Official intervention in Foreign Exchange Market in Malawi: A comparison of GARCH and Equilibrium Exchange Rate approaches

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15. April 2010

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By
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Abstract

The Malawi kwacha was floated in February 1994. Since then, the Reserve Bank of Malawi (RBM) has periodically intervened in the foreign exchange market. This report analyses the effectiveness of foreign exchange market interventions by RBM. We used a generalized autoregressive conditional heteroskedastic (GARCH; 1, 1) model to simultaneously estimate the effect of intervention on the mean and volatility of the kwacha. We also ran an equilibrium exchange rate model and use the equilibrium exchange rate criterion to compare results with those from the GARCH model.

Using monthly exchange rates and official intervention data from January 1995 to June 2008, results from the GARCH model indicated that net sales of United States dollars by RBM depreciate, rather than appreciate, the kwacha. Empirically, this implies the RBM "leans against the wind", i.e., the RBM intervenes to reduce, but not reverse, around-trend exchange rate depreciation. However, results from the GARCH model for the post-2003 period indicated that RBM intervention in the market stabilizes the kwacha. In general, results from both the GARCH model and the real equilibrium exchange rate criterion for the entire study period showed that RBM interventions have been associated with increased exchange rate volatility, except during the post-2003 period. The implication of this finding is that intervention can only have a temporary influence on the exchange rate, as it is difficult to find empirical evidence showing that intervention has a long-lasting, quantitatively significant effect.

JEL:E5 E52 E58

Key Words: foreign exchange market, official intervention, GARCH, equilibrium exchange rate

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Acknowledgements

We would like to express our sincere gratitude to the African Economic Research Consortium (AERC) for the technical and financial support that enabled us to undertake and complete this research. We would also like to thank professors Ibi Ajayi, Steve O'Connell, Njuguna Ndung'u, Leslie Lipschitz, as well as other resource persons and research colleagues for their valuable comments on previous versions of this paper. We are also grateful to two anonymous external reviewers of this paper for well articulated comments and observations. Finally, our appreciation goes to the Reserve Bank of Malawi, for the first author to travel and make presentations on our research project. The views expressed in this study are entirely ours and do not necessarily represent those of the Reserve Bank of Malawi.

1.0 Introduction

Most central banks, especially in developing countries, use foreign exchange market intervention[1] as a policy tool for macroeconomic stabilization. In Malawi, the exchange rate was floated in February 1994. Since then, the Reserve Bank of Malawi (RBM) has periodically intervened in the foreign exchange market. In line with the International Monetary Fund (IMF) conditions under the structural adjustment package, the RBM has also intervened to buy foreign exchange in order to build up reserves for the government and to moderate exchange rate fluctuations.

There has been much debate in the literature on the question of whether these interventions affect the value of the kwacha. Friedman (1953) provides the classic argument against central bank intervention in foreign exchange markets. Later, the introduction of models that allowed for imperfect information (Brainard, 1967; Poole, 1970) led to the conclusion that exchange rate policies could be used for stabilization purposes. Work on optimal foreign exchange market intervention by Boyer (1978) helped achieve an uneasy consensus in the theoretical literature. It was shown that optimal exchange rate policies lie between the theoretical extremes of complete exchange rate fixity and flexibility. Optimal policy responses were shown to be a function of the nature of the shocks to the economy and to be dependent on the degree of capital mobility in the economy (Doroodian and Caporale, 2001).

In contrast, empirical work on the actual impact of foreign exchange intervention has not yielded a consensus. Studies that regressed exchange rate on intervention variable have often found coefficients with ambiguous signs (Doroodian and Caporale, 2001). For example, one might interpret a negative coefficient as evidence that official sales of foreign exchange depreciate the local currency (a perverse response) or that officials prevented a steeper depreciation from occurring, a "leaning against the wind response" (Humpage, 1988 ; Dominguez and Frankel, 1993). Friedman (1953) suggests that a simple way to determine the desirability of intervention is to test if it is profitable. Taylor (1982) finds that official intervention is almost always unprofitable. These initial findings led to numerous studies on

[1] Intervention refers to official sales or purchases of foreign exchange to influence exchange rate. In this report, we have used net sales of foreign exchange as our intervention variable.

this topic, some of which find strong evidence of profitable intervention. Most recently, Leahy (1995) finds that official intervention by the Federal Reserve has consistently generated profits. However, using generalized autoregressive conditional heteroskedastic (GARCH) methodology, Doroodian and Caporale (2001) find a statistically significant impact of intervention on spot rates for the United States of America.

These conflicting results have led many researchers to adopt different empirical methodologies to study the impact of intervention. However, these studies have done little to narrow the gap in opinion concerning intervention (Doroodian and Caporale, 2001). Recent academic work concerning the appropriateness and effectiveness of official intervention range from the generally favourable view of Dominguez and Frankel (1993) to the contention that intervention is an "exercise in futility" that at best can have only a very short-run effect on exchange values and at worst serve to introduce harmful amounts of uncertainty and volatility in foreign exchange markets (Schwartz, 1996).

1.1 Objective of the study

The main objective of the study is to examine the efficacy of the official intervention in foreign exchange markets. Specifically, the report tries to answer the following questions:

- Floatation of the kwacha was intended to be market determined, but has it really been market determined?
- Has intervention influenced movements of the kwacha?
- Has intervention dampened and smoothened the volatility of the Malawi kwacha?
- What is the role of the balance of payments pressures on the direction and volatility of the Malawi kwacha?

In view of the conflicting results from empirical literature, there has been a rising need for researchers to adopt different methodologies to resolve conflicting findings. In this study, we used two methodologies to evaluate the impact of Reserve Bank of Malawi intervention in the foreign exchange market. The first was a GARCH approach, a recent development in econometric methodology for assessing the degree of volatility. Results from the GARCH methodology were compared with results from another approach, the equilibrium exchange rate criterion.

The issue of the effect of intervention on the exchange market in Malawi is significant on both research and policy fronts. On the research front, very few such papers have been done on Africa and only one is known to the authors. It is of policy interest because, if intervention has an effect on the kwacha, this offers the monetary authorities an additional policy tool independent from general monetary policy.

In the next section, we discuss exchange rate management in Malawi. This is followed by the theoretical underpinnings for the study and a review of results in recent contributions to empirical literature on effectiveness of central bank interventions. The next section outlines the methodology used in the study. This is followed by a summary of the main findings of our empirical research. The final section concludes the report and offers some policy recommendations.

2.0 Monetary policy and exchange rate management in Malawi

2.1 Monetary policy

The objective of monetary policy continues to be price stability. To achieve this, reserve money remains the anchor of monetary policy. RBM uses a combination of instruments to achieve its objective on monetary policy. These include the bank rate, liquidity reserve requirements, open market operations, and sales and purchases of foreign exchange. This framework, however, requires flexibility of interest and foreign exchange rates.

The Central Bank closely watches all indicators that would entail price developments including consumer price index (CPI) inflation, growth in gross domestic product (GDP), monetary growth and expansion of credit (see Table 1).

Table 1: Selected macroeconomic indicators

	2000	2001	2002	2003	2004	2005
Real GDP [1]	0.2	-4.1	1.8	3.9	5.1	1.9
CPI inflation[2]	29.3	27.5	14.8	9.6	11.5	16.5
M2 (money supply)[3]	47.1	22.1	25.2	29.3	29.8	14.3
MK/US$ rate[3]	80.09	72.15	76.69	108.57	108.94	123.63

1. Annual percentage change.
2. Year-on-year of inflation.
3. Period average.

Source: Reserve Bank of Malawi Monthly Economic Reviews (December 2003 and December 2009).

Deleted:

In trying to attain its goal of price stability, RBM establishes an annual inflation rate target, announced by the Minister of Finance in the Budget Statement to Parliament, and monetary aggregates as intermediate targets.

2.2 Exchange management in Malawi

The management of the exchange rate in Malawi has been pursued with three major policy objectives in mind:

i. Maintenance of a sustainable balance of payments position.
ii. Attainment of stable domestic prices.
iii. Attainment of growth in real income.

These objectives were attained to some extent in the 1970s. However, owing to both external and internal factors, they were difficult to achieve in the 1980s. The late 1990s and early 2000s brought unique challenges emanating from the opening up of the economy and from globalization. A common feature of developing countries like Malawi is that their international trade is in terms of major world currencies rather than their own. Thus the operation of the global financial system is of paramount importance to such economies. These countries therefore have to consider the fluctuations of the major world currencies when deciding on exchange arrangements.

In most cases, large exchange rate fluctuations do not reflect economic fundamentals, while in some cases they may only be equilibrating or reflecting diverging cyclical positions or monetary policies. Consequently, the issue becomes whether a policy initiative aimed at stabilizing the exchange rate is necessary. In other words, to what extent do the medium term exchange rate fluctuations represent misalignments that have detrimental implications on the allocation of resources and for macroeconomic stability? This question will have to be answered honestly, but we first give the background to the current situation.

2.2.1 The floatation of the kwacha

In February 1994 Malawi adopted a managed float exchange rate regime. This was aimed at resolving the foreign exchange crisis that had hit the country due to suspension of balance of payments support from donors, and the lagged effects of the 1992–1993 drought. The switch from the fixed regime to the floating one was meant to achieve certain objectives which can be summed up as:

i. Improvement of the country's export competitiveness.

