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Simeon Coleman, Juan Carlos Cuestas and Estefanía Mourelle

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Department of Economics
University of Sheffield
9 Mappin Street
Sheffield
S1 4DT
United Kingdom
www.shef.ac.uk/economics

Investigating the oil price-exchange rate nexus: Evidence from Africa

Simeon Coleman
Nottingham Trent University

Juan Carlos Cuestas
University of Sheffield

Estefanía Mourelle[†]
Universidade da Coruña

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Abstract

In this paper, we aim to provide further insights into the importance of real oil price as a determinant of real exchange rates for a pool of African countries. While this relationship has been explored substantially for many industrialised economies, African countries have received little attention. By means of cointegration techniques and nonlinear dynamics we find that, for some of these countries, shocks in the real price of oil are particularly important in determining the real exchange rates, even in the long run. These results would be of interest for policymakers in order to deal more effectively with exchange rate policy decisions, aiming at promoting economic growth in the area.

J.E.L. Classification : C32, F15, F31, O55.
Key words: Oil prices, real exchange rates, cointegration, nonlinearities.

[†]Corresponding author: Facultad de Ciencias Económicas y Empresariales, Universidade da Coruña, Campus de Elviña, s/n, 15071 A Coruña, Spain. e-mail: emourelle@udc.es. Juan Carlos Cuestas gratefully acknowledges the financial support from the CICYT project ECO2008-05908-C02-01 and Junta de Castilla y León project SA003B10-1. Estefanía Mourelle acknowledges support from the Xunta de Galicia (Spain) and the European Social Fund, within the Plan Galego INCITE (2006-2010) for 2009. Finally, comments on a previous version by Paul Mosley and Abrar Suleiman are gratefully acknowledged. The usual disclaimer applies.

1 Introduction

Recent years have seen a resurgence in the debate on the pros and cons of exchange rate policy amendments around the world. For example, the much debated policy implications of China's announcement of a number of changes to its foreign exchange regime on July 21, 2005 *vis-à-vis* reaction by US and Asian economies has sparked an increase in the number of empirical studies examining the topic (see Makin, 2009). In light of such examples, and the policy implications of exchange rate movements, analyses of exchange rates and their dynamics have become a cornerstone of the decision-making process in international markets. Moreover, with real effective exchange rate being an index that is used to measure international competitiveness of countries, exchange rates dynamics and their long run determinants are widely considered to play a key role in foreign exchange rate policy decisions, which is of particular importance in developing economies.

Two additional points are worthy of note. First, following Edwards (1989), the degree of exchange rate misalignment has been associated with the extent of over- or under-valuation of currencies and is typically used as a yardstick for economic integration in the real markets of countries. Second, rigorous examination of the real exchange rate (hereafter RER) has become even more important in view of the crucial role that misalignment has assumed in explaining economic underdevelopment (see World Bank, 1984; Dollar, 1992; Edwards,1988; Ghura and Grennes, 1993; Rodrik, 1994; Yotopoulos, 1996). In this vein, RER may affect long run growth *via* sectoral allocation of resources and also influence export performance, hence the trade balance (see Hinkle and Montiel, 1999). This is a crucial feature of RERs, which may serve as a means of promoting (or undermining) economic growth, a particularly important fact for developing economies (see examples Razin and Collins, 1997, and Faria and Leon-Ledesma, 2003).

Surveys of exchange rate models point out that monetary models for RER determination are unsatisfactory, in particular in the post Bretton-Woods period (Meese, 1990; Mussa, 1990; Backus, 1984, among others). The consensus is that a random walk model outperforms traditional models of exchange rate determination, in terms of forecasting. The reasons for RER deviations from its fundamental equilibrium can either be structural changes in the fundamentals, or due to random components. Typically, the two main sources of fluctuations in the RER include the *financial markets* and the *real economy* view. According to the former (*à la* Dornbusch's 1976 "disequilibrium approach") shocks in money markets lead to volatility in exchange rate markets as an equilibrating mechanism, particularly when prices are slow to adjust (see Frankel and Rose, 1996; Chen, 2004). The second approach, the *real economy* view (*à la* Stockman, 1980), attributes fluctuations in RER to shocks in factors influencing output, such as government expenditure, labour supply or productivity (see Zhou, 1995; Bjornland, 2004).

Although several studies have confirmed the important role of oil prices on the RER, the literature has mainly focussed on the US and other developed economies (see examples Zhou, 1995; Amano and Norden, 1998b; Chaudhuri and Daniel, 1998; Dibooglu and Koray, 2001). While African countries form the bulk of developing economies, not much attention has been paid to the role of real oil prices on RER of African countries. Individually, African economies are not among the highest consumers of oil, but collectively their imports and consumption of oil become significant.[1] Between 2004 and 2008, the inflation-adjusted price of crude oil approximately quadrupled, and reached a peak of nearly US150 dollars/barrel. More recently, prices have still been hovering just over the US100 dollar mark. Given the empirically established relationship with economic performance in the literature, an analysis of the recent history of country's RER would lead to a better knowledge of its behaviour and subsequently guide policymakers in their decisions to promote economic growth. The discussion of the potential effects of oil price shocks is not new. The 1970s 'oil crisis' stimulated substantial interest in this question and generated extensive research into how oil price shocks affect the economy.

Contributions to the literature on developing economies highlight how they are severely

[1]See Country Energy Data and Analysis page of US Energy Information Administration website.

affected by external influences. Given that they are usually oil importing economies, oil price fluctuations become an important factor to consider. First, real oil prices might be a proxy for exogenous changes of the terms of trade, and arguably the most important exchange rate long run determinant (Amano and van Norden, 1998b). Second, movements in oil prices may be linked to wealth transfers among oil-importing and oil-exporting countries, i.e. to the balance of payments and international portfolio choices (Golub, 1983, Ozturk *et al.*, 2008). Therefore, the effects of movements in oil prices may be through different transmission channels. The study of this relationship has received much more attention in the literature following the 1973-1974 oil price crisis (Ozturk *et al.* 2008), but still less so in the case of African economies. This forms the basis and purpose of this research, i.e. to analyse the evolution of the RER in a group of African countries, so as to understand how they evolve and how they should, if possible, be managed to boost economic growth.

Due to the potential policy implications it offers, the *real economy* view appears to have enjoyed much more attention in the empirical literature, and one this paper employs. Along these lines and owing to the important role played by real price of oil *vis-à-vis* economic growth, it is instructive for research to incorporate oil price shocks into the decision making process. More specifically, this paper seeks to contribute to the empirical literature in this field and, on this basis, we propose the use of the real price of oil as the main long run determinant of RERs for a group of developing, specifically, African countries. We then investigate the evidence of a long run relationship between the countries' RERs and real oil prices. The remainder of the paper is organised as follows. The next section provides a brief overview and describes the econometric methodology we employ. Section 3 presents the empirical evidence and preliminary analysis. Section 4 offers some relevant policy implications. Section 5 summarises the main findings and concludes.

2 Background and econometric methodology

From the empirical point of view, Clarida and Galí (1994) use the Blanchard-Quah identification strategy to estimate the share of exchange rate variability that is due to different shocks by using quarterly US/Canada, US/Germany, US/Japan, and US/UK real exchange rate data from 1974:Q3 to 1992:Q4 find that real shocks can account for more than 50% of the variance of real exchange rate changes over all time horizons. Similar results are obtained by Lastrapes (1992), who also use the Blanchard-Quah approach but in a structural VARs framework.

Rogoff (1996) and Evans and Lothian (1993) claim that RER misalignment from the fundamental equilibrium may be due to real shocks, and among them, supply shocks may be behind the empirical failure of the purchasing power parity (PPP) theory (Edwards, 1987). This is corroborated by Gruen and Wilkinson (1994), who find that the RER of Australia can be explained by shocks to the goods and services and real interest rate differentials. Moreover, Chen and Rogoff (2003), Cashin, *et al.* (2004) and Camarero *et al.* (2008) find evidence of long run dependence of the RER on prices of primary products for some developing countries, which explains RER misalignment, from the supply side. Among the different sources of real disturbances, such as oil prices, fiscal policy, and productivity shocks, it has been shown that oil price fluctuations play a major role in explaining real exchange rate movements (see examples Chaudhuri and Daniel, 1998; Amano and van Norden, 1995, 1998a, 1998b, and Camarero and Tamarit, 2002).

From the theoretical point of view, Neary (1988) and Blundell-Wignall and Gregory (1990) justify the role of real shocks, proxied by terms of trade, on the RER long run behaviour. In the same spirit, Cashin *et al.* (2004) find that the effect of commodity terms of trade is similar to the Balassa-Samuelson effect on RER. To sum up, the key point lies in identifying the long run driver of the RER. By doing so, some insights into the determinants of the exchange rates will be gained, which will lead to a better understanding of the variable, as well as serve to help foreign exchange policy design. Against this background, we employ a simple model which allows us to study the relationship between real exchange rates and oil price.

