The Exchange Rate and Macroeconomic Fundamentals in South Africa

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Abstract

This paper estimates four versions of the monetary model of rand per United States dollar exchange rates using South African and United States (US) quarterly data for the period 1986Q1to 2005Q4. The models are estimated using the Johansen (1995) cointegration framework. We obtain robust results showing the existence of a long-run relation between the rand per US dollar exchange rates, money, income and interest rate differentials between the two countries. The results further show that the rising current account balance as a ratio of gross domestic product as well as commodity prices depreciate the rand per US dollar exchange rate.

JEL Classification: F31, F41

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* The views expressed are those of the author(s) and do not necessarily represent those of the South African Reserve Bank or Reserve Bank policy. This work is very preliminary and cannot be quoted without the authors' prior permission.

1 INTRODUCTION

The exchange rate of the rand has depreciated by about 96 per cent between the months of April 1994 and December 2007. During this period, the rand exhibited considerable volatility, reaching levels of about 13 rands to the United States (US) dollar towards the end of 2001 (see Figure A1). Within this background and given the relative importance of exchange rates not only in the external adjustment process but also in the transmission mechanism of monetary policy, South Africa's exchange rates developments of the past several years have generated interest in attempting to analyse and understand the underlying relationships.

The objective of this paper therefore is to determine the economic fundamentals which are useful in explaining the long run path of the rand per US dollar exchange rates using the monetary model of exchange rate determination[1]. Although similar studies have been done for South Africa, this study uses a more up-to-date South African data set and a more robust estimation techniques and specifications. The focus here is empirical and no new exchange rates theories are advanced. The paper is organised as follows. The next section reviews the literature with more focus on the types of models that have been used. The theoretical as well as the econometrics methods are discussed in section 4, followed by estimation and results. The last section provides some concluding remarks and points out areas of further research.

2 BRIEF REVIEW OF LITERATURE[2]

A vast amount of theoretical and empirical models have been undertaken in an attempt to study the link between macroeconomic fundamentals and the exchange rates[3]. In general, these studies mainly address three major areas characterised by MacDonald (1999) and Chen (2005) as; a) studies that sought to understand the long-run relationships between exchange rates and macro fundamentals, b) those that seek to test if fundamental based models can forecast the exchange rates and, c) those that analysed volatility and persistence observed in exchange rates data. The most common approach

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1 Although this is not done in this paper, but as part of our research agenda an additional objective is to further develop these models into forecasting tools.

2 More extensive surveys can be found in, for example, Froot and Rogoff (1995) as well as in Edwards and Savastano (2000).

3 Although most of the studies are based on industrialised countries, there are studies that have been done using South African data such as Aron, et al (2000), Ricci (2005), Chinn (1999) and Frankle (2007).

adopted in these studies is the use of a variety of structural models. The broad categorization would include the monetary model of exchange rate determination, models based on long-run exchange rate equilibrium concepts that rely on joint internal and external balance and models of short-run exchange rate behaviour. The monetary approach to exchange rate determination[4] is sketched in section 3 and additional details are provided in, amongst others, Frankel (1976) and Chen, et al (2008) and Engel and West (2005). The class of structural models based the on long-run exchange rate equilibrium concepts that rely on joint internal and external balance, include the fundamental equilibrium exchange rate (FEER) and the behavioural equilibrium exchange rate (BEER) discussed in detail in Clark and MacDonald (1998). The other class of models are those that Cheung, et al (2003) describe as the composite models. These models seek to explain the exchange rate by augmenting the standard models with a variety of other variables, such as commodity prices (Chen, et al, 2008), productivity differentials in the Balassa-Samuelson vein (Lee, et al, 2008), and other variables[5]. Models of short-run exchange rate behaviour include models such as those in Evans and Lyons (2002). These are based on micro structure finance which includes variables such as order flow[6] variable. Other authors including Nason and Rogers (2007) have formalised exchange rate determination in the context of dynamic stochastic general-equilibrium (DSGE) models with explicit micro foundations.

