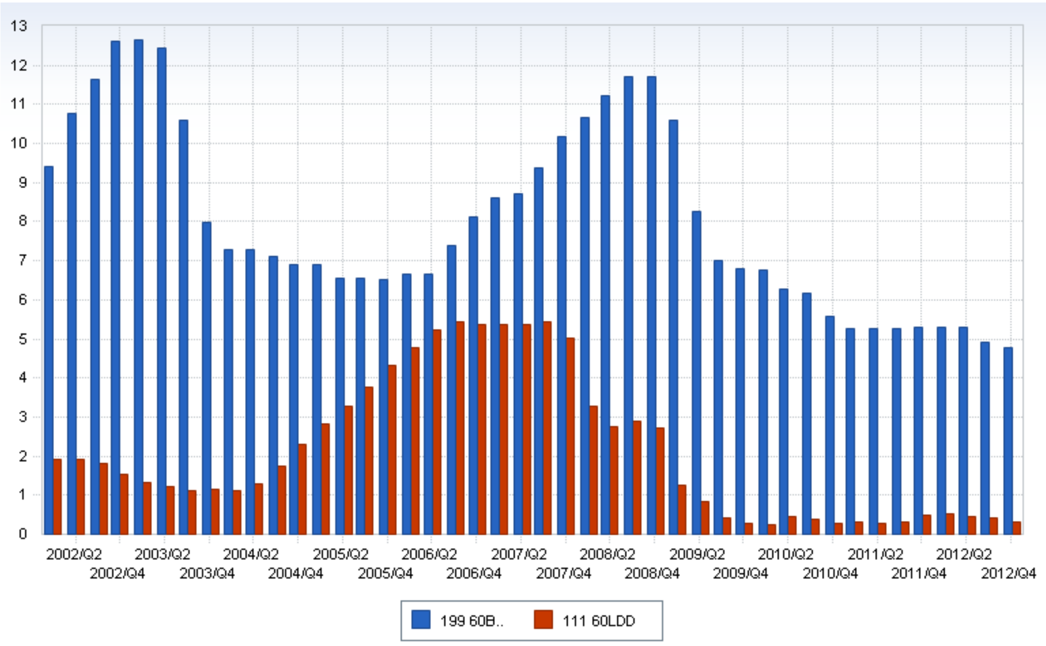
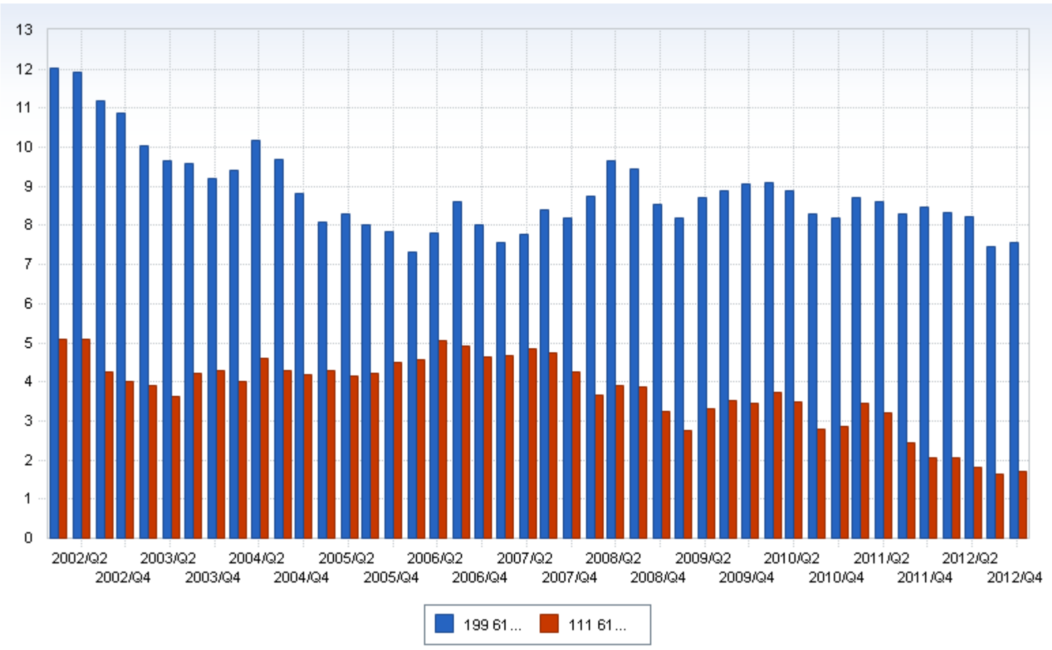


Figure 13. S. Africa and USA government bond yields (columns)



Then we create the logarithms and the first differences of the variables above:

- **za_yieldcurve, which is the difference between za_bonds and za_rates,**
- **us_yieldcurve, which is the difference between us_bonds and us_rates,**
- **yieldcurveDif, which is the difference between za_yieldcurve and us_yieldcurve and**
- **d_yieldcurveDif, which is the first difference of yieldcurveDif.**

3.3.2 METHODOLOGY

We investigate the long-run equilibrium exchange-rate equation by adopting the previously found co-integrating relationship between the ZAR/USD exchange rate and the ppp differential and adding the yield curve differential between South Africa and the U.S.A. as a parameter that may improve the results of the regression. The target of this chapter is to explore if the model becomes more stable and robust for the link between the exchange rate and both the ppp and the yield curve differentials.