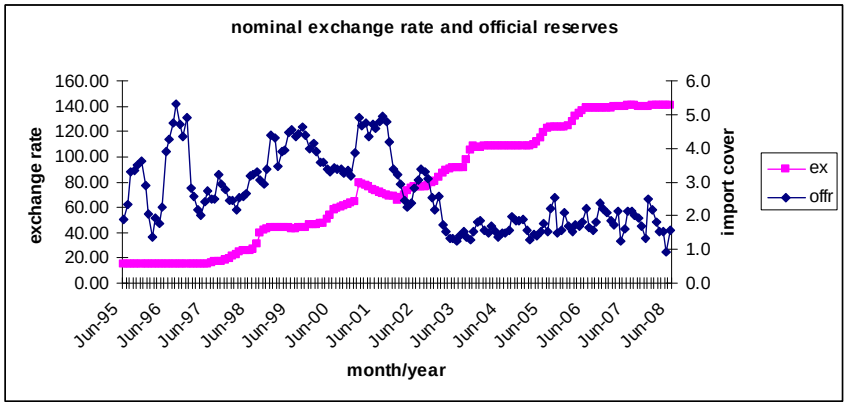
ii. Provision of an efficient foreign exchange allocation mechanism.

iii. Dampening speculative attacks on the kwacha. Before the floatation, devaluations had become more frequent and very predictable thereby making the whole system unstable.

iv. Restoration of investor and donor confidence. The country's foreign reserves had dwindled to such low levels that it was difficult to do business with the rest of the world.

After the floatation, the Malawi kwacha/US dollar exchange rate depreciated from around K4.5 in February to over K17 in September 1994. The pass-through effect from exchange rate fluctuations to inflation is very high in Malawi due to the high import content in the CPI. Consequently, the rise in the inflation rate undermined *inter alia* monetary aggregates, which were deemed unsustainable by the monetary authorities. It therefore became necessary to adopt the exchange rate as a nominal anchor for inflation and for macroeconomic convergence.

Figure 1: Evolution of nominal exchange rate and official foreign reserves



Note: ex stands for exchange rate; offr stands for official reserves import cover.

Source: Reserve Bank of Malawi, Monthly Economic Reviews (December, 2009; December, 2003, and December, 2000).

The nominal exchange rate has maintained a steady but depreciating long-run trend, while foreign reserves which were on the rise in the 1990s, have since dropped and have remained on the lower side (Figure 1). This is similar to the trends in gross foreign reserves (see Appendix 2). In the short- run, the kwacha appears to have some level of stability.

2.2.2 RBM intervention in the foreign exchange market

The RBM intervenes in the foreign exchange market primarily to smooth seasonal fluctuations related to the agricultural cycle and the build foreign exchange reserves.

The major players in the foreign exchange market in Malawi are the two major commercial banks (authorized dealer banks), the tobacco companies (Limbe Leaf and STANCOM), the sugar company (ILLOVO), and the foreign exchange bureaus. The foreign exchange bureaus were granted permission to operate from the mid 1990s to incorporate a parallel market into the legal foreign exchange system in Malawi. Operators in the bureaux de change are private entrepreneurs who have been formally recognized by government to deal in foreign exchange and provide access to foreign exchange in a convenient and informal manner.

Due to the seasonal nature of the foreign exchange earnings related to agricultural activities coupled with the fact that tobacco exports account for about 60% of the foreign exchange earnings, the Malawi kwacha is normally expected to appreciate during the tobacco marketing season (April to August), reflecting increased supply of foreign exchange on the market, and to depreciate during the off-season reflecting increased demand for foreign exchange, as the economy imports farm inputs such as fertilizer. This seasonal pattern may vary if, during that time of the year, the country has received substantial donor inflows.

A liberalized foreign exchange market environment implies that the Reserve Bank cannot dictate the value of the Malawi Kwacha. However, it is possible for the RBM to influence the value of the Kwacha by buying foreign exchange when there is an excess in the market and selling when there is a shortage (see Table 2 for basic statistics on RBM intervention).

Table 2: RBM intervention: Basic statistics

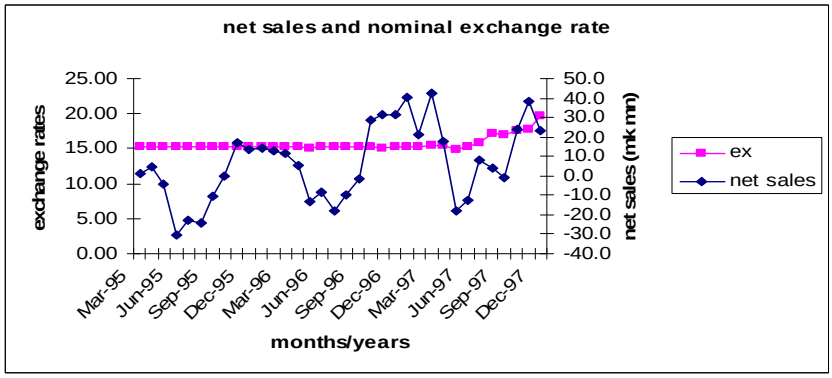
	Malawi kwacha/US dollar	
	Purchases	*Sales*
Mean	-6.144813	12.25119
Median	-1.900000	9.35000
Standard deviation	-9.927213	12.21028
Maximum	-84.690000	57.70000
Minimum	0.00000	0.00000
No. of observations	160	160

The figures are in million Malawi kwacha.
Source: author's calculation using RBM data.

This means therefore that in theory RBM can maintain a stable exchange rate by intervening in the foreign exchange market. In practice, however, RBM has to consider the monetary implications and the implications of such interventions on the position of official foreign reserves. As the Reserve Bank buys foreign exchange from the market, the supply of Malawi kwacha in the economy increases and this has potential to cause inflationary pressures. For the Reserve Bank to sell foreign exchange to the market, it must first have adequate foreign exchange reserves. And, as a source of its own foreign exchange reserves, RBM also relies on whatever it is able to buy from the market, and on if there were any inflows of donor funds. Any constraints on these two sources means RBM will have inadequate capacity to support the market effectively, thereby affecting the surplus/demand balance in the market. Overall, RBM has to do a lot of balancing in managing the exchange rate to ensure that the achievement of a stable exchange rate, which is good for the farmer, does not come at the expense of inflation and the depletion of foreign exchange reserves.

During the period 1995–1997, the exchange rate fluctuated within a very narrow fixed band and accordingly, foreign reserves were used to support the exchange rate (see Figure 2). The main objective of attaining low inflation rates was achieved towards the end of 1997 but at the expense of huge foreign exchange reserves and high interest rates, which were used to support the exchange rate. Consequently, the real exchange rate appreciated and had a negative impact on the current account balance. In other words, the current account imbalance that emerged during the period of fixed exchange rates was being covered by a run down of reserves.

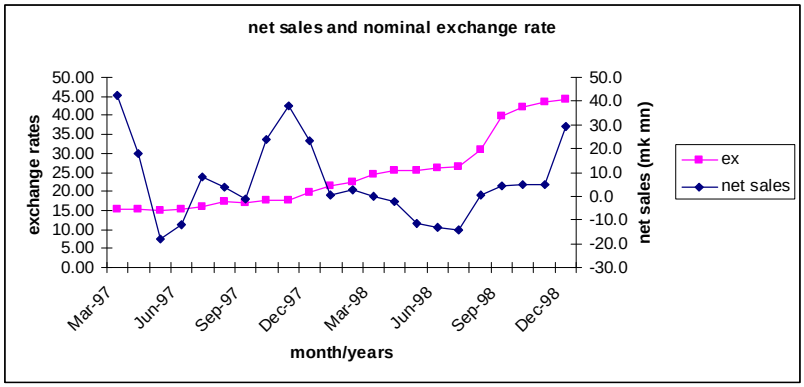
Figure 2: RBM intervention and nominal exchange rates (1995–1997)



Data source: Reserve Bank of Malawi, Monthly Economic Review (December, 2000)

After achieving the inflation objective during 1997, the target of the monetary authorities was then to revive the lost competitiveness within a reasonable period of time. It soon became clear that the narrow band had to be abandoned in favour of an unannounced crawling peg. During this period the authorities were not committed to defend the currency thus the central parity rate was adjusted every time the maximum level (i.e. the upper limit of the band) was reached. Thus between 1997 and 1998 the exchange rate moved from around K15 to K38 to the US dollar (Figure 3).

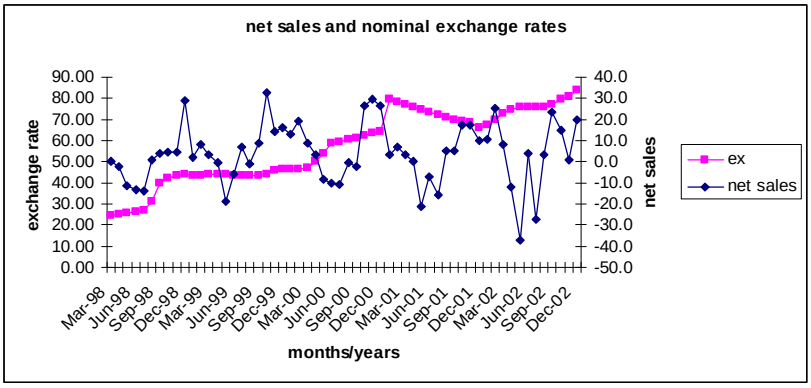
Figure 3: RBM intervention and nominal exchange rate (1997–1998)



Data source: Reserve Bank of Malawi, Monthly Economic Review (December, 2000)

This adjustment in the exchange rate brought back some competitiveness in the country's foreign trade. Consequently, the system was abandoned towards the end of 1998 and the exchange rate started operating in a more market fashion, i.e. the free-floating system. This system saw authorized dealer banks taking a more active role in determining the path for the Kwacha. Unfortunately, during this period (1998–2002), the exchange rate was very unstable and, not surprisingly, there was public outcry.

