MACROECONOMIC EFFECTS OF EXCHANGE RATE VOLATILITY IN ZAMBIA

Thesis submitted for the degree of

Doctor of Philosophy

at the University of Leicester

by

Jonathan Mpundu Chipili

BA (University of Zambia)
Postgraduate Diploma, MSc (University of Birmingham)

Department of Economics
University of Leicester

March 2010

To the memory of my father, mother and first born sister

Volatility – volatilis (latin) from volare - 'to fly'
(Merriam-Webster Online Dictionary)

ABSTRACT

MACROECONOMIC EFFECTS OF EXCHANGE RATE VOLATILITY IN ZAMBIA

by

Jonathan Mpundu Chipili

Similar to global currencies, the Zambian currency (kwacha) has varied considerably against major currencies since the early 1990s. Existing empirical evidence reveals that fluctuations in exchange rates can potentially generate distortions in the economy. However, insufficient empirical evidence on Zambia exists. Thus, this thesis contributes empirically to the literature on exchange rate volatility and its impact on the economy with Zambia as a case study. Consequently, volatility in the kwacha bilateral exchange rates is modelled using three alternative GARCH models in order to characterise the underlying currency volatility. The influence of fundamental factors on conditional volatility of exchange rates is also examined. In addition, principal components analysis (PCA) is used to capture the common underlying pattern in the estimated conditional volatility series through which a new GARCH series (GARCH-PCA) is constructed and used in trade and monetary and foreign exchange intervention rule analysis as an alternative measure of exchange rate risk. PCA has not been previously employed in such analyses. Cointegration analysis is used for trade-exchange rate volatility analysis while SVAR and GMM are employed with variations to the conventional specification of monetary and foreign exchange intervention rules in the literature in determining the relevance of exchange rate volatility in monetary and foreign exchange policies. The results reveal that the kwacha bilateral exchange rates examined are characterised by different conditional dynamics in terms of volatility persistence and response to price shocks. The positive influences of exchange rate regime, money supply and openness on conditional volatility predominate. Exchange rate volatility affects international trade flows and underpins monetary policy and foreign exchange decision-making process. Thus, the results are amenable for trade policy formulation and monetary policy improvements and they justify foreign exchange interventions. GARCH-PCA, *an index of exchange rate volatility*, reflecting influences from Zambia proves to be a useful alternative measure of exchange rate volatility. Its performance is comparable to the trade-weighted measure in terms of sign, size and statistical significance of the estimated coefficients.

ACKNOWLEDGEMENTS

I am deeply grateful to my supervisor Professor Stephen G. Hall for incisively guiding me in my research. He bears a rare quality of supervision. I also wish to thank my second supervisor and member of the Thesis Committee Professor Kevin Lee as well as Dr. Martin Hoskins, Chairperson of the Thesis Committee for their invaluable suggestions.

I am grateful to Mr. Peter Banda (Bank of Zambia) for advice and encouragement to pursue a PhD. In addition, I would like to thank the following colleagues from the Bank of Zambia for their help with data: Ivan Zyuulu, Isaac Muhanga, Nancy Mwilwa, Douglas Kalamatila, Wilson Phiri and Dr. Francis Chipimo. Justin Mubanga (Ministry of Finance and National Planning), Joseph Silavwe (Zambia Development Agency) and Dr. Munacinga Simatele (University of Hertfordshire) also thankfully assisted me with data. I sincerely appreciate the valuable assistance I received from Paul Mukabila in formatting the thesis; Dr. Simeon Coleman (Nottingham Trent University) for manipulating data used in Chapter 3; Dr Emmanuel Mulenga Pamu (Bank of Zambia) for insightful corrections on the monetary policy framework in Zambia; Rabah Arezki, Fuad Hasanov, Julian di Giovanni and Akito Matsumoto of the IMF for intuitive views on the initial draft of Chapter 5 whilst at the IMF from 30 March to 8 May 2009 as an AERC/IMF Visiting Scholar. My sincere gratitude to Isaac Muhanga, Dionysius Makunka, Ken Lumbwe Chiwele, Uncle Dan Assa Makutuma and Colonel Eddie Kasoma for undertaking numerous tasks in Zambia on my behalf.

I wish to thank my employer, the Bank of Zambia, for granting me paid study leave. Financial support from the University of Leicester through the Graduate Teaching Assistantship is greatly appreciated.

The successs of my PhD is attributed to my family. My wife Lynn, my son Chibuye and my two daughters Lupo and Chaato remained strong, positive and supportive during my studies. They deserve the best of my love. I would like to thank my brothers Dennis and Raymond and my young sister Emeldah for their encouragement during my studies.

I thank fellow doctoral students who shared thoughts with me on various issues. I also wish to acknowledge support in various ways from friends and families.

TABLE OF CONTENTS

List of Tables

List of Figures

Chapter 1 INTRODUCTION

This chapter provides the background, objectives, motivation and structure of the thesis. The contributions of the thesis are also highlighted.

1.1 Background of the Study

The assessment of exchange rate volatility[1] effects on the economy remains an active subject of empirical investigation. This stems from the substantial increase in the volatility of exchange rates of major industrial countries including those of developing countries after the breakdown of the Bretton Wood System in March 1973. Volatility in exchange rates was initially perceived to be temporary. However, it has persisted and varied considerably over time and across countries (Pozo, 1992; Jeong, 2000; and Chit, 2008).

Policy makers have taken a keen interest in the subject of exchange rate volatility for the purpose of formulating suitable macroeconomic policies (Bauwens and Sucarrat, 2006). Similarly, corporate entities are concerned about its implications on profits. They are interested in mitigating the effects of exchange rate uncertainty by designing appropriate risk management tools as investor participation in international portfolio markets has increased considerably (Bauwens and Sucarrat, 2006; and Bollen, 2008).

While the changeover to flexible exchange rate provides monetary policy autonomy and allows the exchange rate to adjust in line with changing economic conditions, it however, generates exchange rate uncertainty that can impose considerable costs on the economy relative to the intended benefits (Mckenzie, 1998; and Grydaki and Fountas, 2009). In contrast, misaligned exchange rates under the fixed

[1] Exchange rate volatility is used interchangeably with exchange rate uncertainty/ risk/fluctuations/variability in this thesis.

exchange rate regime imposed costs on the economy and thus the floating of the exchange rate was advocated in order to reduce real volatility in the economy.

Volatility in the exchange rate introduces uncertainty which in turn generates negative economic welfare effects (Bergin, 2004). The fluctuations in the exchange rate affect consumer goods prices (quoted in either foreign or home currency) which in turn affect demand and consequently consumption. The work by Obstfeld and Rogoff (1998) has been extended in analysing welfare effects of exchange rate uncertainty but the results are mixed.

Monetary policy is also affected by currency fluctuations especially where domestic growth is underpinned by exports as authorities attempt to support the external sector through exchange rate stabilisation at the expense of inflation stabilisation, the core objective of monetary policy (Crosby, 2000). Further, exchange rate uncertainty can create incentives for trade protectionist tendencies and sharp currency reversals which in turn impose further costs on the economy (Bayoumi and Eichengreen, 1998; Esquivel and Larrain, 2002; and Sengupta, 2002).

Volatility in exchange rates can also restrict the flow of international capital by reducing direct and portfolio investments. Speculative capital flows may also be induced by exchange rate volatility under the flexible regime that could in turn contribute to the instability in economic conditions (Willett, 1982). Greater exchange rate volatility increases uncertainty over the return of a given investment. Potential investors are attracted to invest in a foreign location as long as the expected returns are high enough to compensate for the currency risk. In view of this, foreign direct investment tends to be lower under higher exchange rate volatility. Further, most developing economies are net debtors such that considerable fluctuations in exchange rates may affect the real cost of servicing their debt. The same applies to banks, corporate entities and individuals exposed to foreign denominated debt (Schnabl, 2009).

Empirical evidence regarding the impact of exchange rate volatility on macroeconomic variables is mixed. For instance, Baxter and Stockman (1989) do not find evidence of exchange rate volatility impacting on macroeconomic aggregates under alternative exchange rate regimes based on cross sectional data analysis involving 49 countries. Low exchange rate volatility is associated with greater output growth and lower inflation (Robertson and Symons, 1992). Sapir and Sekkat (1995) find no appreciable impact of exchange rate volatility on trade, investment and growth. On the contrary, Chit (2008) argues that evidence of exchange rate volatility adversely affecting investment, growth and trade exists. Schnabl (2009) finds exchange rate volatility to exert negative effect on growth in a sample of countries examined in emerging Europe and East Asia.

It is noted that volatility in nominal and real exchange rate under flexible exchange rates is much larger than volatility in fundamentals (Crosby, 2000; and Craighead, 2009). At the same time, it is observed that instability in underlying economic factors can cause variability in the exchange rate (Willett, 1982). Flood and Rose (1995) compare real exchange rate volatility and volatilities of macroeconomic variables. They find a robust negative correlation between exchange rate volatility and output based on bivariate comparisons. However, no convincing explanation for the rise in volatility of macroeconomic variables attributed to the change in exchange rate regime is found based on the estimated structural models of exchange rate. Further, Rose and Flood (1995) compare volatility of macroeconomic variables three years before and after the floating of currencies. Little evidence of significant increases in volatility of macroeconomic variables attributed to changes in the exchange rate regime is found. Thus, they conclude that there is little evidence to suggest that "reducing exchange rate volatility comprises the stability of other macroeconomic variables". However, Morana (2009) finds a strong linkage between macroeconomic volatility (output, money growth, inflation and the interest rate) and exchange rate volatility with causality running from the former to the latter and not vice-versa.

There is growing and firm evidence that exchange rate volatility imposes significant effects on the volume of trade (see Farrell et al. 1983; IMF, 1984; Côté, 1994; McKenzie, 1999; UK Treasury, 2003; Clark et al. 2004; and Ozturk, 2006). This evidence is borne out of a variety of empirical tests that have been conducted over the years. Exchange rate variability affects international specialisation in production which in turn leads to a reduction in the welfare of people as output declines and consequently income and consumption (Clark, 1973). Volatility in the exchange rate can lead to the reduction in the volume of international trade due to increases in the level of trade riskiness that creates uncertainty about profits. In addition, it causes prices of tradeables to rise due to the risk mark-up (risk premium) imposed by sellers in order to protect profits. This tends to affect the competitiveness of exports. In response to fluctuations in the exchange rate, firms shift resources from the risky tradeable sector to the less risky non-tradeable sector in order to protect their profits. Further, a rise in exchange rate uncertainty increases transaction costs as agents attempt to hedge against exchange rate risk (Schnabl, 2009). This is the subject of chapter 4.

The importance of exchange rate in monetary policy and foreign exchange interventions is established. Most empirical work especially in developed countries is dominated by estimations of the interest rate rule proposed by Taylor (1993) as most central banks typically use the nominal short-term interest rate as the main operating policy instrument (see Clarida et al. 1998; Adam et al. 2005; and Eleftheriou et al.

2006). Central banks mostly adjust the nominal short-term interest rate in response to deviations of output and inflation from potential level and target, respectively. The application of the Taylor rule type to developing countries particularly in Africa is limited but growing (see Aron and Muellbauer, 2000; Rotich et al. 2008; and Ngalawa, 2009). Similarly, extensive empirical work on central bank intervention in foreign exchange markets has been undertaken on Japan, Germany, the USA and the UK based on Edison's (1993) intervention rule (see Edison, 1993 and Kamil, 2008). Empirical work on developing countries too is expanding. Chapter 5 deals with this in much more detail.

While a number of studies report negligible exchange rate volatility effects on real economic activity, Aghion et al. (2009) find exchange rate volatility to exert significant negative impact on productivity growth subject to a country's level of financial development: the impact is severe in thin and less developed capital markets. GMM dynamic panel data estimator is used over the period 1960-2000 on a sample of countries that includes Zambia.

In response to adverse effects of exchange rate volatility, most governments/ central banks have assumed an active role in the foreign exchange market through interventions in order to limit the undesirable effects of exchange rate volatility. Additionally, the creation of monetary unions such as the European Monetary Union is intended among other objectives to limit the influence of exchange rate volatility on trade and the economy in general (Chit, 2008; and Choudhry, 2008).

1.2 Objectives of the Study

As the scope of exchange rate volatility and its effect on the economy is broad, the thesis narrows the focus to three areas of study. Specifically, the thesis seeks to

a) Model conditional volatility in kwacha exchange rates;

b) Assess the impact of exchange rate volatility derived in (a) on trade flows in Zambia; and

c) Determine the relevance of exchange rate volatility derived in (a) in monetary policy and foreign exchange intervention decision-making process.

1.3 Motivations for the Study

In line with the evidence in the literature (see Craighead, 2009), fluctuations in the kwacha exchange rate have been high relative to some macroeconomic variables as shown in table 1.1 below. For instance, the real kwacha/US$ exchange rate was three times more volatile than real GDP over the period 1971-2008 and equally as volatile as real money supply, imports and exports[2]. Overall, volatility in all variables except real GDP and imports reduced post-exchange rate reform (1994-2008) relative to the pre-reform period (1971-1993). However, volatility in the rate of inflation, (nominal) exchange rate and the T-bill rate tends to be higher than the rest of the variables.

[2] Table 1.1 shows descriptive statistics for selected macroeconomic variables for the full sample period 1971-2008 and two sub sample periods: 1971-93 and 1994-2008 corresponding to pre- and post-exchange rate liberalisation, respectively. The standard deviation is used as a measure of variability in variables.

Table 1.1 Descriptive Statistics for Selected Macroeconomic Indicators (annual data)

1971-2008	Mean	Median	Max	Min	Std. Dev	Skew	Kurt	J-B [prob]	obs
Real GDP	3.127	3.108	3.428	2.912	0.113	0.886	3.619	5.139 [0.077]	35
Inflation	1.431	0.262	6.947	-2.745	3.648	0.262	1.376	4.249 [0.119]	35
Real M	21.720	21.830	22.244	21.067	0.373	-0.274	1.552	3.495 [0.174]	35
T-bill rate	23.524	16.316	124.025	3.340	24.829	2.175	8.922	78.742 [0.000]	35
Lending rate	3.044	3.054	4.30	1.946	0.810	0.070	1.729	2.385 [0.304]	35
Imports	6.760	6.707	7.854	6.279	0.362	1.113	4.206	9.350 [0.009]	35
Exports	6.906	6.939	7.501	6.179	0.267	-0.251	3.424	0.630 [0.730]	35
Nominal KUS$	3.406	2.253	8.472	-0.441	3.572	0.254	1.360	4.299 [0.117]	35
Real KUS$	6.191	6.270	6.836	5.531	0.369	-0.215	1.720	2.659 [0.265]	35
1971-1993	**Mean**	**Median**	**Max**	**Min**	**Std. Dev**	**Skew**	**Kurt**	**J-B [prob]**	**obs**
Real GDP	3.072	3.060	3.199	2.912	0.065	-0.182	3.198	0.165 [0.921]	23
Inflation	-0.876	-1.800	4.102	-2.745	2.010	1.163	3.197	5.224 [0.073]	23
Real M	21.942	22.009	22.244	21.199	0.239	-1.429	5.111	12.094 [0.002]	23
T-bill rate	17.255	6.000	124.025	3.340	26.408	3.126	12.874	130.891 [0.000]	23
Lending rate	2.682	2.251	4.730	1.946	0.763	1.122	3.441	5.010 [0.082]	23
Imports	6.625	6.619	7.106	6.279	0.238	0.278	2.130	1.023 [0.600]	23
Exports	6.877	6.931	7.249	6.179	0.274	-0.567	2.868	1.251 [0.535]	23
Nominal KUS$	1.147	-0.074	6.115	-0.441	1.979	1.169	3.211	5.277 [0.071]	23
Real KUS$	6.043	5.876	6.836	5.531	0.361	0.497	2.175	1.598 [0.450]	23
1994-2008	**Mean**	**Median**	**Max**	**Min**	**Std. Dev**	**Skew**	**Kurt**	**J-B [prob]**	**obs**
Real GDP	3.234	3.203	3.428	3.080	0.110	0.391	1.997	0.810 [0.667]	15
Inflation	5.854	5.868	6.947	4.605	0.759	-0.120	1.813	0.733 [0.693]	15
Real M	21.295	21.255	21.461	21.067	0.126	-0.057	1.991	0.516 [0.773]	15
T-bill rate	35.540	32.951	74.211	12.604	16.464	0.912	3.724	1.926 [0.000]	15
Lending rate	3.736	3.757	4.256	3.340	0.253	0.263	2.835	0.152 [0.927]	15
Imports	7.019	6.952	7.854	6.502	0.425	0.618	2.347	0.976 [0.614]	15
Exports	6.963	6.939	7.501	6.501	0.254	0.668	3.688	1.130 [0.568]	15
Nominal KUS$	7.735	7.910	8.472	6.506	0.705	-0.466	1.786	1.172 [0.557]	15
Real KUS$	6.474	6.522	6.649	6.062	0.168	-1.160	3.905	3.101 [0.212]	15
Stock MI	3.937	3.522	5.874	2.864	1.076	0.670	2.026	1.373 [0.503]	12

Source: Computed by author. Data were obtained from IMF-IFS and World Development Indicators. All variables are expressed in logarithmic form except interest rates. Max=maximum, min=minimum, std.dev=standard deviation, skew=skewness, kurt=kurtosis, J-B=Jarque-Bera, M=money supply and MI=market index

While a vast amount of literature on the impact of a country's exchange rate volatility on macroeconomic variables exists, very little has been undertaken in Zambia. This is despite the observed considerable fluctuations in the exchange rate. Notable studies conducted on Zambia include Savvides (1990), Hausmann et al. (2006) and Bangaké (2008) who have analysed the sources of exchange rate volatility in Zambia; Tenreyro (2007) and Musonda (2008) have examined the exchange rate volatility-trade link; and Aghion et al. (2009) have analysed the impact of exchange rate volatility on productivity growth. These studies use cross-country panel data except Musonda (2008) who uses time series data. Thus, country-specific characteristics of exchange rate volatility are not isolated in these studies.

There is no consensus in the literature regarding the factors that influence exchange rate volatility due to divergent theoretical models of exchange rate determination. In view of this, it is imperative to characterise the specific behaviour of the kwacha exchange rate as exchange rates are not uniquely driven by the same factors across countries and the dynamic nature of volatility in these exchange rates tends to differ. It is noteworthy mentioning that the influence of commodity prices on exchange rates of most developing countries whose currencies are coomodity-based[3] is documented (Cashin et al. 2002). This constrasts with exchange rates for developed countres where capital flows induced by changes in interest rates tend to play a key role in currency fluctuations.

Available empirical work on Zambia has mostly focused on analysing the determinants of the level of the exchange rate and estimating the long-run equilibrium level and its misalignment (Mkenda, 2001; and Mungule, 2004). This thesis focuses on exchange rate volatility that captures uncertainty which is key to trade analysis and

[3] A commodity currency is a currency of country whose economy is strongly influenced by changes in the price of a dominant export commodity.

monetary policy decision-making for instance in as far as it affects agents' expectations. Moreover, by understanding the structure of volatility in kwacha exchange rates, agents in particular firms engaged in trade may hedge against exchange rate risk exposure if they are able to anticipate or have a good understanding of the nature of volatility characterising the currencies used in trade. The objective here is to characterise the dynamic nature of conditional variance present in kwacha bilateral exchange rates involving currencies of Zambia's main trading partner currencies using alternative GARCH models. This analysis is useful in shaping appropriate exchange rate policies so as not to undermine the objectives of economic liberalisation.

The theoretical prediction of the exchange rate volatility-trade relationship is ambiguous: exchange rate volatility can either stimulate or depress trade (Clark, 1973; Ethier, 1973; Baron, 1976; and Hooper and Kohlhagen, 1978). Similarly, empirical evidence is inconclusive (see Côté, 1994; McKenzie, 1999; Clark et al. 2004; and Ozturk, 2006). Subsequent empirical work continues to be undertaken to verify the theoretical validity of existing evidence by assessing the size and direction of the impact of exchange rate volatility on trade in an attempt to establish robust and systematic evidence.

The value of trade in Zambia has been rising while the exchange rate has exhibited considerable fluctuations. Two notable studies by Tenreyro (2007) and Musonda (2008) have been conducted on this relationship in Zambia. Both studies use aggregate annual trade data but provide seemingly contradictory results. This study attempts to investigate the extent of the influence of exchange rate volatility on trade flows in Zambia in line with the observations by McKenzie (1999) which underpin most recent empirical work.

In an open economy setting, the exchange rate is important in monetary policy. It influences the overall price level either directly through import prices or indirectly through the aggregate demand channel[4]. Empirical support and practical usefulness of monetary policy and foreign exchange intervention rules exists (Edison, 1993; and Eleftheriou et al. 2006). To the knowledge of the author, no empirical modelling of monetary and foreign exchange intervention rules that include output gap, inflation gap and exchange rate volatility has been conducted on Zambia. The thesis therefore attempts to provide evidence on this for Zambia.

Previous empirical work elsewhere does not broaden the structural vector autoregression (SVAR) specification to include foreign exchange intervention data in the estimation of monetary policy rules. Conventionally, monetary policy rules include output gap, inflation gap and the level of the exchange rate as policy goals in the Taylor rule (and the extensions) specification. However, exchange rate volatility matters for monetary policy as it reflects uncertainty that in turn affects agents' expectations and hence underlies policy considerations. Hence, to capture this aspect, the SVAR specification here includes conditional variance as opposed to the level of the exchange rate. In addition, the SVAR specification includes foreign exchange intervention data. A similar specification of policy goal variables is used in the generalised method of moments (GMM) estimator. The idea is to capture the extent to which monetary policy and foreign exchange intervention respond to the same policy goal variables via their respective instruments. In essence, this approach captures simultaneously the interaction between the two policies and hence the degree of synchronisation. This kind of specification has not been done in the literature.

---

[4] As prices are sticky in the short-run, changes in the nominal exchange rate affect the real exchange rate which translates into changes in relative prices for domestic and foreign goods and subsequently impact on demand for domestic and foreign goods (Svensson, 1999).

1.4 Structure of the Thesis

A brief overview of the macroeconomic policies undertaken in Zambia from the time of independence in 1964 to 2008 is outlined in chapter 2. This provides the basis for the nature of policies undertaken as this could have a bearing on the exchange rate volatility relationships under study. Chapter 3 models the behaviour of the kwacha exchange rate volatility. Before the impact of exchange rate volatility on the economy is assessed, it is imperative to first define and model it in order to appreciate the degree of currency volatility and its underlying causes. The focus in this chapter is on a sample of bilateral exchange rates involving currencies of Zambia's main trading partners. Principal components analysis is conducted on the estimated conditional variance generated from GARCH models in order to capture the common underlying pattern in the kwacha exchange rates (referred to here as GARCH-PCA). This has not been studied before in the literature thus far. Chapter 4 examines the impact of exchange rate volatility on trade. The idea is to establish whether exchange rate volatility and thus exchange rate policy is important in trade. The thesis makes a contribution to the exchange rate volatility-trade link literature by focusing on disaggregated export data which has not been studied before in Zambia. The interaction between monetary policy and exchange rate volatility is examined in chapter 5. In addition, the relevance of exchange rate volatility in foreign exchange intervention is assessed. In this chapter, the contribution of the thesis takes the form of variation to the specification of the SVAR relative to the conventional approach in the literature. Intervention data are included in a set of variables that contains output gap, inflation gap, exchange rate volatility and monetary policy instruments (i.e. base money and the interest rate). Chapter 6 concludes the thesis and some areas for further research are suggested. In all the three empirical chapters (3, 4 and 5), the relevance of the new measure of exchange rate volatility, GARCH-PCA, not studied before in the literature is emphasised.