Since we are interested in accounting for the yield curves' dynamics and the exchange rate is determined not only by the fundamentals (ppp) but also by the expectations, we re-write the equation (1) to include the differential between the long and the short interest rates, which is supposed to affect these expectations, as follows:

$$l\_xr_t = a + b * pppDif_t + c * yieldcurveDif_t + u_t \qquad (5)$$

where a = constant, b = coefficient of variable pppDif, c = coefficient of variable yieldcurveDif and u = error term. The stochastic error term is a catchall that includes all the variables that cannot be readily quantified. It may represent variables that cannot be included in the model for lack of data availability or errors of measurement in the data or intrinsic randomness in human behavior.

Furthermore, given the Granger representation theorem, we will explore the short-run dynamics of such a relationship by the way of standard error-correction (EC) model, re-writing the equation (5) as follows:

$$d\_l\_xr_t = a + b * d\_pppDif_t + c * d\_yieldcurveDif_t + u_{t-1} \qquad (6)$$

We will first test the hypothesis that b $\neq$ 0 and c $\neq$ 0, as well as the theoretical restrictions that imply that a=0 and the value of the yield curve differential is negative and statistically significant. The expected sign on the yield

curve differential is negative, because an increase in the yield curve differential will make the domestic currency appreciate.

3.3.3 UNIT ROOT TESTS

After the determination of the variables and the methodology, it is possible to conduct the econometric analysis, with the very first step (for reasons that were analyzed in section 3.2.3) to be the determination of the order of integration of the series.

Both the informal test of the graphical analysis of the series for stationarity and the formal hypothesis testing procedure of the Augmented Dickey-Fuller (ADF) test are employed.

Figures 14 to 18 plot the variables we created against time:

Figure 14. S. Africa and USA interest rates (lines)

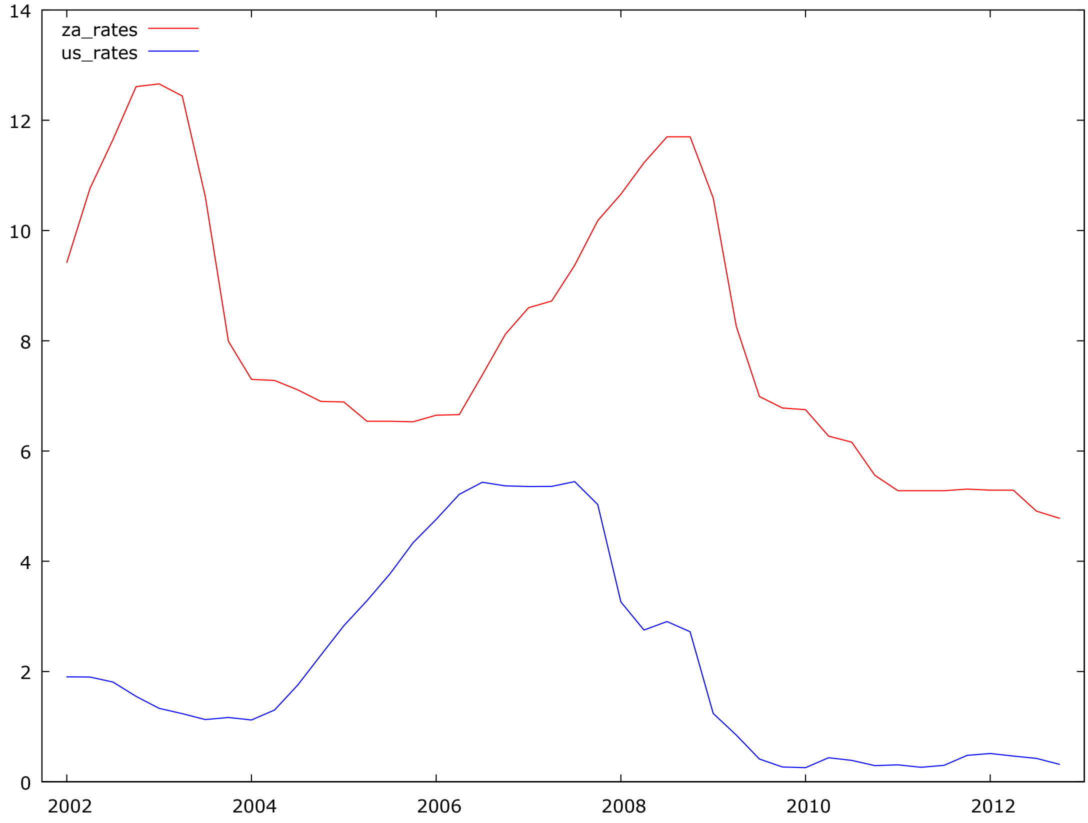


Figure 15. S. Africa and USA government bond yields (lines)

Figure 16. S. Africa and USA yield curves (lines)