In general, the majority of models share some common features. They describe the evolution of exchange rates either in nominal or real terms. They differ in the choice of the set of macroeconomic fundamental that are used as regressors. They also differ with respect to the econometric techniques used in estimation which range from single-equation to vector autoregressive econometric methods with other authors introducing nonlinearities[7] in these models. Overall, the results from these studies have not been able to convincingly overturn the trademark result of Meese and Rogoff (1983) about the inability of macroeconomic fundamentals to predict short-run movements in the exchange rate (Neely and Sarno, 2002). However as noted in (Lee, et al , 2008) there is more consensus that economic fundamentals do explain, at least partly, movements in

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[4] There are variants of this model such as the sticky-price version of the monetary model attributable to Dornbusch (1976) that have been used in the literature.

[5] Included in this class of structural exchange rate models would be the portfolio-balance model discussed in detail in Driskill (1980).

[6] This is defined as the net balance of orders initiated by buyers and sellers in the foreign exchange market, thus it is a measure of the net pressure of demand for a foreign currency (De Medeiros, 2005).

[7] See for example Frommel, et al (2005) and Neely and Sarno (2002).

the exchange rates at medium to long-term horizon. There is also some evidence that models based on micro structure finance models are beginning to find some explanation for short-term exchange rates movements.

3 THE MONETARY MODEL OF EXCHANGE RATE DETERMINATION

The monetary approach to exchange rate determination starts from the definition of the exchange rate as the relative price of two currencies. These relative prices are then modelled in terms of the relative supply of, and demand for those currencies. Specifically consider the following equilibrium domestic demand for money:

$$m_t - p_t = \lambda y_t - \phi i_t \qquad [1]$$

where m_t is money supply, p_t is the price level, y_t is real income, i_t is the nominal interest rate, λ is the income elasticity of money demand and ϕ is the interest semi-elasticity of money demand. Denote the equilibrium foreign country money demand as:

$$m^*_t - p^*_t = \lambda y^*_t - \phi i^*_t \qquad [2]$$

Explicit from equations 1 and 2, the elasticity of income and the semi-elasticity of interest are assumed equal between the two economies. Assuming further that Purchasing Power Parity (PPP) holds so that:

$$ER_t = p_t - p^*_t \qquad [3]$$

where ER_t is the nominal bilateral exchange rate. By subtracting equation (2) from equation (1) and solving for $p_t - p^*_t$ and then using (3), the fundamental flexible price monetary model is obtained:

$$ER_t = (m_t - m^*_t) - \lambda(y_t - y^*_t) + \phi(i_t - i^*_t) \qquad [4]$$

The PPP assumption in equation 5 is be relaxed in a sticky price version of the monetary model. This model assumes the presence of some short run price stickiness such that the PPP condition would not hold, at least temporarily. This model has been derived in Dornbusch (1976), Frankel (1979, 1982) and is of the following form.

$$ER_t = (m_t - m_t^*) + \varphi(y_t - y_t^*) + \psi(i_t - i_t^*) + \eta(\pi_t - \pi_t^*) \quad [5]$$

Where $(\pi_t - \pi_t^*)$ denotes the inflation rates differential between the domestic and foreign economies. Although our focus is mainly on testing the monetary model, we also estimate the commodity price-augmented and the current account-augmented versions of the model.