2.1 Cointegration analysis

In order to explain the long run determinants of the African RER, we apply the Johansen cointegration approach (Johansen, 1988, and Johansen and Juselius,1990). The empirical analysis is based on the following vector error correction model of order p, VECM(p),

$$\Delta x_t = \sum_{i=1}^{p-1} \Gamma_i \Delta x_{t-i} + \alpha\beta' x_{t-1} + \alpha\delta_0 Ds_t + \Phi_1 Dp + \mu_0 + \varepsilon_t \tag{1}$$

where x_t is a vector of $I(1)$ variables, i.e. RER and real oil price, $\mu_0 = \alpha\beta_0 + \alpha_\perp \gamma_0$, so that β_0 is a drift restricted in the cointegrating space and γ_0 is equal to zero, δ_0 is the coefficient for the mean shift that does not cancel out in the cointegrating space and finally, the coefficient Φ_1 captures the effect of outlier dummies in the dynamics of the process. Initially, we aim at estimating the long run elasticities of real oil prices on the RER. Exogeneity of the dependent variable is not imposed, but tested instead. In addition, we test for the stability of the parameters by applying the Hansen and Johansen (1999) test for the long run parameters β and the loadings, α.

Although cointegration techniques might indeed reveal a long run relationship between African RERs and real oil prices, it will be characterised as a linear one. Given this fact, the following question immediately arises: Do short-run deviations of exchange rates from their equilibrium state exhibit a linear or nonlinear behaviour? The key point is that exchange rates might re-adjust to equilibrium in a different way depending on the evolution of certain variable(s), so nonlinearities may affect the response of exchange rates to such deviations. In fact, detecting nonlinearities, i.e. investigating data-generating processes of inherently asymmetric realisations, has long been of interest to applied economists. More recently, a number of empirical works have found evidence of nonlinear evolution in observed economic series (see examples, van Dijk and Franses, 1999, Öcal and Osborn, 2000, Skalin and Teräsvirta 2002, and Sensier *et al.*, 2002). In this vein, this is the focus of the next stage of the current investigation.

2.2 Nonlinear framework

2.2.1 The specification

The long run relationship between African exchange rates and real oil prices revealed by the cointegration techniques are based upon a linear specification of the dynamics. In practice, this restriction may be misplaced, and (non)linearity modelling may be more appropriate.

Amongst the most usual nonlinear specifications, we have the Smooth Transition (ST) model, which is the framework we apply in this paper. STs belong to the family of state-dependent models where the data-generating process is a linear one that switches between a certain number of regimes according to some rule. This parameterisation has several advantages, including being flexible enough to capture different types of nonlinearity; standard nonlinear estimation techniques can be used, and there exists a well-defined modelling cycle in the literature (Granger and Teräsvirta, 1993, Teräsvirta, 1994, 1998, and van Dijk *et al.*, 2002, amongst others, describe STs in detail).

In this paper we resort to the widest generalisation of the ST model, the Smooth Transition Regression (hereafter, STR). This specification contains an endogenous structure, as well as exogenous variables. Let y_t be a stationary, ergodic process, and, without loss of generality, only one exogenous variable x_t. The STR model is defined as

$$y_t = w_t'\pi + (w_t'\theta)F(s_t;\gamma,c) + u_t \tag{2}$$

where $w_t = (1, y_{t-1}, ..., y_{t-p_1}; x_t, x_{t-1}, ..., x_{t-p_2})'$ is a vector of regressors, $\pi = (\pi_0, \pi_1, ..., \pi_p)'$ and $\theta = (\theta_0, \theta_1, ..., \theta_p)'$ are parameter vectors $p = (p_1 + p_2 + 1)$, and u_t is an error process, $u_t \sim Niid(0, \sigma^2)$. The transition variable, s_t, can be a lagged endogenous variable, an exogenous variable or just another variable. The function $F(s_t; \gamma, c)$ is the transition function, customarily bounded between 0 and 1, making the STR coefficients vary between π_j and $\pi_j + \theta_j$ $(j = 0, ..., p)$ respectively. The transition function contains the slope parameter γ and the location parameter c. The former points out how rapid the transition between the extreme regimes is, whilst the latter indicates the threshold between these regimes. The transition variable and the associated value of $F(s_t)$ determine the regime at each t.

The usual formulations for F are the logistic and the exponential function. A proper selection of F is a main issue in such nonlinear analysis, since Logistic STR (LSTR) and Exponential STR (ESTR) models describe quite different types of behaviour. The logistic function implies extreme regimes associated with s_t values far above or below c, where dynamics may be different. In the exponential case, the extreme regimes are related to low and high absolute values of s_t, with rather similar dynamics, which can be different in the transition period.

Accordingly, the exponential model appears to be the most suitable for describing the evolution of the exchange rates. The reason is that this specification permits incorporation of the location parameter into the equilibrium RER value, and the dynamics of the variable would vary depending on the distance from the equilibrium state. In the latter case, there would not be differences between largely overvalued or largely undervalued exchange rates.

Thus, two points arise. On the one hand, according to the debate in the introduction, we consider two main forces to be driving the nonlinear behaviour in the exchange rates, i.e. idiosyncratic components specific to international trade, and oil prices. On the other hand, for the purposes of this research, linear and STR Error Correction Models (ECM) will be set out, as they reflect short run and long run effects on the data.

2.2.2 Modelling cycle

The nonlinear modelling procedure we carry out is partially based on that developed by Granger and Teräsvirta (1993) and Teräsvirta (1994, 1998), who reproduce the Box and

Jenkins (1970) iterative methodology. First, we take into account the results of the cointegration study. For those countries where a cointegration relationship between the African RERs and the real oil prices is found, we determine the linear model that would describe the evolution of the exchange rates by Ordinary Least Squares (OLS). In cases where none of our two variables is exogenous, we also estimate an equation for the real oil prices. The models include regular differences of both variables and their lags, the error correction term obtained from the cointegration vector, and, if necessary, step dummy variables in differences.

Once the linear formulation is obtained, the linearity hypothesis is tested against a STR specification. In this vein, there is a well-established procedure by Teräsvirta (1994) and it is quite commonplace to account for it. However, several authors from the most recent empirical literature also claim that it is possible to develop valid nonlinear models that improve the fit of the linear ones without having to do the previous tests, as they are not always conclusive. Following this strand, the strategy is to carry out an extensive search of STR models by defining several combinations for (γ, c, d) and the one offering the best statistical properties will be selected. The emphasis lies in the evaluation of the proposed model and any possible inadequacy will be unveiled at the validation stage (van Dijk *et al.*, 2002; Sensier *et al.*, 2002).

At this stage, we estimate the parameters of the STR models by nonlinear least squares, and proceed to evaluate their properties so as to verify whether they describe the behaviour of the variable in a satisfactory manner.[2]

Applying this nonlinear procedure we are able to answer the key question of whether the nonlinear specification better captures the evolution of the exchange rates dynamics more adequately than a linear formulation.

[2]The usual validation tests for dynamic models apply for STR specifications. Apart from these, the tests especially derived for STs by Eitrheim and Teräsvirta (1996) are also developed and applied.

3 Empirical Evidence

3.1 The data

In this paper, we consider a sample of thirteen African countries, namely Burkina Faso, Cameroon, Ivory Coast, Kenya, Madagascar, Mauritius, Morocco, Nigeria, Rwanda, Senegal, Seychelles, South Africa and Togo. Data for real effective exchange rates (REER) is obtained from Bahmani-Oskooee and Gelan (2007), who construct RER *vis-à-vis* the main trading partners, i.e. defined as the price of local currency in foreign currency, for each country, weighted by trade volumes.[3] By way of construction, a decrease in the REER reflects a real depreciation of the home country's currency. The real oil prices have been obtained by dividing the nominal oil price previously transformed into national currency ($P(oil)_i$) by the corresponding consumer price Index (CPI) for each country(CPI_i), both of which have been obtained from the International Monetary Fund's International Financial Statistics (IFS) database, and spans 1970Q1-2004Q4. The analysis has been carried out using the natural logs of both variables.

For the sake of brevity, the logs if the REER and real oil prices for only a sub-sample of the countries in our sample is presented in Figures 1 - 2. A cursory look at these figures suggest a certain degree of co-movement between the two variables, suggesting a long-run relationship, which we later test empirically.

3.2 Long run analysis

To proceed with the cointegration analysis, we specify the unrestricted Vector Autoregression (VAR) models in terms of lag length and statistical properties of the residuals. The bivariate model is based on the log of the REER (q_t) and the log of the real oil price (oil_t). The primary aim here is to analyse whether oil_t explains the long run path of q_t. Also, it has

[3]By using an effective exchange rate, we are implicitly considering competitiveness of each country with its main trading partners.

been necessary to include some dummy variables, and a shift restricted to the cointegration space given that some shocks did not cancel out in the cointegrating space.[4] The lag length for each VAR has been chosen by means of goodness of residual tests specification. The baseline models were tested for misspecification using a variety of diagnostic statistics, which are summarised in Tables 1 and 2. We find that some normality and heteroskedasticity problems persist even after inclusion of the dummy variables. However, following Gonzalo (1994), the Johansen maximum likelihood estimation procedure is robust to normality and heteroskedasticity problems.