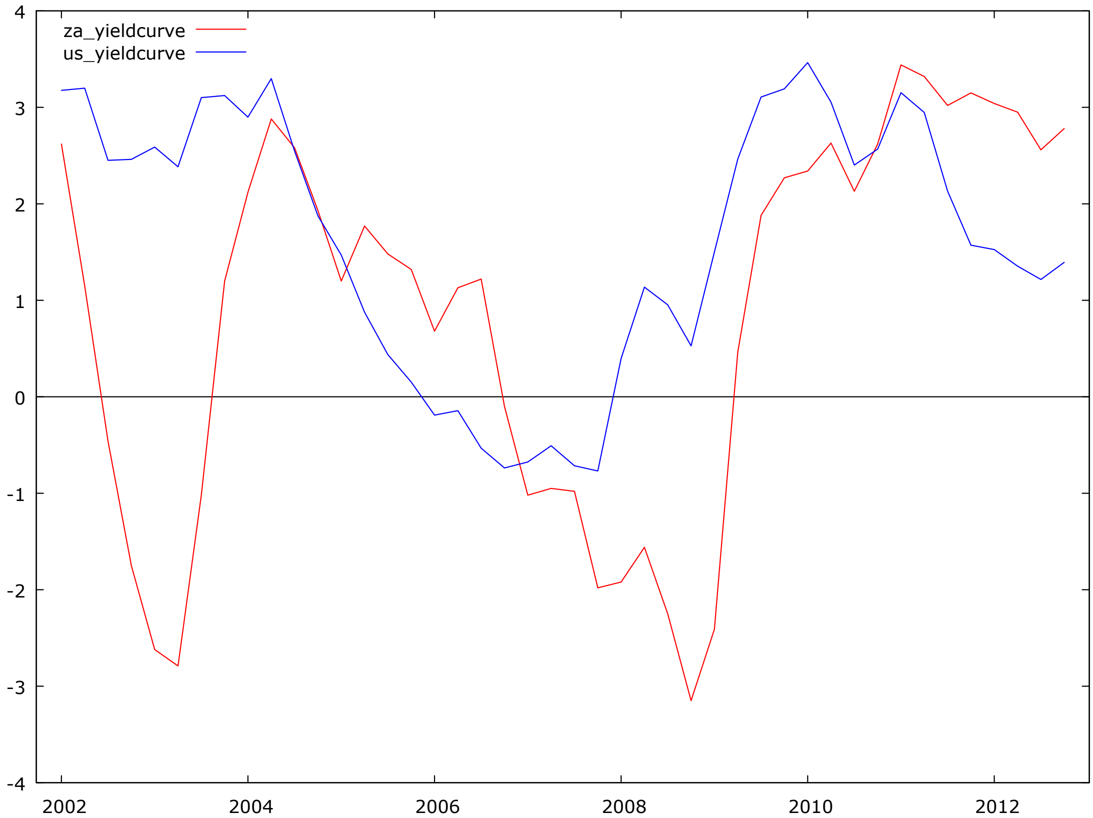


Figure 17. Logarithm of ZAR/USD xr and S. Africa and USA yield curve differential

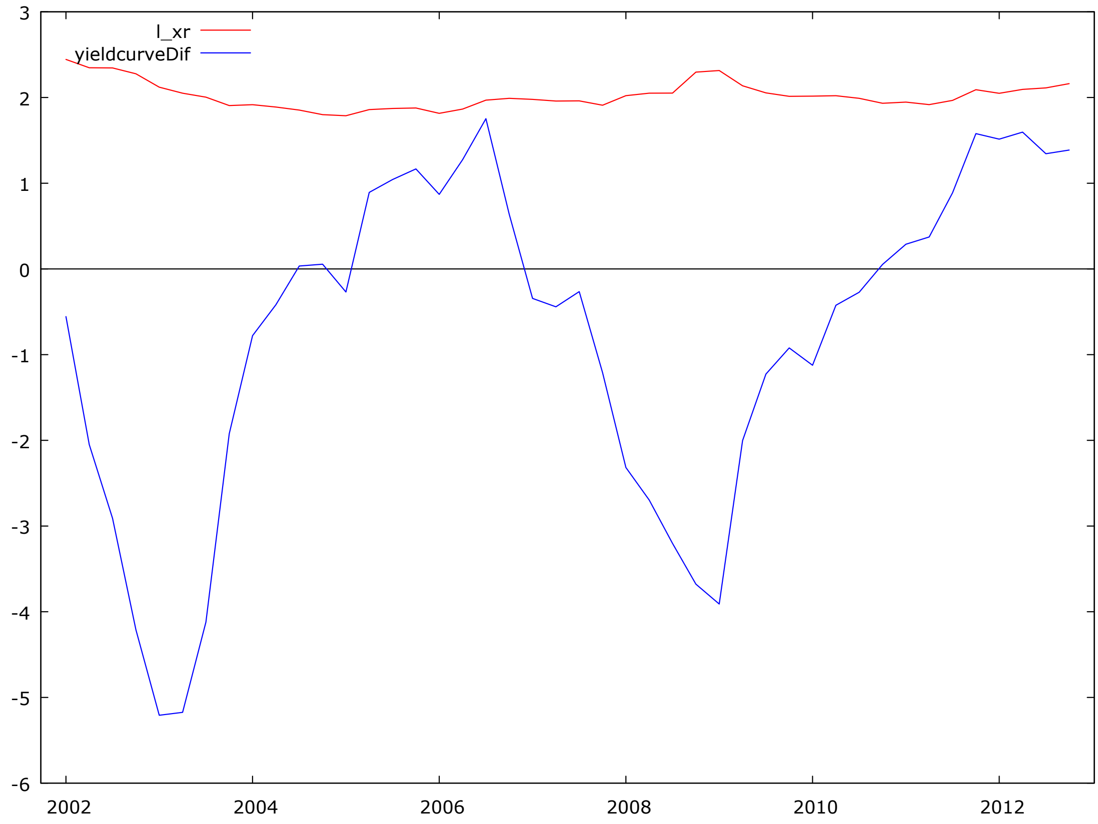
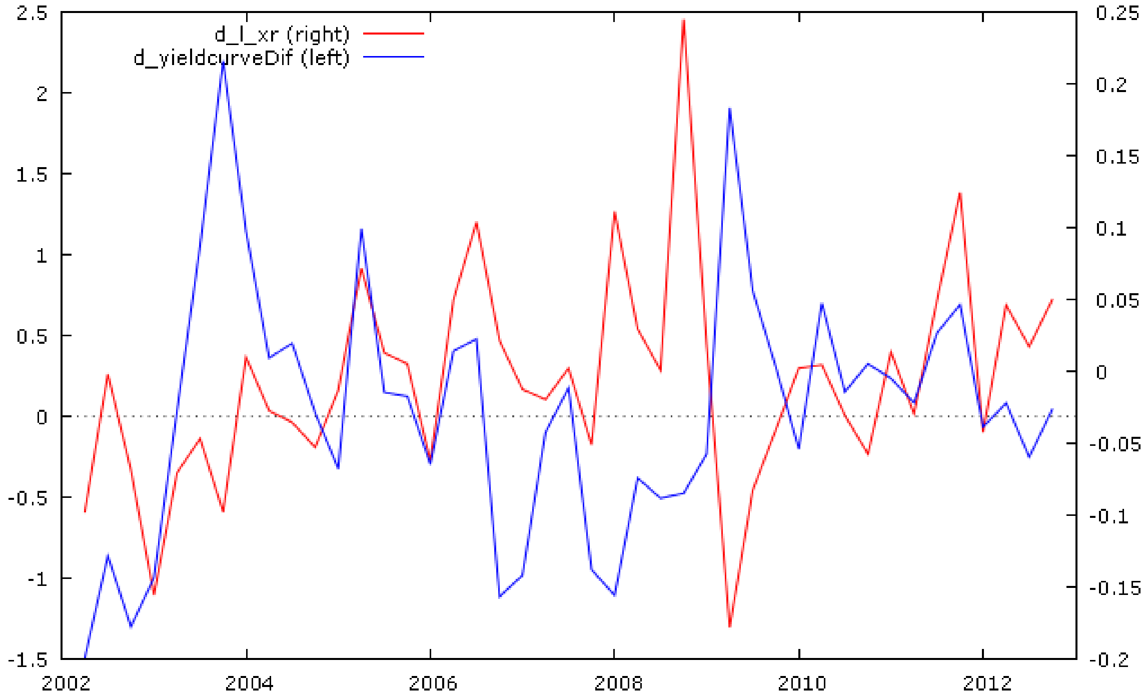


