



## 7 Chapter 7: Microstructure approach to the determination puzzle

### 7.1 Introduction

The market microstructure approach has been applied to the three major puzzles of exchange rate economics: the forward bias puzzle, the excess volatility puzzle, and the exchange rate determination puzzle. The details of how the microstructure approach addresses the first two puzzles mentioned above are found in Chapter 7 of Lyons (2001). In this chapter we focus on the market microstructure approach to the exchange rate determination puzzle. Later the chapter presents estimation results.

As pointed out in the previous chapter, Meese and Rogoff (1983) found that the out-of-sample performance of fundamentals-based monetary models have been unable to outperform a random walk model. This finding has remained largely robust ever since. In a survey, Frankel and Rose (1995) concluded that no model based on standard fundamentals like money supplies, real income, interest rates, inflation rates, and current account balances would succeed in explaining or predicting a high percentage of the variation in the exchange rate in the short- or medium-term frequencies. Moreover, Evans and Lyons (1999) have pointed out that the main weaknesses of the fundamentals-based models are that these models assume that all information relevant for exchange rate determination is common knowledge and that the transmission from that information to equilibrium prices is also common knowledge. The poor explanatory power of macro-based models, coupled with the empirical evidence that micro-structural aspects of the functioning of financial markets are a significant consideration in explaining short-term movements, have swayed the attention of economists toward what has been termed “order flow” in foreign exchange markets. In point of fact, order flow constitutes the mainstay of the market microstructure approach to the exchange rate puzzles. Order flow, as defined by Vitale (2006) is the difference between buyer-initiated and seller-initiated orders in a securities market.



The market microstructure approach has gained popularity because it recognises that, in the short run, the news associated with macroeconomic variables has an impact on the exchange rates. In different words, the arrival of news condition market expectations of future values of the exchange rate fundamentals, leading to immediate reactions by the markets in anticipation of the shifts in the fundamentals. In this context, the market microstructure approach claims that the imbalances between 'buyer-initiated and seller-initiated trades' in foreign exchange markets are indicative of the transmission link between exchange rates and fundamental determinants of exchange rates (Vitale, 2006).

To reinforce the usefulness of the microstructure approach, Love and Payne (2002) utilise 10 months of transaction-level exchange rate data on the dollar-euro, pound-euro and dollar-pound exchange rates and data on euro-area to test whether announcement surprises have a systematic and significant effect on both the order flow and prices. They find that, at a 1 minute sampling frequency, macroeconomic data releases have systematic effects on order flow and on exchange rate transaction prices. Their results show that the release of positive news tend to lead to exchange rate appreciation and that order flow tends to be positive, reflecting excessive buying pressure relative to aggressive selling. Furthermore, Love and Payne (2002) show that in periods just after macroeconomic announcements, the significance of order flow in exchange rate determination is much greater than in normal times. The results suggest that between 50 and 66 per cent of the final price reaction to news comes via this order flow mechanism.

With regard to the relationship between macro-based models and microstructure approaches, the authors conclude as follows:

*Within the context of exchange rate determination our results suggest that the recent distinctions drawn between macroeconomic and microstructure models are not clear cut; the modelling of exchange rates should incorporate both elements of macro and microstructure. Further effort needs to be expended on theoretical and empirical work to merge the two sides of exchange rate determination in an attempt to more accurately explain how exchange rates are determined (Love and Payne, 2002: 2-3).*



Another relevant study supportive of the microstructure approach is Danielsson, Payne and Luo (2002), which assesses the forecasting ability of the order flows in forecasting exchange rates. The authors use the Meese and Rogoff (1983) framework to establish whether the order flow model yields a better forecast in mean square error terms than does a random walk model. The authors find that the order flow model passes the Meese–Rogoff test that macroeconomic models have failed.

The above analysis suggests that, while microstructure approach represents a clear paradigm shift, it cannot substitute the fundamentals-based monetary models. In fact, Evans and Lyons, who are at the vanguard of the microstructure frontier, have emphatically clarified this point:

*Note that order flow being a proximate determinant of exchange rates does not preclude macro fundamentals from being the underlying determinant. Macro fundamentals in exchange rate equations may be so imprecisely measured that order-flow provides a better “proxy” of their variation. This interpretation of order flow as a proxy for macro fundamentals is particularly plausible with respect to expectations: standard empirical measures of expected future fundamentals are obviously imprecise. Orders, on the other hand, reflect a willingness to back one's beliefs with real money (unlike survey-based measures of expectations). Measuring order flow under this interpretation is akin to counting the backed-by-money expectational votes (Evans and Lyons, 1999: 5).*