4 THE ECONOMETRICS MODEL

The model adopted in this paper is the well-known vector autoregressive model. For an n-vector of time series $\{X_t\}$, it is assumed that a k^{th} order VAR representation of $\{X_t\}$ exists and is of the following error correction form[8]:

$$\Delta X_t = \alpha\beta' X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \alpha\beta_0^{'} t + \Theta D_t + \delta_0 + \varepsilon_t \quad [6]$$

where the initial values $X_{-k+1},...,X_0$ are assumed fixed, Δ is the first difference operator and ε_t are independent and identically distributed innovations, with mean zero and positive definite covariance matrix Ω, i.e. $\varepsilon_t \sim IN(0,\Omega)$. Γ_i, for $i = 1,...,k-1$, is a matrix of short-run parameters. The number of long-run relations/cointegrating vectors, r is given by the rank of $\alpha\beta$, where α and β are full column rank matrices of dimension $n \times r$. The matrix α contains adjustment parameters that characterises disequilibrium correction while the cointegrating vector β contains long-run parameters. The deterministic components include an unrestricted constant δ_0, transitory dummies

[8] Only a sketch of this model is provided here and more rigorous and detailed treatment can be found in Johansen (1995), Johansen, et al (2000) and Juselius (2006), amongst others.

included in D_t with unrestricted coefficients Θ and a linear trend t that is restricted to the cointegration space.

5 DATA

The sample consist of quarterly seasonally adjusted data spanning the period 1986:Q1 to 2005:Q4. The dependent variable, i.e. the exchange rate (ER_t), is the end of quarter nominal South African rand per U.S. dollar foreign exchange rate[9]. Income differentials $(y - y_t^*)$ are calculated on the basis of gross domestic product (GDP) in both countries. The short-term treasury bill rates are used as the basis for determining the interest differentials, $(i_t - i_t^*)$. Money differentials $(m_t - m_t^*)$ are calculated using M3. Inflation differentials $(\pi_t - \pi_t^*)$, measured as annualised log first differences, are calculated on the basis of the consumer prices indices (CPI) in both South Africa and the US. The commodity prices (com_t) are the Economist all items price index in US dollar terms. The current account (cab_t) is in South African rands. The commodity prices, current account and rand per US dollar exchange rates are sourced from the South African Reserve Bank (SARB) database and the rest of the data are sourced from the International Monetary Fund's International Financial Statistics (IFS). All data are in logs except interest rates and are portrayed in Figure A1 in the Appendix in both levels and in first log differences[10].

6 Estimation and results

We estimate four versions of the monetary model, denoted as model 1 through 4. Models 1 and 2 are represented by equations 5 and 6 respectively, while models 3 and 4 are equation 5 augmented by commodity prices and current account as a ratio of GDP, respectively. To this end we set up equation 6 for the following variables corresponding to models 1 through 4 respectively:

[9] A dual exchange rate system, consisting of a commercial rand rate and a financial rand rate, was in effect between September 1985 and March 1995. .Data for this period refer to the commercial rand rate.
[10] Stationarity tests are conducted within the multivariate framework discussed in Juselius (2006). The results, depicted in Table A2, shows that most of the variable are stationery although stationarity of inflation differential is questionable.

$$\text{Model 1}: \quad X_t = [ER_t, (y_t - y_t^*), (m_t - m_t^*), (i_t - i_t^*)]$$

$$\text{Model 2}: \quad X_t = [ER_t, (y_t - y_t^*), (m_t - m_t^*), (i_t - i_t^*), (\pi_t - \pi_t^*)]$$

$$\text{Model 3}: \quad X_t = [ER_t, (y_t - y_t^*), (m_t - m_t^*), (i_t - i_t^*), com_t]$$

$$\text{Model 4}: \quad X_t = [ER_t, (y_t - y_t^*), (m_t - m_t^*), (i_t - i_t^*), cab_t]$$

The first step is to estimate a well-specified unrestricted VAR model (Juselius, 2006). The lag reduction procedure results summarised in Table 1 suggest a lag of two[11] i.e. VAR(2).

Table 1 Lag reduction tests[12]

	lags	χ^2	χ^2 -value	*P-value*
Model 1	VAR(2) << VAR(3)	ChiSqr(16)	11.399	0.784
Model 2	VAR(2) << VAR(3)	ChiSqr(25)	32.453	0.145
Model 3	VAR(2) << VAR(3)	ChiSqr(25)	36.640	0.062
Model 4	VAR(2) << VAR(3)	ChiSqr(25)	31.433	0.175

Note: VAR(2) and VAR(3) are VAR with 2 and 3 lags respectively.