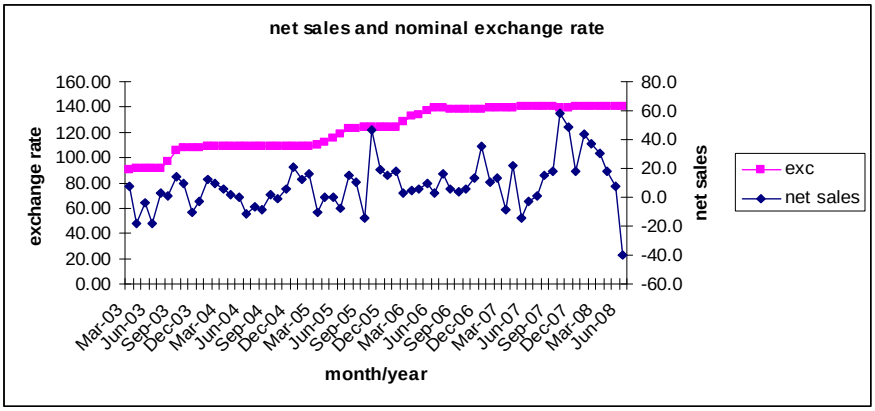
Figure 4: RBM intervention and nominal exchange rate (1998–2002)



Data source: Reserve Bank of Malawi, Monthly Economic Reviews, (December, 2003, and December2000).

The free-float system, is perhaps remembered by the first ever appreciation of the Kwacha in 2001 (see figure 4). This appreciation came on the back of huge foreign reserves. (A short period of exchange rate instability followed until a policy decision was taken in August 2003 to stabilize the Kwacha at a rate of K108 against the US dollar. The decision was in response to serious economic disequilibrium or instability following the suspension of the first IMF Poverty Reduction Growth Facility (PRGF) and the droughts in the early 2000s. The kwacha–US dollar exchange rate remained largely unchanged from August 2003 until mid-March 2005 when a series of adjustments saw the Kwacha resting at K123 against the US dollar. The Kwacha then stabilized at those levels until early 2006, when economic conditions necessitated a further review (see figure 5).

Figure 5: RBM intervention and nominal exchange rate (2003–2008)



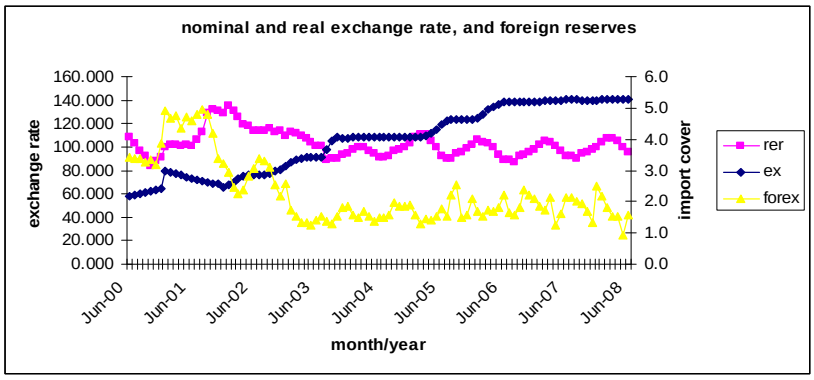
Data source: Reserve Bank of Malawi, Monthly Economic Reviews (December, 2009, and December, 2006).

2.2.3 Nominal and real exchange rate, and foreign reserves

Regarding the behaviour of the kwacha in real terms, the real exchange rate (RER), which had been appreciating since 2000,[2] with a rapid rise in official reserves, started depreciating in late 2001 as official reserves started declining. Since 2004, the real exchange rate has stabilized except for a few short-run fluctuations related to the seasonal cycle of agricultural activities (Figure 6). During this period, rising aid and productivity have supported the real exchange rate, but declining terms of trade (TOT) have outweighed these factors, as indicated by slow reserve accumulation.

Figure 6: Nominal and real exchange rate, and foreign reserves (2000–2008)

[2] The huge reserves in 2001also supported the first ever appreciation of the kwacha.



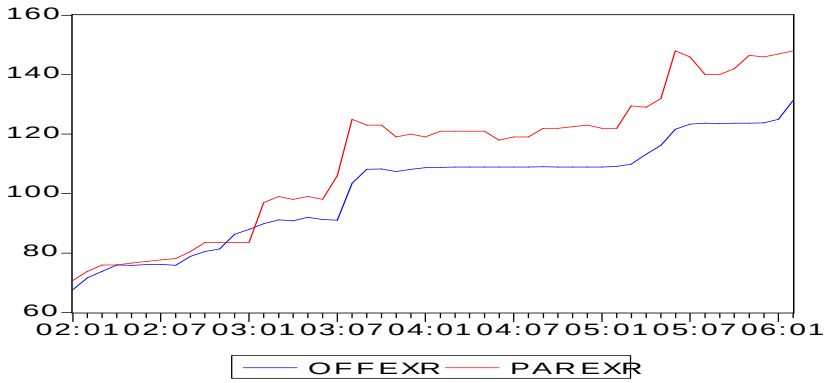
Data source: Reserve Bank of Malawi, Monthly Economic Reviews (December, 2009, and December, 2006)

International reserves have been declining since late 2001 (see Figure 6). But it is clear that from 2004, the kwacha has been largely stable and yet the levels of reserves have been too low and fluctuating. Even gross official reserves have been on the lower side (Figure 1b in the appendix). So what explains the stability of the kwacha in the face of low international reserves? One could argue that the explanation could be found in the proportion of official reserves (RBM) and commercial bank reserves respectively to gross reserves (Appendix 2). The Reserve Bank is a dormant player in Malawi's foreign exchange market (as evidenced by the wide gap between official reserves and commercial bank reserves). Using its market power coupled with moral suasion, it is possible for RBM to conduct its transactions with commercial banks at administrative exchange rates and consequently influence the commercial banks to maintain their rates at low levels.

The limited supply of foreign exchange on the market has resulted in the widening spreads, i.e. the difference between rates offered by commercial banks and foreign exchange bureaus.[3] These spreads, also known as exchange rate premium, rose substantially in June 2007 and have remained wide (Figure 7).

[3] The foreign exchange bureaus were established to incorporate and absorb the parallel market into the legal foreign exchange market.

Figure 7: Official and parallel exchange rate trends



Data source: Reserve Bank of Malawi, Monthly Economic Review (December, 2009, December 2003)

3.0 Literature review

3.1 Theory of intervention[4]

Most studies in literature on the impact of intervention consider sterilized intervention. The papers do not focus on unsterilized intervention which, because it affects the monetary base, is generally assumed to have a significant influence on the exchange rate. There is general agreement in literature that unsterilized sale of foreign exchange would be expected, other things being equal, to appreciate the exchange rate through contraction of money supply and therefore interest rates. Sterilized intervention is where the authorities take deliberate action to offset intervention in the foreign exchange market with an equal change in the net domestic credit; this happens either simultaneously or with some short lag, while leaving interest rates unchanged. Conversely, intervention is non-sterilized when it is conducted without any action taken to offset the impact of intervention.

The relationship between exchange rates and monetary control largely comes from the balance sheets of central banks. On the liabilities side, there is the base money *(BM)* which comprises reserves, currency and the central bank's net worth. On the assets side, there is net foreign assets *(NFA)* and net domestic assets *(NDA)*. Any intervention in the foreign exchange market will change *NFA* (Simatele, 2004). Assuming that net worth is insignificant, a summary of the balance sheet can be presented as:

$$BM = NFA + NDA$$

[4] This section relies heavily on the work of Simatele (2004).

Sterilization needs the central bank to take deliberate action such as open market operation sales or purchases of securities. Once this is done, the result will be an equal change in domestic assets. Without sterilization, the monetary base also changes, i.e.

$$\Delta BM = \Delta NFA$$

The size of sterilization largely depends on the extent to which simultaneous changes take place in *NDA* as *NFA* changes (Simatele, 2004). Full sterilization happens when changes in NFA are totally offset by changes in *NDA*, thus the expressions:

$$-\Delta NFA = \Delta NDA$$

and

$$\Delta BM = 0$$

In this case there would be no impact on the monetary base. The changes will eventually result in changes in broader money aggregates and interest rates. Consequently, this will affect expectations, capital inflows and eventually the exchange rate.

Sterilized intervention[5] can affect exchange rate through two channels: the portfolio balance and the signalling channels. The literature on effectiveness of intervention adopts the general view that exchange rates are determined in asset markets and they adjust to equilibrate global demands for stocks of national assets rather than demand for flows of national goods. In the class asset market models using the portfolio balance approach, domestic and foreign markets are deemed to be imperfect substitutes. In these models, asset holders allocate their portfolios to balance exchange rate risk against expected rates of return which are affected by relative supplies of assets. In the class of asset market models using the monetary approach, domestic and foreign assets are deemed to be perfect substitutes. This approach makes portfolio shares infinitely sensitive to changes in expected rates of return. In contrast to portfolio balance models, monetary models typically focus on demand for and supply of money, bond supplies being irrelevant when all bonds are perfect substitutes.

[5] RBM sterilizes its foreign exchange market intervention whenever it is perceived that intervention in the foreign exchange market will affect reserve money targets to the extent that the targets will be missed. Since money targets are usually tight, the Bank therefore often sterilizes its foreign exchange market intervention.

3.1.1 The portfolio balance channel

The portfolio approach is commonly used to assess the effectiveness of intervention because it identifies a direct channel through which intervention can influence exchange rate. This one states that sterilizing intervention through typical open market operations will change the currency composition of government securities held by the public (Humpage, 2003). A sterilized purchase of foreign exchange, for example, increases the amount of domestic bonds held by the public relative to foreign bonds, resulting in a depreciation of the local currency. Unfortunately, most empirical studies find the relationship to be statistically insignificant. The reason offered for the lack of a portfolio effect is that the typical intervention transaction is minor relative to the stock of outstanding assets. Dominguez (1998) is a notable exception to this conclusion.