Figure 18. First differences of ZAR/USD l_xr and S. Africa and USA yield curve differential



A visual plot of the series above is the first step in the analysis of any time series before pursuing any formal tests. This preliminary examination of the data gives the impression that the yield curve differential has a time variant mean and variance suggesting that it is not a stationary time series, while the first difference of the variable clearly follows a stationary process (white noise process), as it moves closely around its mean.

However, based on this analysis alone, we cannot be completely sure about the stationarity status of the variables. Therefore, an Augmented Dickey-Fuller (ADF) test is applied. The results are depicted in the tables 19 and 20:

Table 19. ADF test for yieldcurveDif

```
Dickey-Fuller test for yieldcurveDif
sample size 43
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.516
   estimated value of (a - 1): -0.0679793
   test statistic: tau_c(1) = -1.0811
   p-value 0.7148

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.529
   estimated value of (a - 1): -0.10861
   test statistic: tau_ct(1) = -1.59005
   p-value 0.7805
```

Table 20. ADF test for d_ yieldcurveDif

```
Dickey-Fuller test for d_yieldcurveDif
sample size 42
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.051
   estimated value of (a - 1): -0.503432
   test statistic: tau_c(1) = -3.91797
   p-value 0.004229

   with constant and trend
   model: (1-L)y = b0 + b1*t + (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.048
   estimated value of (a - 1): -0.501303
   test statistic: tau_ct(1) = -3.81893
   p-value 0.02522
```

It is clear that for yieldcurveDif the asymptotic p-value of 0,7148 is higher than the 5 per cent level of significance. Thus, the unit root hypothesis cannot be rejected and the variable is a non-stationary time series, integrated of order one (I_1).

The same test applied for the first difference of the logarithm show an asymptotic p-value of 0,004229 (lower than 0,05), which means that the null hypothesis is rejected, there are no unit roots and these series are stationary, integrated of order zero (I_0).

3.3.4 LONG-RUN COINTEGRATION

Since both l_xr, pppDif and yieldcurveDif series are (I_1), a long-run cointegration relationship can be achieved by applying an ordinary least squares model (OLS). We set l_xr as the dependent variable and constant, pppDif and yieldcurveDif as the regressors. This method will first estimate the regression coefficients of the equation for the time period 2002:1 - 2012:4 and the next step is to save the residuals, to name them "resids2" and to perform an ADF test to them in order to be also examined for stationarity. If the residuals are stationary, then the variables are cointegrated. The results are shown in tables 21 and 22.

Table 21. OLS regression model of depended l_xr and independed pppDif and yieldcurveDif