## 7.2 The basic model

This brings us to the methodological issues pertaining to microstructure modelling. Evans (2001) develops a hybrid model that combines micro and macro fundamentals:

$$\Delta S_t = f(i, m, o) + g(X, I, Z) \quad (7.1)$$

where the function  $f(i, m, o)$  denotes the macro component of the model and  $g(X, I, Z)$  is the microstructure component, and  $\Delta S_t$  represents the change in the exchange rate. The main variables in the function  $f(i, m, o)$  include current and past values of home and foreign nominal interest rates, money supply  $m$ , and other macro determinants  $o$ . In the function  $g(X, I, Z)$  there is the order flow  $X$ , a measure of dealer net positions  $I$ , and other micro determinants, denoted by  $Z$ . Lyons (2001) notes that  $f(i, m, o)$  and  $g(X, I, Z)$  depends on current and past values of their determinants as well as on expectations of determinants' future values, suggesting that rational markets are forward looking.

When they use the hybrid model, the authors report that their model explains more than 60 per cent of the daily changes in the log of the exchange rate between the Deutschmark and the US dollar and more than 40 per cent of the daily variations of the log of the exchange rate between the Yen and the US dollar. They also argue that their analysis bridges the gap between previous work on market microstructure, which utilises data transaction by transaction, and the macroeconomic studies utilising monthly data.

An apposite question facing the microstructure approach is whether causality runs strictly from order flow to the exchange rate, rather than running in both directions. According to Lyons (2001), causality runs strictly from order flow to price. This observation is based on the study by Killieen, Lyons, and Moore (2004), in which the authors test this by estimating the error-correction term in both the exchange rate and order flow equations. They find that the error-correction term to be significant in the exchange rate equation, whereas the error-correction term in the order flow equation was found to be insignificant, implying that the adjustment to long-run equilibrium occurred via the exchange rate. The appropriate conclusion is that order flow is weakly exogenous, meaning it must appear on the right hand side of an exchange rate model, if nothing else.



### 7.3 Hybrid regression models

This chapter tests empirically the variant of Lyons (2001) model in the South African foreign exchange market context. We wish to test this model for the exchange rate between the South African rand and the US dollar. In particular, we wish to test a country-risk-augmented and commodity-price index-augmented specification that might add explanatory power to the original model.

Our basic test regression takes the following form:

$$\Delta s_t = a_1 \Delta(i - i^*)_t + a_2 \Delta x_t + e_t \quad (7.2)$$

where  $\Delta s_t$  is the log of exchange rate change,  $\Delta(i - i^*)_t$  denotes changes in interest rate differentials,  $a_1$  and  $a_2$  are regression parameters,  $\Delta x$  is the order flow, and the subscript  $t$  refers to time. From the stand point of the sticky price model, the coefficient  $a_1$  is expected to be negative, because an increase in the foreign interest rate  $i^*$  requires an immediate increase in the exchange rate to compensate for the depreciation caused by the uncovered interest parity. The coefficient  $a_2$  is also expected to have a negative sign, indicating that net purchases of the foreign currency result in a higher price of the domestic currency in terms of the foreign currency.

An important difference between the present study and that of Evans and Lyons (1999) is that the order flow variable used in this chapter is the net average daily turnover of foreign currency exchange transactions in the South African market in dollar terms, whereas in Evans and Lyons study order flow is based on the net quantity of foreign exchange transactions. The reason we adopted the transactions monetary flow instead of the number of transactions is simply the absence of transactions data in the public domain. It is necessary nonetheless to point out that preliminary regressions suggested that the transaction money volumes were statistically significant as a measure of the demand and supply pressures for dollar-denominated transactions.



### 7.3.1 Commodity-price-augmented exchange rate model

The relevance of links between commodity prices to exchange rate determination has been discussed in detail by Chen and Rogoff (2002). The study was based on the recognition that for Australia, Canada, and New Zealand, primary commodities constitute a significant component of their exports. It was therefore likely that world commodity price movements could potentially explain a major component of their terms-of-trade fluctuations and exchange rates.

This above analysis suggests the following test regression:

$$\Delta s_t = a_1 \Delta(i - i^*)_t + a_2 \Delta x_t + a_3 com_t + e_t, \quad (7.3)$$

where *com* stands for the Economist commodity price index.