Given that we have two variables, there can be a maximum of one cointegrating vector.[5] Table 3 reports the results of the Johansen stationarity tests and suggest that for Ivory Coast, it is not possible to reject the null of stationarity for at least one of the variables, i.e. the real price of oil. Therefore, for this country, we conclude that there is no long run relationship between REER and real oil prices.

Now, testing for the existence of a cointegrating relationship, Table 4 reports results of Johansen's Trace test. The results imply that, in all cases, the null of a unique cointegrating relationship is rejected, except for Kenya, Madagascar, Mauritius, Morocco, Seychelles and South Africa.[6] Next, we test for weak exogeneity of the REER and real price of oil, we find that in most cases the hypothesis that the real price of oil is weakly exogenous cannot be rejected at conventional significance level.[7] The only exception is Seychelles, where the hypothesis that real oil prices are weakly exogenous is rejected. One interpretation may be that, for Seychelles, the extent to which the real price of oil in national currency depends on the real exchange rate is high enough to make the real oil prices endogenous. We note that while Kenya, Madagascar, Mauritius are not oil-producing, Morocco and South Africa produce some oil. Nonetheless, with the exception of Mauritius, all these countries export

[4] See Appendix I.

[5] A full rank would imply that both variables are stationary.

[6] Furthermore, the roots of the companion matrix corroborate these results. Although test results are not reported here for the sake of brevity, they are available from the authors upon request.

[7] Results available upon request.

some oil and petroleum products.[8] However, Seychelles is somewhat different, in that the re-export of petroleum products feature heavily in its exports. The relative importance of the real exchange rate in this process, therefore, may explain why we do not find evidence of (weak) exogeneity in the real price of oil.

The cointegrating relationships are reported in Table 5. On the one hand, for Morocco and South Africa, the sign of the parameter for the oil price (oil_t) is negative, which implies that a rise in oil prices leads to a depreciation in their currency in real terms. On the other hand, for Kenya, Madagascar, Mauritius and Seychelles the picture is different, where an increase in oil prices appreciates the national currency in real terms. Based on the relative oil-production status of these countries, these results appear counter to the expected effect. However, this 'reverse' effect is neither unusual nor counter-intuitive as noted by authors including Amano and van Norden (1995, 1998b) who suggest possible reasons for similar findings for Canada and the US respectively.

We suggest here that while an increase in the price of oil is more likely to lead to higher wealth transfer from the relative oil importers i.e. Kenya, Madagascar, Mauritius and Seychelles, it may also be argued that an increase in oil prices leads to an adverse shift in the aggregate supply curve which in turn raises aggregate prices and a decrease in output. This 'Dutch disease' situation has been reported as a stylised fact within the literature, whereby a depreciation of the currency in real terms may affect the export sector, since products exported by the country will be more expensive in foreign currency. Darby (1982) argues that with an increase in inflation, the domestic interest rate is likely to be increased as a policy response to counter the effects of inflation. There is likely to be an inflow of foreign capital in response to a rise in the domestic interest rate, leading to an appreciation of the domestic currency. Moreover, with the higher inflow of wealth into the oil exporting nations, the resulting impact on the trade balance is ambiguous. A resulting higher level of imports from and spending on these oil importing countries would lead to improved trade

[8] Oil exported in barrels per day (bbl/day): Kenya (7,270); Madagascar (365); Morocco (17,420); South Africa (128,500). Source: The World Factbook page of http://www.cia.gov.

balance and an appreciation in the domestic currency.

The dummy variables appear to adequately capture significant incidents in the countries. For example, Morocco's policy actions in 1985 to tackle their heavy debt burden which included a series of devaluations of the Dirham is captured. The negative relationship captured by the cointegrating vector for Morocco also points to the effort put in by the Moroccan authorities to minimise appreciation of the currency i.e. aiming at minimising the 'Dutch disease' effect on their exports.[9] As shown is Figure 1 (d), there is a general trend towards the depreciation of the currency during the period analysed, which is particularly strong during the first half of the sample. Similarly, South Africa's major financial crisis in 1985, following the imposition of a state of emergency, and the resulting loss of confidence on the international front leading to the worst devaluation of the Rand is also captured. Similarly, the Central Bank of Kenya's depreciation of the shilling by 85% and policy moves towards liberalization 1993 and Madagascar's 20% devaluation of the Malagasy Ariary in 1986 also appear to be adequately captured.

Figures 3-4 provide the graphical representation of the recursive Hansen and Johansen (1999) stability tests for the cointegration relationship. Bearing in mind that the graphical representations of the tests are, during most of the sample, below the critical level, which is 1, we can conclude that the relationships identified in Table 5 are globally stable. In the case of Mautirius and Morocco some minor instability is evident, therefore we should consider these elasticities as average figures for the whole sample.[10]

[9] In recent years, China, for example, has been accused of manipulating the yuan's true value, in order to keep exports high.

[10] We subsequently show that the nonlinear models are globally stable in the remaining four cases.

3.3 Nonlinear dynamics

3.3.1 Detecting nonlinearities

The modelling procedure begins with the linear specification that describes the behaviour of the exchange rates for those countries where a cointegration relationship is found. Two equations, one for the exchange rate and the other for the oil price, are estimated in the only case where none of these variables are exogenous. The maximum lag order (p) of the variables is the one considered in the cointegration analysis (i.e. 1 in Kenya; 2 in Madagascar and Mauritius; 4 in South Africa; 6 in Morocco; 7 in Seychelles). In addition to the first difference of (the logarithm of) REERs and real oil prices, we introduce the variation in the dummy variable and the error correction term at $t-1$. The constant term is also included in the cointegration relationship.

Linear models are estimated by OLS with all parameters initially introduced, but then we successively exclude those with the lowest t-values (the limit is 1.6). As in Seychelles we find that the REERs and the real oil prices are not exogenous, one equation for each variable is estimated for this country. The exogeneity of the real oil prices in Kenya, Madagascar, Mauritius, Morocco and South Africa leads to only one model for the exchange rates.[11] Upon obtaining the linear models, we then test whether there is evidence of the type of nonlinear behaviour generated by STRs.

It is worth pointing out at this point that the linearity test process consists of completing a sequence of auxiliary regressions. Owing to the fact that we have an adequate number of observations, we use the so-called *unconditional* approach. This approach is based on the notion that for each transition variable candidate, the transition lag d is unknown. The transition variable is assumed to be the linear combination $\sum_{i=0,1}^{p} \upsilon_i s_{t-i}$, where $\upsilon' = (0...1...0)'$ is a selection vector with the only unit element corresponding to the transition

[11]For the sake of brevity, we do not report the final linear estimated models here, but they are available upon request.

lag.[12] The transition variables taken into account are the differences of (the logarithm of) REERs and real oil prices, and the error correction term. The transition lag d goes from 0 or 1 to the maximum p contemplated in each country. For increased flexibility, we permit the transition function to be either logistic or exponential, even in the case of the exchange rates (although the exponential function is deemed to be the most appropriate for this variable).

Table 6 presents the p-values of the linearity tests for the exchange rates in all countries and the oil prices in Seychelles. Rejection of linearity is stronger when dealing with oil prices, for both types of transition function. As it can be appreciated, the evidence of nonlinear behaviour in the two variables under study is not overwhelming but it is considerable at a 0.10 significance level. As the results are not conclusive for the whole set of countries, we follow the aforementioned strategy of an extensive search of STR models for the REERs and, where necessary, the real oil prices.

3.3.2 Nonlinear modelling

The starting point for the nonlinear specification is the estimated linear model. The extensive search of STR specifications results in a substantial number of models as we consider all the combinations of the distinct transition variables (for all the values of d), the different values of γ and a location parameter c in the neighborhood of the sample mean of the transition variable. As suggested by Teräsvirta (1994), the argument of the logistic (exponential) function is scaled through division by the standard error (variance) of the transition variable. The models are estimated by nonlinear least squares. Those specifications attaining parameter convergence are subjected to further refinement. Nonsignificant coefficients are removed to conserve degrees of freedom and cross-parameter restrictions are evaluated to gain efficiency. At this stage, we select the models offering the best properties, which are then validated by means of a battery of evaluation and diagnostic tests. The features of the estimated transition functions are also carefully examined.

[12]The reader is referred to Teräsvirta (1994, 1998) and van Dijk *et al.* 2002 for a more detailed discussion on the linearity tests procedure employed.

Given the linear long run relationship between exchange rates and oil prices, the empirical evidence suggests nonlinear behaviour in the short-run deviations of both variables from that equilibrium. We achieve valid STR-ECMs for the exchange rates in all six countries; and for the oil prices in only Seychelles. The estimated models are reported in Table 7, together with some descriptive statistics and misspecification tests. The descriptive statistics presented are the residual standard error(s) and the variance ratio of the residuals from the nonlinear model and the linear specification (s^2/s_L^2). With regard to the misspecification tests, those employed are the test of no Autoregressive Conditional Heteroskedasticity (ARCH) with four lags and the three specific tests proposed by Eitrheim and Teräsvirta (1996).[13]

First, focusing on the modelling of the exchange rates, their variations depend on their own recent history only in some countries (Mauritius and Morocco) and on the changes in oil prices in almost all cases (the exception is Morocco). Remarkably, movements in the exchange rates appear to react to deviations from the long run state in all 6 countries. The dynamics of the dummy variables are also present in the models.