With a lag of two imposed, preliminary diagnostics were undertaken and a well specified model was found after inserting three dummy variables[13]. Dummy variable *dum9803p* correspond to the third quarter of 1998, a period characterised by very high interest rates due to the emerging-markets crisis.

Table 2 Specification tests for the unrestricted VAR(2) – Model 1

Tests for Autocorrelation				
Ljung-Box(19):	ChiSqr(425)	=	549.442	[0.000]
LM(1):	ChiSqr(25)	=	21.759	[0.650]
LM(2):	ChiSqr(25)	=	31.601	[0.170]
Test for Normality:				
	ChiSqr(10)	=	12.937	[0.227]
Test for ARCH:				
LM(1):	ChiSqr(225)	=	210.533	[0.747]
LM(2):	ChiSqr(450)	=	404.779	[0.938]

Note: *P-values* in square brackets

[11] Detailed tables are available from the authors.

[12] Table 2 should be read as follows: VAR (*j*) << VAR(*i*) means that with a *p-value* greater than 0.05 a reduction from lag *i* to lag *j* cannot be rejected.

[13] The need for dummy variables was detected by conducting appropriate residual analysis. An attempt was made to capture the structural break that may result from the period of dual exchange rate system using an appropriate shift dummy. However, we did not get statistically significant results.

Dummy variables *dum0104p* and *dum0201p* correspond third quarter of 2001 and first quarter of 2002, periods characterised by the rapid rand depreciation. The misspecification test results are presented in Table 2 for Model 1 while the other models' results are relegated to Table A1 in the appendix.

In Table 2, the model diagnostics indicate a well-specified VAR model. The test of normality is based on Doornik and Hansen (1994) and, with a *p*-value of 0,227, it shows that the hypothesis of normally distributed residuals cannot be rejected. The Lagrangian multiplier *(LM)* test of no autocorrelation against autocorrelation of at most the first and second order (denoted *LM(1)* and *LM(2)*, respectively, do not reject the null hypothesis at the 5-per-cent level of significance. The multivariate test of no conditional heteroskedasticity (ARCH) also cannot be rejected at conventional level of significance. With a well specified VAR model cointegration analysis can proceed.

6.1 Rank determination

Table 3 summarises the trace test statistic for all the four models. Based on the Bartlett small sample corrected statistic, the test suggest $r = 2$ for models 1, 2 and 4, while $r = 1$ is suggested for model 3. Explained differently the test suggests two cointegrating vectors for models 1, 2 and 4 and one cointegrating vector for model 3.

Table 3 Trace Test Statistic

	r	Trace	Trace*	Frac95	P-value	p-value*
Model 1	2	29.366	25.370	25.731	0.016	0.056
Model 2	2	43.661	39.150	42.770	0.0.40	0.113
Model 3	1	72.717	62.475	63.659	0.006	0.063
Model 4	2	41.776	38.199	42.770	0.063	0.137

Note: Trace* is the Bartlett small sample corrected trace statistics and its corresponding *p-value**

6.2 Identification

All models but model 3 have 2 cointergrating vectors. Although the trace test point to $r = 2$ for model 1, we imposed $r = 1$. This is because $r = 2$ is borderline significant for this model and experimenting with $r = 2$ did not yield any significantly different results. For model 2 and 4 however we imposed $r = 2$ as the trace test suggests. It is important to underscore here that our focus is on estimating the long run the exchange rate equation. Given that there does not seem be any theoretical basis for the second relations, we therefore impose just enough restrictions to identify the exchange rate equation. This is achieved by imposing a restriction on money differential in addition to the normalisation. Then we further impose at least three restrictions in the second vector.