### 7.3.2 Country-risk-augmented exchange rate model

The traditional exchange rate models assume risk-neutrality. As a result, non-fundamental risk-related variables end up being excluded in those models. If indeed investors are risk averse, as it is usually the case, it becomes necessary to take into account the premium that compensates investors for the risk of holding assets in foreign currency. In this setting, a country risk premium serves to compensate the investor for “emerging market grouping” and other movements that may affect dollar-denominated returns to investment.

This suggests the following model:

$$\Delta s_t = a_1 \Delta(i - i^*)_t + a_2 \Delta x_t + a_3 com_t + a_4 risk_t + e_t \quad (7.4)$$



## 7.4 Econometric issues and data analysis

The study utilises the autoregressive distributed lag model (ARDL) of Persaran, Shin and Smith (2001) and as explained in Persaran and Persaran (1997). The ARDL approach to cointegration, which does not require pre-testing for the integration properties of the individual series used in the empirical analysis, relies on a bounds testing procedure.

### 7.4.1 The autoregressive distributed lag model

Formally the ARDL model takes the following form:

$$\left[ 1 - \sum_{i=1}^p \theta_i L^i \right] y_t = \sum_{i=1}^k \beta_i(L, q_i) x_{it} + \delta' z_t + \varepsilon_t, \quad (7.5)$$

where  $\beta_i(L, q_i) = \beta_{i0} + \beta_{i1}L + \dots + \beta_{iq}L^{q_i}$  for  $i = 1, 2, \dots, k$ ,  $L$  is a lag operator such that  $Ly_t = y_{t-1}$  and  $z_t$  is a vector of exogenous variables with fixed lags and/or deterministic variables such as the time trends and an intercept term.

The error correction representation takes the following form:

$$\begin{aligned} \Delta y_t = & \sum_{i=1}^k \beta_{i0} \Delta x_{it} + \varphi' \Delta z_t - \sum_{j=1}^{p-1} \gamma \Delta y_{i,t-j} - \phi(1, \hat{p}) EC_{t-1} \\ & - \sum_{i=1}^k \sum_{j=1}^{\hat{q}_i-1} \lambda \Delta x_{i,t-j} + \varepsilon_t \end{aligned} \quad (7.6)$$

where the error correction term is given by  $EC_t = \left[ y_t - \sum_{i=1}^k \hat{\theta}_i x_{it} - \Psi' z_t \right]$ , and

$\phi(1, p) = 1 - \sum_{i=1}^p \hat{\phi}_i$  measures the quantitative significance of the error correction term.

The coefficients,  $\gamma$  and  $\lambda$  determine the short run dynamics of the model's convergence to equilibrium.

As a first step the econometrician determines the lag length of the model. This is done by estimating the model with and without the deterministic trend and the appropriate lag is selected on the basis of the Akaike Information Criterion (AIC), the Schwarz's Bayesian Information Criterion (SBC) or the Lagrange Multiplier (LM) test. The author prefers the Schwarz Bayesian Criterion as recommended by Pesaran and Pesaran (1997).

The second step is to test the existence of a long-run relationship between the variables. Essentially, the researcher must conduct an F-test on the significance of lagged levels of variables in the error correction form. As explained in Pesaran and Pesaran (1997), the F distribution is non-standard irrespective of the integration order of the variables.

#### 7.4.2 ARDL algorithm for inference

Inference is based on the following algorithm:

- The calculated F-statistic is compared with the critical values tabulated by Pesaran, Shin and Smith (2001).
- If the calculated F-statistic *falls above* the upper bound, then the researcher can draw the conclusion that there exists a long-run relationship, without knowing the order of integration in the underlying variables.
- If the calculated F-statistic falls below the lower bound, the researcher cannot reject the null hypothesis of no cointegration.
- If the calculated F-statistic falls between the critical value bounds, the result is inconclusive. In this case, the researcher may have to test the order of integration of the underlying variables by using the standard unit roots techniques.

#### 7.5 Empirical evidence

The dependent variable is the log-level of the ZAR/USD real exchange rate, denoted RAND. Denote the 'forcing' variables included in equation (7.4) in vector form as





$x_t = [USSA, TURN]'$  and let the exogenous variables be  $z_t = [COMM, EMB, TIME, ITN]'$ .