We find that the transition between regimes is an exponential one in the case of the exchange rates, which fits with the findings in the literature (see Michael *et al.* 1997, Taylor and Peel 2000). The variations of the oil prices determine the nonlinear behaviour of the exchange rates in 4 out of 6 countries; the own past values of the exchange rate growth and their deviations from the equilibrium path are the source of nonlinearities in Kenya and Mauritius, respectively.

Figure 5 presents the estimated transition functions. Madagascar, Morocco, Seychelles and South Africa show two extreme regimes associated with the changes in the prices of oil, i.e. the inner regime for an (approximately) null growth and the outer regime for (larger) positive and negative values. In Kenya the extreme regimes are related to (approximately) null and large (positive and negative) variations in the exchange rates; most observations

[13]These include the test of residual serial independence against a fourth-order process (AUTO), the test of no remaining nonlinearity in the residuals (NL, computed for all the potential transition variables under the alternative, but only the one minimizing the p-value is displayed), and the test of parameter constancy that allows for changing parameters under the alternative (PC).

lie to the right of the location parameter, so that the function mimics a logistic one in this country. Mauritius presents an inner regime for values of the error correction term reasonably close to zero and an outer regime covering the remaining (positive and negative) values. The asymmetric evolution is clearly observable in all countries; the higher the absolute deviations from the corresponding threshold, the more pronounced the reaction of the exchange rates.

The exchange rates appear to evolve more rapidly from one extreme regime to the other in Madagascar, Mauritius and Seychelles than in Kenya, Morocco and South Africa. That is, the exchange rates seem to be more sensitive to shocks in the first set of countries than in the remaining ones, as they react in a more immediate way. This is unsurprising, given that the first set of countries are, within the sample, most dependent on imported oil, and with low nominal GDPs (see World Economic Outlook Databases), are therefore likely to be more susceptible to oil price shocks.

In fact, the nearly abrupt regime changes we observe suggest the need for threshold specifications and further strengthens the importance of employing STR models. According to the validation tests, there is no evidence of misspecification in the proposed ESTR models for the exchange rates, so one may conclude that they are adequate. A fact to emphasize is the high explanatory power of the nonlinear models compared to the linear regressions. Further, the variance ratios indicate that the estimated STRs explain 8 to 22% of the residual variance of the linear specifications in all six countries.

Focussing now on oil prices in the case of Seychelles, their growth displays dependence on their own past values and on the evolution of the exchange rate; the deviations from the equilibrium path also influence the behaviour of these prices, as well as the dynamics of a dummy variable for the first quarter of 1985.

The transition function is logistic and it is determined by the variations in the exchange rate; oil prices growth show different dynamics for negative (lower regime) and positive (upper regime) exchange rate variations. As shown in Figure 5, the observations display a rather equal distribution, giving rise to a clear representation of a logistic function. Following the validation stage, there are no indications of misspecification in the nonlinear model. Moreover, according to the variance ratio, the STR model explains 14% of the residual variance of the linear regression. The key point we have found out is the nonlinear nature of both the exchange rate dynamics in all our countries and the oil prices in the only one where this variable is not exogenous. The underlying factors in the asymmetric evolution of the exchange rates in most countries are the movements in the price of oil; the dependence of these economies on this product contributes to a large extent to this fact.

In the framework of our analysis, a shock in the oil price has two basic implications, i.e. an immediate variation in the price of oil, and an alteration in the long run relationship with the exchange rates. These two effects must be taken into account as their relevance, or weight, would differ across countries. Interestingly, the relationship "exchange rates-oil prices" is not only mirrored in the dynamic structure of the exchange rates in the 6 countries (and the oil prices in Seychelles), but also in the transition variable (see the case of Mauritius). With regard to oil prices in Seychelles, the exchange rate dynamics appear to cause nonlinear effects in their behaviour.

4 Policy implications

First, of the 13 countries in our original sample, our inability to find a long run relationship between REER and real oil prices for any of the countries in the *Communauté Financiére Africaine*, i.e. CFA Franc zone, is relevant and suggest that other determinants are more important than oil price in these countries. Moreover, such findings of asymmetry would have been theoretically difficult to justify, given the provisions of Article 10 of the BEAC Constitution and Article 6 of the UEMOA Accord, both of which provide for the freedom of capital flow across the zone. Besides, with policy coordination and fixed nominal exchange rate being foundations of the union, heterogeneity in long run behaviour would pose significant difficulties for (monetary) policy formulation if price stability and provisions of the

Constitution are paramount. Differences in price effects, *vis-à-vis* the unrestricted flow of capital across the zone, would skew money supply from some countries to the detriment of economic growth in others. In such a case, in order to maintain the peg, there would have been the need for uniform monetary policy to be augmented with country-specific measures, which may include increasing government intervention in energy regulation, or even planned transfer of funds, as required.[14]

Second, our finding of long run relationship between REER and real oil prices for South Africa and Morocco, but not for both Cameroon and Nigeria, all of which export some oil, suggest that having a status as an oil exporter *per se* does not imply the existence of a long run relationship. However, our results from Table 5 suggest that once the long run relationship exists, then the oil exporting status becomes relevant. For the main oil exporters in the group, Morocco and South Africa, an oil price shock has a negative long run impact on the REER, whereas the opposite effect is observed in the case of the non oil exporters.

Third, for Kenya, the significant role played by the manufacturing sector has been well documented, and the country is widely touted as the regional hub for trade and finance in East Africa.[15] In the light of this, and the fact that Kenya is a net importer of oil, the argument that an increase in oil prices increases the possibility of a shift in the supply dynamics is a plausible one. Similarly, for oil importers Madagascar, Mauritius, and the Seychelles, high dependence on imported oil for the domestic economy drives domestic prices up, relative to trading partners, hence the observed increase in the REER.

Last, but not least, for these 6 countries i.e., Kenya, Madagascar, Mauritius, Morocco,

[14]Technically, Cameroon is somewhat distinct in this subset of countries, as it is under the jurisdiction of a separate central bank, the BEAC, while the remaining (West African, or UMOA) countries fall under the control of a common central bank, the BCEAO. Although Cameroon is not a world level exporter of oil, it is considered one of Africa's main oil producers and exported (imported) 108,800 (50,750) barrels/day at 2005 estimates. Proved oil reserves are 98 million barrels at 2008 estimates.(*Source*: CIA World Factbook).

[15]According to Kenya's Export Promotion Council (EPC), the manufacturing sector contributed 10.5% to the country's GDP in 2005, an increase of 0.6% over the previous year. We also note that, as of 2006, Kenya had no proven oil reserves.

Seychelles and South Africa, where we find evidence of a long run relationship, the nonlinear behaviour we uncover for exchange rates dynamics provides support for some policy intervention, if price stability is considered important. The effects generated by more pronounced real oil price shocks should elicit a more rapid and tailored corrective response compared to less pronounced ones.

5 Summary and conclusions

As volatility in oil prices continue to dominate global energy markets, and as governments and countries grapple with achieving some stability in real exchange rates, the need for evidence on how this volatility impacts on countries becomes crucial. Aiming to contribute to studies determining the sources of shocks to real exchange rates, we have analysed the role of oil prices as a long run determinant of real exchange rates in a sample of African countries. Whether or not real exchange rates depend in the long run on real oil prices has important implications for exchange rate modelling. If shocks that affect real exchange rates have permanent effects on the variable and there is no evidence of a long run relationship, then effectiveness of policy measures aimed at returning the real exchange rate to its equilibrium will be limited or, at best, temporary. However, if real exchange rates are indeed driven by oil prices, then countries lose or gain competitiveness (albeit, with a time lag) depending on the direction of the shock. To this end, foreign exchange rate policy authorities should be better equipped to stabilise the real value of the currency given that a measurable relation has been established between the long run values of both variables. Precisely, by monitoring real oil prices, it should be possible to adequately predict the existence of real shocks that affect the real exchange rate.

Using cointegration techniques and allowing for nonlinear dynamics, we find that real oil prices and real exchange rates are indeed cointegrated in some African countries, but not in others. A number of conclusions follow from our results. First, we find evidence to suggest that in Kenya, Madagascar, Mauritius, Morocco, Seychelles and South Africa, where we find evidence of cointegration, the important role the price of oil plays in real exchange rate determination is established. Second, the effects of oil price shocks on the evolution of the real exchange rates in each of these countries is different, which highlights the fact that oil plays a different role for each of them. This may be due to the different economic structures of these economies, and whether the country exports some oil. Finally, our results also suggest that allowing for a more flexible exchange rate system would allow them to improve their international competitiveness.