Overall, volatility in the kwacha exchange rate is found to be relevant in Zambia in so far as it affects trade and underpins monetary policy and foreign exchange decision-making process.

Chapter 2 OVERVIEW OF MACROECONOMIC POLICIES IN ZAMBIA

2.1 Introduction

This chapter provides a brief outline of the main macroeconomic policies pursued in Zambia since attaining independence in 1964 and presents a synopsis of economic performance up to 2008[5].

2.2 Brief Outline of Macroeconomic Policies

An import substitution industrialisation development strategy was adopted soon after gaining independence in 1964. State owned enterprises (SOEs) were created to spur this development strategy. The main sector of the economy was mining which accounted for about half of GDP and about 90 percent of total export earnings (UNDP, 2006)[6]. Strong copper revenues initially supported the development strategy as copper prices (figure 2.1 in US$ per metric tonne) and output (figure 2.2 in thousands of metric tonnes) steadily rose. Subsequently, revenue from copper weakened due to the fall in copper prices in early 1970 and the decline in copper output. Oil prices also shot up in 19973/74 and again in 1979/80 (oil price shocks) causing the terms of trade to decline[7].

The fall in the terms of trade was initially viewed to be temporary. Thus, the government sought to mitigate its effect by borrowing a substantial amount externally in order to sustain the industrialisation development strategy. However, as copper prices remained depressed through the 1980s and copper export volumes also declined due to lack of re-investment in the mining sector, fiscal revenues fell without a corresponding cut in expenditure. Thus, the stock of external debt mounted (figure 2.3), terms of trade deteriorated further, balance of payments pressures escalated (figure 2.4) and public

[5] A detailed discussion is provided by Adam (1995) and UNDP (2006).
[6] Mining continues to be a dominant sector and underpins the performance and structure of the economy (UNDP, 2006).
[7] Zambia is a landlocked oil importing country.

investment too declined. The government continued to support SOEs despite being inefficient and loss making. Thus, as government budget financing was mostly done through central bank borrowing, inflation accelerated sharply in the early 1980s from around 6 percent to the peak of about 165 percent in 1992 (figure 2.5 in annual percent change). Fiscal deficits (as a percent of GDP) increased almost fivefold to 21 percent in 1986, over a 20-year period (figure 2.6). Thus, it became apparent that the industrial development strategy could not be sustained.

The government responded by imposing exchange and trade controls (foreign exchange controls on current and capital account transactions plus import licensing) as well as price controls on goods. Interest rate ceilings were also introduced. The fixed exchange rate combined with expansionary monetary and fiscal policies, led to the overvaluation of the real kwacha exchange rate and thus loss of external competitiveness. Attempts to diversify the economy away from copper dependence and limit the dominance of SOEs in the late 1980s failed due to underlying distortions created by the policies in place (see Adam, 1995). Consequently, by the mid 1990s, negative real GDP growth rates became entrenched (figure 2.7 in annual percent change).

In an attempt to reverse the general decline in economic growth, the economy was liberalised as market-oriented reforms were adopted in early 1990s with the support of the IMF/World Bank. The reform package included de-control of product prices, trade liberalisation and elimination of exchange controls in 1994 making both current and capital account fully convertible that subsequently gave way to a market determined exchange rate. The removal of interest rate ceilings in 1991, introduction of Treasury bill (T-bill) auctions in 1993 and adoption of indirect instruments of monetary policy in 1995, privatisation of SOEs including mining companies and rationalisation of expenditures (especially non-essential) and enhancement of domestic revenue collection were other reform measures undertaken.

Some remarkable economic improvements have been posted. As shown in figure 2.7, real GDP growth recovered from -2.0 percent in 1998 to about 3.5 percent in 2000 and the positive trend sustained. Underlying this positive growth is the turn-around in mining production spurred by the privatisation of mines (UNDP, 2006). Re-capitalisation and opening up of new mines have boosted copper output (figure 2.1)[8] while copper prices picked up strongly in the recent past after a long trend decline that begun in the 1970s (figure 2.2).

Monetary policy has remained focused on containing inflationary pressures with subsequent reduction in inflationary financing of the government budget. The rate of inflation fell markedly from the peak of 165 percent in 1992 to around 16 percent in 2008, having dropped to a single digit, about 9 percent, in 2007[9] (see figure 2.5). Though erratic, money supply growth (figure 2.8 – annual percent change) has slowed down since 1993 and has been on a downward trend. The behaviour of interest rates mimics the pattern in inflation. Interest rates in particular T-bill rates (figure 2.9 in annual percent) fell sharply too from the three digit level in 1993 to below 20 percent by 2008. While lending rates have declined too, they however, remain relatively high (figure 2.10 in annual percent). Gross domestic savings as a percentage of GDP (figure 2.11) exceeded 20 percent in 2006 from low and negative levels observed especially during pre-liberalisation period. The capital market too has grown since the stock exchange was established in 1997 as indicated by the sharp rise in the stock market index (figure 2.12: 2005=100).

---

[8] This follows a long period of low investment and lack of modernisation of mines (UNDP, 2006).
[9] Near hyper-inflation levels were reached during 1990-95 (Andersson and Sjöö, 2000).

Fiscal deficits (as a percent of GDP) have improved from around 20 percent in 1986 to 2.5 percent in 2008 (figure 2.6) owing largely to improvements in domestic revenue collections (average about 18 percent as a proportion of GDP over the last 19 years – figure 2.13) and contraction in expenditure through prioritisation. However, the stock of domestic debt as a percentage of GDP has risen considerably in recent years to about 18 percent in 2008 from about 5 percent in 1997 (figure 2.14). In contrast, the external debt has shrunk to about 10 percent of GNI from over 400 percent in 1986 following debt relief under the Heavily Indebted Poor Countries (HIPC) Initiative in 2005 (after reaching the Completion Point) and Multilateral Debt Relief Initiative **(**MDRI**)** in 2006 (figure 2.3).

Finally, the current account deficit as a percent of GDP has narrowed, with notable improvements observed since 2000 (figure 2.4). Export growth has steadily risen (figure 2.15) with the share of exports in GDP in excess of 40 percent, reversing a declining trend prior to 2000 (figure 2.16). Accounting for this is mainly copper exports while non-traditional exports (NTEs)[10] have been on the rising trend, picking up strongly towards the end of the 1990s (figure 2.17 in millions of US$). Imports have remained strong over the years, growing substantially since the early 1990s (figure 2.18) and taking up almost a 40 percent share of GDP over the review period (figure 2.19). Foreign direct investment (net inflows) as a percent of GDP (figure 2.20) has tremendously increased post-liberalisation from as low as 1 percent of GDP to close to 10 percent. The exchange rate has been on a rising trend (figure 2.21 in level – kwacha per US dollar), exhibiting considerable fluctuations (figure 2.22). The exchange rate depreciated rapidly during 1985-87 and moderately soon after 1994.

[10] NTEs are non-metal (copper and cobalt) export commodities.

Figure 2.1-2.22: Selected Macroeconomic Indicators

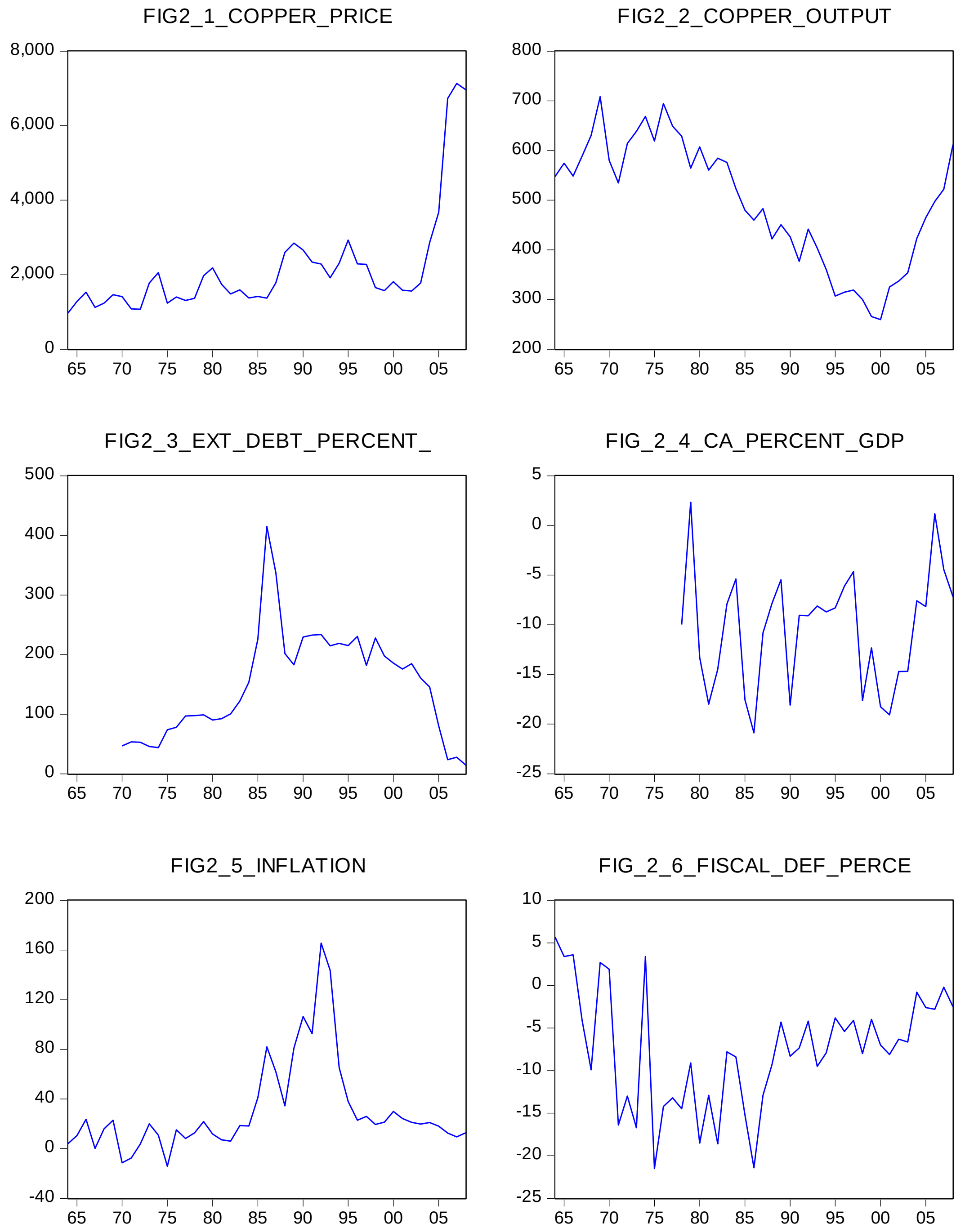


FIG2_7_GDP_GROWTH

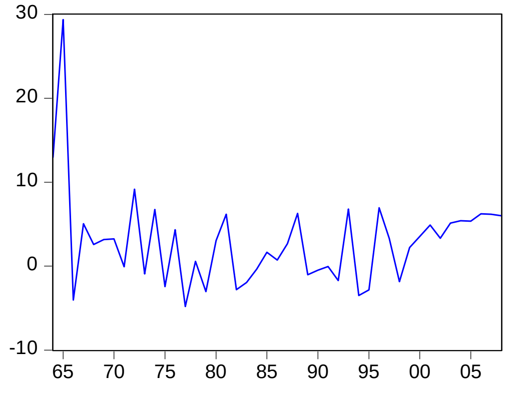


FIG2_8_MONEY_SUPPLY_GROW

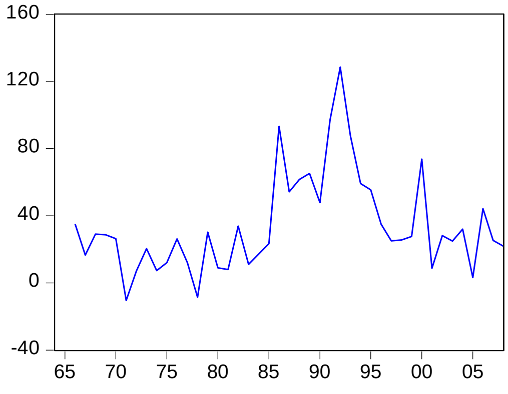


FIG2_9_T_BILL_RATE

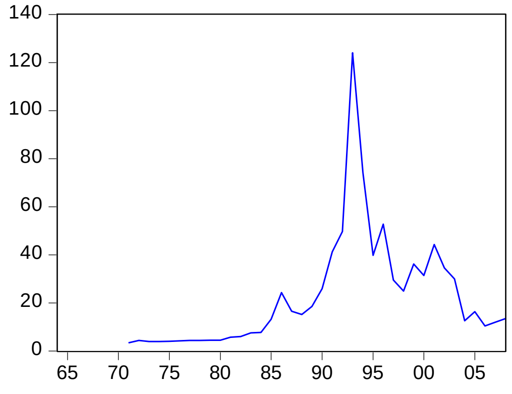


FIG2_10_LENDING_RATE

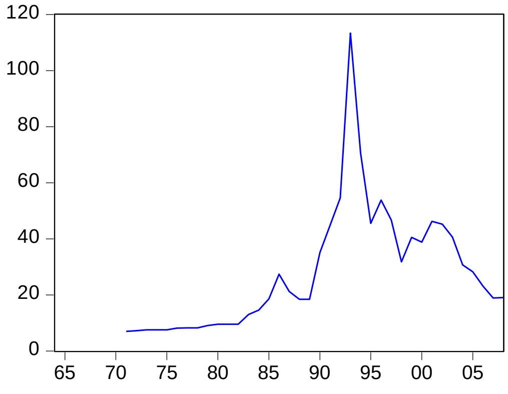


FIG2_11_SAVINGS_PERCENT_

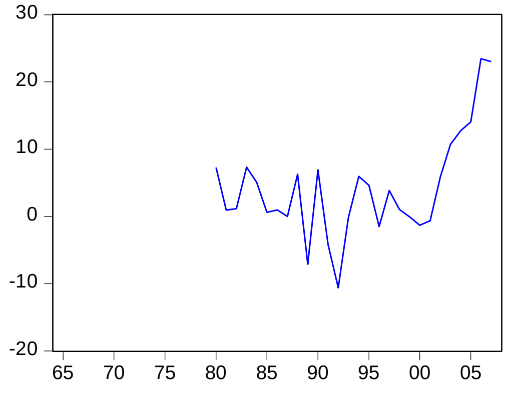


FIG2_12_STOCK_MKT_INDEX

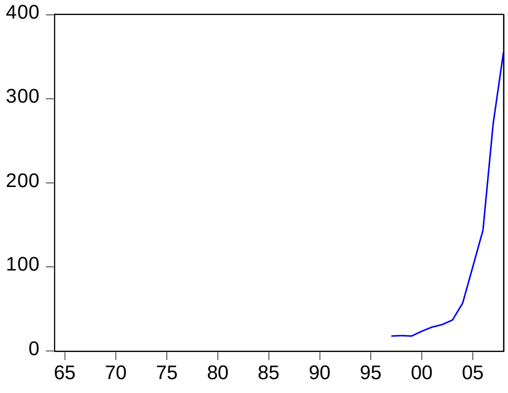


FIG2_13_REVENUE_PERCENT_

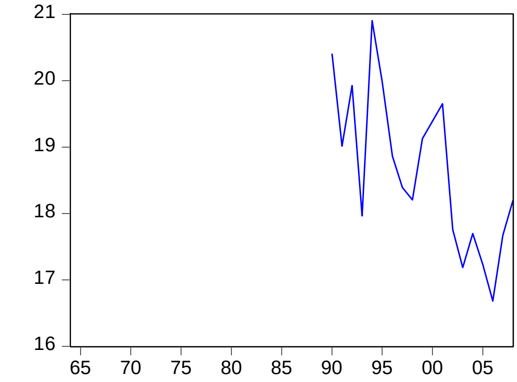


FIG2_14_DOM_DEBT_PERCENT

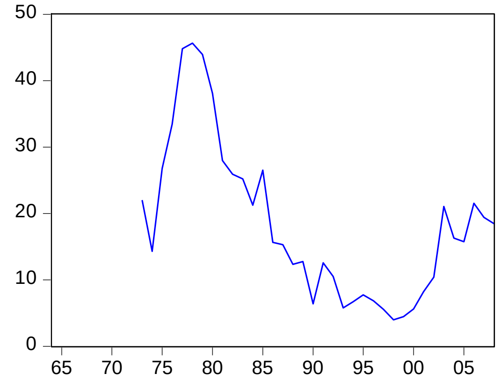


FIG2_15_EXPORTS_GROWTH

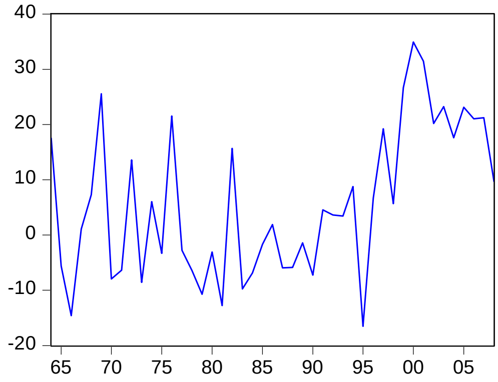


FIG2_16_EXPORTS_PERCENT_

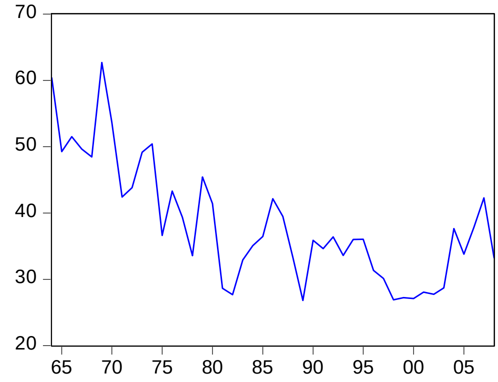


FIG2_17_NTES

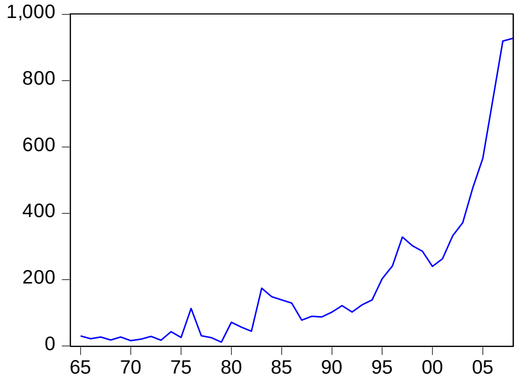
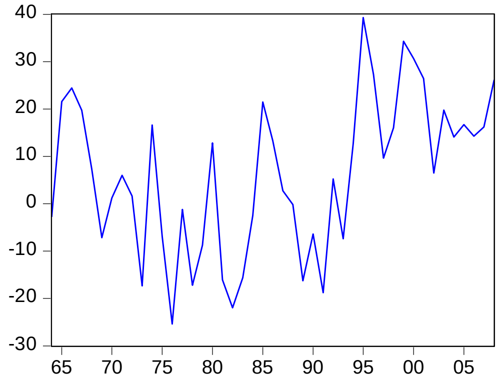
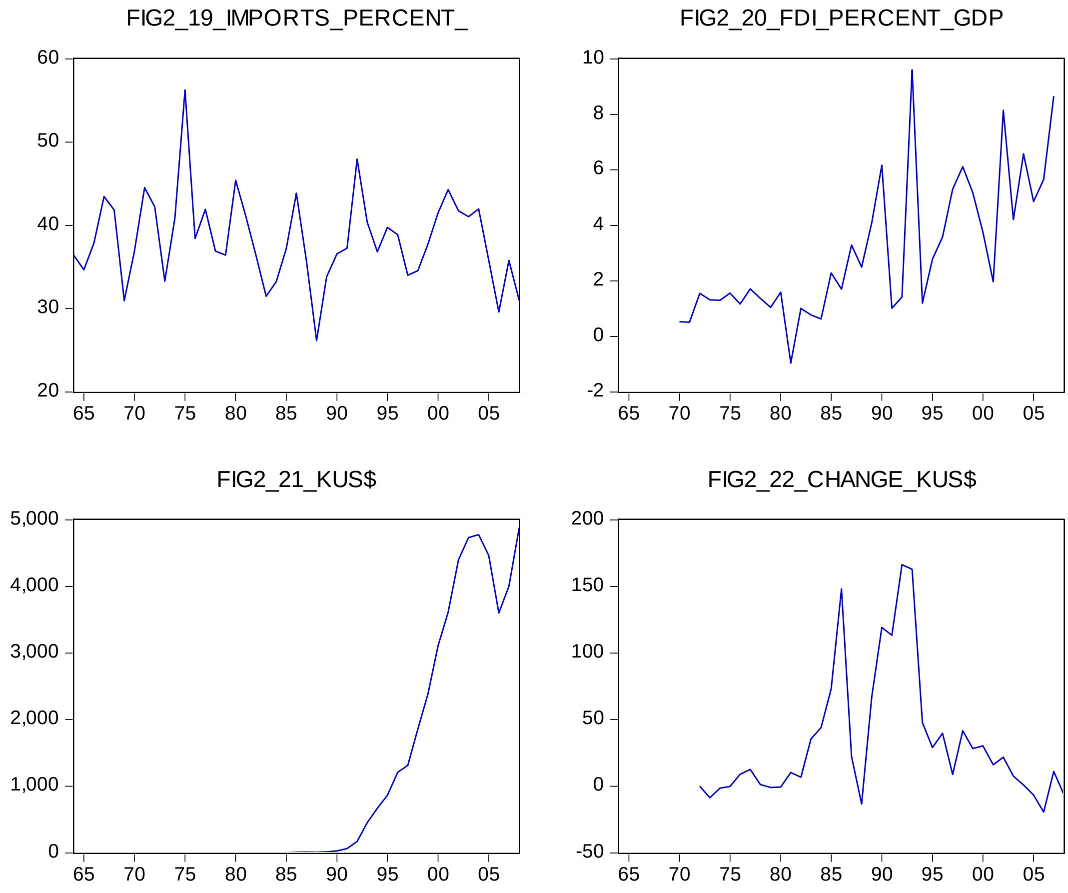


FIG2_18_IMPORTS_GROWTH





Data sourced from IMF and World Development Indicators of the World Bank

2.3 Conclusion

In recent years, the focus of economic policy has been on raising economic growth and reducing poverty by consolidating the stabilisation gains achieved. Financial sector and private sector development plus public financial management and accountability reforms are other areas of priority concern to the government.

Chapter 3 MODELLING EXCHANGE RATE VOLATILITY IN ZAMBIA

This chapter benefited from comments from participants at the African Finance Journal (10-11 July 2008, Cape Town, South Africa) and The Centre for the Study of African Economies (22-24 March 2009, University of Oxford, UK) Annual Conferences

3.1 Introduction

Modelling exchange rate volatility continues to attract interest from both academic and policy researchers especially after the breakdown of the Bretton Woods system in March 1973 due to its significance for the economy (refer to chapter 1). Nonetheless, consensus regarding the sources of exchange rate volatility is lacking despite the considerable amount of empirical work undertaken. This is partly reflected in the existence of numerous theoretical models of exchange rate determination and several modelling approaches employed.

SVAR is widely used while GARCH models have gained prominence in the recent past as estimation techniques (see Bauwens and Sucarrat, 2006; Sfia, 2006; Stančík, 2007; and Narayan et al. 2009). In SVAR analysis, fluctuations in exchange rates are determined by examining the dynamic response of exchange rates to influences (shocks) from other variables via impulse response analysis. Conversely, in GARCH models, the variance structure of residuals derived from the exchange rate conditional mean equation are modelled to capture the extent to which the exchange rate moves around.