The variables are described as follows:

- USSA* = The short-term interest rate differential between the US and South African interest rates;
- TURN* = The dollar-denominated net average daily turnover on the South African foreign exchange market or SARB Quarterly Bulletin's time series number 5478M;
- COMM* = Economist commodity price index in dollar terms;
- EMB* = The spread between South Africa's dollar-denominated bonds and Global Emerging Market Bond Index, which is used as a measure of country risk.
- TIME* = Time trend
- ITN* = Intercept term.

The following are the Error Correction Model results using Microfit:

**Table 9 Bounds-testing results for the Rand-dollar real exchange rate**

Results of ARDL model based on Akaike Information Criterion			
The number of forcing variables is 2			
	10 per cent significance level		
	F-stat	I(0) Critical bounds	I(1) Critical bounds
Including time trend and intercept	4.77	4.19	5.06
Including intercept and no time trend	4.70	3.17	4.14
No intercept and no time trend	1.57	2.17	3.19

Results of ARDL model based on Schwarz Bayesian Criterion			
The number of forcing variables is 2			
	10 per cent significance level		
	F-stat	I(0) Critical bounds	I(1) Critical bounds
Including time trend and intercept	9.10	4.19	5.06
Including intercept and no time trend	6.22	3.17	4.14
No intercept and no time trend	2.96	2.17	3.19



**Table 10 Error Correction Representation for the ARDL Model**

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ARDL(1,0,0) selected based on Schwarz Bayesian Criterion
*****
Dependent variable is dDRAND
132 observations used for estimation from 1995M7 to 2006M6
*****
Regressor      Coefficient      Standard Error      T-Ratio[Prob]
dDTURN         -.0013712         .019860             -.069044[.945]
dDUSSA         -.012146         .0050295           -2.4150[.017]
dCOMM          .2626E-3         .2333E-3           1.1259[.262]
dEMB           .0037617         .0034334           1.0956[.275]
dTIME          -.6057E-4         .8519E-4           -.71102[.478]
dITN           -.030322         .034603            -.87628[.383]
ecm(-1)        -.74180          .090553            -8.1919[.000]
*****
List of additional temporary variables created:
dDRAND = DRAND-DRAND(-1)
dDTURN = DTURN-DTURN(-1)
dDUSSA = DUSSA-DUSSA(-1)
dCOMM = COMM-COMM(-1)
dEMB = EMB-EMB(-1)
dTIME = TIME-TIME(-1)
dITN = ITN-ITN(-1)
ecm = DRAND + .0018485*DTURN + .016374*DUSSA -.3540E-3*COMM -.0050711*EMB +
.8165E-4*TIME + .040876*ITN
*****
R-Squared      .35699      R-Bar-Squared      .32613
S.E. of Regression .035141      F-stat.      F( 6, 125)      11.5666[.000]
Mean of Dependent Variable .7862E-3      S.D. of Dependent Variable .042808
Residual Sum of Squares .15436      Equation Log-likelihood      258.2842
Akaike Info. Criterion      251.2842      Schwarz Bayesian Criterion      241.1944
DW-statistic      1.8451
*****
R-Squared and R-Bar-Squared measures refer to the dependent variable
dDRAND and in cases where the error correction model is highly
restricted, these measures could become negative.

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The inference is based on the results appearing in Table 10. The most consistent results are the one based on the Schwarz Bayesian Criterion. In this context, a long-run relationship is confirmed at 10 per cent significance level.

## 7.6 Conclusions

The results, based on the Schwarz Bayesian Criterion and ten per cent significance level, show that a long-un relationship between the rand-dollar real exchange rate and the interest differential and the proxy for order flow, which is proxied by the dollar-denominated daily net turnover on the South African markets. However, the t-statistic for order-flow proxy was insignificant. The specification favoured by SBC and AIC is the one that includes the intercept term with no time trend.



The results support the view that the market microstructure approach is a viable way of finding reliable determinants of exchange rates. As indicated in Chapter 3, the market microstructure approach can be enriched to accommodate many components of the foreign exchange markets. For instance, we have seen that Evans and Lyons (2005) incorporate dealers who act as intermediaries in four financial markets: the home money markets and bond markets; the foreign money markets and bond markets. In their model the authors suggest that order flow contains both backward-looking and forward-looking components.

The jury is still out as to whether the market microstructure approach can resolve the major puzzles of exchange rate economics. However, the approach is promising.



## 8 Chapter 8: Conclusions and implications

### 8.1 Background summary

The thesis focused on finding solutions to major exchange rate puzzles, which were discussed in detail by Obstfeld and Rogoff (2000). The first puzzle of concern was the purchasing power parity (PPP) puzzle. To resolve the puzzle, the thesis used Bayesian unit root testing and nonlinear nonstationarity tests associated with smooth transition autoregressive (STAR) family of models.