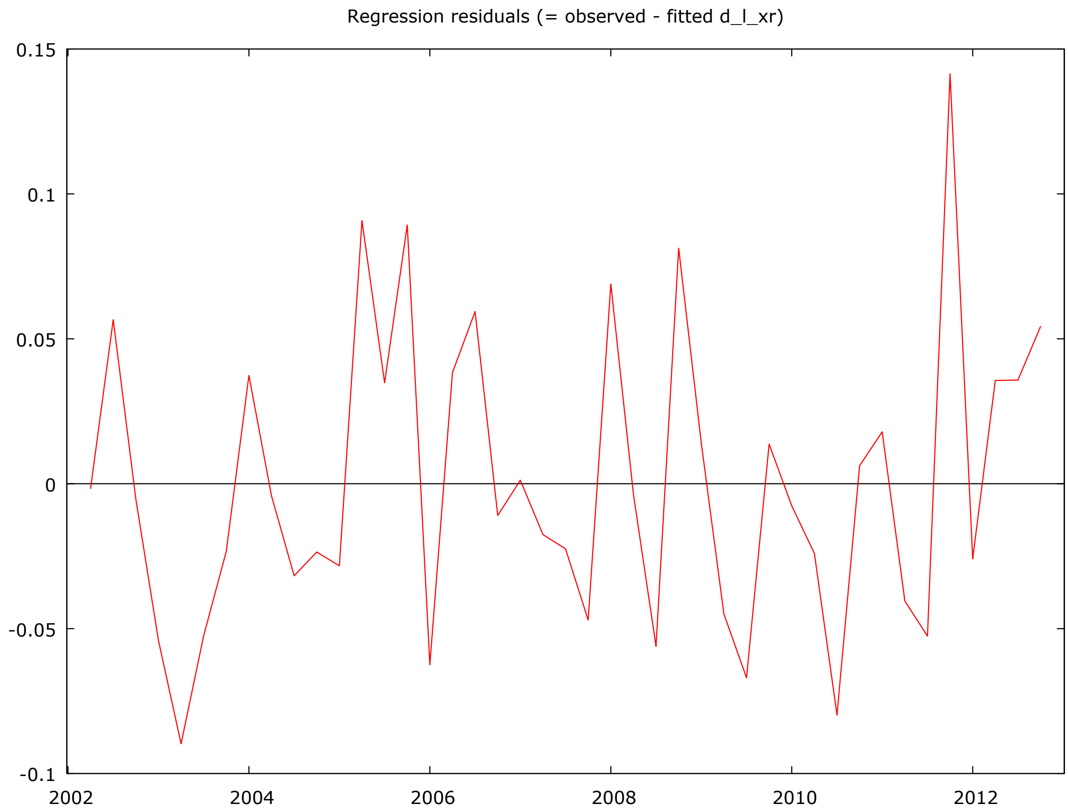
```
Model 3: OLS, using observations 2002:1-2012:4 (T = 44)
Dependent variable: l_xr
HAC standard errors, bandwidth 2 (Bartlett kernel)

                  coefficient   std. error   t-ratio    p-value
  -------------------------------------------------------------
  const            1.89166      0.0387893    48.77      6.21e-038 ***
  pppDif           0.814753     0.202564      4.022     0.0002    ***
  yieldcurveDif   -0.0370356    0.00994712   -3.723     0.0006    ***

Mean dependent var    2.023660   S.D. dependent var   0.156027
Sum squared resid     0.620458   S.E. of regression   0.123017
R-squared             0.407287   Adjusted R-squared   0.378374
F(2, 41)              19.97944   P-value(F)           8.76e-07
Log-likelihood        31.31943   Akaike criterion    -56.63885
Schwarz criterion    -51.28628   Hannan-Quinn        -54.65386
rho                   0.653189   Durbin-Watson        0.338923

Log-likelihood for xr = -57.7216
```

Table 22. ADF test for resids2

```
Dickey-Fuller test for resids2
sample size 43
unit-root null hypothesis: a = 1

   test without constant
   model: (1-L)y = (a-1)*y(-1) + e
   1st-order autocorrelation coeff. for e: 0.164
   estimated value of (a - 1): -0.346811
   test statistic: tau_nc(1) = -4.75456
   p-value 1.283e-005
```

The estimated from OLS model residuals are stationary, as the asymptotic p-value of 1,283e-005 is lower than 0,05. Thus, the unit root hypothesis is rejected and resids2 is integrated of order zero (I_0). The same conclusion can be made also by the graphical analysis of the time series as depicted in figure 19.

Figure 19. Regression Residuals (observed - fitted d_l_xr)



It is obvious that the mean and the variance are constant over time and the value of covariance between two time periods depends only on the distance or gap between the two periods and not the actual time at which the covariance is computed. Thus, the time series "resids2" is cointegrated and we come to the conclusion that there is a long-term equilibrium relationship between the exchange rate and both the ppp differential and yield curve differential of South Africa and the U.S.A.

In order to examine how this cointegration works, the correlation matrix is proved to be very helpful, as we see that with a p-value of 0.0019, lower than the critical value of 0.05, the null hypothesis of no correlation is rejected. Moreover,

the negative sign (-0.45558535) indicates that there is a negative correlation, which means that, if the yield curve differential rises, the exchange rate will depreciate.

Table 23. Corr l_xr to yieldcurveDif

```
corr(l_xr, yieldcurveDif) = -0.45558535
Under the null hypothesis of no correlation:
 t(42) = -3.31673, with two-tailed p-value 0.0019
```

At last, but not least, we have to examine the results of our model as depicted on table 21. At first glance, reaching the statistically significance of 1% level for both our variables is very satisfactory, as * indicate, as well as their p-values (6.21e-038, 0.0002 and 0.0006), both well lower than 0.05. This conclusion also derives from the omission tests in which both const, pppDif and yieldcurveDif are proved to be essential for the model, as presented at tables 24, 25 and 26.**

Table 24. Const omission test result

```
Test on Model 3:

  Null hypothesis: the regression parameter is zero for const
  Test statistic: Robust F(1, 41) = 2378.28, p-value 6.20805e-038
  Omitting variables improved 0 of 3 model selection statistics.
```

Table 25. PppDif omission test result

```
Test on Model 3:

  Null hypothesis: the regression parameter is zero for pppDif
  Test statistic: Robust F(1, 41) = 16.1781, p-value 0.000241649
  Omitting variables improved 0 of 3 model selection statistics.
```