Appendix I

The following dummy variables have been included in the VAR models in order to capture the presence of significant socio-political events e.g., devaluations that have affected the variables.

Burkina Faso, Cameroon, Ivory Coast, Nigeria, Senegal and Togo: ds941

Kenya: $ds932$

Madagascar: $ds862$

Mauritius: $ds794$

Morocco: $ds852$

Rwanda: $ds952$

Seychelles: $ds851$

South Africa: $ds853$

where $dsxxy = 1$ from 19xx:y to the end of the sample and 0 otherwise. This shift variables are restricted to the cointegration space ad appear in the dynamics in first differences.

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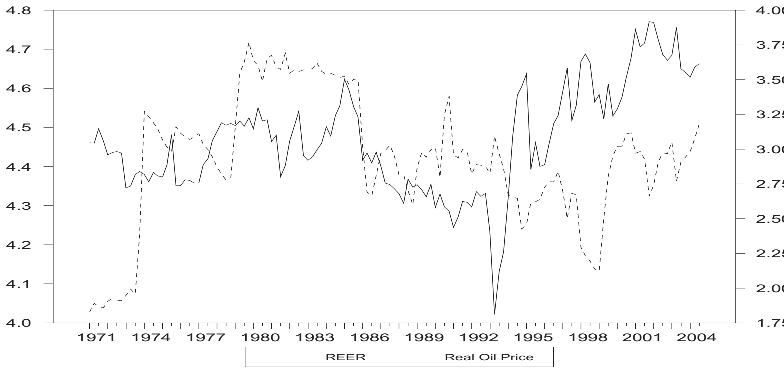
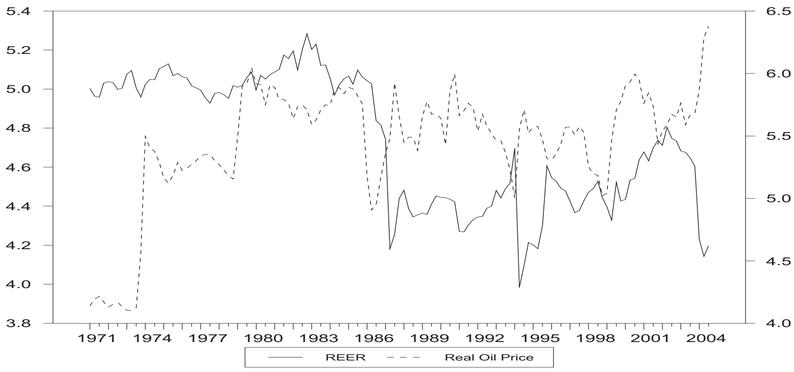
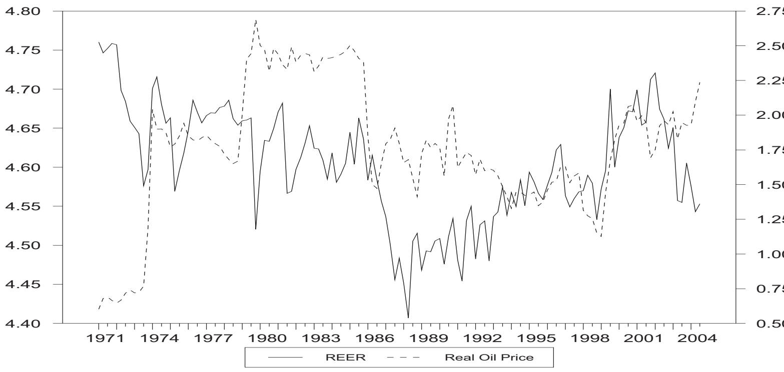
Figure 1: Real Effective Exchange Rates (left axis) and Real Oil Prices (right axis), in logs



(a) Kenya



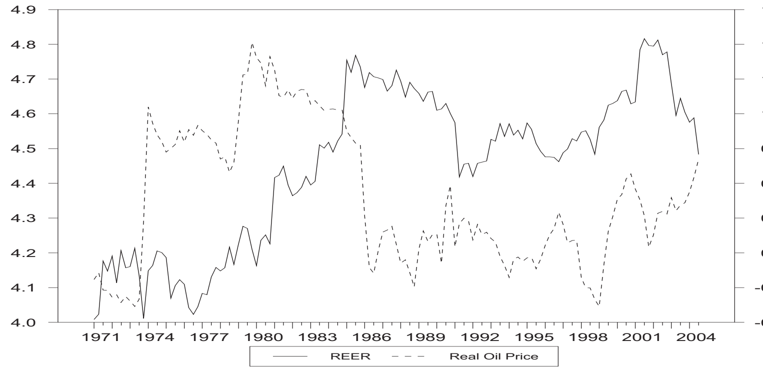
(b) Madagascar



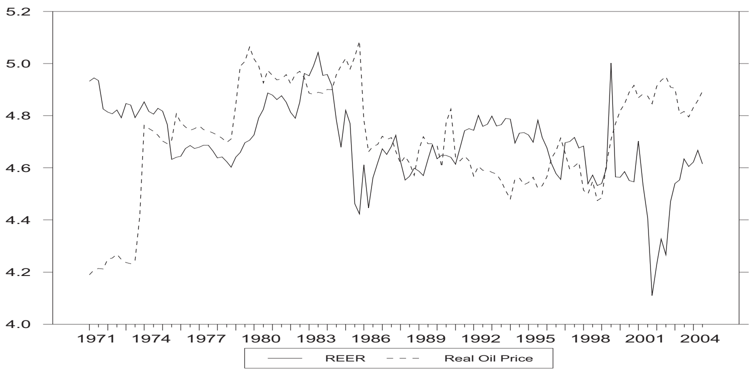
(c) Mauritania

(d) Morocco

Figure 2: Real Effective Exchange Rates (left axis) and Real Oil Prices (right axis), in logs (cont'd)