6.3 Results

The results of the preferred models are depicted in Table 4. In all the four models we find a statistically significant positive relationship between exchange rate and income differentials. For example, in the flexible monetary exchange rate model, i.e. model 1, a one per cent rise in South Africa's income relative to the US depreciates the rand per dollar exchange rate by about 13 per cent. This is in line with observation in South Africa where it would seem that rising growth rates were also accompanied by rising imports which, other things being constant, have weakened the rand per US dollar exchange rate.

Table 4 Estimates of cointegrating relations

		ER_t	$y_t - y_t^*$	$m_t - m_t^*$	$i_t - i_t^*$	$\pi_t - \pi_t^*$	com_t	cab_t	$trend$
Model 1	β	1	-12.937 (-5.905)	4.911 (3.672)	0.094 (3.511)	---	---	---	0.107 (4.908)
	α	-0.040 (-2.111)	0.003 (0.801)	-0.019 (-3.174)	-0.989 (-4.893)	---	---	---	---
Model 2	β	1	-7.621 (-2.603)	0	0.124 (2.004)	7.026 (5.763)	-----	-----	0.152 (3.128)
	α	-0.029 (-4.535)	0.000 (0.015)	-0.006 (-2.601)	-0.195 (-2.562)	-0.056 (-4.598)	---	---	---
Model 3	β	1	-45.190 (-7.305)	24.396 (5.993)	0.138 (1.804)	---	-6.578 (-5.479)	---	0.296 (5.082)
	α	-0.007 (-1.287)	0.001 (0.763)	-0.008 (-4.529)	-0.333 (-5.875)		0.000 (0.055)		---
Model 4	β	1	-7.184 (-7.726)	0	0.095 (6.671)	---	---	-2.967 (-6.181)	0
	α	-0.050 (-1.917)	0.004 (0.786)	-0.003 (-0.384)	-0.823 (-3.080)			0.119 (5.670)	---

Note: t-statistic in brackets

In models 1 and 3, we consistently find that rising money in South Africa relative to US leads to the appreciation of the rand relative to the US dollar. This is contrary to what theory dictates. However, it could be a result of expectations arising from rising money supply. When money supply increases, it could be the case that economic agents expect inflation to rise and interest rates to adjust accordingly. This would lead to the appreciation of the domestic currency. The results further show that rising interest rates in South Africa relative to the US lead to the appreciation of the rand relative to the dollar in line with expectations.

When the flexible monetary model is augmented with the inflation differential, i.e. model 2, the money differential ceases to be statistically significant. We restrict the coefficient thereof to zero as part of the identification scheme. The resulting model is accepted with a *p-value* of 0.823. The identified model however shows that rising inflation appreciate the currency, contrary to expectations. Again this may be due to expectations of monetary policy tightening in response to rising inflation, which would tend to appreciate the currency. The results for model 3, which is the flexible monetary model augmented with commodity prices show suspiciously large coefficients on the income and money differentials. Furthermore, the sign on the coefficient of the commodity prices violates prior expectations. However, there may be a potential explanation for the sign on commodity prices' coefficient. The index used here is the Economist all items price index which includes all commodities, such as food, metal, oil, etc. Therefore it could be the case that commodity prices seem to be depreciating the rand as a result of the impact of oil imports.

The results for model 4 show that an increase in the current account balance depreciates the rand. This is contrary to theoretical expectations, but it is not necessarily at odds against what we observed. In the sample period the current account has been in surplus yet the currency was consistently depreciating. Although the model with commodity prices may requires a second look in terms of trying other measures of commodity prices, overall, we find that macroeconomic fundamentals used here are cointegrated with the exchange rate in the long-run.