Table 26. YieldcurveDif omission test result

```
Test on Model 3:

  Null hypothesis: the regression parameter is zero for yieldcurveDif
  Test statistic: Robust F(1, 41) = 13.8626, p-value 0.000592174
  Omitting variables improved 0 of 3 model selection statistics.
```

In contrary to the theory, the coefficient of the constant is 1.89166 (not zero), but the coefficient of the pppDif is 0.814753, relatively close to 1. Even so the values of these two coefficients are slightly better than those found in the cointegration analysis of chapter 3.3.4 (1.92195 and 0.807559 respectively) that is we may have achieved a better adjustment of the model with the inclusion of the new term of yield curve differential. Hence, to be certain, we should investigate whether these values are such that we can accept that equal 0 and 1 respectively, applying the linear restriction tests. Setting b [const] = 0 and b [pppDif] = 1 result as follows:

Table 27. Restriction of const (b=0)

```
Restriction:
 b[const] = 0

Test statistic: Robust F(1, 41) = 2378.28, with p-value = 6.20805e-038

Restricted estimates:

                   coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------------
  const              0.00000     0.00000      NA         NA
  pppDif            10.6315      1.10627       9.610      3.63e-012 ***
  yieldcurveDif     -0.161386    0.0810350    -1.992      0.0529    *

  Standard error of the regression = 1.05727
```

Table 28. Restriction of pppDif (b=1)

```
Restriction:
 b[pppDif] = 1

Test statistic: Robust F(1, 41) = 0.836331, with p-value = 0.365795

Restricted estimates:

                   coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------------
  const             1.86827      0.0200082    93.38      2.42e-050 ***
  pppDif            1.00000      0.00000      NA         NA
  yieldcurveDif    -0.0371059    0.00965946   -3.841      0.0004    ***

  Standard error of the regression = 0.122597
```

The possibility that b=0 for the constant is 6.20805e-038 (< 0.05). This value means that we should reject the linear restriction and that the theory is not confirmed.

For pppDif though, the possibility that b=1 is 0,365795 (> 0.05). This value means that we should accept the linear restriction and that the theory is confirmed.

Nevertheless, the sign of the coefficient of pppDif is positive (+0.814753), in compliance to the PPP theory and of crucial importance is the fact that the coefficient of yieldcurveDif has a negative sign (-0.0370356), in compliance to the UIP theory. The size of 3.70356% has the meaning that, if the yield curve differential rises 1%, the exchange rate will be 3.70% depreciated. When the expected rate of depreciation is just equal to the yield curve differential and the UIP holds, a short-run equilibrium is achieved. Since the domestic currency must be expected to depreciate because of the yield curve differential, the domestic currency must have appreciated beyond its long-run, PPP equilibrium. In the medium run, though, domestic prices begin to fall in response to the fall in the money supply causing the decline of the domestic interest rates. The exchange rate then depreciates slowly toward long-run PPP.

Moreover, the adjusted R-squared indicates that now 37,84% of the actual observations of l_xr are interpreted by the model (instead of 17,71% we found in the first model), which is a percentage that is much more satisfactory.

3.3.5 ERROR CORRECTION MODEL

We noticed that indeed there is a relationship between the exchange rate movements and the yield curve differential of the two countries with statistical significant slope coefficients. Also, the signs of all parameters are in the correct sign. The slope coefficient (-0.037) of the contemporaneous term suggests that 1% increase in the yield curve differential (domestic minus foreign yield curve), leads down the exchange rate ZAR per USD by about 3,70%, ceteris paribus. It means that the ZAR appreciates instantaneously against the USD because of capital inflows that want to take advantage of higher interest rates and government bonds.

Since l_xr, pppDif and yieldcurveDif time series are cointegrated, which means that they have a long-term, or equilibrium, relationship, how is this equilibrium achieved and is there a disequilibrium in the short-run?

If we rewrite the equation (5) as

$$u_t = l\_xr_t - a - b*pppDif_t – c*yieldcurveDif_t \qquad (7) \text{ or}$$

$$u_t = l\_xr_t - 1.89166 - 0.814753*pppDif_t + 0.0371059*yieldcurveDif_t \qquad (8)$$

where a = constant, b = coefficient of variable pppDif, c = coefficient of variable yieldcurveDif and u = error term, we obtain the error term u which can be treated as the term which corrects the ZAR/USD exchange rate deviations from its equilibrium.

The next step is to apply again the OLS method, setting d_l_xr as the dependent variable and constant, d_pppDif, d_yieldcurveDif and resids2_1 as the regressors. We note that after some trials the residuals of lag order one were proved to be more statistically significant than those of every other lag order tested and this is the reason why this variable was chosen in our model instead of the resids2 that were saved from model (2). The results are depicted in table 29.

Table 29. OLS regression model of depended d_l_xr and independed d_pppDif and d_yieldcurveDif

```
Model 4: OLS, using observations 2002:2-2012:4 (T = 43)
Dependent variable: d_l_xr
HAC standard errors, bandwidth 2 (Bartlett kernel)

                     coefficient   std. error   t-ratio   p-value
  -------------------------------------------------------------
  const              -0.0145590    0.00757554   -1.922    0.0620    *
  d_pppDif            1.78605      0.382943      4.664    3.59e-05 ***
  d_yieldcurveDif    -0.0303874    0.0114787    -2.647    0.0116   **
  resids2_1          -0.364782     0.0606889    -6.011    5.00e-07 ***

Mean dependent var   -0.006570   S.D. dependent var   0.073691
Sum squared resid     0.110062   S.E. of regression   0.053123
R-squared             0.517427   Adjusted R-squared   0.480306
F(3, 39)              15.93526   P-value(F)           6.44e-07
Log-likelihood        67.29573   Akaike criterion    -126.5915
Schwarz criterion    -119.5467   Hannan-Quinn        -123.9935
rho                  -0.009911   Durbin-Watson        1.992535
```

The 3 stars (***) we see next to the residuals' p-value indicate significance at the 1 percent level. Moreover, based on resids 2_1 coefficient, about 36.5 per cent of the gap between the actual exchange rate and its equilibrium value is eliminated every next quarter. This suggests a rather high rate of adjustment to equilibrium.