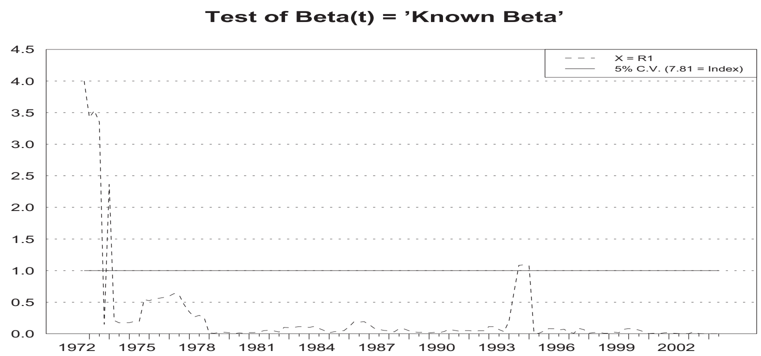


(a) Seychelles

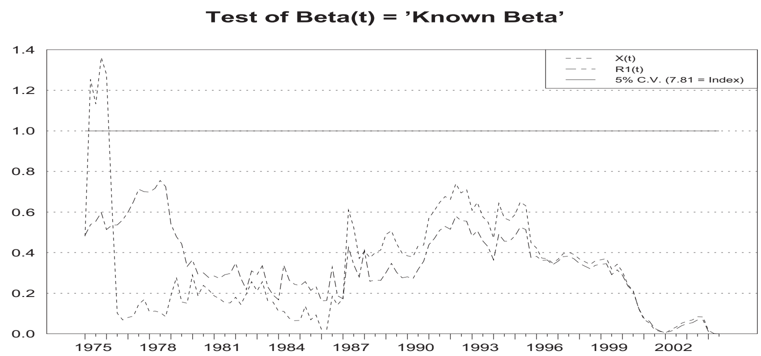


(b) South Africa

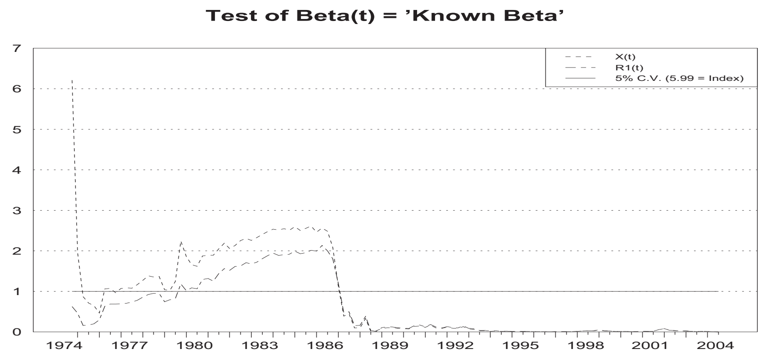
Figure 3: Structural stability tests



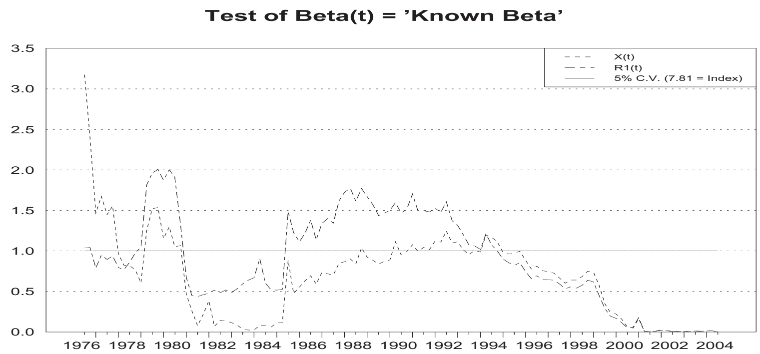
(a) Kenya



(b) Madagascar

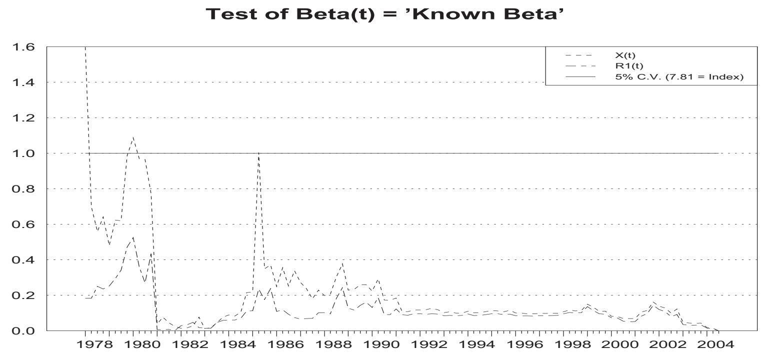


(c) Mauritius

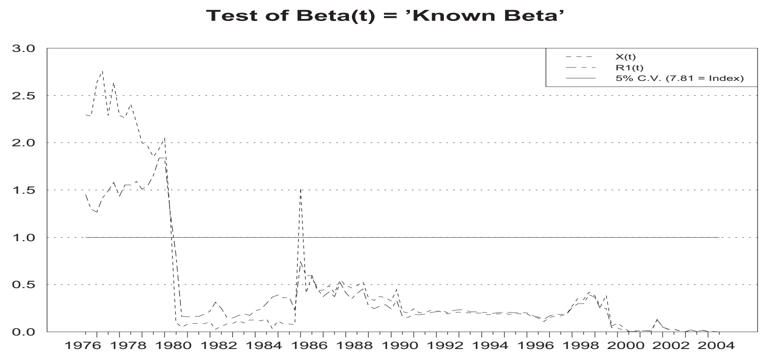


(d) Morocco

Figure 4: Structural stability tests, cont'd

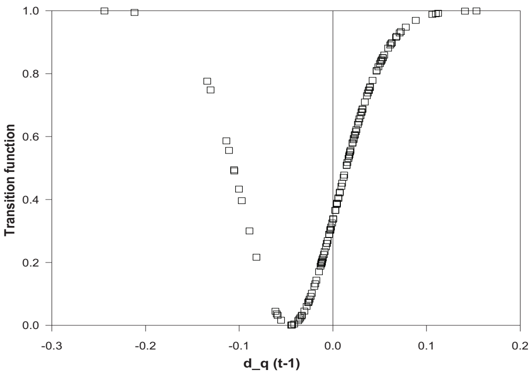


(a) Seychelles

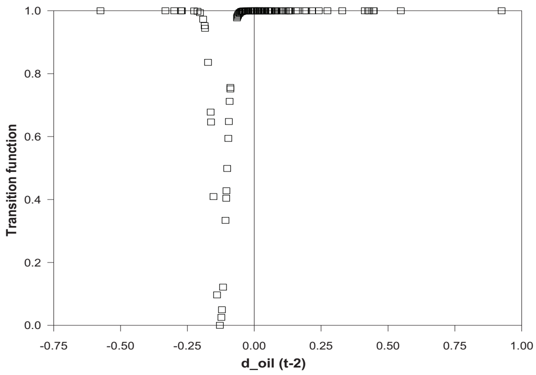


(b) South Africa

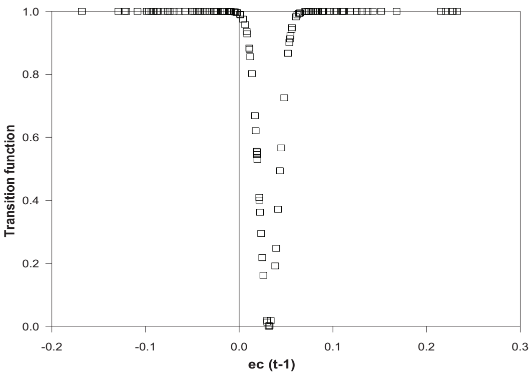
Figure 5: Estimated STAR functions



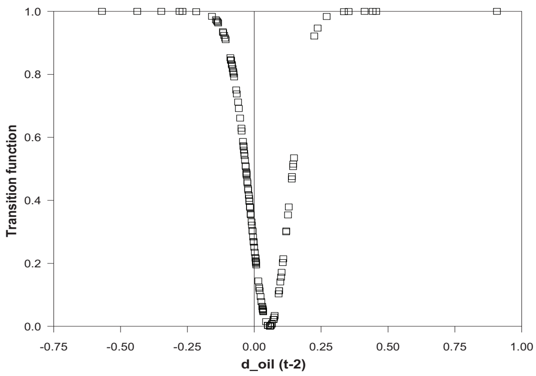
(a) Kenya



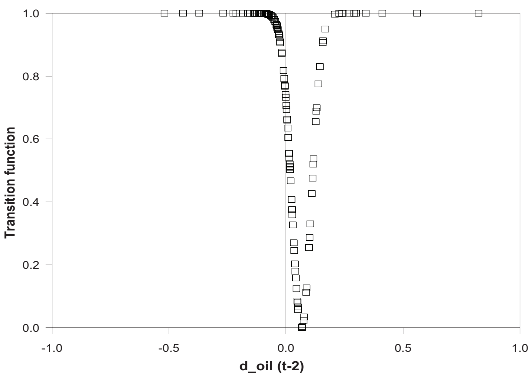
(b) Madagascar



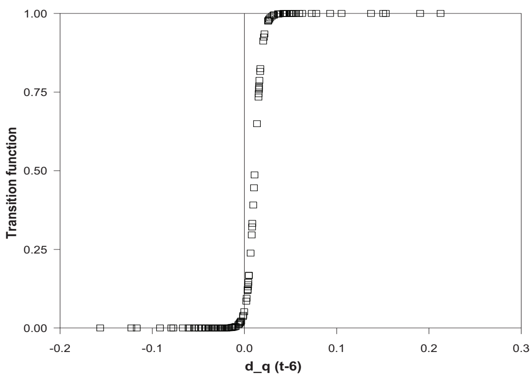
(c) Mauritius



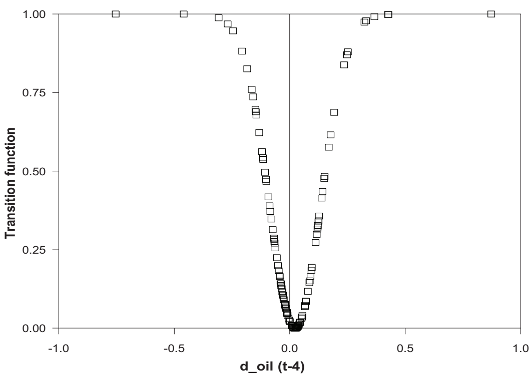
(d) Morocco



(e) Seychelles, REER



(f) Seychelles, Oil Prices



(g) South Africa

Table 1: Univariate misspecification tests

Country/VAR(p)	Variable	ARCH	Normality	Skewness	Kurotsis
Burkina Faso	Δq_t	19.021 [0.000]	11.461 [0.003]	0.758	4.253
VAR(2)	Δoil_t	4.955 [0.175]	42.922 [0.000]	0.809	7.692
Cameroon	Δq_t	4.685 [0.096	28.053 [0.000]	0.615	6.118
VAR(2)	Δoil_t	8.663 [0.013]	51.806 [0.000]	1.040	9.193
Ivory Coast	Δq_t	0.007 [0.996]	43.292 [0.000]	1.562	7.247
VAR(2)	Δoil_t	8.463 [0.015]	56.753 [0.000]	0.930	9.041
Kenya	Δq_t	0.285 [0.594]	24.631 [0.000]	-1.226	6.716
VAR(1)	Δoil_t	2.293 [0.130]	53.706 [0.000]	1.035	9.284
Madagascar	Δq_t	0.571 [0.966]	73.895 [0.000]	-2.726	18.614
VAR(2)	Δoil_t	1.775 [0.777]	30.339 [0.000]	0.993	7.340
Mauritius	Δq_t	1.050 [0.902]	5.933 [0.051]	-0.421	3.851
VAR(2)	Δoil_t	4.332 [0.363]	37.176 [0.000]	0.768	7.179
Morocco	Δq_t	10.278 [0.113]	121.629 [0.000]	-0.082	10.473
VAR(6)	Δoil_t	5.048 [0.538]	29.503 [0.000]	1.190	7.899
Nigeria	Δq_t	8.596 [0.014]	6.683 [0.035]	0.226	3.942
VAR(2)	Δoil_t	0.094 [0.954]	146.256 [0.000]	2.811	15.585
Rwanda	Δq_t	4.838 [0.304]	15.897 [0.000]	0.904	4.481
VAR(4)	Δoil_t	5.724 [0.221]	46.379 [0.000]	0.968	8.531
Senegal	Δq_t	4.053 [0.542]	13.186 [0.001]	0.796	3.994
VAR(5)	Δoil_t	5.566 [0.351]	44.040 [0.000]	1.048	8.706
Seychelles	Δq_t	3.530 [0.832]	16.963 [0.000]	0.073	4.770
VAR(7)	Δoil_t	8.169 [0.318]	15.873 [0.000]	0.621	5.158
South Africa	Δq_t	18.094 [0.001]	127.674 [0.000]	-0.305	10.938
VAR(4)	Δoil_t	0.774 [0.942]	62.747 [0.000]	0.564	8.170
Togo	Δq_t	21.571 [0.001]	22.033 [0.000]	0.344	5.293
VAR(6)	Δoil_t	3.653 [0.724]	34.238 [0.000]	1.076	8.013

Note: P-values are reported in brackets.