While volatility can mean different things depending on the context in which it is applied, as can be inferred from the quoted Merriam-Webster Online Dictionary definition, Bauwens and Sucarrat (2006) define it as the conditional standard deviation or variance of a financial return. By and large, volatility is a latent or unobservable variable, deterministic or stochastic and reflects the tendency of a variable to rise or fall sharply within a short period of time (Bauwens and Sucarrat, 2006). With respect to the exchange rate, Akhtar and Spence-Hilton (1984) state that volatility is associated with unanticipated movements or innovations, which generate uncertainty or "state of doubt about future rates at which various currencies will be exchanged against each other". Uncertainty is approximated by (observed) exchange rate variability (Akhtar and Spence, 1984). An appropriate measure of exchange rate volatility should reveal volatility during periods of high and sustained change in the exchange rate or reproduce the characteristic features of the exchange rate series. This chapter intends to explore this aspect of volatility.

A large body of empirical work has employed fundamentals-based models in modelling exchange rate volatility (see Pozo, 1992; Bayoumi and Eichengreen, 1998; Devereux and Lane, 2003; Kočenda and Valachy, 2006; and Sfia, 2006). Most of these studies document real shocks with large permanent effects as the dominant source of exchange rate volatility. Notwithstanding this evidence, fundamentals tend to explain only a small proportion of exchange rate volatility due to the weak link between the two popularly referred to as the 'disconnect argument', thus lending support for the role of microstructure factors in exchange rate fluctuations in the short-term (see Baxter and Stockman, 1989; Flood and Rose, 1995; Obstfeld and Rogoff, 2000; Canales-Kriljenko and Habermeier, 2004; De Grauwe et al. 2005; and Bjørnland, 2008 for an extensive discussion). However, Morana (2009) provides more recent support for fundamentals in terms of linkages (causes and trade-off) between exchange rate volatility and volatility in macroeconomic factors (i.e. output, inflation, interest rate and money supply). Although the direction of causality is bi-directional, it is however, stronger from macroeconomic factors to exchange rate volatility than vice-versa. Thus, stability in the macroeconomic is recommended to reduce exchange rate volatility in sharp contrast to Flood and Rose (1995).

The study of the dynamics and sources of exchange rate volatility in Zambia is largely unexplored. This is despite the evidence that fluctuations in the kwacha exchange rate impose a strong positive influence on inflation dynamics (see Andersson and Sjöö, 2000; and Mutoti, 2006). Known empirical studies on exchange rate in Zambia have mostly concentrated on analysing the determinants of the level of the exchange rate and estimating the long-run (real) equilibrium level and its misalignment (Mkenda, 2001; and Mungule, 2004). Studies known to the author that analyse the sources of exchange rate volatility in Zambia are Savvides (1990)[11], Hausmann et al. (2006)[12] and Bangaké (2008)[13]. Cross-country panel data are used in these studies. However, the effects of control factors in the regression equations are generalised to the sample of countries studied without isolating how individual countries are specifically affected by these control variables. Moreover, the measure of exchange rate volatility employed, standard deviation of the percentage change in the exchange rate, by Savvides and Bangaké is not robust (see Pagan and Ullah, 1988; and Singh, 2002)[14].

This chapter contributes to the debate about the exchange rate in Zambia by analysing the sources of exchange rate volatility using a time series approach as follows.

Firstly, unlike most previous empirical work, a relatively large sample of eight kwacha bilateral exchange rates involving currencies of Zambia's main trading partner currencies is examined. Both real and nominal bilateral as well as trade-weighted

[11] Find both real and monetary variables to be key determinants of exchange rate variability over the period 1976-84.

[12] Consider a host of factors in particular real and nominal shocks on real exchange rate volatility for industrial and developing countries over the period 1980-2000 using annual data.

[13] Examine exchange rate volatility in selected African countries in the context of OCA framework over the period 1990.01-2003.12 using GLS and GMM.

[14] Standard deviation assumes normality distribution of a series; does not distinguish between predictable and unpredictable elements of a series; and tends to overstate total risk.

(effective) exchange rates are analysed. The inclusion of trade-weighted exchange rates is intended to explore the structural macroeconomic linkages between Zambia and her major trading partners in addition to capturing variations occurring to individual bilateral exchange rates. Most empirical studies focus on either real or nominal bilateral/trade-weighted exchange rates (i.e. Kahya et al. 1994; Singh, 2002; and Olowe, 2009).

Secondly, the analysis is conducted over a longer sample period, 1964 to 2006, using relatively higher frequency data at monthly interval. Annual and quarterly data have been used in a large number of previous empirical studies including those on Zambia mentioned above.

Thirdly, GARCH models are employed. Unlike the widely used SVAR models that assume a constant variance and account for the sources of exchange rate volatility via impulse response and variance decomposition analysis, GARCH models introduced by Engle (1982) and extended by Bollerslev (1986) take into account the distributional form of the exchange rate. Exchange rates exhibit leptokurtic, volatility clustering and leverage behaviour typically present in financial time series data and GARCH-type models capture this (Hu et al. 1997; Koutmos and Theodossiou, 1994; Brooks, 2001; Bauwens and Sucarrat, 2006; and Koay and Kwek, 2006). Thus, GARCH models estimate the path for the time-varying conditional variance of the exchange rate. This is in addition to determining the sources of volatility by specifying fundamental or control factors directly in and/or the mean and variance equations. Both symmetric and asymmetric versions of GARCH models are examined in order to capture the conditional volatility characterising each exchange rate along its trend[15]. Despite mixed results, recent empirical evidence has increasingly found strong support for the

[15] This is despite the argument that there is no rigorous theoretical argument for asymmetry to exist in foreign exchange markets due to the two-sided nature of the market (see Bollerslev at al. 1992).

existence of asymmetry in foreign exchange markets (e.g. Koay and Kwek, 2006; and Fidrmuc and Horváth, 2008). Thus, this evidence motivates us to extent the investigation to the kwacha exchange rates to determine whether price shocks (unexpected appreciations and depreciations) have different effect on the volatility of kwacha exchange rates.

Finally, principal components analysis (PCA) is conducted on the estimated conditional variance. The motivation is to generate a new GARCH series (GARCH-PCA) that captures a common pattern in the estimated conditional variance. GARCH-PCA links volatility in all kwacha exchange rates and reflects influences attributed to either the domestic currency country (Zambia) or trading partner countries. GARCH-PCA series can be used in subsequent empirical work examining the interaction between exchange rate volatility and other economic variables. The author is not aware of any study that has generated PCA exchange rate volatility series from GARCH models and applied it in empirical work as an alternative measure of exchange rate uncertainty. As the results indicate in chapters 4 and 5, the performance of GARCH-PCA as an alternative measure of exchange rate risk is comparable to existing measures.

The results reveal that the eight bilateral exchange rates are characterised by different conditional volatility dynamics in terms of conditional volatility persistence and response to shocks. In addition, the positive influence of exchange rate regime, money supply and openness on conditional volatility predominates. GARCH-PCA mimics the pattern in the original exchange rate series and can thus be described as an *index of exchange rate volatility* capturing influences specific to Zambia.

The rest of the chapter is organised as follows. The next section provides a historical overview of the exchange rate policy in Zambia while a review of some theoretical and empirical literature on exchange rate volatility modelling is presented in section 3.3. Section 3.4 outlines the estimation procedure and presents empirical results. The conclusion is contained in section 3.5.

3.2 Overview of the Exchange Rate Policy in Zambia

The exchange rate policy in Zambia is broadly characterised by two distinct regimes, namely fixed and flexible[16]. A fixed exchange rate regime existed from 1964 to 1982 and 1987 to 1991 while a crawling peg was adopted between 1983 and 1985. An initial float of the kwacha took place between 1985 and 1987. A more flexible exchange rate regime was adopted in the early 1990s as part of the economic reforms. The decision to choose each of these exchange rate regimes was largely influenced by conventional economic and political arguments. A fixed exchange rate was mainly sustained by official decree (i.e. occasional adjustments of the exchange rate and administrative controls such as issuance of import licenses) as opposed to official interventions in the foreign exchange market (Mkenda, 2001).

A new fully convertible currency, the Zambian pound, was introduced and pegged to the British pound at the time of independence in 1964. However, in January 1968, the Zambian pound was replaced by the Zambian kwacha (hereinafter referred to as kwacha) at an official rate of K0.714 per US dollar or K1.70 per British pound sterling. The new peg of the kwacha to the British pound remained in place until December 1971 when the kwacha was linked to the US dollar. In February 1973, the kwacha was re-valued by 11.1 percent to K0.643 per US dollar. The rate was maintained until July 1976 when the kwacha was devalued by 20 percent against the US dollar and consequently linked to the Special Drawing Rights (SDR) at an official rate of SDR1.0848. This was necessitated by the continued deterioration in the external balance position induced by the strong US dollar relative to other currencies and the

[16] For a comprehensive review of the chronology of the exchange rate policy in Zambia, refer to Adam (1995), Mwenda (1996), Mkenda (2001) and Mungule (2004).

deterioration in Zambia's terms of trade as the price of copper fell significantly while oil prices surged (oil shock). Two devaluations followed thereafter: 10 percent in March 1978 to SDR0.9763 and a further 20 percent in January 1983 to SDR0.7813. Devaluations were done on an ad hoc basis without specific reference to economic fundamentals.

In July 1983, the kwacha was de-linked from the SDR and pegged to a weighted average basket of five major trading partner currencies. The kwacha was allowed to adjust but within a narrow range: 1 percent devaluation every month.

As the external position deteriorated further, copper revenues fell drastically and the external debt mounted, the kwacha was allowed to float against major currencies in October 1985 via an auction system[17]. The auction system was designed to eliminate the parallel market for foreign exchange which had emerged during the fixed regime, improve the allocation of foreign exchange previously allocated on non-price criteria and allow supply and demand to interact in determining the external value of the kwacha (Mkenda, 2001). However, the auction was suspended in January 1987 and the exchange rate set at K9.00 per US dollar. Three months later, a two-tier system was adopted with a ‘set’ rate applied to official transactions while the ‘float’ rate applied to the rest of the transactions. Due to the drastic depreciation of the second tier (float) kwacha exchange rate and the subsequent rise in inflation attributed to exchange rate pass-through, the auction system was abandoned in May 1987 and replaced by a fixed exchange rate system administered by the Foreign Exchange Management Committee (FEMAC). The kwacha was fixed to the US dollar again at K9.00. In November 1988,

[17] The kwacha was floated through the Dutch auction system. Auctions were conducted by the central bank on a weekly basis. The official rate was determined by the marginal market-clearing bid that exhausted the foreign exchange on offer. Bids were submitted through commercial banks. A dual exchange rate existed during this time whereby transactions deemed of strategic national importance such as debt servicing, educational and medical requirements, oil imports, mining companies and parastatals were conducted at the rate below the auction rate while the auction rate applied to the rest of the transactions (Mkenda, 2001).

the kwacha was devalued by 20 percent and re-linked to the SDR. In July 1989, the kwacha was devalued by 49 percent accompanied by a monthly crawl and a further 50 percent devaluation occurred in December the same year.

A dual exchange rate system managed by FEMAC was adopted in 1990. The system included a retail window for importers, an open general licence system (OGL), and an official window with a lower rate. In 1991, the OGL retail and official exchange rates were unified when the process of economic liberalisation commenced. In 1992, the OGL list was expanded, exporters of non-traditional commodities were allowed 100 percent foreign exchange earnings retention, a bureaux de change system was allowed to operate in October in order to widen foreign exchange participation and Zambia Consolidated Copper Mines (ZCCM)[18] earnings were allowed to be sold at the 'market rate' in order to integrate the foreign exchange market. Furthermore, the official exchange rate was devalued by 30 percent and the rate of crawl accelerated to 8 percent per month. In 1993, the OGL system was further modified and most exchange controls transferred to commercial banks. In December the same year, the dealing system[19] was established. In January 1994, the Exchange Control Act of 1965 was suspended and all import restrictions removed, paving way for a full convertibility of the kwacha. Both current and capital accounts were liberalised and in 1996, the public was allowed to open foreign currency accounts with local commercial banks.

Finally, further changes to the flexible foreign exchange regime were made after 1994. In April 1995, the frequency at the dealing window changed from three times a

[18] ZCCM was a state-owned copper mining conglomerate that accounted for the largest foreign exchange earnings in Zambia. As a matter of foreign exchange management policy at the time, ZCCM was allowed to retain a certain percentage of its foreign exchange earnings for operations and sell the remainder to the Bank of Zambia which in turn allocated the foreign exchange to the rest of the economy.

[19] The dealing system was a mechanism for allocating foreign exchange through an auction process. Commercial banks were allowed to buy and sell foreign exchange from the central bank. The official exchange rate was determined by the rate struck at the auction.

week to daily. In 1996, the ZCCM retention scheme was abolished. ZCCM was allowed to transact its foreign exchange directly in the market. However, in January 2001, the dealing system was re-established having been suspended in 1996 as the government announced measures to stabilise the foreign exchange market following a sharp depreciation of the kwacha. Nonetheless, volatility in the exchange rate increased and multiple exchange rates emerged. Consequently, a broad-based interbank foreign exchange market (IFEM) system was introduced in July 2003 (currently in operation) to address the shortcomings noted in previous systems.

3.3 Literature Review

The study of underlying determinants of exchange rate volatility is based on either a specific or a synthesis of exchange rate models. For instance, Bartolini and Bodnar (1996) employ the monetary model of exchange rate, Bayoumi and Eichengreen (1998) base the analysis on optimum currency areas (OCA) factors while Hausmann et al. (2006) incorporate factors from different exchange rate models.

By and large, there is no consensus in the literature regarding factors that influence exchange rate volatility. The factors are numerous compounded by the inability to predict them and their effect on real exchange rate volatility varies considerably to be quantified with certainty (Korteweg, 1980; Dungey, 1999; and Canales-Kriljenko and Habermeier, 2004). This stems from divergent theoretical models of exchange rate determination. Some models are based on fundamentals while others are not.

The standard model of the exchange rate can be specified as[20]

[20] Equation 1 is obtained based on the law of iterative expectations and assuming rational expectations and absence of exchange rate bubbles (see Bartolini and Bodnar, 1996 for the derivation of the monetary model).

$$s_t = (1-\theta)\sum_{j=0}^{\infty}\theta^j E_t f_{t+j} \tag{1}$$

where s_t is the logarithm of the exchange rate, f_t is the logarithm of fundamentals and θ is the discount factor set equal to $\alpha/(1+\alpha)$ where α is the semi-elasticity of money demand in monetary models and E_t is the rational expectations operator based on information available at time t (Lewis, 1995). f_t includes among other variables real income, money supply, inflation, interest rates and trade linkages (i.e. terms of trade and openness).

MacDonald (1999) argues that the relevance of fundamentals in influencing the behaviour of the exchange rate should reflect their ability to explain its long-run behaviour and its volatility as well as generate out-of-sample forecasts better than the random walk.

As noted by Flood and Rose (1995) and others, fundamentals account for a small proportion of the observed volatility in exchange rates. Several reasons are advanced. Firstly, a weak link exists between underlying fundamentals and exchange rate volatility: changes in exchange rates take place even when there are no detectable changes in fundamentals. Secondly, post-1973, volatility in exchange rates has increased considerably while that of macroeconomic variables has remained virtually unchanged. Thirdly, exchange rate series have non-normal distributions reflected in fat tails and excess kurtosis while fundamentals do not have similar distributional characteristics. Finally, in the short-run, exchange rates deviate from their equilibrium level implied by purchasing power parity (PPP) and these deviations are large and persist for a long time due to sluggish prices.

Disequilibrium models by Dornbusch (1976), Mussa (1986) and Edwards (1987) emphasise the importance of nominal shocks with transitory effects on exchange rates. On the other hand, equilibrium models by Stockman (1983) emphasise real shocks with permanent effects as key sources of real and nominal exchange rate fluctuations and empirical support exists for this (see Sfia, 2006).

According to Dornbusch (1976), real exchange rate volatility is due to slow adjustment of commodity prices against rapid response of nominal exchange rates (asset prices) to exogenous shocks. The nominal exchange rate overshoots its long-run equilibrium level immediately after the shock (e.g. unanticipated money supply increase) thereby inducing volatility in the real exchange rate. The implication of the sluggish commodity price adjustment is that unlike under the fixed exchange rate regime, the nominal exchange rate is characterised by volatile behaviour under the flexible exchange rate system that in turn causes the real exchange rate to be volatile. Stickiness in prices generates a large co-variation of real and nominal exchange rates. Hence, the more variable the money stock, the more variable will be exchange rates and vice-versa.

De Grauwe et al. (1985) predict a non-linear positive relationship between exchange rate volatility and variability of monetary disturbances (defined to include money supply and inflation) based on a synthesis of sticky-price and news models of exchange rate determination. Korteweg (1980) emphasises inflation differentials as a potential source of real and nominal exchange rate volatility. High inflation rates erode the purchasing power of a currency. Thus, agents respond by shifting assets into a stronger currency which leads to the depreciation of the currency as the exchange rate adjusts to accommodate inflation differentials between countries. Empirical support for domestic monetary policy as a potential source of real exchange rate variability is provided by De Grauwe et al. (1985), Edwards (1987), Jeong (2000) and Cady and Gonzalez-Garcia (2006).

A positive relationship between interest rate and exchange rate volatility is underpinned by capital mobility between countries via the uncovered interest rate parity (UIP) condition (Suliman, 2005). Higher domestic interest rates relative to foreign interest rates attract capital inflows. According to the UIP condition, the domestic currency is expected to depreciate against the foreign currency and consequently increase the variance of the exchange rate (Grydaki and Fountas, 2009).

Hviding et al. (2004) focus on the role of international reserves on real exchange rate volatility and find higher international reserves defined as a ratio of gross reserves to short-term debt to have a negative effect on exchange rate volatility. High and adequate international reserves are critical for the prevention of currency crisis. This signals the ability of the central bank to intervene in the foreign exchange market and reduces the cost of foreign debt by improving credit rating as well as boosting the creditworthiness confidence.

Non-monetary factors such as productivity shocks, terms of trade, openness and government spending account for exchange rate volatility as well (Calderón, 2004). Greater variability in real productivity shocks usually proxied by variability in the rate of growth of real GDP results in higher exchange rate variability.

Optimum currency area (OCA) factors that include trade linkages, similarity of economic shocks to output among countries, country size and commodity composition of exports are potential sources of exchange rate volatility. Further, geographical factors such as distance and borders between countries account for relative price volatility and hence real exchange rate volatility (MacDonald, 1999).

Countries with greater bilateral trade tend to experience lower bilateral exchange rate volatility as governments have the incentive to keep the exchange rate stable through official interventions in foreign exchange markets. Katseli (1984) predicts a positive relationship between increased variability in terms of trade and variability in the real effective exchange rate while a negative relationship between economic openness and real exchange rate volatility is predicted (Obstfeld and Rogoff, 2000; and Hau, 2002). More open economies with high trade integration tend to experience lower exchange rate volatility. The aggregate price level tends to be flexible in more open economies (via import prices), moderates the effects of monetary shocks on real household balances and thus consumption in the short-term. Further, Melvin and Bernstein (1984) postulate that traded goods have a greater role in influencing the overall price index or domestic price level in more open economies such that deviations of the exchange rate from PPP are smaller resulting in a relatively stable exchange rate. However, if trade is concentrated in one good (e.g. exportable), deviations from PPP are more likely than if trade is diversified. Countries with diversified trade tend to have stable exchange rates as random shocks affecting each good tend to cancel out. However, random shocks to the good are directly transmitted to the overall index resulting in a volatile exchange rate if trade is concentrated in one or two goods. Thus, countries with more open economies tend to withstand external shocks (Hausmann et al. 2006).

Bayoumi and Eichengreen (1998) find OCA factors (i.e. asymmetric shocks to output and high degree of trade links) to have a negative effect on bilateral exchange rate volatility for 21 industrial countries studied over the period 1963-92. Similar results for selected African countries including Zambia are reported by Bangaké (2008) that exchange rate volatility is driven by conventional OCA variables. Countries with similar shocks tend to experience low bilateral exchange rate volatility. Further, evidence of trade flows and openness being negatively related to exchange rate volatility is confirmed by Hau (2002), Devereux and Lane (2003), Bleaney (2006)[21] and Stančík (2007). Devereux and Lane (2003) estimate an empirical model that includes OCA and financial (external financial liabilities) variables as determinants of bilateral exchange rate volatility. They establish that a developing country with high levels of financial linkages in the form of portfolio debt or bank loans with a creditor developed country tends to experience lower levels of bilateral exchange rate volatility. Hausmann et al. (2006) attribute higher real exchange rate volatility in developing countries relative to industrial countries to larger terms of trade shocks, larger volatility in GDP growth, larger nominal shocks, sudden stops in capital flows that generate currency crisis, limited openness and the adoption of non-credible peg exchange rate regime in particular pegs.

The exchange rate news model does not perform well in explaining exchange rate volatility as it accounts for a relatively small proportion, not exceeding 20 percent, of the variation in exchange rates (Copeland, 2005). Copeland attributes this to irrationality in currency markets, peso problem[22] and the presence of bubbles that weaken the link between the exchange rate and fundamentals.

Existing evidence suggests that exchange rate volatility is not regime-neutral. The switch to the flexible exchange rate system has resulted in a significant increase in real exchange rate volatility (Stockman, 1983; Mussa, 1986; Savvides, 1990; Pozo, 1992; Hasan and Wallace, 1996; Canales-Kriljenko and Habermeier, 2004; Kočenda and Valachy, 2006; and Stančík, 2007). Kočenda and Valachy (2006) argue that the

[21] Unlike other studies, Bleaney employs current account balance to GDP ratio as a measure of openness which acts as a misalignment signal.
[22] The Peso problem refers to the possibility of occurrence of a major shift in fundamentals on which a small probability is attached e.g. once-and-for all discrete change in currency regime (Copeland, 2005).

exchange rate regime represents a shock for currency markets. The switch from fixed to flexible exchange rate regime generates 'volatility explosion' as the pressure caused by exchange controls is released. The market adjusts to the new exchange rate arrangement and the exchange rate moves to its equilibrium several months after the change of regime. Pozo (1992) conjectures that the effect of exchange rate regime is temporary as volatility exploded during the initial switch from fixed to flexible, lasting only a short period of time and returned to fixed period levels. The expected sign on the exchange rate regime coefficient is ambiguous (Savvides, 1990).

In recent years, a number of studies have employed GARCH models in modelling underlying causes of exchange rate volatility. For instance, Hua and Gau (2006) employ the periodic GARCH model in analysing intraday Taiwan dollar/US dollar exchange rates by controlling for the impact of news, central bank intervention and inventory control in the conditional variance equation. All these factors impact positively on conditional volatility. Bauwens et al. (2006) model the Norwegian krone volatility by investigating the role of information arrival on the market using the EGARCH specification. Exchange rate volatility is specified as a function of information variables, measure of general currency market turbulence captured through the euro/US dollar exchange rate, measure of oil price volatility taken as a sector that plays a key role in the Norwegian economy, stock market variable (stock market index), and the interest rate (policy rate) as explanatory variables. Stančík (2007) estimates the Threshold ARCH (TGARCH) model when analysing volatility in the Czech Republic, Hungary, Poland, Slovakia and Slovenia exchange rates against the euro by controlling for news factors, openness and exchange rate regime with variable effect across countries. Similarly, Fidrmuc and Horváth (2008) focus on new EU countries: the

Czech Republic, Hungary, Poland, Slovakia and Romania. GARCH and TGARCH models are used.