Furthermore, both d_pppDif and d_yieldcurveDif are statistically significant (p-values lower than 0.05, 3.59e-05 and 0.0116 respectively), even at 5% the latter. This conclusion also derives from the omission tests in which both const and pppDif are proved to be essential for the model, as presented at tables 30, 31 and 32.

Table 30. D_pppDif omission test result

```
Test on Model 4:

  Null hypothesis: the regression parameter is zero for d_pppDif
  Test statistic: Robust F(1, 39) = 21.7529, p-value 3.59349e-005
  Omitting variables improved 0 of 3 model selection statistics.
```

Table 31. D_yieldcurveDif omission test result

```
Test on Model 4:

  Null hypothesis: the regression parameter is zero for d_yieldcurveDif
  Test statistic: Robust F(1, 39) = 7.00814, p-value 0.0116455
  Omitting variables improved 0 of 3 model selection statistics.
```

Table 32. Resids2_1 omission test result

```
Test on Model 4:

  Null hypothesis: the regression parameter is zero for resids2_1
  Test statistic: Robust F(1, 39) = 36.1282, p-value 5.005e-007
  Omitting variables improved 0 of 3 model selection statistics.
```

However, the constant, is in the short term not statistical significant (p – value 0.062 > 0.05), which can be confirmed be its omission test table:

Table 33. Const omission test result

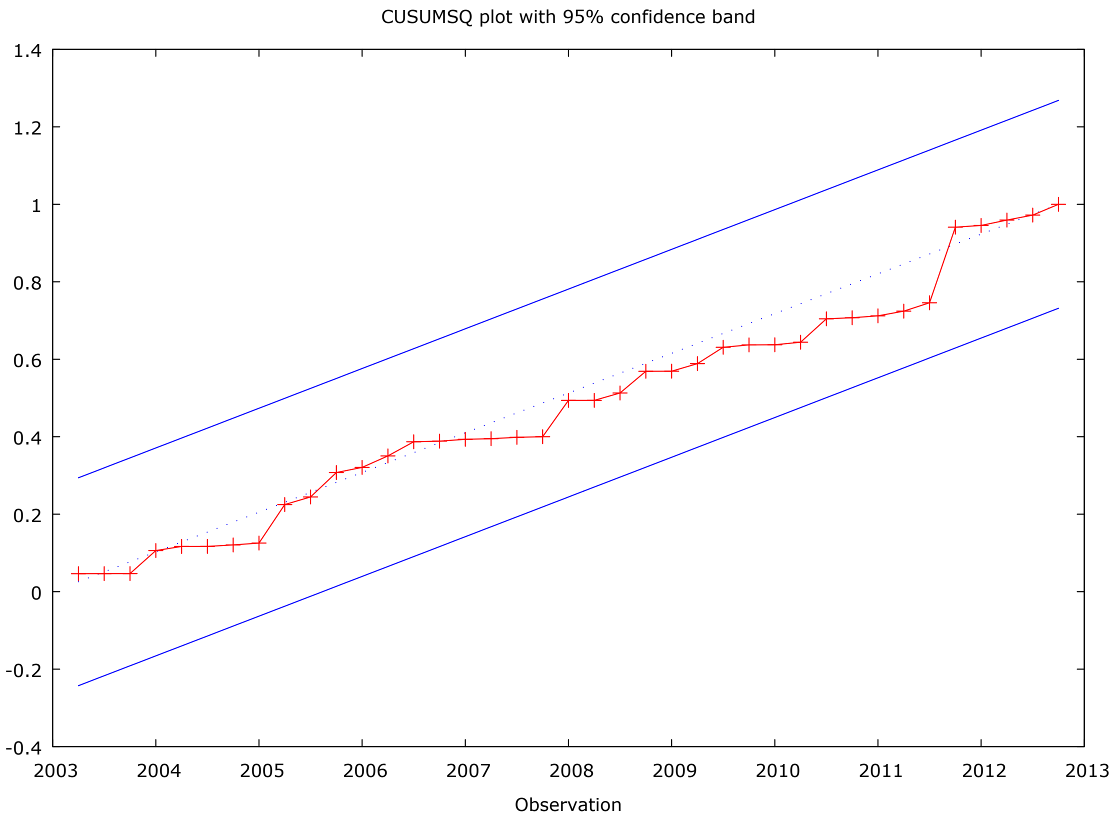
```
Test on Model 4:

  Null hypothesis: the regression parameter is zero for const
  Test statistic: Robust F(1, 39) = 3.69347, p-value 0.0619543
  Omitting variables improved 1 of 3 model selection statistics.
```

The value of the coefficient of the constant dropped to almost zero (-0.0145590) which agrees to the theory and the sign of the coefficient of d_pppDif is positive (+1.78605), in accordance with the PPP theory. Nevertheless, the coefficient of d_yieldcurveDif has a negative sign (-0.0303874), in compliance to the UIP theory. The size of 3.04% has the meaning that, if the yield curve differential rises 1%, the exchange rate will be 3.04% depreciated.