Chapter 3 argued that nonlinear approaches to exchange rate adjustments are likely to provide a firmer basis of inference and stronger support for the PPP in the long-term. The results obtained from the KSS tests suggested that the behaviour of 4 dollar-based real exchange rates should be treated as nonlinear and stationary rather than linear and nonstationary. At 10 per cent significance level the real exchange rates of 4 countries were stationary: Mozambique, Madagascar, Mauritius, South Africa, Swaziland, and Tanzania were found to be stationary. This finding of nonlinear behaviour provides statistical evidence in support of a smooth transition mean-reverting behaviour in 4 out of 10 real exchange rates. As such, any deviation from the PPP, either over- or under-appreciation of real exchange rates should be seen as temporary.

In Chapter 4 we presented hypothesis testing in respect of Bayesian unit root tests and joint tests of nonlinearity and stationarity associated with the seminal contribution by Kapetanios, Shin and Snell (2003). We also presented the results of Augmented Dickey-Fuller tests at conventional levels.

In the context of Bayesian unit root testing, the nonstationarity hypothesis received small posterior probability relative to other hypotheses. In this setting, the Bayesian results strongly supported the hypothesis that all the real exchange rates were to be treated as trend-stationary autoregressive processes. The Bayesian unit root test results were found to be sharply at odds with the ADF results in that the hypothesis



of a unit root does not receive significant posterior probability in all cases. However, Ahking (2004) found that the Bayesian tests could not distinguish between a trend-stationary autoregressive model from a stationary autoregressive one, especially when the time trend effect was relatively small, and the time series was highly persistent. The latter author found that the bias was in favour of finding a trend-stationary model. Thus, the results in the context of Bayesian analysis should be treated with caution.

Chapter 5 dealt with the half life version of the PPP puzzle. It followed Rossi (2005a) to generate for the SADC point estimates and confidence intervals in which deviations from PPP are in some cases compatible with nominal price and wage stickiness. The motivation for using Rossi's methodology is that she used local-to-unity asymptotic theory in the presence, in most cases, of highly persistent data. As it is commonly observed, real exchange rates manifest themselves as processes with roots near-unity. This characteristic makes them provide no good small-sample approximation to the distribution of estimators and test statistics. We used an alternative approach by modelling the dominant root of the autoregressive lag order polynomial as local-to-unity. This approach led to an alternative asymptotic approximation that provided a better small-sample approximation than imposing the order of integration. According to the empirical results, point estimates of half life deviations less than 36 months depended on the method used. Such cases include all countries except Tanzania, Zambia, and Malawi. It is noteworthy, however, that the median unbiased point estimates appear quite reasonable in the context of PPP.

Chapter 6 employed "a class test for fractional integration" associated with the seminal contribution of Hinich and Chong (2007) to appraise the possibility that Southern African Development Community (SADC) country real exchange rates can be treated as long memory processes. The justification for considering fractional integration arises from the general failure to reject the unit-root hypothesis in real exchange rates when standard Dickey-Fuller unit-root tests are used. In allowing for only integer orders of integration in the series dynamics, the linear tests of nonstationarity were found by authors such as Diebold and Rudebusch (1991) to have low power against fractional alternatives.



Empirical results showed cases of antipersistence – an unappealing empirical result. Antipersistence, which represents the negative values of the long memory parameter, were associated with Madagascar, Malawi, Swaziland, and Tanzania. At the 5-per-cent significance level, the null hypothesis could not be rejected that the real exchange rate associated with Angola, Botswana, and Zambia were  $I(d)$  processes. In the case of Mozambique the null hypothesis could be rejected when  $n$  was either 6 or 7. In addition, at the 5 per cent significance level, the real exchange rates associated with Mauritius, Swaziland and South Africa were found not to be fractionally integrated.

Chapter 7 relied on the market microstructure approach, which has been applied to exchange rate determination puzzle. It claims that the imbalances between ‘buyer-initiated and seller-initiated trades’ in foreign exchange markets are indicative of the transmission link between exchange rates and fundamental determinants of exchange rates. In the context of the exchange rate determination puzzle, Chapter 7 discussed the market microstructure approach from the stand point of hybrid models that integrate order flow, fundamentals and non-fundamental variables to establish the determinants of the rand-dollar exchange rate. Among the non-fundamentals considered was the Economist commodity price index, the relevance of which is based on Chen and Rogoff (2002). Another non-fundamental variable included was a proxy for country risk — the differential between the Global Emerging Market Bond Index and the South African long-term bond.