3.1.2 Signalling channel

The second channel is the signalling or expectations channel. Mussa (1981) suggests that central banks might give indications regarding future, unanticipated changes in monetary policy through their sterilized interventions, with sales or purchases of foreign exchange implying monetary tightening or easing respectively. This would have direct implications for future fundamentals and traders would immediately adjust spot exchange rate quotations. Mussa suggests that such signals could be particularly strong—more so than a mere announcement of monetary policy intentions—because interventions give monetary authorities open positions in foreign currencies that would result in losses if they failed to confirm their signal. Reeves (1997) has formalized Mussa's approach and demonstrates that if the signal is not fully realistic or if the market does not use all available information, then the response of the exchange rate intervention will be low. However, Edison (1993) argues that intervention is effective and occurs through both the portfolio balance and signalling channels.

3.2 Empirical findings

Studies in empirical literature use various approaches to evaluate the impact of central bank intervention. Problems arise in surveying studies of intervention. One of them is that literature is somewhat fragmented. Although there are often several articles on a particular topic, they tend not to build on one another or to broaden previous research. This self-imposed isolation makes it difficult to explain why results differ from study to study, a problem that is particularly acute in the recent literature on the signalling and portfolio balance channels (Edison, 1993).

Danker et al. (1987) estimate portfolio balance models and evaluate separate balance of separate bilateral equations for US dollar exchange rates with the Deutsche mark, the yen, and the Canadian dollar. Their findings provide little evidence to support the portfolio balance model. Loopesko (1984) analyses the impact of sterilized intervention using data on US exchange rate vis-à-vis the currencies of other G-7 countries. She finds that in about half the cases, cumulated intervention is significant, which leads her to conclude that sterilized intervention may have an impact on the exchange rate through a portfolio balance channel. However, Dominguez and Frankel (1992) investigate both the signalling and portfolio balance channels. They use mean variance optimization restrictions employed by many other portfolio balance studies, but differs from previous studies in finding that intervention works through both channels. They, however, fail to explain precisely how their findings contradict other research on the same subject.

Leayah (1989) uses daily data to examine the profitability of US intervention. In general, his results show that the calculations are sensitive to changes in sample periods. Murray et al. (1990) give empirical evidence of the profitability of Canadian intervention from 1975 to 1988. Their results suggest that Canadian intervention has been very profitable over the post-Bretton Woods period as a whole, although substantial trading losses were realized through most of the 1980s. Mayer and Taguchi (1983) attempt to circumvent some of the problems inherent in the profit criterion by proposing a number of criteria to evaluate intervention. All of the alternatives involve the calculation of the equilibrium exchange rate for use as the reference rate. Using monthly data they find that German, Japanese and British intervention was primarily stabilizing from January 1994 to June 1982.

Doroodian and Caporale (2001) provide additional empirical evidence on the topic of the effectiveness of Federal Reserve intervention on the US exchange rate. Using a daily measure of exchange rate intervention in the yen/dollar and mark/dollar exchange rate market for the period 1985–1997, they find a statistically significant effect of intervention on spot rates. A generalized autoregressive conditional heteroskedasticity exchange rate equation is used to measure the impact of intervention on exchange rate uncertainty. The study finds that intervention is associated with a significant increase in the inter-day conditional variance (uncertainty) of both bilateral spot exchange rates. This supports the view of Friedman and Schwartz (1953) that exchange rate intervention serves to destabilize the foreign exchange market by introducing additional levels of exchange rate uncertainty. Simatele (2004) investigates the effect of central bank intervention on the Zambian kwacha. She uses a GARCH (1,1) model simultaneously estimating the effect of intervention on the mean and variance. She finds that central bank

intervention in the foreign exchange market increases the mean but reduces the volatility of the Zambian kwacha. The explanation supports the "speculative bandwagon" and a "leaning against the wind" strategy. Although there is no attempt to distinguish the channel through which intervention works, Simatele (2004) argues that this is more likely to be a signalling affect rather than a portfolio balance. Dominguez (1992) uses GARCH models to investigate whether intervention by US and German authorities has influenced the variance of the exchange rate. She finds that intervention has tended to decrease exchange rate volatility, the exception being US intervention from 1985 to 1987, which increased volatility.

Lewis (1991) develops and implements a target-zone model in which intervention is used to keep exchange rates near their target levels. She employs a multi-nominal model to estimate the probability of intervention by the G-3 central banks. She finds that intervention increases the exchange rates, as they deviate from their targets.

Simatele et al. 920090 investigates Bank of Zambia intervention. Results indicate that Bank of Zambia leans against the wind: it intervenes to reduce but not reverse around-trend exchange-rate depreciation, giving positive correlation of intervention with depreciation. The study also states that these shorter-term, transitory effects arise through the leaning against the wind channel, not through the signalling or portfolio balance channels. Bank of Zambia intervention affects deviations around trend; trend depreciation appears to depend on trend monetary growth. Rogers and Siklos (2003) find leaning against the wind behaviour for Canada and Australia; they comment: "Most studies find evidence that central banks intervene mainly to smooth exchange rate fluctuations and not their levels." Herrera and Özbay (2005) argue that in the Central Bank of Turkey's intervention function, the asymmetric effects they find for positive and negative deviations from trend signifies leaning against the wind.

In general, literature finds no significant impact of intervention through the portfolio balance channel. In contrast, most of the empirical evidence suggests that intervention can affect the exchange rate through the signalling channel. The implication from the studies is that intervention can only have a temporary influence on the exchange rate. The conclusion from the survey is that although we may be able to explain why a central bank intervenes in the foreign exchange market, it remains difficult to find empirical evidence showing that intervention has a long-lasting, quantitatively significantly effect.

4.0 Methodology

In both macroeconomic and financial economics, empirical research is based on time series, and time series are generally viewed as stochastic processes. The model builder is therefore allowed to use statistical inference in developing and testing equations that describe the relationships between economic variables. The two key properties of many economic time series that have been common in research work are non-stationarity and time-varying volatility. Foreign exchange market intervention falls under the second property, as such an action would result in unpredictable volatility. Researchers have attempted to model foreign exchange market intervention using various methodologies and approaches. The broad range of techniques presents researchers with different types of problems about which anyone assessing their results needs to be careful due to techniques used. The main problem in all empirical research on intervention is the simultaneous determination of official intervention and exchange rate changes.

4.1 Alternative approaches

In this study we considered a number of approaches to modelling foreign exchange market intervention and economic responses.

4.1.1 Event study

An incident of intervention is defined as a period of days with official intervention in foreign exchange in one direction, including up to 10 days of no further intervention between the initial and subsequent intervention transaction. It requires systematic intervention transactions (Humpage, 1999). A quick look at Malawi's experience shows that intervention transactions are not systematic. It takes long periods between one official purchase or sale of foreign exchange to the next.

4.1.2 VAR models

Structural VAR models have been used to identify dynamic responses of an economy to particular shocks and this reveals the information about the dynamic properties of the economy that is being investigated. The results can be used to inform policy makers and economic forecasters how economic variables such as exchange rate and prices respond over time to changes in policy or other events. However, the discrete values and periodic nature of intervention make it difficult to estimate parameter values of reaction functions in a VAR (Kim, 2003).

4.1.3 Profit criterion

One simple yardstick to evaluate the role of official intervention is the profitability criterion: if official intervention yields a profit, it will reduce unnecessary exchange rate fluctuations, if it entails losses it will be an additional source of exchange rate instability. Friedman et al. (1953) stimulates academics to carry out studies in this field. Their main interest was to examine possibility of profitable but destabilizing speculation. Their conclusion was as follows: if a speculator[6] is defined properly, and the excess demand curve of non-speculators is linear and has a negative slope, profitable speculation is bound to be destabilizing in the sense that it will reduce the variance in the exchange rate movement (Mayer and Taguchi, 1983).

It has, however, been argued in Taguchi (1983) that except under very special circumstances, the profitability criterion cannot be employed in any meaningful sense as an indicator of the stabilizing effect of the official intervention. The profit criterion suffers from one basic shortcoming: it can at best tell whether official intervention was in the right direction, but it cannot provide information on the extent to which that intervention was successful in actually influencing exchange rate movements. On the contrary, to the extent that intervention was fully successful in ironing out unwanted exchange rate movements, the profit criterion would not be applicable. Conversely, if intervention was ineffective and failed to exert a significant influence on the exchange rate movements, the profit criterion would perform best, but would be irrelevant, since in that case official intervention would be meaningless from a macroeconomic point of view. The use of this criterion is therefore based on the implicit assumption that official intervention has had an impact on exchange rate movements, but only a limited one (Mayer and Taguchi, 1983).

To sum up, in order for the profit criterion, even if used in more restrictive sense, to perform well, several conditions must apply. These are: the interest rate differential must be taken into account; the interest rate differential must be equal to the slope the underlying trend of equilibrium exchange rate level; if the intervention is not closed, instead of taking the last market rate to gauge the profitability of intervention, the equilibrium rate for that date must apply; and finally the effectiveness of intervention over the whole observation period has to be constant (Mayer and Taguchi, 1983).

[6] A non-speculator is an economic agent who makes a decision independently of any rate other than the prevailing one; all other agents should be regarded as speculators.