In conclusion, identifying the sources of exchange rate volatility facilitates the design of appropriate policy response. By and large, real (external) sources tend to constrain policy response due to their unpredictability of occurrence and highly differential impact on the exchange rate. This is in contrast to the domestically generated factors such as monetary over which authorities have reasonable control. If the sources are monetary in nature, the policy response is to reduce the trend rate in monetary expansion and/or raise trend rate in real output growth. This entails adopting a predictable monetary policy rule that involves pre-announcement of monetary targets, instruments and their timing.

3.4 Econometric Specification, Methodology, Data and Empirical Results

3.4.1 Brief Description of GARCH Models

Conditional and unconditional variance models are typically used to estimate volatility of variables. De Grauwe and Rosiers (1987) define unconditional variance as observed ex-post variance while conditional variance is the variability of the unexpected part of the time series. Unconditional variance is represented by the standard measure of variance (or standard deviation), a crude measure of total risk of financial assets. On the other hand, conditional variance captures the true measure of uncertainty. It reflects uncertainty about a variable given a model and information set. Conditional volatility models include ARCH-type, stochastic volatility and implied volatility. This chapter focuses on ARCH-type models introduced by Engle (1982) and extended by Bollerslev (1986).

The behaviour of the exchange rate approximates a martingale process such that future changes in the exchange rate are unpredictable but time series volatility is not independently identically distributed (Engle et al. 1990). In addition, exchange rates exhibit volatility clustering whereby large changes tend to be followed by large changes and small changes by small changes alike and periods of tranquillity interchange with periods of high volatility making successive exchange rate changes dependent on each other (Koay and Kwek, 2006).

Existing empirical evidence confirms that exchange rates like other financial time series exhibit non-linear behaviour (Koutmos and Theodossiou, 1994; Brooks, 2001; and Bauwens and Sucarrat, 2006). Thus, non-linear models are appropriate, the most popular being GARCH. GARCH models are used to model and forecast conditional volatility by estimating the path of time-varying variance[23]. GARCH models are also used to describe the autoregressive process of exchange rate volatility if interested in the stochastic process of short-term volatility (Hviding et al. 2004).

Three GARCH models namely GARCH (1, 1), TGARCH (1, 1) and EGARCH (1, 1) are employed in this study to avoid a "one-size-fits all" approach in modelling exchange rate volatility as some previous studies have done i.e. Koutmos and Theodossiou (1994), Singh (2002) and Stančík (2007). More importantly this chapter is concerned about determining the appropriate conditional volatility characterising each kwacha exchange rate and how each exchange rate responds to price shocks (i.e. unexpected appreciations and depreciations). Both TGARCH (1, 1) and EGARCH (1, 1) models capture asymmetric or leverage effects typically present in financial variables while the GARCH (1, 1) model imposes symmetric behaviour[24]. Further, a GARCH (1, 1) specification is adopted despite the existence of higher order GARCH specifications

[23] Conditional volatility is used interchangeably with conditional variance.

[24] Asymmetric GARCH models address the symmetric response of volatility to positive and negative shocks restriction imposed by the standard GARCH model. Thus, asymmetric GARCH models capture the leverage effect such that bad news tends to increase volatility by more than good news of the same magnitude reduces volatility. In short, negative and positive shocks have differential effects on conditional volatility. Empirical evidence regarding the asymmetric response of conditional variance to shocks in exchange rate is mixed (Narayan et al. 2009).

as it is the most common specification largely used in empirical studies for being parsimonious (thus avoids over-fitting of the model and violation of non-negativity constraint) and sufficiently characterising the behaviour of the exchange rate (Brooks, 2006; Kočenda and Valachy, 2006; and Harrathi and Darmoul, 2007).

(a) GARCH Model

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \Delta y_{t-i} + \varepsilon_t \quad (2)$$

$$\varepsilon_t \left| \Omega_{t-1} \sim N(0, \sigma_t^2) \right.$$

$$\sigma_t^2 = h_t$$

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j h_{t-j} \quad (3)$$

where y_t is the variable under study, ε_t is residuals[25] which are used to test for ARCH effects based on the Engle (1982) LM test statistic[26]. Equation 2 specified in log first difference represents the conditional mean. It describes how the variable y_t evolves over time. Equation 3 is the GARCH model which capture conditional volatility such that $\alpha_i \geq 0$, $\forall_i = 0,1,2,3,....p$; $\beta_i \geq 0$, $\forall_i = 0,1,2,3,....q$; and α_0 is the long-term average value of conditional variance. The persistence of shocks to conditional variance is captured by the sum of α and β. The closer the sum is to 1 the more persistent the

[25] ε_t can be generated either from an autoregressive (AR), autoregressive moving average (ARMA) or standard regression model.

[26] To test for the presence of ARCH effects, squared residuals $\hat{\varepsilon}_t^2$ are regressed on a constant and q lags (set by the researcher) of squared residuals and the Engle (1982) LM test statistic under the null $H_0: \delta_0 = 0, \delta_1 = 0, \delta_2 = 0, ..., \delta_q = 0$ against $H_1: \delta_0 \neq 0$ or $\delta_1 \neq 0$ or $\delta_2 \neq 0$ or …. or $\delta_q \neq 0$ is conducted. $LM = TR^2$ where LM approximate $\chi^2(q)$, T is the number of observations while R^2 is computed from the $\hat{\varepsilon}_t^2$ equation.

shocks are. Shocks exert a permanent effect on volatility if $\alpha+\beta=1$ (i.e. a unit root in variance is obtained and this kind of GARCH model is referred to as Integrated GARCH (IGARCH) model). Convergence of conditional volatility to its long-term value is not achieved when $\alpha+\beta>1$ or $\alpha+\beta=1$. Instead volatility is explosive and tends to infinity as shocks persist forever. However, a stationary GARCH that ensures model stability or convergence of conditional variance forecast to α_0 as the prediction horizon increases obtains if $\alpha+\beta<1$ holds.

(b) TGARCH Model

$$h_t=\alpha_0+\alpha_1\varepsilon_{t-1}^2+\beta h_{t-1}+\gamma\varepsilon_{t-1}^2 z_{t-1} \tag{4}$$

where the dummy $z_{t-1}=1$ if $\varepsilon_{t-1}<0$ and zero if $\varepsilon_{t-1}\geq 0$. Non-negativity conditions are given by $\alpha_0\geq 0$, $\alpha_1\geq 0$, $\beta\geq 0$ and $\alpha_1+\gamma\geq 0$. Leverage effect is captured by a statistically significant $\gamma>0$.

(c) EGARCH Model

There are various expressions of the EGARCH model. The most popular one is

$$\ln(h_t)=\alpha_0+\beta\ln(h_{t-1})+\gamma\frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}}+\alpha\left[\frac{|\varepsilon_{t-1}|}{\sqrt{h_{t-1}}}-\sqrt{\frac{2}{\pi}}\right] \tag{5}$$

The EGARCH model allows for oscillatory behaviour of the variance as the β coefficient can either be positive or negative. The degree of volatility persistence is captured by the β coefficient while α captures the magnitude of the shock on conditional variance. In addition, parameter restriction of non-negativity of coefficients like in the GARCH model is not required in the EGARCH specification since h_t is modelled in log-linear form. Further, asymmetric or leverage effects are captured via a statistically significant γ which can take on either a positive or negative sign.

Exogenous or control variables can be included in the specification of the conditional variance equation in GARCH-type models i.e.

$$h_t = \alpha_0 + \alpha_i \varepsilon_{t-1}^2 + \beta h_{t-1} + \zeta X_t \qquad (6)$$

where X_t is a vector of exogenous variables (equivalent to f_t in equation 1) deemed to have influence on exchange rate volatility. Exogenous variables can also be specified either in the conditional mean or variance equations or simultaneously in both equations.

In terms of the estimation procedure, GARCH models are estimated by the maximum likelihood method in order to obtain efficient parameter estimates. This involves specifying appropriate mean and variance equations. In addition, a log-likelihood function (LLF) to maximise must be formed in order to generate values of the GARCH model parameters for a given data sample. Further, assumptions about the distribution of the disturbances must be made[27]. Nelson proposed to estimate the GARCH model on the assumption of errors drawn from a generalised exponential distribution (GED) instead of a normal distribution. Most econometric packages however, employ the Gaussian distribution instead of GED (e.g. Brooks, 2006; Narayan

---

[27] A quasi-maximum likelihood procedure (i.e. an estimator that involves a different variance-covariance matrix robust to non-normality of errors) is used in instances when normality of errors is violated.

et al. 2009; and Fang and Miller, 2009). To maximise the LLF, a numerical optimisation algorithm is employed in deriving parameter estimates. The commonly employed algorithms are Berndt, Hall, Hall and Hausman (BHHH, 1974) and Marquardt.

3.4.2 Model Specification

A GARCH model capturing the influence of fundamental factors and exchange rate regime is estimated similar to Stančík (2007), Fidrmuc and Horváth (2008) and Hassan (2009)[28]. As it is not practical to include all fundamental variables in an empirical model due to data constraints and the need to preserve degrees of freedom, a relatively small model with a reasonable number of explanatory variables is estimated. The idea is to build the best (parsimonious) GARCH model that captures underlying volatility in kwacha exchange rates. Besides theory and data availability, the variables chosen are those that reflect significant importance for the exchange rate movement in Zambia[29]. Fundamental factors are split into monetary (money supply (m_t), inflation ($zcpi_t$), foreign exchange reserves ($fxres_t$) and interest rates: domestic (i_t), and foreign (i_t^*)) and real (terms of trade (tot_t), openness ($open_t$) and real output (cu_t)). Exchange rate regime is represented by three dummies $D1, D2$ and $D3$ in line with the exchange rate system discussed in section 3.2 and defined later in sub-section 3.4.3.1. Real exchange rate volatility is estimated over the period 1964-2006 period whereas nominal exchange rate volatility is examined over the sub-sample 1994-2006 when the exchange rate was allowed to vary according to market conditions.

---

[28] Rather than studying a particular model of exchange rate determination, our specification incorporates factors drawn from different structural models of exchange rate similar to Hausmann et al. (2006).

[29] As the exact proxy for fundamental variables is not precisely stated in theoretical models, variables that typically characterise the implied fundamentals are chosen. Exogenous variables could be chosen based on particular theoretical exchange rate model, ad hoc criteria, practical considerations of data availability and market knowledge (Copeland, 2005).

As the objective of the study is to determine the influence of fundamental factors and exchange rate regime on conditional volatility rather than the level (mean equation) of the exchange rate, control factors are specified in the conditional variance equation similar to Fidrmuc and Horváth (2008)[30]. However, a dummy D and its lagged value ($D(-1)$) is simultaneously included in both conditional mean and variance equations for the nominal exchange rate volatility specification to take account of the spike in volatility that occurred in 2002 due to the significant depreciation of the kwacha (29 percent in September) related to maize (staple food) imports. However, in the case of the Kzim$, the dummy reflects the the devaluation of the zim$ that took place after 2002[31]. The treatment of the dummy in this way allows us to capture ARCH effects similar to Fang and Miller (2009). ARCH effects could not be detected when the dummy was excluded in the specification over the period 1994-2006.

The estimated empirical equations are AR(q)-GARCH (1, 1), AR(q)-TGARCH (1, 1) and AR(q)-EGARCH (1, 1) expressed as

(a) AR(q) is defined as

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \Delta y_{t-i} + \varepsilon_t \tag{2.1}$$

$$\varepsilon_t \left| I_{t-1} \sim N(0, h_t)\right.$$

$$h_t \sim \text{GARCH(1,1)/TARCH(1,1)/EGARCH(1,1)}$$

[30] It is noted that while control factors could be included in the mean equation specification, this was not done to avoid overparametersing the model given the small sample size.
[31] Only one dummy is used for the series of devaluations that took place on assumption that the impact of subsequent devaluations was constant.

(b) AR(q)-GARCH (1,1)

Mean AR(q) for nominal exchange rate volatility

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \Delta y_{t-i} + \rho_1 D + \rho_2 D(-1) + \varepsilon_t \tag{2.1}$$

Variance equation for nominal exchange rate volatility

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta h_{t-1} + \rho_1 D + \rho_2 D(-1) + \phi_1 \sqrt{(\Delta \ln m_t)^2} + \phi_2 \sqrt{(\Delta \ln zcpi_t)^2} +$$

$$\phi_3 \sqrt{(\Delta \ln fxres_t)^2} + \phi_4 \sqrt{(\Delta i_t)^2} + \phi_5 \sqrt{(\Delta i_t^*)^2} + \phi_6 \sqrt{(\Delta \ln tot_t)^2} + \phi_7 \sqrt{(\Delta \ln open_t)^2}$$

$$+ \phi_8 \sqrt{(\Delta \ln cu_t)^2} + \upsilon_t \tag{7}$$

Mean AR(q) for real exchange rate volatility

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \Delta y_{t-i} + \varepsilon_t \tag{2.1}$$

Variance equation for real exchange rate volatility

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta h_{t-1} + \tau_1 D1 + \tau_2 D2 + \tau_3 D3 + \phi_1 \sqrt{(\Delta \ln m_t)^2} + \phi_2 \sqrt{(\Delta \ln zcpi_t)^2} +$$
$$\phi_3 \sqrt{(\Delta \ln fxres_t)^2} + \phi_4 \sqrt{(\Delta i_t)^2} + \phi_5 \sqrt{(\Delta i_t^*)^2} + \phi_6 \sqrt{(\Delta \ln tot_t)^2} + \phi_7 \sqrt{(\Delta \ln open_t)^2}$$

$$+ \phi_8 \sqrt{(\Delta \ln cu_t)^2} + \upsilon_t \tag{8}$$

(c) AR(q)-TGARCH (1,1)

Mean AR(q) for nominal exchange rate volatility

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \Delta y_{t-i} + \rho_1 D + \rho_2 D(-1) + \varepsilon_t \tag{2.1}$$

Variance equation for nominal exchange rate volatility

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \gamma \varepsilon_{t-1}^2 z_{t-1} + \beta h_{t-1} + \rho_1 D + \rho_2 D(-1) + \phi_1 \sqrt{(\Delta \ln M_t)^2} +$$
$$\phi_2 \sqrt{(\Delta \ln ZCPI_t)^2} + \phi_3 \sqrt{(\Delta \ln FXRES_t)^2} + \phi_4 \sqrt{(\Delta i_t)^2} + \phi_5 \sqrt{(\Delta i_t^*)^2} +$$
$$\phi_6 \sqrt{(\Delta \ln ToT_t)^2} + \phi_7 \sqrt{(\Delta \ln OPEN_t)^2} + \phi_8 \sqrt{(\Delta \ln Cu_t)^2} + \upsilon_t \tag{9}$$

Mean AR(q) for real exchange rate volatility

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \Delta y_{t-i} + \varepsilon_t \tag{2.1}$$

Variance equation for real exchange rate volatility

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \gamma \varepsilon_{t-1}^2 z_{t-1} + \beta h_{t-1} + \tau_1 D1 + \tau_2 D2 + \tau_3 D3 + \phi_1 \sqrt{(\Delta \ln M_t)^2} + \phi_2 \sqrt{(\Delta \ln ZCPI_t)^2} + \phi_3 \sqrt{(\Delta \ln FXRES_t)^2} + \phi_4 \sqrt{(\Delta i_t)^2} + \phi_5 \sqrt{(\Delta i_t^*)^2} + \phi_6 \sqrt{(\Delta \ln ToT_t)^2} + \phi_7 \sqrt{(\Delta \ln OPEN_t)^2} + \phi_8 \sqrt{(\Delta \ln Cu_t)^2} + \upsilon_t \tag{10}$$

(d) AR(q)-EGARCH (1, 1)

Mean AR(q) for nominal exchange rate volatility

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \Delta y_{t-i} + \rho_1 D + \rho_2 D(-1) + \varepsilon_t \tag{2.1}$$

Variance equation for nominal exchange rate volatility

$$h_t = \alpha_0 + \alpha \left[\frac{|\varepsilon_{t-1}|}{\sqrt{h_{t-1}}} \right] + \gamma \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \beta \ln(h_{t-1}) + \rho_1 D + \rho_2 D(-1) + \phi_1 \sqrt{(\Delta \ln M_t)^2} + + \phi_2 \sqrt{(\Delta \ln ZCPI_t)^2} + \phi_3 \sqrt{(\Delta \ln FXRES_t)^2} + \phi_4 \sqrt{(\Delta i_t)^2} + \phi_5 \sqrt{(\Delta i_t^*)^2} + \phi_6 \sqrt{(\Delta \ln ToT_t)^2} + \phi_7 \sqrt{(\Delta \ln OPEN_t)^2} + \phi_8 \sqrt{(\Delta \ln Cu_t)^2} + \upsilon_t \tag{11}$$

Mean AR(q) for real exchange rate volatility

$$\Delta y_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \Delta y_{t-i} + \varepsilon_t \tag{2.1}$$

Variance equation for real exchange rate volatility

$$h_t = \alpha_0 + \alpha \left[\frac{|\varepsilon_{t-1}|}{\sqrt{h_{t-1}}} \right] + \gamma \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \beta \ln(h_{t-1}) + \tau_1 D1 + \tau_2 D2 + \tau_3 D3 + \phi_1 \sqrt{(\Delta \ln M_t)^2} + \phi_2 \sqrt{(\Delta \ln ZCPI_t)^2} + \phi_3 \sqrt{(\Delta \ln FXRES_t)^2} + \phi_4 \sqrt{(\Delta i_t)^2} + \phi_5 \sqrt{(\Delta i_t^*)^2} + \phi_6 \sqrt{(\Delta \ln ToT_t)^2} + \phi_7 \sqrt{(\Delta \ln OPEN_t)^2} + \phi_8 \sqrt{(\Delta \ln Cu_t)^2} + \upsilon_t \tag{12}$$

where Δy_t is the logarithmic first difference in the exchange rate (y_t); ε_t is residuals that are used to test for the presence of ARCH effects in the exchange rate; I_{t-1} is the information set at time $t-1$; q is the lag length; h_t is conditional variance of y_t derived from GARCH (1, 1), TGARCH (1, 1) and EGARCH (1, 1); $\alpha_0, \alpha_i, \alpha_1, \alpha, \beta, \gamma, \rho_1, \rho_2, \tau_1, \tau_2, \tau_3$ and $\phi_1, \ldots, \phi_8$ are parameter coefficients to be estimated. Equation 2.1 is the empirical mirror of equation 2.

The square root of the squared logarithmic changes in fundamental variables is taken to ensure that the estimated coefficient parameters are robust and comply with the non-negativity condition for h_t[32]. Real factors influence the (real) exchange rate volatility in the long-run while monetary factors are important for short-run exchange rate volatility (Edwards, 1987). However, the present methodology does not explicitly distinguish between short- and long-run exchange rate volatility. Consequently, both real and monetary factors are simultaneously included in the conditional variance equation. In addition, the model is not estimated for sub-samples according to exchange rate regime due to fewer observations to warrant the use of the GARCH method. Further, domestic (i_t) and foreign (i_t^*) real interest rates enter separately in the conditional variance equations as opposed to taking their difference to avoid imposing equal sign and magnitude restriction on both interest rates. The empirical results in sub-section 3.4.3.4 support this approach.

[32] This is particularly applicable to the GARCH and TGARCH models in that besides a negative parameter coefficient, a sufficiently large negative change in any of the exogenous variable could potentially generate a negative h_t. The idea is to ensure uniformity in variable definition across models to facilitate comparison. Further, it is noted that defining fundamental variables in this way forces changes in fundamentals of either sign (positive and negative) to have a symmetric impact on exchange rate volatility. However, we could not create dummies for each fundamental variable to reflect asymmetric effect to avoid overfitting the model due to the small sample size.

Finally, since three GARCH model specifications are fitted to each exchange rate, an optimal model must be chosen[33]. Notwithstanding the argument that direction on the choice of an optimal GARCH model is limited from an econometric theory perspective (see McKenzie, 1997), a model with the highest log-likelihood value which fulfils diagnostic tests performed on standardised residuals for model adequacy is preferred in line with Enders (2004), Malmsten and Terasvirta (2004) and Koay and Kwek (2006)[34]. In addition, a model with smaller values of AIC and/or SBC is considered similar to Olowe (2009)[35].

3.4.3 Data and Empirical Results

3.4.3.1 Data Description and Sources

Monthly data from 1964 to 2006 are used to analyse conditional volatility in kwacha exchange rates.

Eight kwacha (K) bilateral exchange rates of Zambia's main trading partner currencies, namely, French franc (FF), British pound sterling (GBP), German mark (DM), South African rand (rand), Swiss franc (swiss), United States dollar (US$), Japanese yen (yen) and Zimbabwe dollar (zim$) are examined. The choice of these currencies is based on Zambia's foreign trade structure shown in table 3.1 below.

---

[33] A number of studies employ different GARCH models to analyse conditional volatility in a country's exchange rate; i.e. Koay and Kwek (2006), Fidrmuc and Horváth (2008) and Olowe (2009).

[34] Parsimony plus AIC and/or SBC in cases where models differ in terms of parameters; forecasting accuracy; how well a model performs relative to other models in terms of misspecification tests; and non-nested models are among other suggested model selection criteria (see Engle and Ng, 1993). In addition, Pagan and Schwert (1990) propose running the regression: $e_t^2 = \alpha + \beta h_t + v_t$ for each ARCH model and the optimal model is chosen on the basis of the highest value of R^2 (see McKenzie, 1997).

[35] AIC and SBC are, however, rarely used because their statistical properties and hence reliability is unknown when volatility is time-varying as their computation is based on the first moment while GARCH series are based on the second moment (McKenzie, 1997).

Table 3.1 Weights of Zambia's Trading Partners from 1970-2006

Country	Trade with Zambia (US$ million)	Weight in total trade (%)
South Africa	13,828	30.1
United Kingdom	9,873	21.5
Japan	6,338	13.8
USA	3,684	8.0
Germany	3,402	7.4
France	3,095	6.8
Switzerland	2,997	6.5
Zimbabwe	2,654	5.8
	45,871	**100.0**

Source: Datastream and Author computations.

The exchange rate is expressed as the domestic currency (K) price of one unit of the trading partner currency. Thus, nominal bilateral exchange rates are abbreviated as KFF for the Kwacha/FF, KGBP for the Kwacha/GBP, KDM for the Kwacha/DM, Krand for the Kwacha/rand, Kswiss for the Kwacha/swiss franc, KUS$ for the Kwacha/US$, Kyen for the Kwacha/yen and Kzim$ for the Kwacha/zim$. Real exchange rates are denoted as nominal exchange rates as defined above but preceded by the letter R e.g. RKFF is real KFF. With the exception of the KUS$ exchange rate and the trading partner currency against the US dollar exchange rates that are directly obtained from the IFS of IMF (series rf.zf), the rest of the nominal bilateral kwacha exchange rates are computed using cross rates. In the case of KFF and KDM, the series from 1999 to 2006 are computed by converting the euro exchange rate at the fixed parity of 1 euro to 6.55957FF and 1.95583DM, respectively following the introduction of the euro in 1999.