Table 5 Estimates of the short-run relations

	ΔER_t	$\Delta(y_t - y_t^*)$	$\Delta(m_t - m_t^*)$	$\Delta(i_t - i_t^*)$	$\Delta(\pi_t - \pi_t^*)$	$\Delta(com_t)$	$\Delta(cab_t)$
Model 1	0.172 (1.569)	-1.049 (1.984)	-0.387 (1.218)	0.003 (0.573)			
Model 2	-0.031 (-0.282)	-0.311 (-0.661)	-0.711 (-2.402)	0.014 (2.326)	0.089 (1.945)		
Model 3	0.164 (1.467)	-0.972 (-1.764)	-0.380 (-1.147)	0.000 (0.059)		-0.083 (-0.556)	
Model 4	0.181 (1.709)	-1.225 (-1.963)	-0.533 (-1.440)	0.004 (0.477)			-0.142 (-0.983)

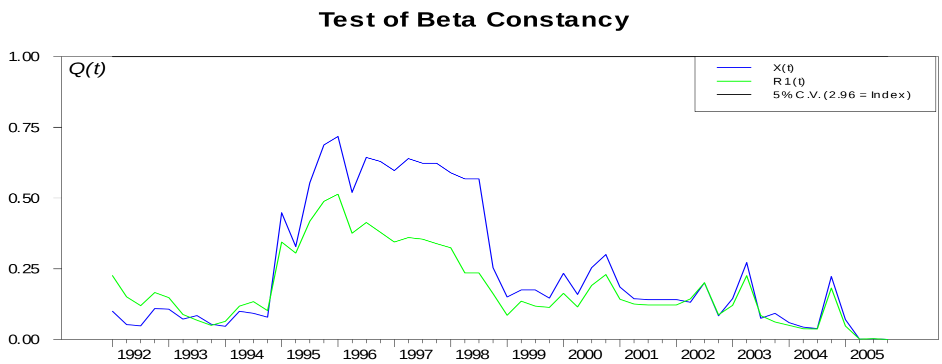
Note: t-statistic in parenthesis

Table 5 shows the short-run parameters. In general, the results show that the macroeconomic fundamentals analysed here fail to explain the short-run movements in the rand per dollar exchange rate as most of the short rum parameters are statistically insignificant. This is in line with the literature and the long standing finding by Meese and Rogoff (1983).

6.3 Stability of the cointergrating relations

To test for the stability of the cointergrating relations, we employ the Nyblom (1989) type *max* test of β constancy discussed in Juselius (2006). The results for model 1 are depicted in Figure 1, while the rest of the results are relegated to Figure A2 in the appendix. Note that the test has been scaled by the 95% quantile of the distribution under the null of stability such that any value above 1 rejects constancy. Although the stability of model 2 (see Figure A2) is problematic, in general, tests for the other models show relative model stability.

Figure 1 Max test of Beta constancy



Note: X(t) is test based on the full VAR(2) model and R(t) is based on the concentrated model.

7 Conclusion and further research

In this paper we analysed the relationship between the rand per US dollar exchanger rate and a selected set of macroeconomic fundamentals. We estimated different versions of the monetary model of exchange rate determination using the Johansen (1995) cointegration framework. The models estimated are robust in terms of the diagnostics. Estimation of the basic flexible monetary model established a log-run cointegration relation between rand per US dollar exchange rate, money, income and interest rate differentials. We find that rising income differential between South Africa and the US tends to depreciate the rand per dollar exchange rate. A rise in money supply differential tends to appreciate the rand relative to the US dollar, while rising interest rates differential also appreciate the currency. The sticky price model shows that rising inflation appreciates the rand. We also found that rising commodity prices depreciate the rand. Although this is contrary to expectations, it could be that the commodity prices used may be heavily biased towards imported commodities in South Africa. Furthermore we found that the current account as a percentage of GDP depreciates the rand relative to the US dollar.