4.1.4 Equilibrium exchange rate criterion

This criterion is also known as the "divergence from equilibrium" criterion, according to which intervention is considered to be stabilizing (destabilizing) when it tends to push the exchange rate towards (away) from its equilibrium path. The equilibrium exchange rate criterion is based on an assumption of a moving equilibrium level. The criterion allows for changes in the underlying fundamentals and therefore movements in the equilibrium levels of the exchange rate itself. This approach requires the computation of the equilibrium path of the exchange rate (Pessach and Razin, 1990). The equilibrium exchange rate approach evaluates the impact of intervention by establishing whether the intervention, when it occurred, tended to push the market rate towards its then prevailing equilibrium level or away from it. Market fundamentals include such factors as money supply and real income. A change in money supply or real income in either country will affect the exchange rate (Pessach and Razin, 1990).

In a system of flexible exchange rates, exchange rate volatility depends on the volatility of market fundamentals and expectations. Hence some analysts believe that if policy makers could reduce the volatility of market fundamentals or the volatility of expectations, exchange rate volatility might also decline. Realignments become likely when exchange rate diverges from market fundamentals.

This method has one technical drawback: it lacks the stabilizing effect of intervention in the same way whether the intervention occurs when the exchange rate is very close to equilibrium (but not at) its equilibrium path or whether it occurs when the exchange rate is out of the line. This may not be very satisfactory since it could be argued that there is no need for intervention as long as the exchange rate was in any event very close to what could be considered its equilibrium level. Again, since at any point in time equilibrium level cannot be defined with certainty and exactitude, there will be a serious danger of misidentification.

4.1.5 Lean against the wind criterion:

Researchers use leaning against the wind to refer to several concepts. The central bank may intervene to: (a1) *reduce but not reverse* short-term deviations that are thought to last a few weeks or, at most, months; (a2) *reverse* short-term deviations thought to last a few weeks or, at most, months; (a3) *reduce* temporary exchange-rate *volatility* for a few days, perhaps a week; (b) *reduce but not reverse* longer-term deviations from trend, perhaps up to a year of two; and (c) *reverse* persistent medium- or longer-term trends away from the bank's perceived long-term trend

or level. In the following, short-term leaning against the wind refers to (a1), (a2) and (a3), and longer-term to (b) and (c) (Simatele and Sweeney, 2009).

Using signalling or portfolio balance channels, central banks may implement leaning-against-the-wind strategies in (b) or (c) for a year or more, perhaps indefinitely. For shorter-term effects as in (a1), signalling a change in monetary policy and then a reversal in a few weeks or months is likely ineffective. First, short-term changes have less effect. Second, there is always noise in the signalling channel that may take some time to overcome; the signal may get through just as it is time to reverse the signal. In what follows, then, short-term leaning against the wind intervention is thus taken as *not* signalling monetary policy changes. Longer-term leaning against the wind intervention may well depend on signalling monetary policy changes. Related, transitory and self-reversing changes in proportions of portfolio assets under short-term leaning against the wind will affect the exchange rate much less than long-term changes (Simatele and Sweeney, 2009).

4.1.6 Hybrid approach

This approach incorporates some elements of the lean against the wind criterion and the equilibrium exchange rate criterion. It distinguishes between two types of exchange rate zones. First, a band through the hypothetical equilibrium rate within which the stabilizing impact of intervention is judged according to the lean against the wind criterion. Secondly, the exchange rate zones outside this band, where official intervention is evaluated in terms of its impact in pushing the exchange rate towards or away from its equilibrium path. In practice, the width of the leaning against the wind band should be a function of the prevailing degree of exchange rate uncertainty and might therefore change over time.

4.1.7 Econometric model

Lagged models are inappropriate since intervention appears to affect exchange rate movements within minutes and hours (Humpage, 1999). But for small open economies, where the financial system is still underdeveloped, econometric models such as the real equilibrium exchange rate models have been applied. Other studies have used monetary reaction functions to assess whether central banks lean against the wind.

4.1.8 The GARCH/ARCH models

Autoregressive conditional heteroskedasticity (ARCH) volatility in asset returns and exchange rates tends to gather around their marginal distributions. Modelling such time varying volatility

was initiated by Robert Engel (1982) through ARCH. To get around this problem Bollerslev (1986) proposes a generalized ARCH or GARCH (p, q) model. This is the model we adopted in this study; it is particularly favoured to take account of variance correlations typically found in financial data. The GARCH model is robust to various types of misspecification, can simultaneously model conditional mean and conditional variance(Edison, 1999). Researchers in finance and economics have argued that a GARCH framework provides an efficient parametric way of modelling uncertainty in high frequency econometric time series (Doroodian and Caporale, 2001).

4.2 Econometric models

4.2.1 GARCH model

We adopted the GARCH and equilibrium exchange rate methodologies. We compared results from the GARCH model with those from the equilibrium exchange rate criterion. The first-order (p = q = 1) GARCH model, suggested by Taylor (1986), has since become the most popular ARCH model in practice. Compared to Engel's (1982) basic ARCH model, the GARCH model is a useful improvement that allows a parsimonious specification. The GARCH (p, q) model on which this study is based takes the form:

$$h_t^2 = \alpha_0 + \sum_{i=1}^{q}(\alpha_i \varepsilon_{t-i}^2) + \sum_{i=1}^{p}(\beta_i h_{t-i}^2) \qquad (1)$$

where $\alpha_0 > 0$, $\alpha_i \geq 0$ for i=1,2, …., q and b≥0 for i=1,2,….,p. The GARCH (p, q) model successfully captures several characteristics of financial time series such as volatility.

This study estimated and tested ARCH models, that is, it built the ARCH into the GARCH (p, q) model using the Eviews. Initially we regressed y on x using ordinary least squares (OLS) and obtained the residuals {ε_t}; then we computed the OLS regression $\varepsilon^2_t = \alpha_0 + \alpha_1 \varepsilon^2_t + \ldots + \alpha_p \varepsilon^2_{t-p}$+error; and tested the joint significance of $\alpha_{..}\alpha_1$. The hypothesis of interest was the extent to which changes in the conditional mean and conditional variance are associated with changes in the intervention variable. The general formulation of the model follows Edison and Liang (1999), adjusted to suit the Malawi situation:

$$\Delta lnex_t = \sigma_0 + + \sigma 1 lnNS_t + \sigma 2 lnPDTP_t + \sigma 3 lnEP_t + \sigma_4 DMV + \varepsilon_t \qquad (2)$$

$$\varepsilon_t / I_{t-1} / \sim N(0, h_t) \quad (3)$$

$$h_t = \beta_o + \beta_1 NS + \sigma \varepsilon^2_{t-1} + \delta h_{t-1} \quad (4)$$

Where $\Delta lnex_t$ = log change in Malawi kwacha/US dollar (MK/US$), *NS* is net sales of foreign exchange (representing intervention), *PDPTD* is inflation differential between Malawi and its main trading partners,[7] *EP* is parallel exchange rate premium (i.e. the spread between official and parallel market rates), *DMV* is dummy variable for seasonal trends in exchange rates,[8] ε is a regression disturbance (forecast error), $| |$ is absolute value operator, I_{t-1} is information set through time $_{t-1}$, and *h* is the time-varying variance of ε.

Equation 2 measures the direct effect of net sales of foreign exchange (US dollars), price differential, exchange rate premium and seasonal factors on exchange rate changes. A positive coefficient on intervention variable indicates that net sales of the foreign currency *(NS)* depreciate the Malawi kwacha. Equation 3, ($\varepsilon_t \mid I_{t-1} \mid \sim N(0, ht)$ states that the regression residuals will be modelled as a GARCH process. Equation 4 describes the conditional variance. The parameters of the model were estimated using the quasi-maximum likelihood approach of Bollerslev and Wooldridge (1992), which yields standard errors that are robust to non-normality in the density function underlying the residuals. Parameters σ and δ in Equation 4 are for the ARCH and GARCH terms respectively. The ARCH term (ε^2_{t-1}) measures volatility from a previous period measured as a lag of the squared residual from the mean equation. The GARCH term (h_{t-1}) measures the last period's forecast variance.

4.2.2 The empirical model equilibrium exchange rate

We used nominal and real exchange rate models (see Appendixes 4c and 4d for the models and Appendixes 4a and 4b for model results). The models were used to compute nominal and real equilibrium exchange rates respectively. For the nominal exchange rate, we used a model that combines features of both the monetary and the portfolio models for nominal exchange rate model. The empirical variant of SPMM is based on a specification form introduced by Frankel

[7] Malawi's main trading partners are USA, France, Germany, Zambia, Australia, Belgium, Netherlands, UK, Japan and South Africa. We created a basket inflation for these countries using their trading weights with Malawi.

[8] Movements in exchange rate follows seasonal patterns related to the agricultural cycle. We used dummy variables for the four seasons in Malawi.

(1979). He argues that in the short run, as in the SPMM model, prices are sticky and thus purchasing power parity (PPP) does not hold continuously.

As for the real exchange rate, we used Edward's (1989) dynamic model[9] for a real exchange rate model. Although this model was developed to describe nominal misalignment in fixed exchange rate regimes, it is well suited to identify fundamental variables that determine the Malawian real equilibrium exchange rate. First, Malawi is a low income country where pubic expenditure accounts for almost one-third of GDP, driven partly by large flows of external assistance. It is also relatively open with exports and imports exceeding 50% of GDP, and dependent on tobacco exports. Malawi is very dependent on import goods, both for consumption and investment. Finally, although the Malawi kwacha was floated in the mid 1990s, it has undergone periods of remarkably stability vis-à-vis the US dollar (Mathisen, 2003).

4.3 Data

We used monthly data series which include exchange rate (*EX*), net sales of foreign exchange as the intervention variable *(NS)*, inflation differential between Malawi and its main trading partners (*PDTP),* parallel exchange rate premium *(EP)* and dummy variable for seasonality in exchange rate developments *(DMV)*. We used nominal bilateral exchange rate of the Malawi kwacha against the US dollar. The parallel exchange rate premium is the difference between official exchange rate and parallel exchange rate. All variables are expressed in logs except for net sales (see Appendix 1a for more description of the variables used).