Real bilateral (R_t) and trade-weighted (nominal effective exchange rate, $NEER_t$; and real effective exchange rate, $REER_t$) exchange rates are calculated as follows

$$R_t = \frac{E_t P_t^*}{P_t} \quad (13)$$

$$NEER_t = \sum_{t=1}^{k} w_{it} E_t \quad (14)$$

$$REER_t = \frac{\sum_{t=1}^{k} w_{it} E_t P_t^*}{P_t} \quad (15)$$

$$P_{it}^* = \sum_{i=1}^{k} w_{it} CPI_{it} \quad (16)$$

where E_t is the nominal bilateral exchange rate, P_t^* is the foreign price index calculated as the weighted consumer price index (CPI) index of all trading partner countries, P_t is domestic CPI for Zambia where CPI_{it} is the measure of inflation for each country at time t (with 2000 as base year) and w_{it} is the trade weight corresponding to each trading partner. CPI data are obtained from the IFS of IMF (series 64..zf) except for Germany which are obtained from Datastream. In the case of Zambia, CPI data (zcpi) are obtained from the IFS of IMF and Bank of Zambia annual reports. However, the two sources use different base years for the CPI. To ensure a smooth series that maintains monthly inflation growth rates calculated for overlapping base periods, a splicing method is used to link the series with 2000 as a new base year, similar to Fang and Miller (2009). Trade weights are computed based on trade in manufactured goods and services consistent with the IMF approach in computing NEER and REER (IMF, 1997). Thus, Saudi Arabia is excluded (not shown above) despite having US$3,068.0 million worth of trade (oil imports) with Zambia. REER is CPI-based and 2000 is used as the base year. Trade data are obtained from Datastream. Trade-weighted exchange rates are calculated with and without the zim$ i.e. NEERZIM$ and REERZIM$ and NEER and

REER, respectively to take account of the special developments in Zimbabwe especially after 2002 (deterioration in macroeconomic conditions) and to determine whether this period has had any effect on volatility of the effective exchange rates.

Similar to Morana (2009), the measure of nominal money supply (m_t) used is M1 (for which data are consistently available over the sample period) defined as currency in circulation plus demand deposits. Data on M1 are obtained from the IFS of IMF (series 59a.zf) and various Bank of Zambia annual reports (1970-2006).

Conventionally, foreign reserves ($fxres_t$) is defined and measured as an adequate reserve ratio defined as the "ratio of reserve assets to short-term debt on a remaining maturity basis" (Hviding et al. 2004). However, due to lack of short-term debt data at monthly frequency in Zambia, gross reserves obtained from Datastream and Bank of Zambia are used as a proxy.

The interest rate (RTB_t) is represented by the 3-month Treasury bill (TB) rate as per practice in the literature (e.g. Morana, 2009). Thus, the real interest rate (RTB_t) is calculated as the difference between the nominal 3-month TB rate and inflation rate (derived from CPI) for each country. Thus RTBF, RTBG, RTBJ, RTBS, RTBSA, RTBUK, RTBUS, RTBZ and RTBZIM are real interest rates for France, Germany, Japan, Switzerland, South Africa, the United Kingdom, the United States of America, Zambia and Zimbabwe, respectively. RTBZ is the domestic interest rate (i_t) while the rest are foreign interest rates (i_t^*). TB rates are available from the IFS of IMF (series 60c…zf).

Terms of trade (tot_t) is defined as

$$tot_t = \frac{P_x}{P_{im}} \tag{17}$$

where P_x is the price index of exports and P_{im} is the price index of imports. Copper is Zambia's main export. Thus, P_x refers to the London US dollar price of copper per metric tonne taken from IFS of IMF (series 11276c.zzf) and P_{im} is the price index of imports calculated as

$$P_{im} = \omega_{mfg} P_{mfg,RSA} + \omega_o P_o \tag{18}$$

where ω_{mfg} is the weight of manufactured imports from South Africa (RSA) to total imports; $P_{mfg,RSA}$ is the price of manufactured goods for South Africa represented by PPI/WPI from IFS (series 63...zf); ω_o is the weight of oil imports to total imports (8 percent) and P_o is the average price in US dollars per barrel of crude oil taken from IFS of IMF (series 0017aazzf). Imports from South Africa account for about 58 percent of total imports while oil and manufactured goods account for about 66 percent of Zambia's total imports based on trade data from 1970 to 2006.

Openness ($open_t$) is widely measured as (see Hau, 2002 for instance)

$$open_t = \frac{X_t + IM_t}{GDP_t} \tag{19}$$

where X_t is exports, IM_t is imports; and GDP_t is gross domestic product, all expressed in domestic currency. However, to capture the effect of trade interdependence between countries on exchange rate volatility, trade must be measured as the sum of imports and exports between country i and j expressed as a ratio of country $j's$ GDP, which reflects the degree of openness (see Bayoumi and Eichengreen, 1998; and Devereux and Lane, 2003). This definition is consistent with the standard OCA theory. Nonetheless, in this chapter, due to the lack of monthly data on bilateral trade between Zambia and her trading partners, aggregate as opposed to bilateral trade data are used. Import and export data expressed in kwacha are taken from Datastream, the Bank of Zambia and Central Statistics Office - Zambia Monthly Digest of Statistics. However, due to the non-existence of monthly GDP data and incomplete industrial production index data, the frequently used proxy in most empirical studies (see for example Flood and Rose, 1995; and Sfia, 2006), monthly GDP data are interpolated from the annual nominal series (expressed in kwacha) using the cubic-match-last method. Nominal annual GDP figures are obtained from Datastream and various Bank of Zambia annual reports. The value of imports and exports are initially expressed in US dollars from the original source. These values are converted into kwacha using the annual KUS$ taken from the IFS (series ae.zf).

Real productivity is proxied by real GDP growth rate (see Savvides, 1990)[36]. In this chapter, the rate of growth of copper output (cu_t) is used as a proxy for real GDP growth as the latter is not available at low frequency and the widely used proxy, industrial production index, is incomplete. The justification for using copper production is that copper output contributes significantly (about 50 percent) to Zambia's GDP and the two are pro-cyclically related: the performance of the economy has historically

[36] The limitation of using copper output as a proxy for real GDP is that all shocks to copper are directly transimitted to Zambia's GDP such that if severe negative shocks inhibited growth in copper output, zero real GDP growth would be recorded which is not reflective of reality as other sectors would still register some positive growth. However, under the circumstances, copper output is used as opposed to generating monthly real GDP series from the available annual real GDP series using interpolation method as the former would have little variation and thus not capture real productivity impact appropriately.

depended on mining (UNDP, 2006). Data on copper output are taken from Bank of Zambia annual reports (1970-2006).

In line with the description given in section 3.2, exchange rate regime is represented by three dummies: $D1$=fixed regime rate when the exchange rate hardly changed (January 1964 to June 1976 and May 1987 to October 1988); $D2$=fixed regime but with frequent exchange rate adjustments (July 1976 to September 1985 and November 1988 to November 1993); and $D3$=initial float of the kwacha (October 1985 to April 1987). The base or reference regime is January 1994 to December 2006. All dummies take the value of 1 during the defined period and 0 otherwise.

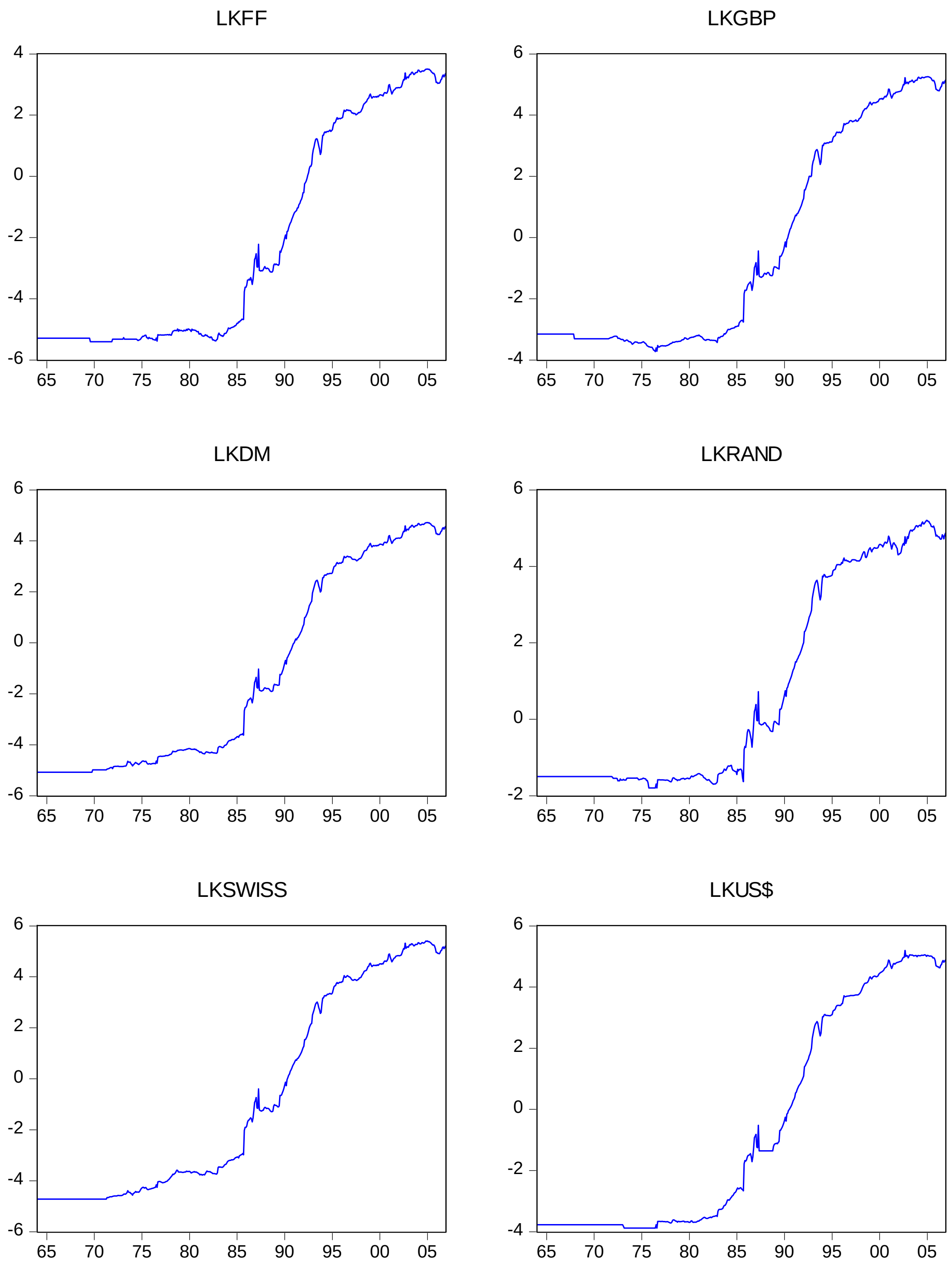
3.4.3.2 Graphical Analysis and Descriptive Statistics

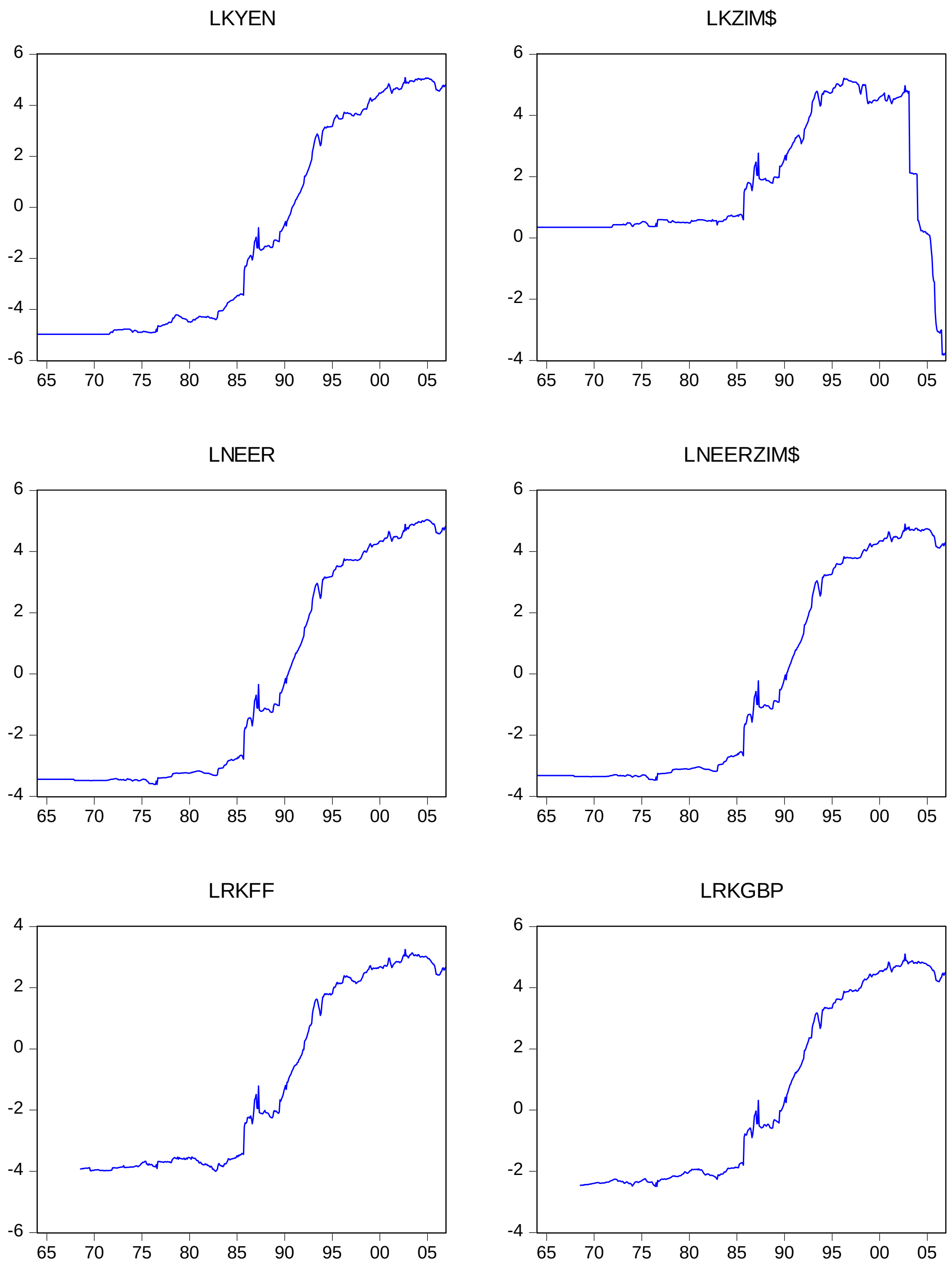
Time series graphs in logarithmic level of both real and nominal exchange rates in figure 3.1 below (LKFF…LRERZIM) reveal a general upward trend over the sample period. The notable exception is the Kzim$ exchange rate (LKZIM and LRKZIM) which fell sharply after September 2002 and the trend sustained as the zim$ was frequently devalued due to the deterioration in the macroeconomic environment in Zimbabwe (IMF, Country Reports for Zimbabwe: 2000-2006). This contributed to a substantial increase in the volatility of the Kzim$ reflected in significant negative changes (DLKZIM and DLRKZIM) towards the end of the sample.

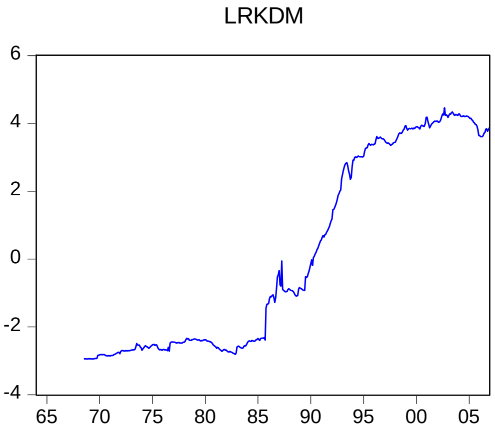
Plots of logarithmic changes in exchange rates (DLKFF…DLRERZIM) reveal low volatility in both real and nominal exchange rate during the fixed regime. However, volatility increased during the flexible regime period. Specifically, the exchange rate was characterised by relative tranquillity during the fixed regime (January 1964 to June 1976 and May 1987 to October 1988) as the exchange rate hardly changed from month to month. However, a rise in volatility was observed during the period of frequent exchange rate adjustments (July 1976 to September 1985 and November 1988 to

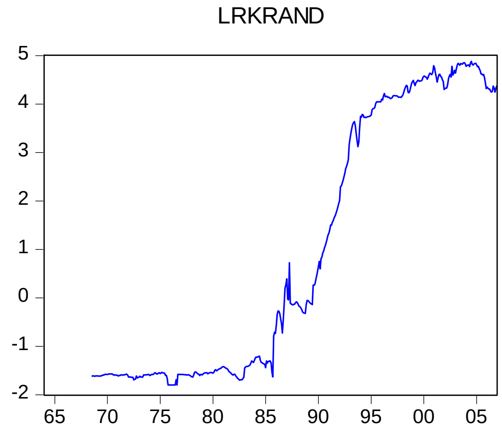
November 1993) evidenced by increases in changes in the exchange rate of either sign. Volatility in the exchange rate became more apparent during the initial float of the currency (October 1985 to April 1987), increasing drastically as both relatively large positive and negative changes were recorded, reflecting a ‘volatility explosion’ after a long period of misalignment (Pozo, 1992). Exchange rate volatility increased again when all exchange rate controls were eliminated post-1994, although the extent of the increase during this period was lower than the initial float.

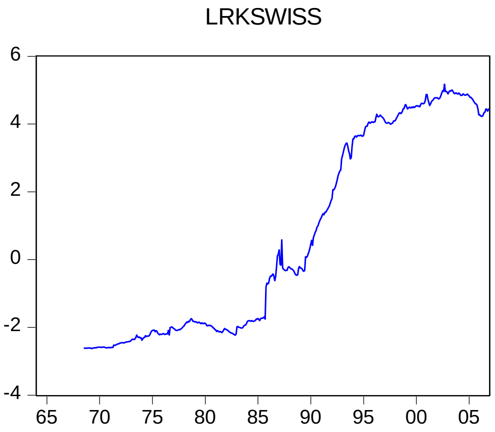
Figure 3.1 Log-level and First Difference for Exchange Rate Series