Table 2: Multivariate misspecification tests

Burkina Faso	**Tests for Autocorrelation:**	Ljung-Box(33):	$\chi^2(120) = 160.523[0.008]$
		LM(1):	$\chi^2(4) = 2.754[0.600]$
		LM(2):	$\chi^2(4) = 6.113[0.191]$
	Test for Normality:		$\chi^2(4) = 58.543[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 30.050[0.000]$
		LM(2):	$\chi^2(18) = 37.417[0.005]$
Cameroon	**Tests for Autocorrelation:**	Ljung-Box(33):	$\chi^2(124) = 131.923[0.296]$
		LM(1):	$\chi^2(4) = 3.217[0.522]$
		LM(2):	$\chi^2(4) = 4.846[0.303]$
	Test for Normality:		$\chi^2(4) = 86.902[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 21.501[0.011]$
		LM(2):	$\chi^2(18) = 23.394[0.176]$
Ivory Coast	**Tests for Autocorrelation:**	Ljung-Box(33):	$\chi^2(124) = 141.357[0.136]$
		LM(1):	$\chi^2(4) = 4.617[0.329]$
		LM(2):	$\chi^2(4) = 3.924[0.416]$
	Test for Normality:		$\chi^2(4) = 113.144[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 15.648[0.075]$
		LM(2):	$\chi^2(18) = 20.230[0.320]$
Kenya	**Tests for Autocorrelation:**	Ljung-Box(33):	$\chi^2(128) = 142.164[0.185]$
		LM(1):	$\chi^2(4) = 9.537[0.049]$
		LM(2):	$\chi^2(4) = 3.994[0.407]$
	Test for Normality:		$\chi^2(4) = 83.606[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 3.171[0.957]$
		LM(2):	$\chi^2(18) = 6.668[0.993]$
Madagascar	**Tests for Autocorrelation:**	Ljung-Box(33):	$\chi^2(112) = 134.564[0.072]$
		LM(1):	$\chi^2(4) = 2.356[0.671]$
		LM(2):	$\chi^2(4) = 0.776[0.942]$
	Test for Normality:		$\chi^2(4) = 102.320[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 1.184[0.999]$
		LM(2):	$\chi^2(18) = 0.052[1.000]$
Mauritius	**Tests for Autocorrelation:**	Ljung-Box(33):	$\chi^2(112) = 124.982[0.189]$
		LM(1):	$\chi^2(4) = 6.583[0.160]$
		LM(2):	$\chi^2(4) = 4.985[0.289]$
	Test for Normality:		$\chi^2(4) = 40.218[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 11.450[0.246]$
		LM(2):	$\chi^2(18) = 17.819[0.468]$
Morocco	**Tests for Autocorrelation:**	Ljung-Box(32):	$\chi^2(104) = 100.457[0.580]$
		LM(1):	$\chi^2(4) = 3.011[0.556]$
		LM(2):	$\chi^2(4) = 4.445[0.349]$
	Test for Normality:		$\chi^2(4) = 153.533[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 31.400[0.000]$
		LM(2):	$\chi^2(18) = 34.567[0.011]$
Nigeria	**Tests for Autocorrelation:**	Ljung-Box(33):	$\chi^2(124) = 137.499[0.192]$
		LM(1):	$\chi^2(4) = 3.758[0.440]$
		LM(2):	$\chi^2(4) = 1.040[0.904]$
	Test for Normality:		$\chi^2(4) = 148.843[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 7.164[0.620]$
		LM(2):	$\chi^2(18) = 10.300[0.922]$
Rwanda	**Tests for Autocorrelation:**	Ljung-Box(32):	$\chi^2(112) = 115.871[0.382]$
		LM(1):	$\chi^2(4) = 4.984[0.289]$
		LM(2):	$\chi^2(4) = 10.660[0.031]$
	Test for Normality:		$\chi^2(4) = 63.852[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 9.556[0.388]$
		LM(2):	$\chi^2(18) = 19.791[0.345]$
Senegal	**Tests for Autocorrelation:**	Ljung-Box(32):	$\chi^2(108) = 112.555[0.363]$
		LM(1):	$\chi^2(4) = 2.146[0.709]$
		LM(2):	$\chi^2(4) = 14.088[0.007]$
	Test for Normality:		$\chi^2(4) = 58.762[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 5.043[0.831]$
		LM(2):	$\chi^2(18) = 12.840[0.801]$
Seychelles	**Tests for Autocorrelation:**	Ljung-Box(32):	$\chi^2(100) = 82.320[0.901]$
		LM(1):	$\chi^2(4) = 3.584[0.465]$
		LM(2):	$\chi^2(4) = 3.165[0.531]$
	Test for Normality:		$\chi^2(4) = 33.227[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 24.539[0.004]$
		LM(2):	$\chi^2(18) = 25.503[0.112]$
South Africa	**Tests for Autocorrelation:**	Ljung-Box(32):	$\chi^2(112) = 109.188[0.558]$
		LM(1):	$\chi^2(4) = 2.100[0.717]$
		LM(2):	$\chi^2(4) = 23.155[0.000]$
	Test for Normality:		$\chi^2(4) = 192.494[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 44.143[0.000]$
		LM(2):	$\chi^2(18) = 48.366[0.000]$
Togo	**Tests for Autocorrelation:**	Ljung-Box(32):	$\chi^2(104) = 112.483[0.268]$
		LM(1):	$\chi^2(4) = 9.658[0.047]$
		LM(2):	$\chi^2(4) = 4.034[0.401]$
	Test for Normality:		$\chi^2(4) = 65.254[0.000]$
	Test for ARCH:	LM(1):	$\chi^2(9) = 21.067[0.012]$
		LM(2):	$\chi^2(18) = 33.575[0.014]$

Note: P-values are reported in brackets.

Table 3: Tests for stationarity

Country	q_t	oil_t
Burkina Faso	5.632 [0.018]	5.162 [0.023]
Cameroon	5.195 [0.023]	9.170 [0.002]
Ivory Coast	3.331 [0.068]	2.117 [0.146]
Kenya	5.350 [0.021]	22.060 [0.000]
Madagascar	3.245 [0.072]	12.668 [0.000]
Mauritius	4.267 [0.039]	3.274 [0.070]
Morocco	6.858 [0.009]	3.820 [0.051]
Nigeria	7.849 [0.005]	5.606 [0.018]
Rwanda	2.987 [0.084]	5.535 [0.019]
Senegal	3.962 [0.047]	6.766 [0.009]
Seychelles	14.654 [0.000]	3.463 [0.063]
South Africa	4.448 [0.035]	3.623 [0.057]
Togo	8.465 [0.004]	5.669 [0.017]

Note: P-values are reported in brackets.

Table 4: Trace test for the cointegration rank

Country	p-r	r	Eig.Value	Trace	Trace*	Frac95	P-Value	P-Value*
Burnika Faso	2	0	0.122	23.664	23.019	27.134	0.122	0.142
	1	1	0.046	6.328	6.141	13.020	0.409	0.429
Cameroon	2	0	0.120	22.847	22.234	27.134	0.147	0.169
	1	1	0.043	5.832	5.618	13.020	0.464	0.489
Ivory Coast	2	0	0.089	18.537	118.025	27.134	0.356	0.389
	1	1	0.045	6.104	5.667	13.020	0.433	0.483
Kenya	2	0	0.209	38.362	38.129	26.953	0.001	0.001
	1	1	0.050	6.869	6.856	12.965	0.365	0.366
Madagascar	2	0	0.177	35.575	34.050	26.415	0.003	0.004
	1	1	0.074	10.084	9.883	12.840	0.142	0.152
Mauritius	2	0	0.097	18.675	17.851	20.164	0.081	0.104
	1	1	0.040	5.300	5.066	9.142	0.261	0.286
Morocco	2	0	0.134	30.142	30.142	26.391	0.016	0.016
	1	1	0.086	11.567	11.567	12.830	0.082	0.082
Nigeria	2	0	0.089	16.635	16.217	27.134	0.486	0.516
	1	1	0.031	4.191	3.978	13.020	0.669	0.696
Rwanda	2	0	0.104	21.952	20.894	27.214	0.183	0.229
	1	1	0.056	7.510	7.227	13.046	0.294	0.318
Senegal	2	0	0.104	20.010	20.010	27.258	0.275	0.275
	1	1	0.044	5.787	5.787	13.060	0.460	0.460
Seychelles	2	0	0.156	27.906	27.906	26.387	0.032	0.032
	1	1	0.048	6.249	6.249	12.827	0.471	0.471
South Africa	2	0	0.119	26.812	26.812	26.395	0.044	0.044
	1	1	0.077	10.373	10.373	12.832	0.128	0.128
Togo	2	0	0.107	18.937	18.937	27.304	0.337	0.337
	1	1	0.033	4.332	4.332	13.076	0.636	0.636

Note: The symbol * represents bartlett corrections.