5.0 Estimation and results

5.1 Time series properties of the data

The second step is to test the variables in the GARCH and equilibrium exchange rate models for unit roots and conduct the necessary cointegration tests (see Appendixes 1b, 2 and 3). The results showed that variables such as exchange rate *(Ex),* exchange rate premium *(EP,* and price differential between Malawi and its main trading partners *(PDTP)* are non-stationary (integrated of order one) and thus become stationary after first difference. However, net sales of foreign exchange *(NS)* is stationary (integrated of order zero)

The next step is to find out whether RBM intervention (net sales of foreign exchange) in the foreign exchange market in Malawi affects the kwacha. Seasonal dummies were introduced for seasonal trends in kwacha movements. We set off by running an OLS equation of the exchange rate deprecations on a constant, the net sales of foreign exchange, parallel exchange rate premium and inflation differential (to take care of balance of payments pressure) and the seasonal dummy

[9] See Williamson 1994 for an in-depth discussion of the model.

variable (to take care of seasonal trends in kwacha fluctuations). The results are indicated in Table 3

Table 3: Conditional mean equation

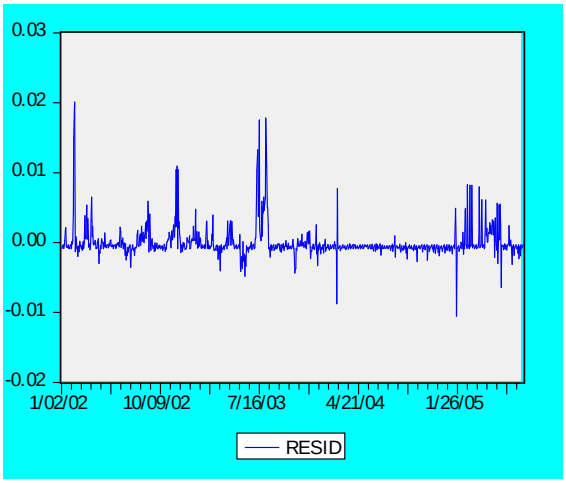
Variable	**Coefficient**	**t-statistic**
C	0.01440	1.15587
DMV	0.082142	1.36969
ΔLNPDTP (-1)	0.84078	3.93214
ΔEP	0.000416	20.451010
NS	0.651467	3.32534
R-squared	0.414862	
D_W test	1.525484	

The results indicate that net sales of foreign exchange by RBM depreciate the kwacha. The results also indicate that price differentials between Malawi and its main trading partners affect the kwacha. As the price differentials widen, the kwacha tends to depreciate. It is also necessary to find out whether net sales of foreign exchange affect the volatility of the kwacha. We conducted ARCH tests on the residuals of the conditional mean equation to test for the presence of ARCH effects. The results are presented in Table 4 below. A graphical exposition of the residuals from the ARCH process show that the residuals are hoteroskedatsic (see Figure 8)

Table 4: ARCH Test

F-statistic 0.32545	Probability 0.04408
Obs*R-squared 0.376507	Probability 0.03675

Figure 8: The residuals are heteroskedastic



Results from the ARCH tests indicated that we reject the null hypothesis of no ARCH effects in the equation. Since ARCH effects were present (i.e. presence of heteroskedasticity in the residuals), we proceeded to estimate a GARCH (1,1) model and simultaneously estimated the effect of net sales of foreign exchange on both the mean and volatility of the kwacha.

In this study, we used the GARCH method to model the heteroskedastic errors in our conditional mean equation. The GARCH model is robust to various types of misspecification compared to Engel's (1982) basic ARCH model. This approach is also beneficial because it allowed us to simultaneously test the effect of intervention on both the mean and conditional volatility of kwacha. We ran GARCH model for two sample periods: *model 1* for the entire period 1995–2008 and *model 2* for the post-2003 period, when the nominal exchange rate was relatively stable. The GARCH equations allow the intervention terms to affect both the conditional mean and variance of the series. The conditional variance provides an excellent proxy for near-term exchange rate volatility. The results from both models are indicated in Table 5.

Table 5: GARCH estimation of exchange rate

Conditional mean equation		
	Model 1	*Model2*
Constant	0.03563 (1.17198)	0.0421 (1.1840
NS	0.61854 (3.20342)	-0.01231 (1.1426)

ΔEP_{t-1}	0.08242 (1.35534)	0.00506 (0.04711)
$PDTP_{t-1}$	0.85312 (3.96541)	0.25783 (2.72062)
DMV	0.075449 (1.32336)	0.06542 (1.26724)
	Conditional variance equation	
	Model 1	*Model2*
Constant	2.5240 (5.18543)	1.6436 (4.0287)
NS	*0.5649* *(3.1824)*	*-0.01384* *(1.1265)*
$ARCH(\varepsilon_{t-1}^2)$	0.422242 (2.42462)	0.53509 (2.56213)
$GARCH(h_{t-1})$	0.505321 (2.48082)	0.42059 (2.43812)

The values in brackets are t-statistics.

The positive sign on the intervention term (*NS*) in the mean equation of *model 1* suggested that official sales of US dollars are associated with the depreciation of the Malawi kwacha. In other words, when the RBM sells foreign exchange with the intention of appreciating the kwacha, the kwacha depreciates instead.[10] This is not a surprising result for Malawi, as US dollars are normally sold when foreign reserves are low, so they coincide with a depreciating kwacha. The results suggest that the Bank intervenes in the market to reduce the rate of depreciation. In the literature, this result is generally interpreted as leaning against the wind, i.e. intervention prevents a steeper depreciation from occurring. In other words, RBM intervenes to reduce, but not to

[10] This reflects an endogeneity problem. In other words, we are picking up influences from an RBM reaction function rather than isolating the impact of intervention. This suggests that RBM is choosing a positive value for NS whenever it thinks EX is going to be too big. What we are estimating is some combination of intervention parameter and reaction function parameter.

reverse, around-trend-exchange rate depreciations. This finding is in line with the results of work done by Simatele (2004), Edison et al. (1999) and Baillie and Osterberg (1997).

We also suspect that the results are reflecting speculation in the foreign exchange market. Typical of small economies, even after a Reserve Bank sale, the dollar tends to quickly dry out on the market due small magnitudes of foreign exchange sales. What happens is that market speculators buy as much foreign exchange as possible after foreign exchange sales by the Reserve Bank; they withhold the money until the exchange rate rises again, and then sell.[11]

However, the negative sign on the intervention term on *model 2* suggests that official sales of US dollars for the post-2003 period were associated with an appreciation of the kwacha. This interpretation might be misleading as the coefficient was both statistically insignificant and too small. Results from both models also indicate that price differentials between Malawi and its main trading partners affect the kwacha. As price differentials widen, the kwacha tends to depreciate. Similarly, a higher exchange rate premium depreciates the kwacha.

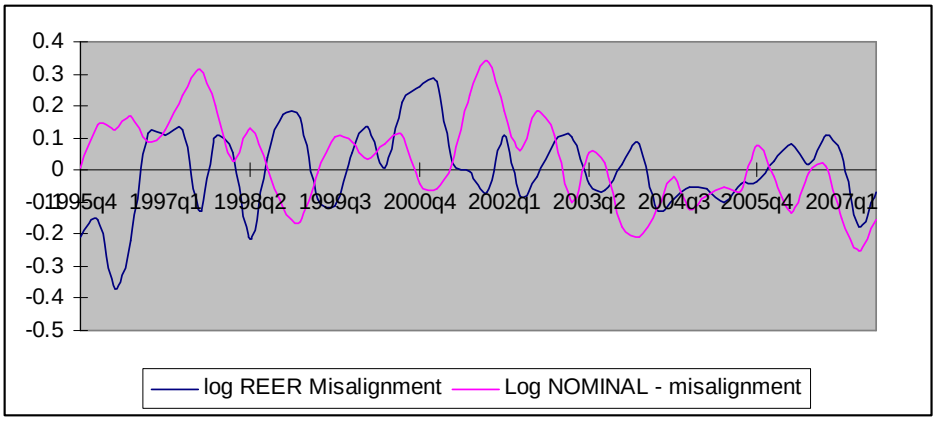
The positive coefficients on the intervention term in the conditional variance equation for *model 1* reveal that official intervention leads to an increase in exchange rate volatility. This is in line with findings in other studies (such as Doroodian and Caporale, 2001). This means that the intervention operations of the RBM may have sent ambiguous signals (of both its intervention operations and future monetary policy) to the foreign exchange market and consequently added some uncertainty to the market. This outcome supports the views of Friedman (1953) and Schwartz (1996) that exchange rate intervention serves to destabilize the foreign exchange market by introducing additional levels of exchange rate uncertainty. However, the coefficient on the intervention variable in the conditional variance equation for *model 2* reveals that official intervention during the post-2003 period tended to reduce volatility. This outcome is in line with the findings of Dominguez (1992)[12] and Simatele (2004). The ARCH (σ) and GARCH (δ) terms are both positive and statistically significant.

The conflicting outcomes from the two GARCH models on the impact of intervention on exchange rate volatility led us to employ another approach: the equilibrium exchange rate criterion. We modelled equilibrium exchange rate for the entire period to help us compute equilibrium exchange rates (see Appendixes 6 and 7 for the results of nominal and real equilibrium models). Our task was to evaluate the Bank's intervention in the foreign exchange

[11] See Simatele (2004).
[12] Dominguez (1992b) finds that U.S. intervention has tended to decrease exchange rate volatility except for the period 1985 to 1987, which increased volatility.

market using the equilibrium exchange rate criterion. We evaluated the impact of official intervention by establishing whether intervention when it occurred pushed the market rate towards its prevailing equilibrium level or away from it.