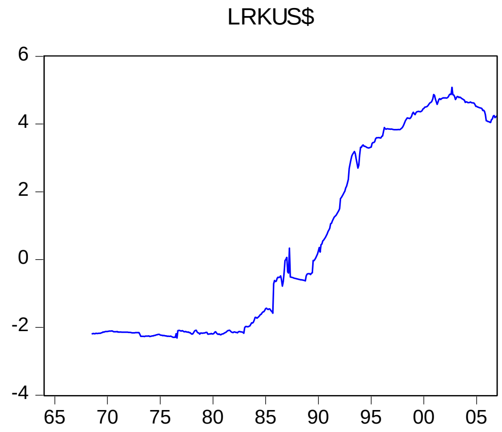


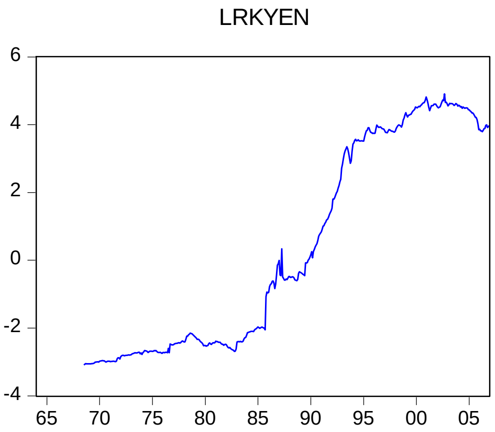

LKYEN
LKZIM$
LNEER
LNEERZIM$
LRKFF
LRKGBP
65 70 75 80 85 90 95 00 05

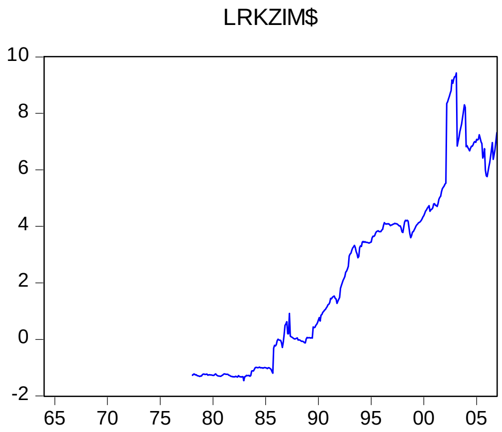

LRKDM
6
4
2
0
-2
-4
65 70 75 80 85 90 95 00 05

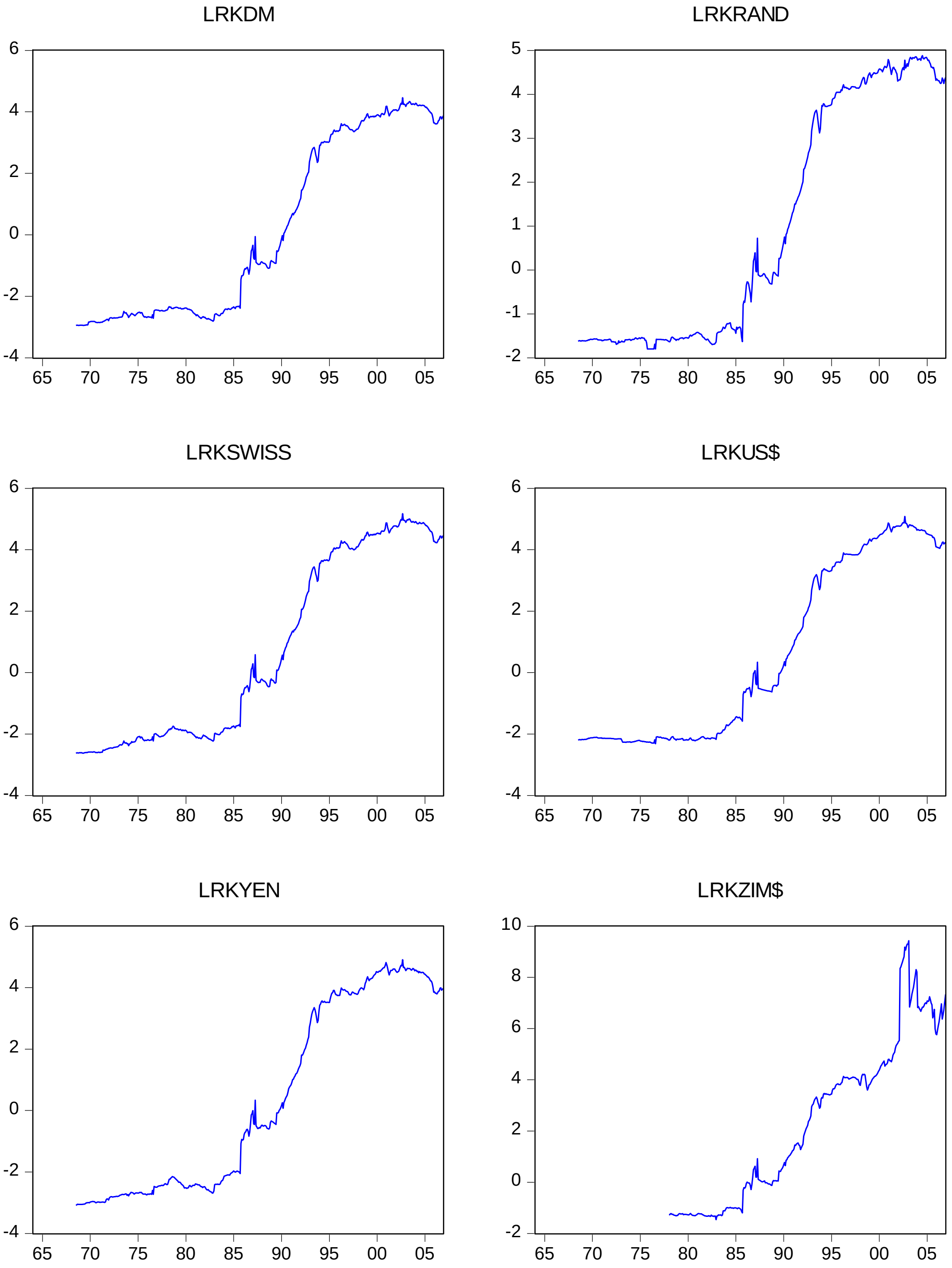

LRKRAND
5
4
3
2
1
0
-1
-2
65 70 75 80 85 90 95 00 05

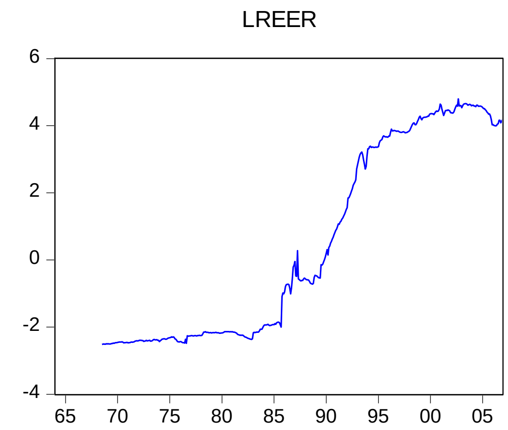

LRKSWISS
6
4
2
0
-2
-4
65 70 75 80 85 90 95 00 05

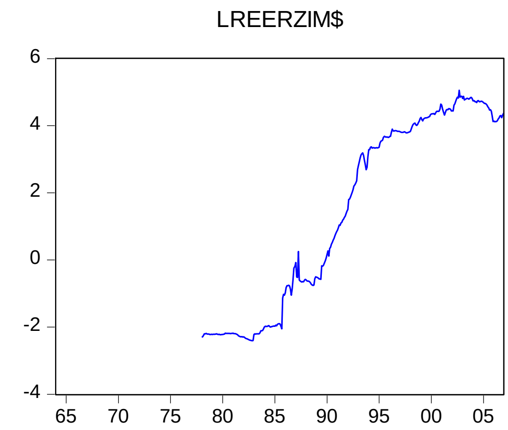

LRKUS$
6
4
2
0
-2
-4
65 70 75 80 85 90 95 00 05

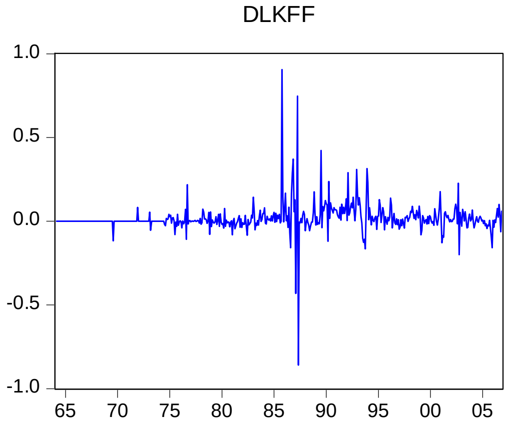

LRKYEN
6
4
2
0
-2
-4
65 70 75 80 85 90 95 00 05

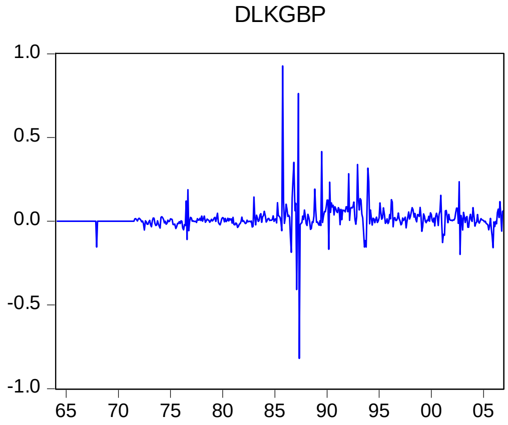

LRKZIM$
10
8
6
4
2
0
-2
65 70 75 80 85 90 95 00 05

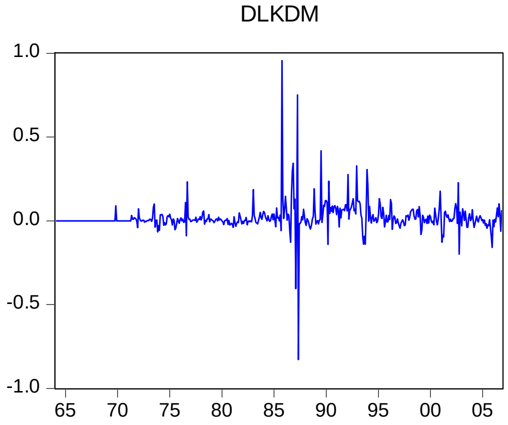

LRKDM
LRKRAND
LRKSWISS
LRKUS$
LRKYEN
LRKZIM$
65 70 75 80 85 90 95 00 05

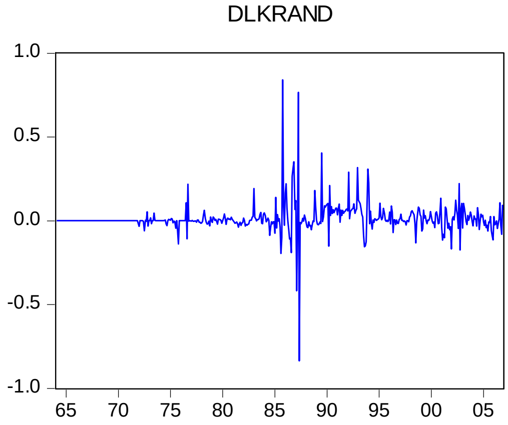

LREER
6
4
2
0
-2
-4
65 70 75 80 85 90 95 00 05

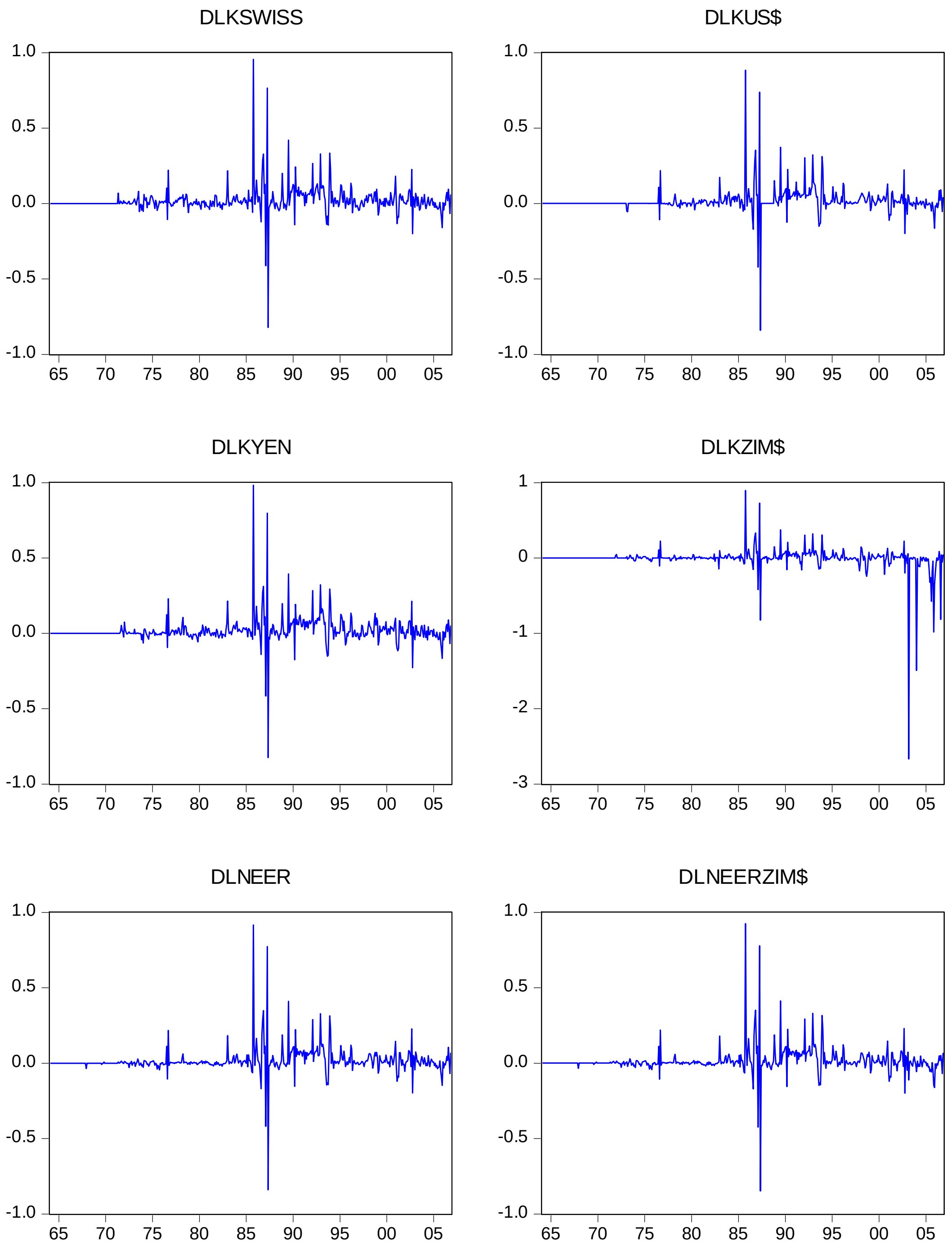

LREERZIM$
6
4
2
0
-2
-4
65 70 75 80 85 90 95 00 05

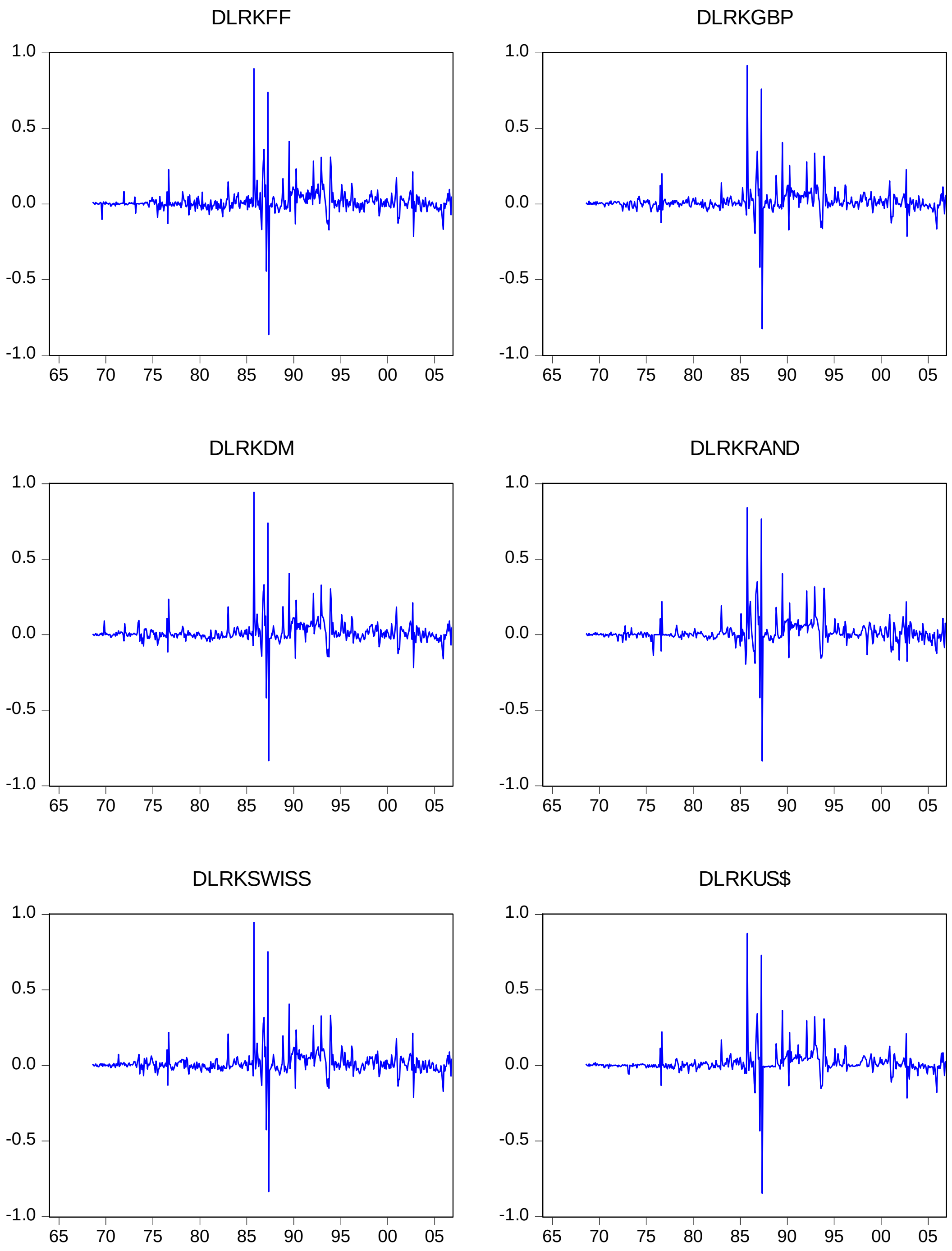

DLKFF
1.0
0.5
0.0
-0.5
-1.0
65 70 75 80 85 90 95 00 05

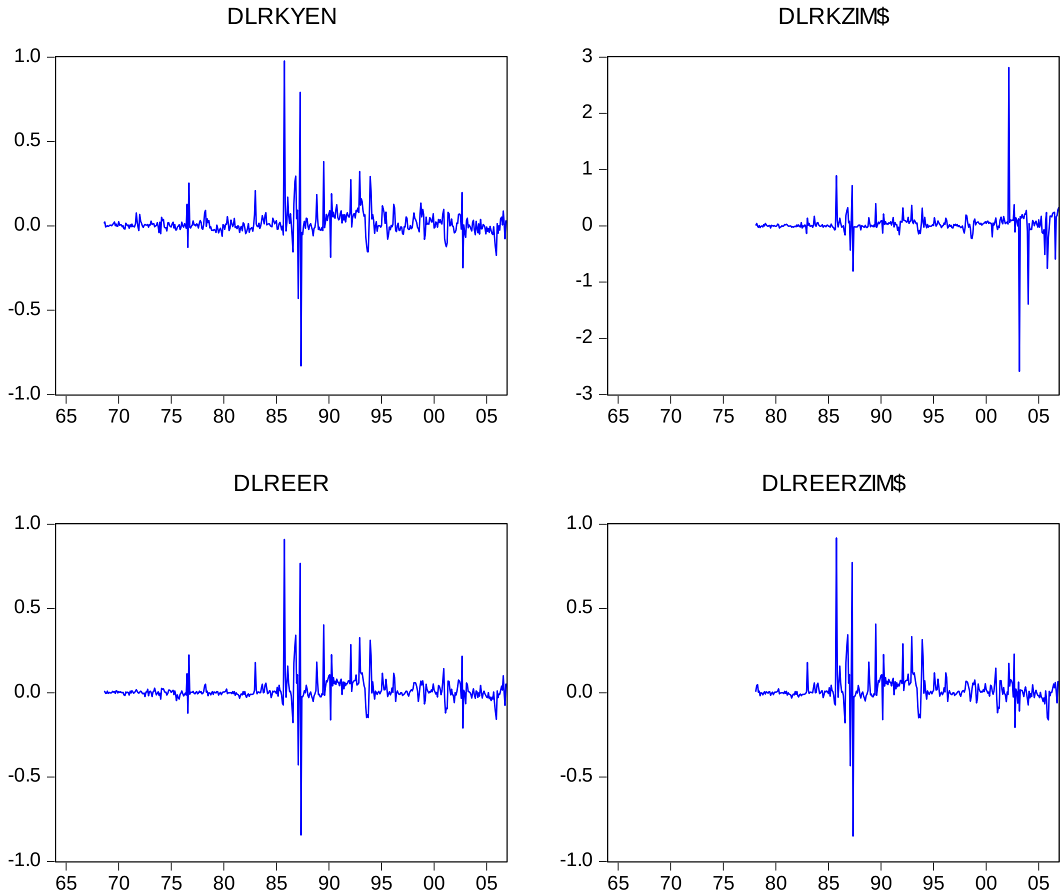

DLKGBP
1.0
0.5
0.0
-0.5
-1.0
65 70 75 80 85 90 95 00 05


DLKDM
1.0
0.5
0.0
-0.5
-1.0
65 70 75 80 85 90 95 00 05


DLKRAND
1.0
0.5
0.0
-0.5
-1.0
65 70 75 80 85 90 95 00 05

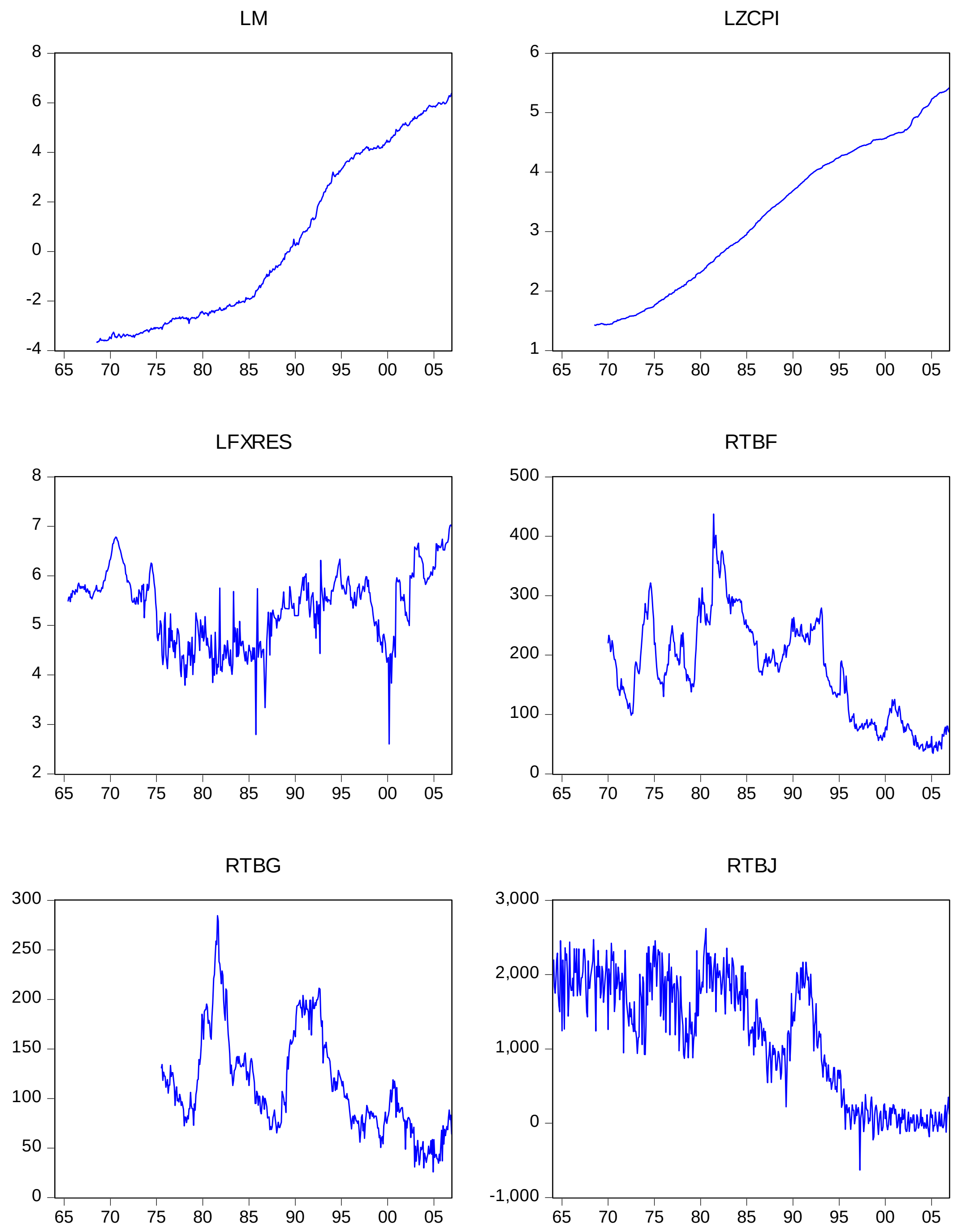

DLKSWISS
DLKUS$
DLKYEN
DLKZIM$
DLNEER
DLNEERZIM$
1.0
0.5
0.0
-0.5
-1.0
1
0
-1
-2
-3
65
70
75
80
85
90
95
00
05

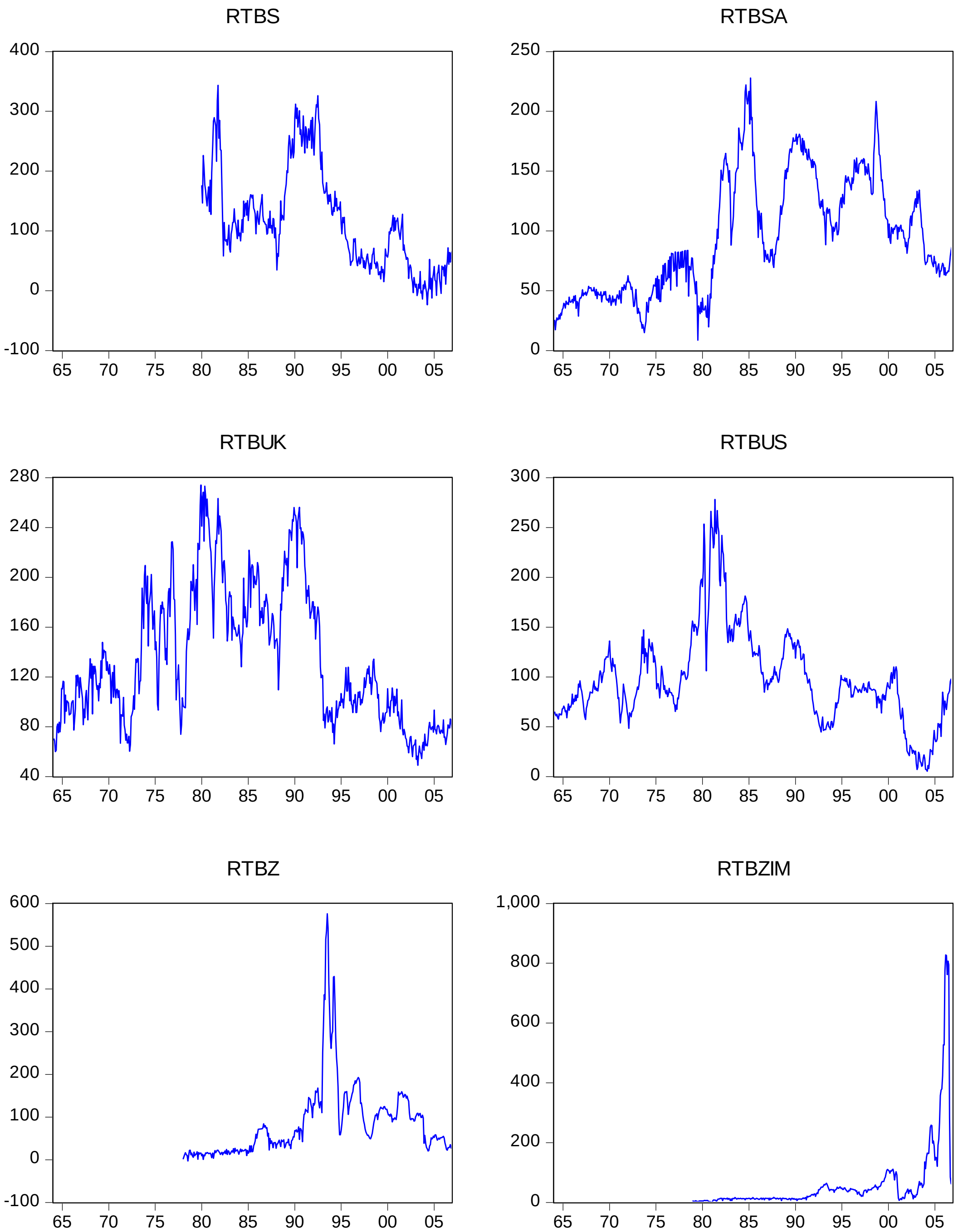

DLRKFF
DLRKGBP
DLRKDM
DLRKRAND
DLRKSWISS
DLRKUS$
1.0
0.5
0.0
-0.5
-1.0
65 70 75 80 85 90 95 00 05

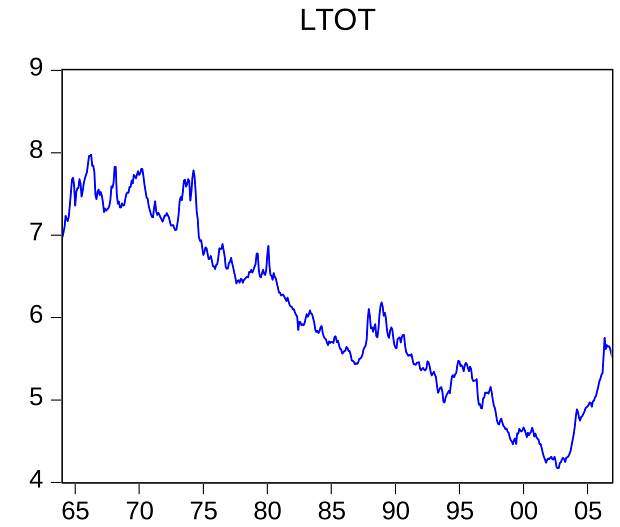


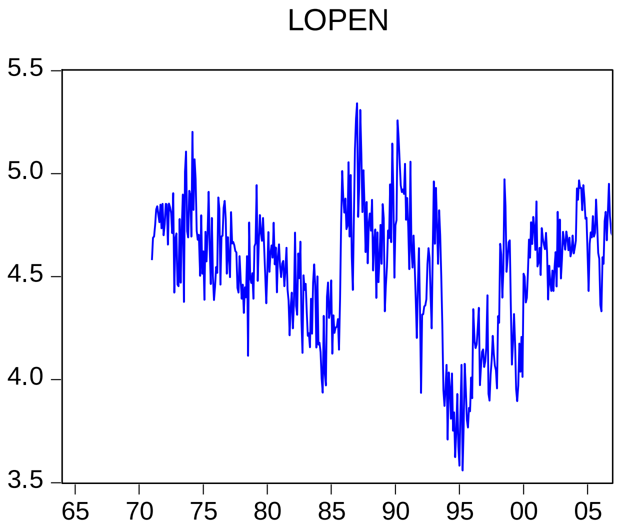
Similar to exchange rates, all monetary and real variables varied over the sample period (see figure 3.2 below). Money supply (LM) and inflation (LZCPI) exhibited an upward trend while terms of trade (LTOT) and copper output (LCU) steadily declined, except in the latter part of the sample when a recovery occurred. The real interest rate (RTBF…RTBZIM), openness (LOPEN) and foreign exchange reserves (LFXRES) display cyclical patterns.