The main objective was to find reliable determinants of exchange rates. Chapter 7 relied on the autoregressive distributed lag (ARDL) model of Persaran, Shin and Smith (2001) and as explained in Persaran and Persaran (1997). The ARDL approach to cointegration does not require pre-testing for the integration properties of the individual series used in the empirical analysis. Instead, it relies on a bounds testing procedure. In this setting, inference was based on an F-test on the significance of lagged levels of variables in the error correction form. The results, based on the Schwarz Bayesian Criterion for choosing a model’s lag length, showed that there was a long-run relationship between the rand-dollar real exchange rate, the fundamentals and the proxy for order flow, which is the dollar-denominated daily net turnover on the South African markets. Interest-rate differentials were found to be



a statistically significant fundamental. The proxy for order flow proxy was found to be statistically insignificant.

Chapter 3 dealt with the exchange rate disconnect puzzle. Economists have generally found exchange rates to be disconnected from macroeconomic fundamentals. Chapter 3 surveyed the latest approaches to the exchange rate disconnect puzzle. In particular, it presented the details of the general equilibrium models that are being developed to make the exchange rate disconnect puzzle less of a puzzle. The latest models are associated with the works of Devereux and Engel (2002), Xu (2005), Duarte and Stockman (2005), Evans and Lyons (2005), and Bacchetta and van Wincoop (2006). We found that the Evans and Lyons (2005) model and Bacchetta and van Wincoop (2006) model are the most promising research areas and have the potential to resolve the puzzle in point.

## 8.2 Conclusions

Based on the results of the above analysis, we advance the following conclusions:

### ***The PPP puzzle: mean reversion***

In the context of policy discussion, the finding of some of the SADC exchange rates to be mean-reverting means that any shocks are temporary and the exchange rate achieves equilibrium in the long-run. Thus, in the presence of a historically high volatility of exchange rates, authorities in those countries don't have to use limited reserves to influence the nominal level of the exchange rate. For countries whose exchange rates are non-mean-reverting, it is necessary to find policies that stabilise the currency because the exchange rate shocks on their economies take a long, long time to dissipate.

As far as econometric analysis is concerned, the PPP puzzle is beginning to be less of a puzzle due to the development of better tests that account for nonlinearities and structural change. In point of fact, there are extensions in the form of joint tests of nonstationarity and nonlinearity that have been developed by, among others, Kilic



(2004), Bec, Ben Salem and Carrasco (2004), Park and Shintani (2005) and Rothe and Sibbertsen (2006).

### 8.2.1 **The PPP puzzle: Half-life deviations**

As indicated, the main weakness of the Rossi (2005a) output is that confidence intervals of half-life deviations are too wide to be informative. The exchange rate half-life as a strand of research is in its infancy in terms of the robustness of the techniques produced and used. It is this author's judgement that the most robust methods have been developed by Pesavento and Rossi (2006) and Kim, Silvapulle and Hyndman (2006). Kim, Silvapulle and Hyndman (2006) propose a bias-corrected bootstrap procedure for the estimation of half-life deviations from PPP by adopting Hyndman (1996) highest density region (HDR) approach to point and interval estimation. Pesavento and Rossi construct confidence bands for multivariate impulse response functions in the presence of highly persistent processes. They use local-to-unity asymptotic approximations. An alternative approach to the calculation of exchange rate half-lives in the context of nonlinearities is associated with the work of Norman (2007).

These new methods are left for future research.

### 8.2.2 **Exchange rate determination puzzle**

Chapter 7 relied on the autoregressive distributed lag (ARDL) model of Persaran, Shin and Smith (2001) and as explained in Persaran and Persaran (1997) to avoid the pre-testing problems mentioned above. We found that risk premia, and interest rate differentials are the main determinants of the ZAR/USD exchange rate.

### 8.3 **Issues for future research**

The Thesis has appraised the extent to which the puzzles of concern can be resolved. It was seen that some of the results were contradictory. One of the main





issues for future research is to compare the robustness of the results of various methods. For instance, can we make non-contradictory inferences using Rossi (2005b) and the highest density approach? The second issue is that economists need to develop a coherent econometric framework that provides reasonable certainty about the statistical properties of exchange rates and related highly persistent processes. For example, we should be able to know with confidence that we are dealing with a long memory nonlinear process.