Figure 9: Nominal and real exchange rate misalignment



Data source: Reserve Bank of Malawi, Monthly Economic Reviews (December, 2009; December, 2003 and December, 2000)

The results in Figure 9 show that, since the exchange rate was floated in 1994, the nominal exchange rate had been mostly undervalued for most of the period (1994–2003). But for most of the post-2003 period, the nominal exchange rate remained overvalued. However, the real effective exchange rate (REER) assumed the opposite behaviour to that of the nominal exchange rate—appreciating as the nominal depreciated. This could be reflecting inflation differentials which seem to have been adversely affecting Malawi's competitiveness for most of the 1990s and from 2003 to 2006. From 2007 onwards the REER regained its competitiveness (depreciating) as inflation levels kept declining.

Almost the entire study period is characterized by wide oscillations, capturing exchange rate misalignments (Figure 9). This implies that both the nominal and real exchange rates were frequently drifting away from their equilibrium rates. This implies that the RBM interventions failed to push the nominal exchange rate toward its equilibrium level. Instead the market exchange rate was pushed away from its equilibrium path. So interventions during this period were destabilizing and increased volatility. This outcome is in line with findings from GARCH methodology (*model1*) which indicates that RBM interventions during the entire study period served to destabilize the foreign exchange market by introducing additional levels of exchange rate uncertainty. The only exception was the post-2003 period, particularly in 2004 and 2005, when the interventions were stabilizing as the market exchange rates were pushed closer to the

equilibrium path. This exception seems to agree with findings from GARCH *model 2* that official intervention during the post- 2003 period reduced exchange rate volatility.

In general, the results from both the GARCH model and the equilibrium exchange rate criterion show that RBM intervention has been associated with increased exchange rate volatility, except during the post-2003 period, particularly in 2004 and 2005.

6.0 Conclusion and Policy implications

This study analysed the effectiveness of foreign exchange market interventions carried out by the RBM using the GARCH model and the equilibrium exchange rate criterion. The study used monthly data of RBM intervention (net sales of foreign exchange), and exchange rate, among others, from January 1995 to June 2008. We started off by running a conditional mean equation using changes in exchange rate as a dependent variable. The results showed the presence of ARCH effects. We then ran a GARCH (1,1) model by quasi-maximum likelihood for the entire study period. In line with similar findings elsewhere in the literature, this study found that net sales of dollars by the RBM depreciate, rather than appreciate, the kwacha. Empirically, this implies that RBM leans against the wind. In other words, the RBM intervenes to reduce, but not to reverse, around-trend exchange rate depreciation. However, the negative sign on the intervention term on *model 2* suggests that official sales of US dollars for the post-2003 period were associated with an appreciation of the kwacha. This interpretation might be misleading as the coefficient is both insignificant and too small.

Results from the equilibrium exchange rate criterion show that RBM interventions failed to push the exchange rate towards its equilibrium levels. Instead the market rate was pushed away from its equilibrium level, indicating that intervention during the study period increased volatility. This outcome is in line with findings from GARCH methodology (*model1*) which indicates that RBM interventions during the entire study period served to destabilize the foreign exchange market by introducing additional levels of exchange rate uncertainty. The only exception was the post-2003 period, particularly in 2004 and 2005, as market exchange rates were close to their equilibrium path. This exception seems to agree with findings from GARCH *model 2* that official intervention during the post-2003 period reduced exchange rate volatility.

In general, the results from both the GARCH model and the equilibrium exchange rate criterion show that RBM intervention has been associated with increased exchange rate volatility, except in 2004 and 2005. The implication of this finding is that intervention can only have a temporary

influence on the exchange rate, as it is difficult to find empirical evidence showing that intervention has a long lasting, quantitatively significant effect.

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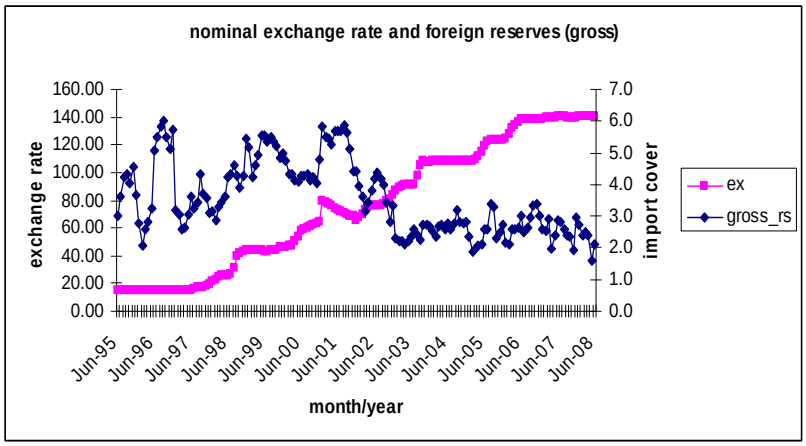
Appendix 1: Variables definitions

Variable name	Variable description
Ex_t	Malawi kwacha – United States dollar exchange rate
NS	Net sales of foreign exchange capturing Reserve Bank of Malawi interventions
DMV	Dummy variable for seasonal trends in exchange rates
EP	Parallel exchange rate premium
PDTP	Inflation differential between Malawi and its main trading partners
$\lvert\ \rvert$	The absolute value operator
I_t	The information set through time t-1
ε_t	The disturbance term
ε^2_{t-1}	ARCH term
h_{t-1}	GARCH term
govgdp	Logarithm of government consumption as a share of GDP
wsgdp	Government spending on wages and salaries as a share of
invgdp	Investment as a share of GDP (*invgdp*),
tot	Terms of trade goods (*tot*),
tp	Technological progress
mp	Monetary policy proxy
fagdp	Fiscal policies proxy

lid	Logarithm of interest rate differential, computed using the short-term (91-day) London Inter-bank offer rate (LIBOR) and the 91-day Treasury bill rate
lpd	Logarithm of inflation differential computed as the difference between domestic inflation and inflation rate in major trading partners.
ca _ gdp	Current account balance as a proportion of nominal (quarterly) GDP
*lm*2	Log of money supply

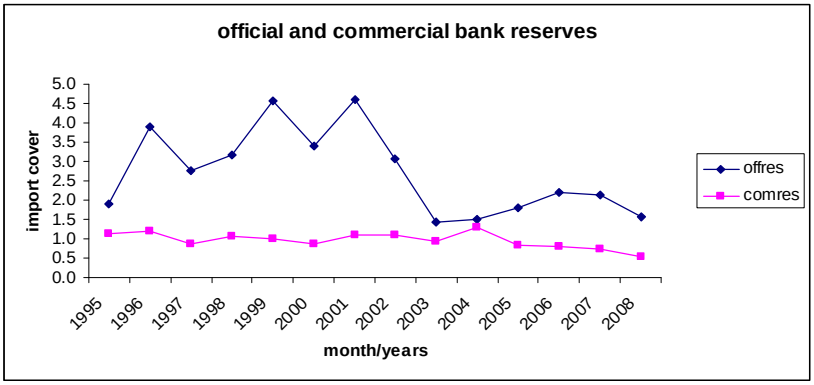
Appendix 2

Figure 10a: Nominal exchange rate and gross official reserves (1995–2008)



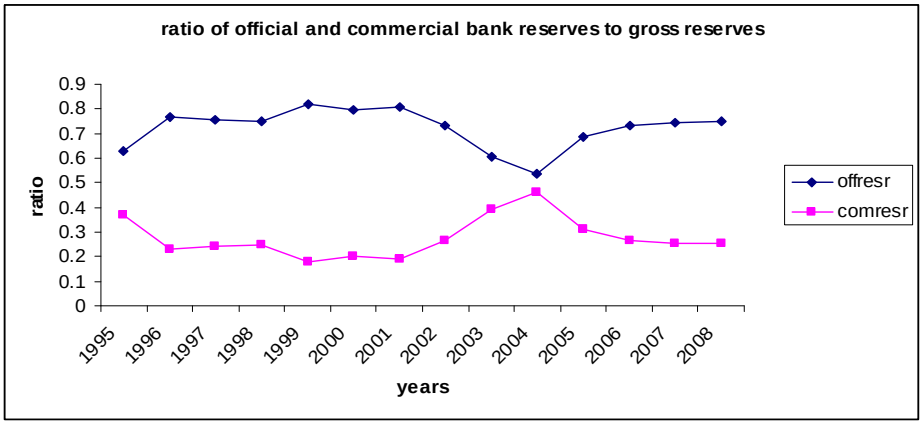
Source: Reserve Bank of Malawi, Monthly Economic Reviews (December, 2000; December, 2003, and December, 2009)

Figure 10b: Official and commercial bank reserves (1995–2008)



Source: Reserve bank of Malawi, Monthly Economic Reviews (December 2009, December, 2003; and December, 2000)

Figure 10c: Ratio of official and commercial bank reserves to gross reserves



Source: Reserve Bank of Malawi, Monthly Economic Reviews (December, 2009; December, 2003; and December, 2000)

Appendix 3: Unit root tests for variables in the models

Variable	ADF test stat	PP test stat.	order of Int.

lne	*-1.754718*	*-1.107811*		
Δ *lne*	*-4.164111*	*-3.900384*		*I(1)*
Ns	*-4.7890*	*-6.29374*	*I(0)*	
pdtp	*1.32462*	*1.524334*		
Δ*pdtp*	*-4.6509*	*5.623109*	*I(1)*	
lnrer	*-2.56436*	*-2.11342*		
Δ *lnrer*	*-5.27519*	*-5.33015*		*I(1)*
ln *govcngdp*	*-2.75410*	*-2.00509*		
lnird	*-1.51355*	*-0.925450*		
Δ *lnird*	*-5.529812*	*-5.69811*		*I(1)*
lnm2	*-0.518479*	*-0.319449*		
Δ *lnm2*	*-7.522544*	*-11.79298*		*I(1)*
nfa_gdp	*-2.581926*	*-4.454167*		
Δ *nfa_gdp*	*-7.378059*			*I(1)*
lnf_gdp	-3.523250	-4.454167		*I(0)*
lnmp	*-2.45329*	*-3.54376*		
Δ ln *mp*	*-5.67840*	*.89064*		*I(1)*
lnpdtp	*-4.161990*	*-3.490758*		*I(0)*

Critical values are -3.5066 and –3.5045 at 5 % significance level.