Table 5: Identified cointegrated vectors

Kenya	$q_t = 4.176 + 0.258ds932 + 0.076oil_t$
Madagascar	$q_t = 4.874 - 0.642ds862 + 0.037oil_t$
Mauritius	$q_t = 4.501 + 0.044oil_t$
Morocco	$q_t = 4.997 - 0.289ds852 - 0.205oil_t$
Seychelles	$q_t = 3.582 + 0.899ds851 + 0.682oil_t$
South Africa	$q_t = 4.806 - 0.164ds853 - 0.051oil_t$

Table 6: Linearity tests against smooth transition regression (p-values)

	Transition Variables					
	Δq_t		Δoil_t		ec_{t-1}	
Country-variable	LSTR	ESTR	LSTR	ESTR	LSTR	ESTR
Kenya - q_t	0.0017	0.0009	0.2837	0.5313	0.9527	0.8138
Madagascar - q_t	0.6558	0.0303	0.0019	0.0001	0.9963	0.9788
Mauritius - q_t	0.4986	0.3295	0.3263	0.0634	0.7714	0.1439
Morocco - q_t	0.1487	0.1939	0.4589	0.6508	0.2916	0.2938
Seychelles - q_t	0.0750	0.2996	0.0362	0.0047	0.1324	0.2662
Seychelles - oil_t	0.0729	0.1349	0.0343	0.0591	0.0809	0.1300
South Africa - q_t	0.0100	0.0002	0.0001	0.0013	0.0214	0.0003

Table 7: Estimated STR models

KENYA

$$\Delta q_t = \underset{(0.06)}{0.17}\Delta oil_t - \underset{(0.02)}{0.09}ec_{t-1} - \underset{(0.05)}{0.22}\Delta ds9302 + \left(-\underset{(0.12)}{0.49}\Delta oil_t - \underset{(0.02)}{0.09}ec_{t-1}\right) \times \left[1 - exp\left\{-\underset{(0.38)}{0.64} \times 303.12 \left(\Delta q_{t-1} + \underset{(0.01)}{0.04}\right)^2\right\}\right] + u_t$$

s=0.04; $s^2/s_L^2 = 0.83$; ARCH=0.74 (0.56); AUTO=1.40 (0.24); NL=1.40 (0.16); PC=0.60 (0.96)

MADAGASCAR

$$\Delta q_t = -\underset{(0.20)}{1.15}\Delta oil_t - \underset{(0.02)}{0.13}ec_{t-1} + \left(\underset{(0.20)}{1.15}\Delta oil_t - \underset{(0.02)}{0.13}ec_{t-1}\right) \times \left[1 - exp\left\{-\underset{(12.61)}{29.53} \times 31.43 \left(\Delta oil_{t-2} + \underset{(0.01)}{0.13}\right)^2\right\}\right] + u_t$$

s=0.08; $s^2/s_L^2 = 0.78$; ARCH=0.11 (0.98); AUTO=1.60 (0.18); NL=1.63 (0.06); PC=1.05 (0.42)

MAURITIUS

$$\Delta q_t = -\underset{(0.04)}{0.11}\Delta q_{t-1} + \underset{(0.05)}{0.12}\Delta oil_t + \underset{(0.08)}{0.22}\Delta oil_{t-1} - \underset{(0.02)}{0.06}ec_{t-1} - \underset{(0.03)}{0.13}\Delta ds7904 + \left(-\underset{(0.04)}{0.11}\Delta q_{t-1} - \underset{(0.08)}{0.22}\Delta q_{t-2} - \underset{(0.05)}{0.13}\Delta oil_t - \underset{(0.08)}{0.20}\Delta oil_{t-1} - \underset{(0.02)}{0.06}ec_{t-1}\right) \times \left[1 - exp\left\{-\underset{(20.31)}{29.08} \times 168.35 \left(ec_{t-1} - \underset{(0.003)}{0.03}\right)^2\right\}\right] + u_t$$

s=0.03; $s^2/s_L^2 = 0.86$; ARCH=0.32 (0.86); AUTO=0.54 (0.71); NL=1.27 (0.21); PC=0.47 (0.99)

MOROCCO

$$\Delta q_t = \underset{(0.20)}{0.36}\Delta q_{t-1} + \underset{(0.18)}{0.52}\Delta q_{t-6} - \underset{(0.02)}{0.05}ec_{t-1} - \underset{(0.03)}{0.09}\Delta ds8502 + \left(-\underset{(0.23)}{0.81}\Delta q_{t-1} - \underset{(0.28)}{0.73}\Delta q_{t-6} - \underset{(0.02)}{0.05}ec_{t-1}\right) \times \left[1 - exp\left\{-\underset{(1.32)}{2.21} \times 40.92 \left(\Delta oil_{t-2} - \underset{(0.01)}{0.06}\right)^2\right\}\right] + u_t$$

s=0.03; $s^2/s_L^2 = 0.86$; ARCH=0.23 (0.92); AUTO=1.42 (0.23); NL=1.43 (0.09); PC=1.63 (0.09)

SEYCHELLES

$$\Delta q_t = \underset{(0.06)}{0.11}ec_{t-1} + \underset{(0.05)}{0.22}\Delta ds8501 + \left(\underset{(0.04)}{0.09}\Delta oil_{t-7} - \underset{(0.07)}{0.17}ec_{t-1}\right) \times \left[1 - exp\left\{-\underset{(6.27)}{6.96} \times 41.43 \left(\Delta oil_{t-2} - \underset{(0.02)}{0.07}\right)^2\right\}\right] + u_t$$

s=0.05; $s^2/s_L^2 = 0.92$; ARCH=0.52 (0.72); AUTO=0.72 (0.58); NL=1.50 (0.06); PC=0.50 (0.98)

$$\Delta oil_t = -\underset{(0.07)}{0.19}\Delta oil_{t-5} + \underset{(0.08)}{0.17}\Delta oil_{t-6} - \underset{(0.23)}{0.41}\Delta q_{t-1} + \underset{(0.03)}{0.13}ec_{t-1} - \underset{(0.13)}{0.20}\Delta ds8501 + \left(\underset{(0.14)}{0.72}\Delta oil_{t-1} - \underset{(0.36)}{0.92}\Delta q_{t-4} + \underset{(0.03)}{0.13}ec_{t-1}\right) \times \left[1 + exp\left\{-\underset{(15.80)}{13.70} \times 347.70 \left(\Delta q_{t-6} - \underset{(0.01)}{0.01}\right)\right\}\right]^{-1} + u_t$$

s=0.13; $s^2/s_L^2 = 0.86$; ARCH=1.95 (0.11); AUTO=2.99 (0.02); NL=1.43 (0.09); PC=1.12 (0.43)

SOUTH AFRICA

$$\Delta q_t = \underset{(0.04)}{0.07}\Delta oil_{t-1} - \underset{(0.08)}{0.29}\Delta ds8503 + \left(-\underset{(0.12)}{0.22}\Delta oil_{t-2} - \underset{(0.31)}{0.71}ec_{t-1}\right) \times \left[1 - exp\left\{-\underset{(0.81)}{1.05} \times 38.56 \left(\Delta oil_{t-4} - \underset{(0.02)}{0.02}\right)^2\right\}\right] + u_t$$

s=0.08; $s^2/s_L^2 = 0.92$; ARCH=1.10 (0.36); AUTO=0.36 (0.83); NL=1.38 (0.12); PC=1.31 (0.15)

Notes: Δq_t stands for the REER in first differences; Δoil_t for the oil price in first differences; ec_t for the error correction term; Δdx for the variation of the step dummy variable at time x. Values under regression coefficients are standard errors of the estimates; s is the residual standard error; s^2/s_L^2 is the variance ratio of the residuals from the nonlinear model and the best linear regression; ARCH is the statistic of no ARCH based on four lags; AUTO is the test for residual autocorrelation of order 4; NL is the test for no remaining nonlinearity; PC is a parameter constancy test. Numbers in parentheses after values of ARCH, AUTO, NL and PC are p-values.