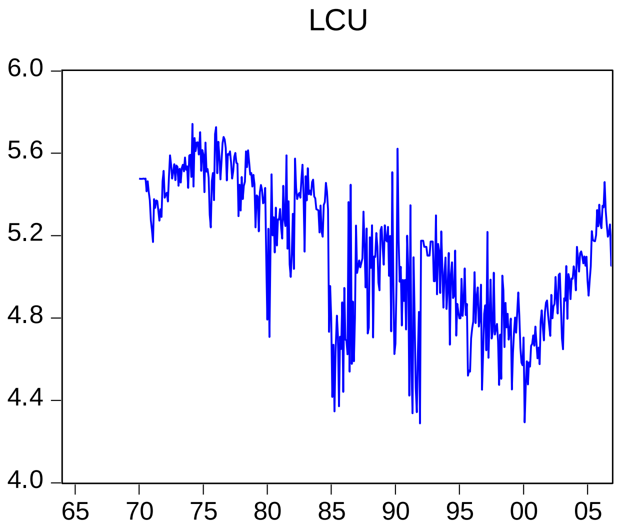
Figure 3.2 Log-level of fundamental factors




RTBS
400
300
200
100
0
-100
65 70 75 80 85 90 95 00 05
RTBSA
250
200
150
100
50
0
65 70 75 80 85 90 95 00 05
RTBUK
280
240
200
160
120
80
40
65 70 75 80 85 90 95 00 05
RTBUS
300
250
200
150
100
50
0
65 70 75 80 85 90 95 00 05
RTBZ
600
500
400
300
200
100
0
-100
65 70 75 80 85 90 95 00 05
RTBZIM
1,000
800
600
400
200
0
65 70 75 80 85 90 95 00 05


LTOT
9
8
7
6
5
4
65
70
75
80
85
90
95
00
05


LOPEN
5.5
5.0
4.5
4.0
3.5
65
70
75
80
85
90
95
00
05


LCU
6.0
5.6
5.2
4.8
4.4
4.0
65
70
75
80
85
90
95
00
05

Fundamental variables varied less than exchange rates based on the standard deviation measure of variability (see table 3.2 below), consistent with Hviding et al. (2004) and De Grauwe et al. (2005). Real variables are the least volatile. Variability in money supply and the real interest rate was exceedingly higher than all the fundamental variables. Real interest rates are the most volatile of all variables similar to the findings by MacDonald (1999). Furthermore, variability in the nominal exchange rates is higher than the variability in real exchange rates post-1994. The Kzim$ is the most volatile of all exchange rates while the Krand is the least volatile. Lower volatility for a currency pair could be attributed to close integration between countries (Munro, 2004). Zimbabwe and South Africa are closest to Zambia geographically among the major trading partners examined and belong to the Southern African Development Community (SADC) whose objective is, inter alia, to further socio-economic co-operation and integration among member countries. However, the Kzim$ is an exception due to special developments that occurred in Zimbabwe starting early 2000.

Table 3.2 Descriptive statistics

1964.01 – 2006.12 (Obs=324)	**Mean**	**Median**	**Max**	**Min**	**Std. Dev.**	**Skew**	**Kurt**	**J-B**	**Prob.**
LRKFF	0.02	1.44	2.72	-4.00	2.50	-0.42	1.47	40.87	0.00
LRKGBP	1.84	2.98	5.10	-2.26	2.67	-0.32	1.44	38.52	0.00
LRKDM	1.20	2.66	3.94	-2.81	2.53	-0.41	1.47	41.01	0.00
LRKRAND	2.10	3.45	4.88	-1.70	2.49	-0.34	1.39	41.32	0.00
LRKSWISS	1.97	3.25	5.17	-2.23	2.69	-0.36	1.46	39.11	0.00
LRKUS$	1.81	3.02	5.08	-2.22	2.63	-0.31	1.44	38.12	0.00
LRKYEN	1.69	3.16	4.91	-2.69	2.73	-0.38	1.49	38.60	0.00
LRKZIM	2.60	3.13	9.43	-1.46	3.04	0.29	1.98	18.45	0.00
LREER	1.70	3.02	4.67	-2.37	2.63	-0.36	1.43	40.03	0.00
LREERZIM$	1.70	3.00	4.93	-2.41	2.68	-0.34	1.43	39.36	0.00
LM	1.91	2.61	6.40	-2.59	3.01	-0.15	1.49	32.19	0.00
LZCPI	3.30	3.39	5.42	1.42	1.25	-0.04	1.63	36.01	0.00
LFXRES	5.33	5.43	7.03	2.61	0.77	-0.14	2.56	5.13	0.08
RTBF	169.36	172.81	437.48	34.68	94.09	0.34	2.10	17.32	0.00
RTBG	114.39	100.17	284.54	25.69	53.89	0.69	2.71	26.57	0.00
RTBJ	827.92	711.81	2619.35	-631.3	791.22	0.40	1.75	29.62	0.00
RTBS	117.55	105.10	343.58	-23.67	84.18	0.68	2.65	26.82	0.00
RTBSA	121.68	119.59	227.89	19.67	40.72	0.04	2.48	3.68	0.16
RTBUK	139.13	121.52	273.14	49.06	59.55	0.45	1.96	25.63	0.00
RTBUS	100.25	91.96	278.11	5.31	55.00	0.84	3.84	47.67	0.00
RTBZ	91.04	67.52	575.84	0.78	89.58	2.60	11.81	1414.12	0.00
RTBZIM	62.31	26.12	828.07	0.55	124.11	4.52	25.24	7777.22	0.00
LTOT	5.84	5.71	7.81	4.17	0.97	0.27	2.12	20.36	0.00
LOPEN	4.49	4.55	5.34	3.56	0.34	-0.35	2.80	7.30	0.03
LCu	1.34	1.20	2.34	0.93	0.37	0.99	2.77	53.80	0.00
1994.01 – 2006.12 (Obs=156)	**Mean**	**Median**	**Max**	**Min**	**Std. Dev.**	**Skew**	**Kurt**	**J-B**	**Prob.**
LKFF	2.65	2.70	3.51	1.34	0.63	-0.37	1.99	10.14	0.01
LKGBP	4.40	4.55	5.26	3.01	0.70	-0.52	1.99	13.72	0.00
LKDM	3.86	3.91	4.72	2.56	0.63	-0.36	1.99	9.91	0.01
LKRAND	4.49	4.50	5.21	3.72	0.41	-0.09	2.10	5.51	0.06
LKSWISS	4.52	4.58	5.41	3.17	0.65	-0.37	1.96	10.52	0.01
LKUS$	4.33	4.57	5.20	3.03	0.67	-0.58	1.94	15.95	0.00
LKYEN	4.28	4.54	5.09	3.00	0.63	-0.43	1.76	14.74	0.00
LKZIM$	3.20	4.59	5.22	-3.83	2.68	-1.41	3.60	53.94	0.00
LNEER	4.25	4.36	5.04	3.09	0.58	-0.41	1.97	11.26	0.00
LNEERZIM$	4.17	4.25	4.89	3.16	0.47	-0.54	2.23	11.39	0.00
LRKFF	2.57	2.64	3.25	1.70	0.39	-0.49	2.34	9.11	0.01
LRKGBP	4.31	4.44	5.10	3.27	0.49	-0.66	2.21	15.20	0.00
LRKDM	3.78	3.85	4.46	2.91	0.38	-0.49	2.36	8.98	0.01
LRKRAND	4.39	4.43	4.88	3.72	0.32	-0.40	2.34	6.96	0.03
LRKSWISS	4.43	4.49	5.17	3.56	0.39	-0.43	2.30	7.99	0.02
LRKUS$	4.24	4.36	5.08	3.30	0.48	-0.48	2.07	11.59	0.00
LRKYEN	4.18	4.27	4.91	3.43	0.38	-0.19	1.67	12.46	0.00
LRKZIM	5.32	4.59	9.42	3.29	1.70	0.76	2.36	17.70	0.00
LREER	4.15	4.25	4.80	3.31	0.40	-0.52	2.18	11.55	0.00
LREERZIM$	4.21	4.26	5.06	3.29	0.46	-0.33	2.09	8.27	0.02

Source: Eviews 6

Max=maximum; min=minimum; std.dev=standard deviation; skew=skewness; kurt=kurtosis; J-B=Jarque-Bera; prob=probability or p-value; and obs= number of observations.

A non-normal distribution of exchange rate returns is confirmed by skewness, kurtosis and J-B statistics, consistent with the evidence in the literature (see Koay and Kwek, 2006; and Hassan, 2009). Thus, large unexpected changes in exchange rates of either sign are likely as observed in figure 3.1.

Volatility clustering in the exchange rate series appears visible in figure 3.1 (DLKFF…DLRERZIM). However, formal testing to confirm its presence is required. Additionally, variations in real exchange rate are similar to the pattern observed in the nominal exchange rate where periods of large changes in the latter that occurred for some sustained period coincide with the former suggesting deviations from PPP[37]. It is noteworthy that the Kzim$ exhibits peculiar behaviour compared with other exchange rates. It has large volatility swings than other exchange rates with the highest kurtosis (with the nominal and real Kzim$ having the smallest and largest values, respectively), implying fatter tails. Further, the Kzim$ has the largest monthly depreciation rate.

3.4.3.3 Unit Root Tests

The augmented Dickey-Fuller (ADF) and Phillips-Perron (P-P) tests are used to determine the time series properties of the variables for the null of the unit root. The unit root results reported in table 3.3 below confirm non-stationarity of all the variables[38].

[37] Variations in all nominal exchange rates are higher than the variation in inflation. This evidence suggests that prices tend to be stickier and thus account for the deviations in real exchange rates from PPP. A constant or stationary real exchange rate is a reflection of PPP holding continuously while a large real exchange rate variance is an indication of PPP failure (De Grauwe et al. 1985).
[38] All variables are I (1) series in log-level and I (0) in log first difference.

Table 3.3 Unit Root Tests

	ADF level	First Difference	lags	P-P level	First Difference
LKFF	-1.81	-23.21*	0	-1.79	-23.34*
LKGBP	-1.99	-23.79*	0	-2.00	-23.77*
LKDM	-1.80	-23.26*	0	-1.79	-23.43*
LKRAND	-1.76	-23.34*	0	-1.76	-23.35*
LKSWISS	-2.02	-23.38*	0	-2.00	-23.42*
LKUS$	-1.98	-23.48*	0	-1.97	-23.47*
LKYEN	-1.96	-22.79*	0	-1.93	-22.92*
LKZIM$	2.83	-22.16*	0	2.73	-22.31*
LRKFF	-1.30	-22.34*	0	-1.34	-22.35*
LRKGBP	-1.62	-22.76*	0	-1.60	-22.76*
LRKDM	-1.16	-22.21*	0	-1.22	-22.25*
LRKRAND	-1.57	-22.00*	0	-1.56	-22.00*
LRKSWISS	-1.37	-22.24*	0	-1.41	-22.24*
LRKUS$	-1.58	-22.33*	0	-1.58	-22.32*
LRKYEN	-1.15	-21.86*	0	-1.20	-21.88*
LRKZIM$	-3.08	-18.63*	0	-3.14	-18.63*
LNEER	-1.90	-23.64*	0	-1.90	-23.62*
LNEERZIM	-1.76	-23.54*	0	-1.75	-23.55*
LREER	-1.45	-22.49*	0	-1.45	-22.46*
LREERZIM	-0.05	-19.47*	0	-0.48	-19.46*
LM	-2.10	-23.31*	0	-2.15	-23.32*
LZCPI	-2.21	-8.34*	3	-2.42	-18.30*
LFXRES	-1.86	-16.51*	4	-0.01	-35.83*
RTBF	-2.97	-9.55*	3	-2.21	-19.03*
RTBG	-2.17	-24.52*	1	-2.56	-24.30*
RTBJ	-3.60	-5.00**	13	-3.11	-87.21**
RTBS	-2.52	-23.69*	1	-2.86	-23.67*
RTBSA	-2.41	-11.58*	3	-2.53	-28.92*
RTBUK	-2.87	-5.76*	12	-3.12	-27.69*
RTBUS	-2.63	-17.95*	2	-2.72	-20.64*
RTBZ	-3.81	-9.41**	2	-2.94	-13.79*
RTBZIM	2.33	6.33*	16	-4.14*	
LTOT	-1.91	-15.64*	2	-2.22	-16.17*
LOPEN	-3.68	-23.19**	2	-7.71*	
LCU	-1.16	-24.34*	2	-1.69	-78.86*

Source: Eviews 6
The critical values for unit root tests are Mackinnon’s (1996) one-sided p-values.
The unit root equations for both ADF and P-P contain a constant and linear trend except LFXRES in P-P tests which has no exogenous variables. RTBJ and RTBZIM in P-P and ADF tests only contain a constant. P-P does not detect presence of unit root in RTBZIM and LOPEN.
*, **, + asterisks refer to 1%, 5% and 10% significance level.

3.4.3.4 GARCH Model Results

Evidence of non-stationarity coupled with statistical evidence of non-normal distribution of exchange rate returns suggests the use of a non-linear model to model volatility. Hence, GARCH models are estimated for the logarithmic changes in exchange rates consistent with Kahya et al. (1994), Koutmos and Theodossiou (1994), Hassan and Wallace (1996)[39] and Singh (2002).

The presence of ARCH effects in exchange rate series is confirmed via the Engle (1982) *LM* test as both the *F* and *LM* test statistics are highly statistically significant at 1 percent level (see table 3.4 below). The lag length for the residuals equation is set at 1 for all exchange rates except the Kzim$ which requires 12 lags to detect the presence of ARCH effects.

Table 3.4 LM Test for the Presence of ARCH Effects in Exchange Rate Series

	F-statistic	Prob.F	LM test statistic	Prob.LM
LKFF	37.84	0.00	35.38	0.00
LKGBP	34.37	0.00	32.34	0.00
LKDM	30.93	0.00	29.28	0.00
LKRAND	51.14	0.00	46.68	0.00
LKSWISS	31.43	0.00	29.73	0.00
LKUSD	39.00	0.00	36.38	0.00
LKYEN	32.48	0.00	30.48	0.00
LKZIM	8.14	0.00	77.95	0.00
LRKFF	33.65	0.00	31.48	0.00
LRKGBP	32.07	0.00	30.10	0.00
LRKDM	27.84	0.00	26.36	0.00
LRKRAND	45.43	0.00	41.51	0.00
LRKSWISS	28.35	0.00	26.81	0.00
LRKUSD	34.78	0.00	32.47	0.00
LRKYEN	28.51	0.00	26.96	0.00
LRKZIM	3.09	0.00	35.43	0.00
LNEER	39.05	0.00	36.42	0.00
LNEERZIM	38.70	0.00	36.12	0.00
LREER	35.18	0.00	32.82	0.00
LREERZIM	25.68	0.00	24.04	0.00

Source: Eviews 6

[39] Hassan and Wallace (1996) argue that volatility of the variable (real exchange rate) should be computed from first difference of the variable as opposed to the level if non-stationary as its variance changes with time.

Consequently, the conditional mean, equation 2.1, is estimated and results for parsimonious conditional variance equations 7-12 satisfying model adequacy[40] are presented in tables 3.5-3.10 below.

The results are robust as there is evidence of no serial correlation and heteroskedasticity based on the Ljung-Box Q-statistic conducted on standardised (υ_t) and squared standardised residuals (υ_t^2), respectively. In addition, there are no remaining ARCH effects in residuals according to the ARCH LM (F-statistic) test. A maximum lag of six chosen according to Tsay (2002)[41] is used in the Q-test while for ARCH LM test, one lag is applied. The normality test (J-B) is however, not fulfilled in the majority of equations similar to Fang and Miller (2009). In view of this the standard errors are inappropriate for inference as the standard errors increase the probability of the estimated parameter values being significantly different from zero. However, parameter estimates are consistent as long as both conditional mean and variance equations are correctly specified (Brooks, 2006). Consequently, the Bollerslev-Wooldridge robust standard errors and covariance are employed and the resulting robust standard errors are reported in tables 3.5-3.10[42].

The coefficients ρ_1 and ρ_2 corresponding to D and $D(-1)$ in the nominal exchange rate specification are statistically significant in the majority of mean equations with opposite sign signifying the temporary nature of the sharp currency movement (flip

---

[40] Model adequacy is determined by performing diagnostic tests on standardised residuals so that residuals should be white noise: no serial correlation, no heteroskedasticity and no further presence of ARCH/GARCH process.

[41] The optimal lag length k is determined according to Tsay (2002): $k = \ln(T)$ where T is the number of observations.

[42] The estimated parameter values remain practically unchanged. Only standard errors change.

up and down of the exchange rate). In addition, the dummy accounts for movements in conditional variance especially in the Kzim$ (tables 3.5, 3.7 and 3.9)[43].

Similar to previous empirical studies (e.g. Stančík, 2007; Fidrmuc and Horváth, 2008; and Narayan et al. 2009), all kwacha exchange rates are characterised by persistent conditional volatility across the three GARCH models, evidenced by the highly statistically significant β coefficient (at 1 percent significance level) except nominal KFF and KDM (table 3.5), real Kswiss (tables 3.6 and 3.8) and real KGBP (table 3.8). Relative to GARCH and TGARCH models, the EGARCH model reveals higher β coefficient values[44] with some exchange rates exhibiting high persistence in conditional volatility: Krand (0.7), KUS$ (0.7), Kyen (0.7) and Kzim$ (0.8). Additionally, conditional variance is mean reverting and augmentations to conditional variance are not permanent as β and $\alpha_1 + \beta$ are less than 1, respectively. Nonetheless, volatility persistence is low (β averaging about 0.5) similar to Hu et al. (1997) and Narayan et al. (2009)[45]. This signifies transitory effect of shocks to exchange rate volatility and thus fast convergence to the unconditional mean. According to the half-life (H-L) measure[46], conditional volatility persists for about a month on average following a shock[47]. However, for the Krand, KUS$ and Kyen, persistence of the shock on conditional volatility lasts about two months while for the Kzim$, the shock persists

[43] Similar to Fang and Miller (2009) overwhelming evidence of ARCH and GARCH effects is found when the dummy is included in the specification, thus confirming the usefulness of outliers in ARCH/GARCH modelling. Negative ARCH and GARCH terms and in some cases large coefficient values in excess of 1 and generally statistically insignificant are obtained when the dummy is excluded in the specification.

[44] Imply more persistence with shocks to exchange rate volatility dying out slowly.

[45] Narayan et al. (2009) for instance find a value of 0.6 and argue that volatility persistence is low unless the coefficient value is much closer to 1.

[46] The persistence of past shocks on conditional volatility measured by H-L is calculated as $\frac{\log(0.5)}{\log(\beta)}$ (see Koutmos and Theodossiou, 1994). H-L captures the period it takes for a shock to volatility to reduce to half its original size. β is the speed of convergence to the steady-state level.

[47] The low persistence of shocks on conditional volatility implies that the usefulness of current information for forecasts of conditional variance is short-lived.

slightly longer, for about three months. This is further evidence of the zim$'s peculiarity.

Similar to Narayan et al. (2009), price shocks raise conditional volatility in all kwacha exchange rates given the positive and statistically significant α coefficient in the EGARCH model (tables 3.9 and 3.10)[48].

The TGARCH model suggests that there is little evidence of asymmetry in all exchange rates evidenced by the statistical insignificance of γ (see tables 3.7 and 3.8). This implies that conditional volatility responds symmetrically to price shocks like in the GARCH model. Conversely, the EGARCH model in tables 3.9 and 3.10 reveals evidence of asymmetry in most exchange rates especially the real similar to Kahya et al. (1994), Koutmos and Theodossiou (1994), Kanas (2002), Kočenda and Valachy (2006), Koay and Kwek (2006), Stančík (2007) and Fidrmuc and Horváth (2008)[49]. Both TGARCH and EGARCH models fail to detect the presence of asymmetry in two exchange rates namely, KFF and Kswiss (both real and nominal). Asymmetry is only exclusively found in the Krand and KUS$ exchange rates (both real and nominal). For the rest of the exchange rates, asymmetry is detected in either the real or nominal: Kzim$ (nominal – table 3.9), KGP (real – table 3.10), KDM (real – table 3.10), Kyen (real – table 3.10) and trade weighted (real – table 3.10). The insignificance of the asymmetry term in TGARCH and EGARCH equations in the nominal KGP, KDM, Kyen and trade weighted exchange rates plus KFF and Kswiss confirms that the linear GARCH specification is appropriate as the magnitude of innovations that exert the same

---

[48] The exception is the nominal KUS$ which has a statistically insignificant coefficient.