Appendix 4: Cointegration test for the nominal exchange rate model variables

Date: 10/25/08 Time: 07:39

Sample(adjusted): 1997:1 2007:4

Included observations: 44 after adjusting endpoints

Trend assumption: Quadratic deterministic trend

Series: LNEX LIRD LM2 TB_GDP

Lags interval (in first differences): 1 to 4

Unrestricted cointegration rank test

Hypothesized No. of CE(s)	Eigenvalue	Trace statistic	5% critical value	1% critical value
None *	0.509457	57.35575	54.64	61.24
At most 1	0.367646	26.01712	34.55	40.49
At most 2	0.124200	5.851667	18.17	23.46
At most 3	0.000375	0.016482	3.74	6.40

* (**) denotes rejection of the hypothesis at the 5% (1%) level; trace test indicates 1 cointegrating equation(s) at the 5% level; trace test indicates no cointegration at the 1% level.

[A]Appendix 5: Johansen cointegration test for the real exchange rate model 1

Hypothesized no. of cointegrating vectors	Eigenvalue	Trace stat	5% critical value	1% critical value
None*	0.4352698	62.36948	56.37	68.57
At most 1	0.3225672	28.36436	38.04	46.20
At most 2	0.2236942	6.416240	20.78	29.66
At most 3	0.0822310	0.012631	4.22	7.95

*(**) indicates rejection of the hypothesis at 5%(1%) level; the trace statistic indicates I cointegrating equation(s) at 5 % level of significance; trace statistic indicates no cointegration at 1% level.

Appendix 6: long run nominal exchange rate equation

Dependent variable: LNEX

Method: Least Squares

Date: 10/24/08 Time: 01:41

Sample: 1995:4 2007:4

Included observations: 49

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LM2	0.864234	0.023943	36.09581	0.0000
LIRD	0.335255	0.038412	8.727815	0.0000
TB_GDP	1.165300	0.687668	1.694567	0.0972
DUM	-0.005179	0.017538	-0.295323	0.7691
C	-4.940967	0.282342	-17.49992	0.0000
R-squared	0.971821	Mean dependent var		4.079290
Adjusted R-squared	0.969259	S.D. dependent var		0.776660
S.E. of regression	0.136172	Akaike info criterion		-1.053340
Sum squared resid	0.815888	Schwarz criterion		-0.860297
Log likelihood	30.80682	F-statistic		379.3601

Appendix 7: Results from the error correction model of real exchange rate[13]

[13] Model 1 shows results using data for the entire period. Model 2 has results from data for the period 2003–2006 when the exchange rate was relatively stable.

Dependent (real exchange rate)

	Model 1	
	Coefficient	*t-stat*
Constant	-0.0564	-0.5523
$\Delta \ln e_{t-1}$	0.0847	0.6652
$\ln govcngdp_{t-2}$	-0.1325	-1.9216
$\Delta \ln nwsgdp_{t-1}$	0.0245	0.2134
$\Delta \ln nwsgdp_{t-2}$	0.0525	0.4213
$\Delta \ln tp_{t-1}$	-0.8617	-0.6285
$\Delta \ln tp_{t-2}$	-0.7465	-0.5442
$\Delta \ln tot_{t-1}$	0.0342	0.1863
$\Delta \ln tot_{t-2}$	-0.1526	-1.9847
$\Delta \ln invgdp_{t-1}$	-0.0365	-0.3572
$\Delta \ln invgdp_{t-2}$	0.0984	0.7453
Δnfa_{t-1}	-0.0219	-0.3252
Δnfa_{t-2}	0.0042	0.1375
$\Delta \ln mp_{t-1}$	0.0434	0.3823
$\Delta \ln mp_{t-2}$	-0.0534	-0. 4841
coint. equat	-0.1357	180960
R^2	0.5253	
Adjusted R^2	0.1874	
S.E. equation	0.1251	
F statistic	1.5250	
Log likelihood	83.204	
Akaike IC	-1.6419	
Schwarz SC	-1.3437	

Appendix 8: The empirical model for nominal exchange rate

We used a model that combines features of both the monetary and the portfolio models. The empirical variant of SPMM is based on a specification form introduced by Frankel (1979). He

argues that in the short run, as in the SPMM model, prices are sticky and thus PPP does not hold continuously. Frankel (1979) modifies the basic assumptions of the original Dornbusch (1993) model to allow for differences in secular rates of inflation.

Based on Meese and Rogoff's (1983,) interpretation that the cumulative trade and current account balance terms are variables that allow for changes in the long-run exchange rate, and by incorporating stochastic elements in the model, we obtain the estimable version as,

$$e_t = \beta_0 + \beta_1(p_t - p_t^*) + \beta_2(i_t - i_t^*) + \beta_3(\rho_t - \rho_t^*) + \beta_4(CA) + \mu_t \quad (1)$$

where

$(p_t - p_t^*)$ = inflation differential

$(i_t - i_t^*)$ = interest rate differential

$(\rho_t - \rho_t^*)$ = expected inflation differential

λ = coefficient of adjustment

$(\rho - \rho^*)$ = expected inflation differential

Using et = $e_t = \ln ex$, $p_t - p_t^*$ = *lpd* and $i_t - i_t^*$ = *lird*, equation 1 is re-written as an autoregressive distributed lag (ADL) model with n lags

$$lex = \sum_{i=1}^{n} \beta_{1i} lird_{t-1} + \sum_{i=0}^{n} \beta_{2i} lpd_{t-1} + \sum_{i=0}^{n} \beta_{3i} ca\_gdp_{t-1} + \sum_{i=0}^{n} \beta_{4i} lm2_{t-1} + \sum_{i=0}^{n} nef_{t-1} + \sum_{i=0}^{n} lex_{t-i} + \mu \quad (2)$$

where *lex* = logarithm of nominal exchange rate

lid = Logarithm of interest rate differential, computed using the short-term (91-day) London Inter-bank offer rate (LIBOR) and the 91-day Treasury bill rate

lpd = logarithm of inflation differential computed as the difference between domestic inflation and inflation rate in major trading partners.

ca_gdp =current account balance as a proportion of nominal (quarterly) GDP

$lm2$ = log of money supply

lNef = net donor inflows

Given the nature of time series data, Equation 2 contains non-stationary variables, which on being differenced become stationary. However, that would imply that the long-run properties of the theoretical model are lost. To recover the long-run information, parameters for Equation 2

need to be reset into an error correction model (ECM), assuming that the non-stationary variables are integrated of the first order. Therefore, Equation 2 parameters are reset into Equation 3 with the error correction term in brackets.

$$\Delta lex = \sum_{i=1}^{n-1} \beta_{1i} \Delta lird_{t-1} + \sum_{i=0}^{n-1} \beta_{2i} \Delta lpd_{t-1} + \sum_{i=0}^{n-1} \beta_{3i} ca\_gdp_{t-1} + \sum_{i=0}^{n-1} \beta_{4i} \Delta lm2_{t-1} + \sum_{i=0}^{n-1} \beta_{5i} nef_{t-1} + \sum_{i=0}^{n-1} \beta_{6i} \Delta lex_{t-i} + \beta_7 [lex - \alpha lird - lpd - lm2] \quad (3)$$

Appendix 9: equilibrium real exchange rate

Edward's (1989) theoretical model identifies the following fundamental variables as the most important ones in determining equilibrium real exchange rate: the level and composition of government expenditure, external terms of trade, investment and capital flows. In addition, a variable has been added to capture the Balassa-Samuelson effect (MacDonald and Ricci, 2001, 2002), and two variables have been added to capture the temporary misalignment induced by inconsistent macroeconomic policies. Hence the empirical model for equilibrium real exchange rate is:

$$\ln ex_t^* = \alpha_0 + \alpha_1 \ln govcngdp_t + \alpha_2 \ln wsgdp_t + \alpha_3 \ln invgdp_t + \alpha_4 tot_t + \alpha_5 \ln tp_t + \alpha_6 \Delta nfagdp_t + \alpha_7 \ln mp_t + \alpha_8 \ln fp_t + \varepsilon_t \quad (4)$$

where the logarithm of real exchange rate (ex_t^*) is a function of logarithm of government consumption as a share of GDP ($govgdp$), government spending on wages and salaries as a share of GDP ($wsgdp$), investment as a share of GDP ($invgdp$), terms of trade of goods (tot), technological progress (tp), i.e., real per capita growth, capital flows ($fagdp$), monetary policies(mp), i.e., money supply as share of GDP, and fiscal policies (fp) i.e. bank credit to government as a share of GDP, and error term (ε).

This analysis concentrates on permanent changes in the explanatory variables that bring about changes in the long run *RER*. The equilibrium real exchange rate (*ERER*) is associated with fundamental variables in their steady state levels. Deviations of these variables from their respective steady states results in deviations in *ERER*. This approach prevents the bias introduced by using the observed values to estimate the long run cointegrating relationship between the real exchange rate and the fundamentals, as a temporary shock would have a permanent impact on *ERER* (Mathisen, 2003).