All in all, we find promising results with respect to which fundamentals are important in the long run determination of the rand per US dollar exchange rate. Although at this preliminary stage the models estimated seem to generate robust results, some aspects still warrant a further examination. For example, the literature suggests that rising commodity prices should appreciate the domestic currency. Such a result is likely to obtain if a commodity price index used is biased towards domestic exports. It may therefore be necessary to consider a measure of commodity prices that mostly comprise South Africa export commodities. Future research should consider testing whether or not the fundamental based models can be used as tools for forecasting exchange rates. In addition, an attempt can be made to understand the volatility and persistence observed in exchange rates data.

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Appendix

Figure A1 Variables in logs and first differences

Table A1 Specification tests for the unrestricted VAR(2)

	Test	Statistic	Value
Model 2	**Tests for Autocorrelation**		
	Ljung-Box(19):	ChiSqr(425) =	550.935 [0.000]
	LM(1):	ChiSqr(25) =	21.618 [0.658]
	LM(2):	ChiSqr(25) =	18.553 [0.818]
	Test for Normality:	ChiSqr(10) =	9.027 [0.530]
	Test for ARCH:		
	LM(1):	ChiSqr(225) =	226.754 [0.455]
	LM(2):	ChiSqr(450) =	465.917 [0.292]
Model 3	**Tests for Autocorrelation**		
	Ljung-Box(19):	ChiSqr(425) =	549.442 [0.000]
	LM(1):	ChiSqr(25) =	21.759 [0.650]
	LM(2):	ChiSqr(25) =	31.601 [0.170]
	Test for Normality:	ChiSqr(10) =	12.937 [0.227]
	Test for ARCH:		
	LM(1):	ChiSqr(225) =	210.533 [0.747]
	LM(2):	ChiSqr(450) =	404.779 [0.938]
Model 4	Tests for Autocorrelation		
	Ljung-Box(19):	ChiSqr(425) =	631.643 [0.000]
	LM(1):	ChiSqr(25) =	31.163 [0.184]
	LM(2):	ChiSqr(25) =	19.574 [0.769]
	Test for Normality:	ChiSqr(10) =	18.054 [0.054]
	Test for ARCH:		
	LM(1):	ChiSqr(225) =	213.105 [0.705]
	LM(2):	ChiSqr(450) =	421.227 [0.831]

Note: p-values in square brackets

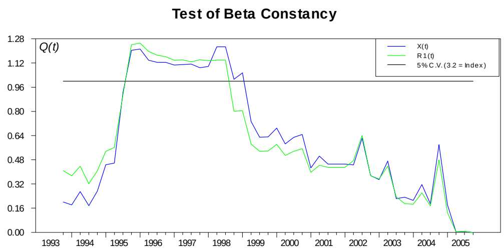
Table A2 Variable stationarity test

	Model 1	**Model 2**	**Model 3**	**Model 4**
r	2	2	1	2
GDF	3	4	4	3
C.V.	7.815	7.815	9.488	7.815
ER_t	16.090 (0.001)	13.518 (0.004)	32.615 (0.000)	28.865 (0.000)
$y_t - y_t^*$	19.097 (0.000)	12.454 (0.006)	35.872 (0.000)	23.455 (0.000)
$m_t - m_t^*$	21.353 (0.000)	13.912 (0.003)	38.104 (0.000)	24.974 (0.000)
$i_t - i_t^*$	18.007 (0.000)	12.526 (0.006)	33.353 (0.000)	25.212 (0.000)
$\pi_t - \pi_t^*$		3.592 (0.309)		
com_t			30.967 (0.000)	
cab_t				26.837 (0.000)

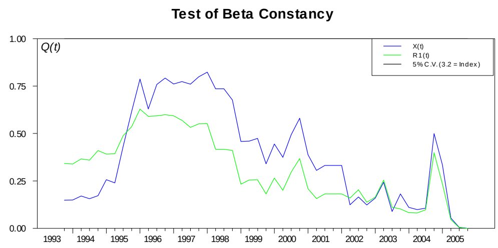
Note: p-values in parenthesis

Figure A2 Recursive estimation – Max test for Beta constancy

Model 2



Model 3



Model 4