3.3.6 STABILITY TESTS

The former equations explain how ECM combines the long-run equilibrium with short-run dynamics in order to reach this equilibrium. To confirm that the results from the ECM we have just reported are deriving from an efficient model with well-behaved residuals, a CUSUMSQ test is performed. The results are depicted in figure 20.

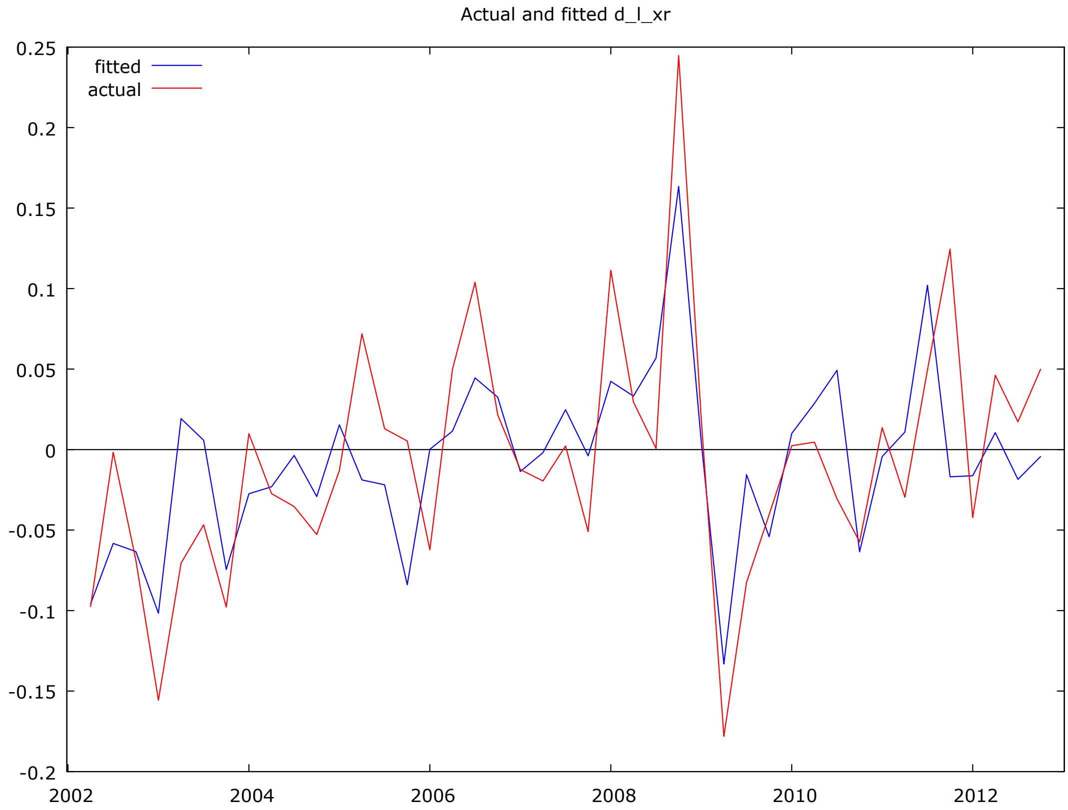
Figure 20. CUSUMSQ plot for the residuals of OLS regression model



According to figure 20, the red line is well within the confidence bands and at no point the confidence band is exceeded. As a consequence, the conclusion of parameter stability should not be rejected, since the null hypothesis of the tests is that the stability of the parameters.

Nevertheless, a plot of the actual and the fitted values of d_l_xr as the one presented below (figure 21) shows that the values calculated by the Error Correction Model are well fitted to the actual ones:

Figure 21. Actual and fitted d_l_xr prices



4. SUMMARY AND CONCLUSIONS

The present thesis has examined the theoretical determinants of South Africa's exchange rate over the period from 2002 to 2012. The importance of the exchange rate was briefly reviewed in this study and is well documented in the literature for both developing economies and South Africa. Based on an extensive review of the literature on the determinants of the real exchange rate, a background of the exchange rate system in South Africa and on data availability, an empirical model that links the exchange rate to its potential determinants was specified. The variables included in this model as potential determinants include price level and yield curve differentials.

Price level and yield curve differentials proved to be variables that have a long run relationship with the exchange rate, as the results showed a relatively good fit; approximately a half of the actual observations of the exchange rate were interpreted by the model. Nevertheless, economic fundamentals were significant and important. The omission tests' results showed that both the regressors were essential for the model and the correlation matrices showed not only that they are correlated with the exchange rate movements but also their signs were as expected; positive for the price level differential, since its rise makes ZAR depreciate, and negative for the yield curve differential, since here a rise makes the domestic currency appreciate. Furthermore, when the linear restriction tests were applied, the price level differential's coefficient proved, in compliance to the theory, to be equal to unity whereas the constant's coefficient was not equal to zero, as expected. The size of the yield curve differential showed that, if it rises 1%, the exchange rate will be 3,04% depreciated. The estimated error-correction model described how the short term dynamics are linked to the long-term relationship, leading the cointegrating relationship to equilibrium. The estimate of the speed of adjustment coefficient found in this study indicates that about a quarter of the variation in the exchange rate from its equilibrium level is corrected within a quarter (26,5%), when price level differential is the only independed variable, whereas a third of variation is corrected (36,5%), if yield

curve differential is also taken into account. This result implies that, in the absence of shocks, the gap would be eliminated in approximately one year. The stability test applied showed that the residuals of the regression were well within the confidence bands and at no point the confidence band was exceeded. This implies that, the results from the ECM that were reported, were deriving from an efficient model with well-behaved residuals.

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