[49] The variation in results between the TGARCH and EGARCH models is not unusual as the construction of models and hence the manner in which leverage effects are captured differ. Olowe (2009) finds similar results whereby the EGARCH (1, 1) model is unable to detect asymmetry in the Naira/US dollar exchange rate but the GJR-GARCH (1, 1) and APARCH (1, 1) models do. Narayan et al. (2009) find similar results when they analyse conditional volatility in the Fiji-US dollar exchange rate using different EGARCH (1, 1) specifications whereby some specifications reveal asymmetric response of conditional volatility to price shocks while others do not.

effect on volatility matters. For other exchange rates, evidence of asymmetry in conditional variance suggests that the symmetry imposed by the GARCH (1, 1) model is restrictive.

Further, the TGARCH model indicates that all nominal exchanges rates (table 3.7) do not react to past shocks as α_1 is statistically insignificant at all conventional significance levels. This suggests that ARCH effects are not overwhelmingly strong. Conversely, α_1 is statistically significant in the GARCH model (table 3.5) except Krand, Kyen, Kzim and NEERZIM. The only currency which does not react to past shocks is the zim$ as shown by the statistical insignificance of α_1 in both GARCH and TGARCH models.

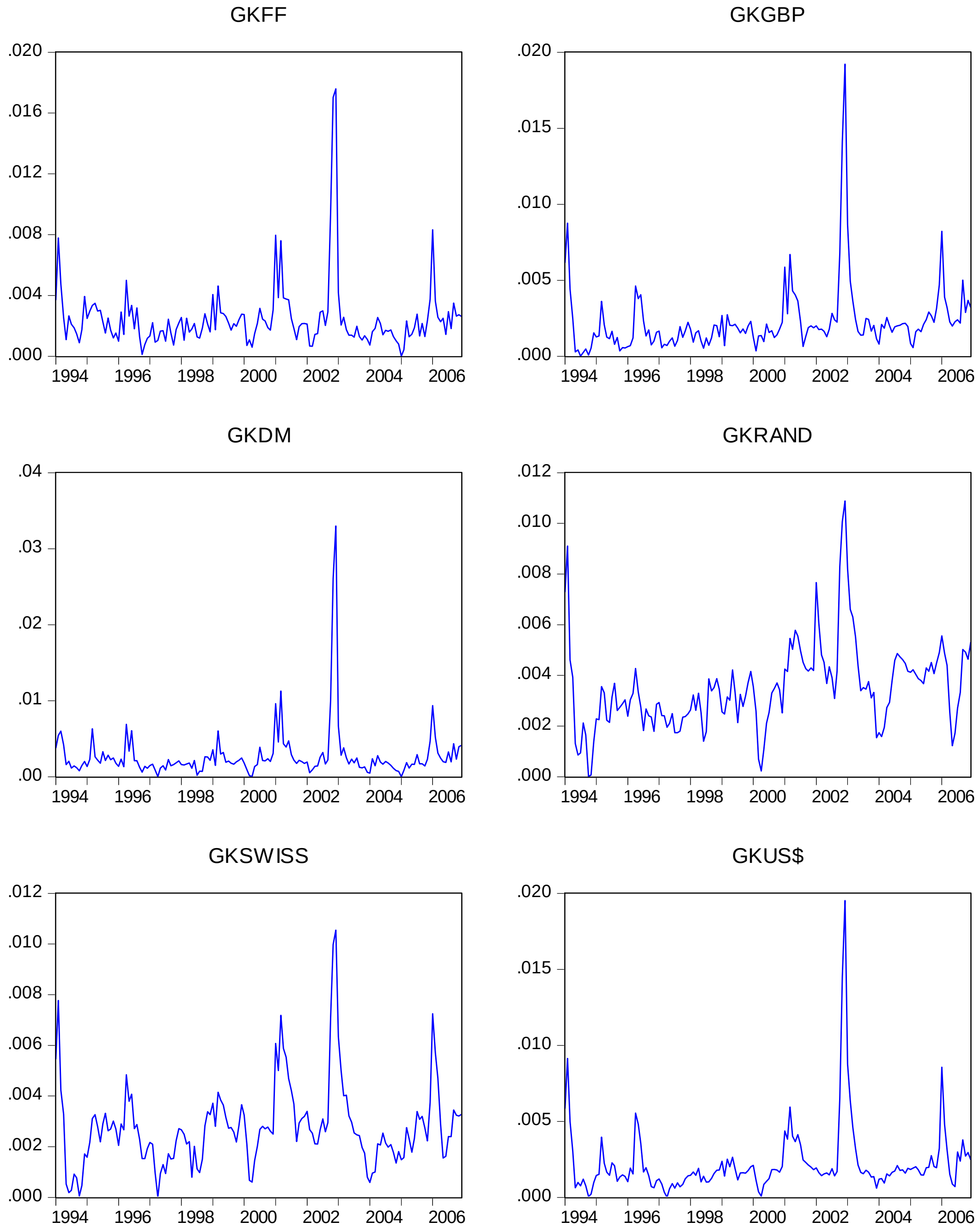
The statistical insignificance of γ reduces the TGARCH model to a GARCH model. In general, the GARCH model has higher log-likelihood values and lower AIC and SBC values than the TGARCH model with statistically significant α_1 and β coefficients in the majority of the real and nominal exchange rates. The β coefficient is statistically significant in the EGARCH model (at all conventional significance levels) in all real and nominal exchange rates whereas in the GARCH model, β is statistically insignificant in the nominal KFF, KDM (Table 3.5) and real Kswiss exchange rates (table 3.6). Further, the EGARCH model has the highest log-likelihood value and lowest AIC and SBC for all exchange rates except the real Kzim$ (Table 3.8). In general, the EGARCH model performs better than the GARCH and TGARCH models. The predominance of an EGARCH process is similar to the finding by Koutmos and Theodossion (1994) and Hu et al. (1997). Thus, it can be concluded that conditional volatility in all but real Kzim$ exchange rates is best represented by an EGARCH (1, 1) process based on the model selection criteria outlined in sub-section 3.4.2.

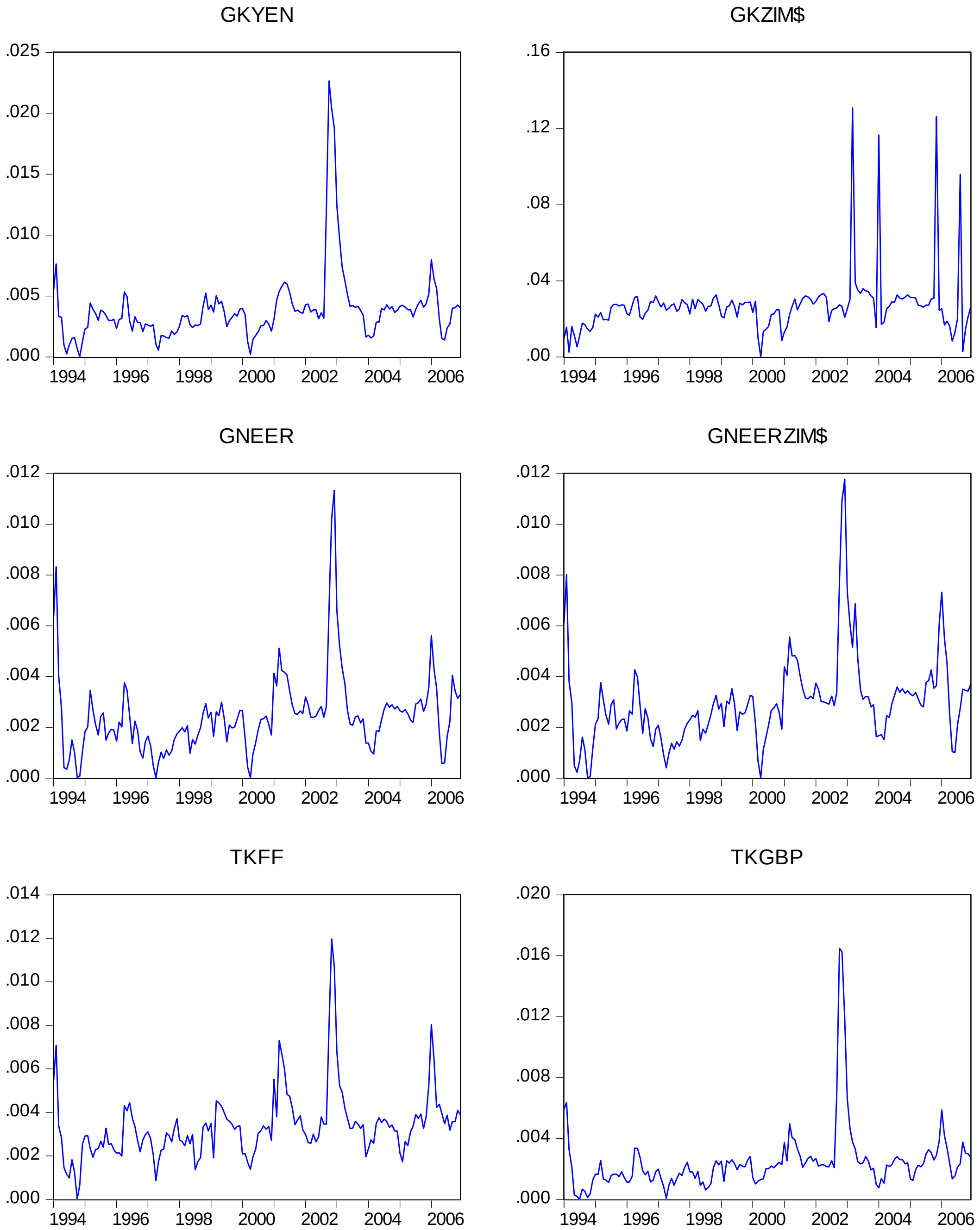
The response of conditional volatility to shocks differs among exchange rates represented by the EGARCH (1, 1) model similar to Kahya et al. (1994) and Stančík (2007). Positive shocks tend to reduce conditional volatility in the nominal KUS$ exchange rate (as it responds positively to shocks). On the contrary, negative shocks tend to raise conditional volatility in the majority of exchange rates namely, real KUS$, Krand, nominal Kzim$, real KGBP, real KDM, real Kyen and the trade-weighted (as these exchange rates respond negatively to shocks).

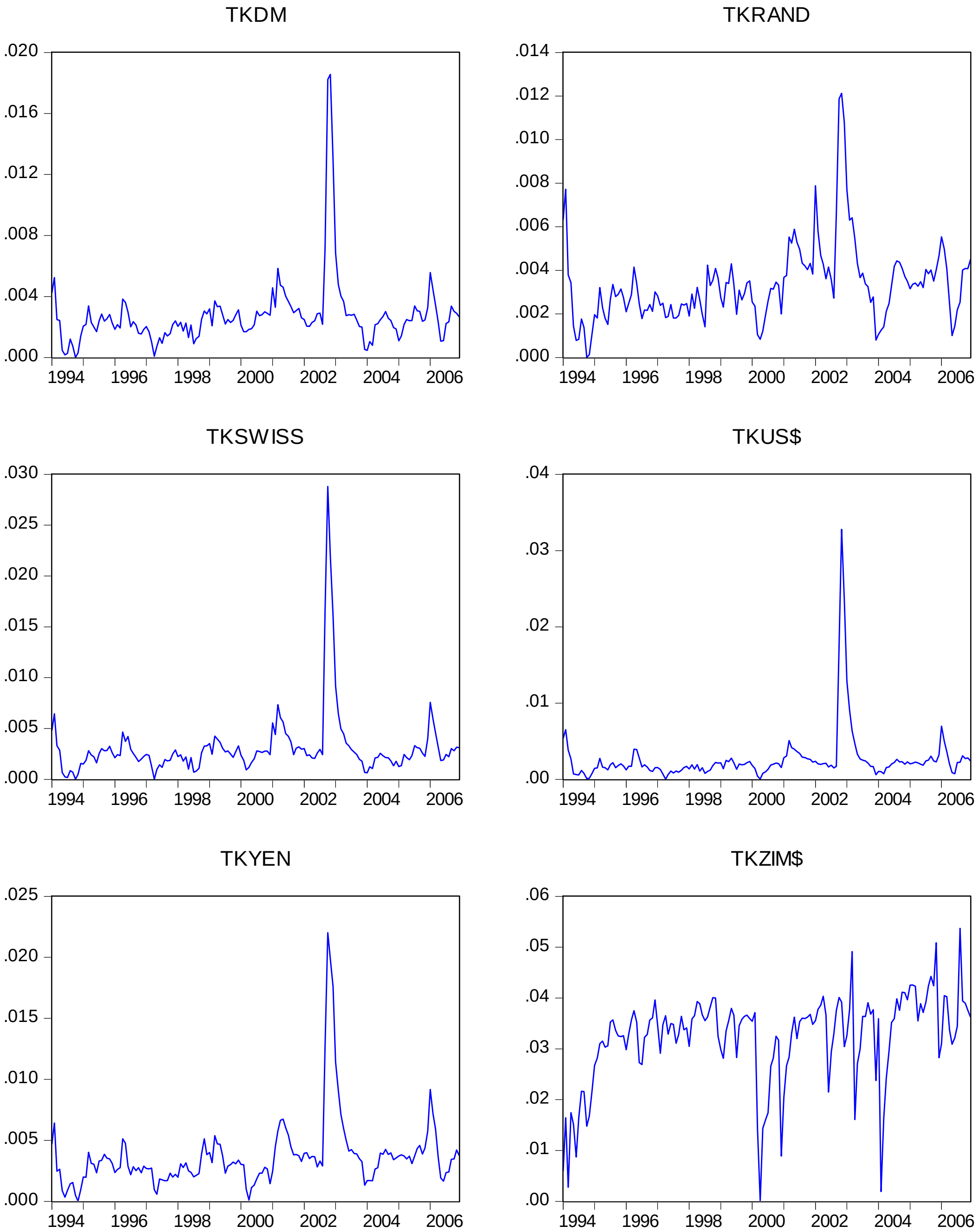
In summary, the results above reveal that kwacha exchange rates are characterised by different conditional volatility dynamics. It is therefore imperative to employ alternative GARCH models in examining conditional variance in exchange rates especially when a large sample of currencies is studied in order to the ascertain results as imposing a uniform GARCH model specification on all exchange rates may be inappropriate. For instance if the TGARCH was the only model used to measure volatility, we could have concluded that asymmetry is lacking in all exchange rates when in fact it is present as evidenced by the EGARCH model results. Further, ARCH effects are not strong in some exchange rates while other exchange rates exhibit asymmetric response to price shocks. Finally, while volatility persistence is generally low, shocks tend to last longer in some exchange rates than in others.

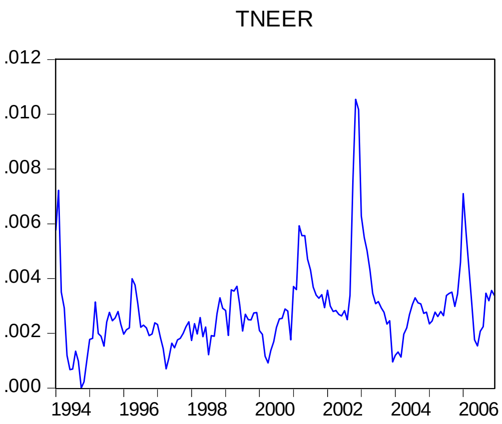
Plots of conditional variance estimates in figures 3.3 and 3.4 below reveal features in exchange rates consistent with the raw data in figure 3.1. Spikes (sharp rise) in conditional volatility are observed during the initial float period while moderate increases in volatility are recorded after 1994 with occasional spurts occurring in 2002 and 2003. The rest of the period is characterised by relatively low conditional volatility.

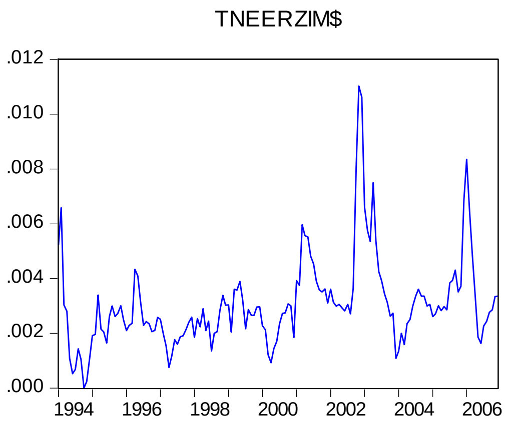
Figure 3.3 Estimated Conditional Variance In Nominal Exchange Rates

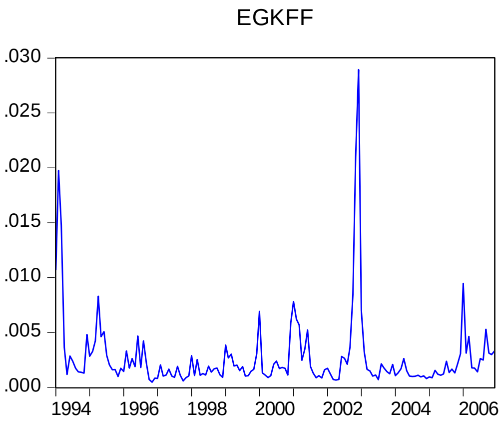


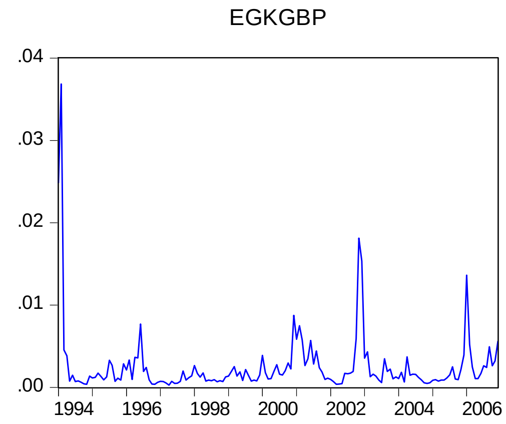

GKYEN
.025
.020
.015
.010
.005
.000
1994 1996 1998 2000 2002 2004 2006
GKZIM$
.16
.12
.08
.04
.00
1994 1996 1998 2000 2002 2004 2006
GNEER
.012
.010
.008
.006
.004
.002
.000
1994 1996 1998 2000 2002 2004 2006
GNEERZIM$
.012
.010
.008
.006
.004
.002
.000
1994 1996 1998 2000 2002 2004 2006
TKFF
.014
.012
.010
.008
.006
.004
.002
.000
1994 1996 1998 2000 2002 2004 2006
TKGBP
.020
.016
.012
.008
.004
.000
1994 1996 1998 2000 2002 2004 2006

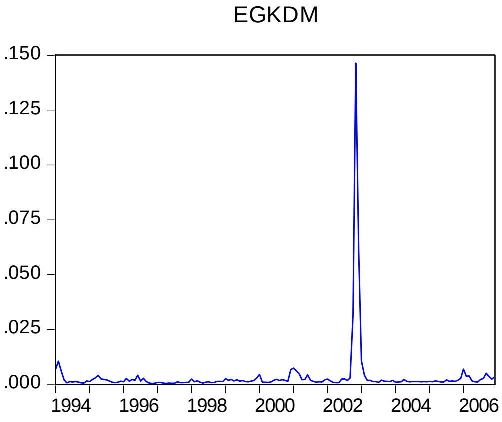

TKDM
.020
.016
.012
.008
.004
.000
1994 1996 1998 2000 2002 2004 2006
TKRAND
.014
.012
.010
.008
.006
.004
.002
.000
1994 1996 1998 2000 2002 2004 2006
TKSWISS
.030
.025
.020
.015
.010
.005
.000
1994 1996 1998 2000 2002 2004 2006
TKUS$
.04
.03
.02
.01
.00
1994 1996 1998 2000 2002 2004 2006
TKYEN
.025
.020
.015
.010
.005
.000
1994 1996 1998 2000 2002 2004 2006
TKZIM$
.06
.05
.04
.03
.02
.01
.00
1994 1996 1998 2000 2002 2004 2006

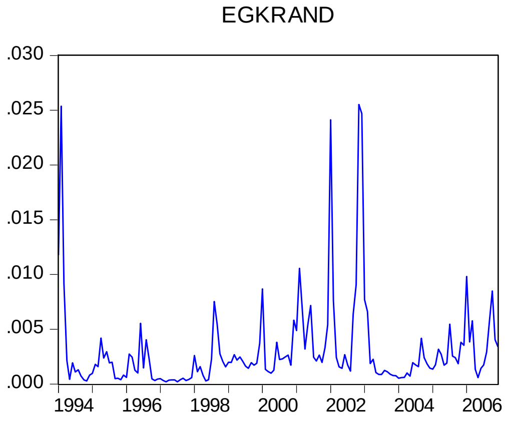

TNEER
.012
.010
.008
.006
.004
.002
.000
1994
1996
1998
2000
2002
2004
2006


TNEERZIM$
.012
.010
.008
.006
.004
.002
.000
1994
1996
1998
2000
2002
2004
2006

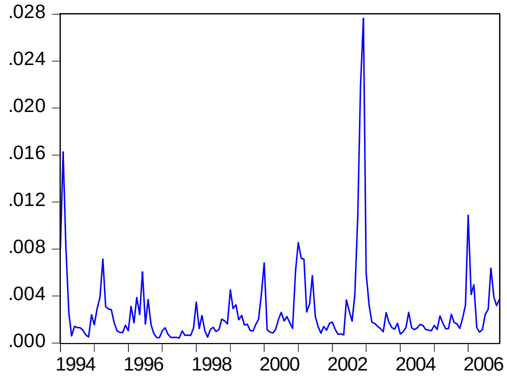

EGKFF
.030
.025
.020
.015
.010
.005
.000
1994
1996
1998
2000
2002
2004
2006


EGKGBP
.04
.03
.02
.01
.00
1994
1996
1998
2000
2002
2004
2006

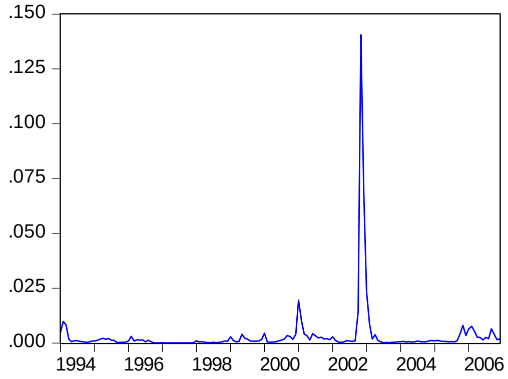

EGKDM
.150
.125
.100
.075
.050
.025
.000
1994
1996
1998
2000
2002
2004
2006


EGKRAND
.030
.025
.020
.015
.010
.005
.000
1994
1996
1998
2000
2002
2004
2006

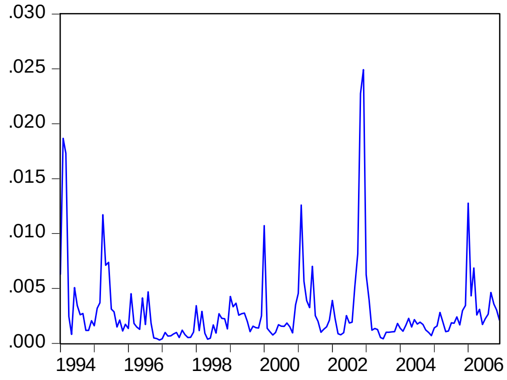
EGKSWISS



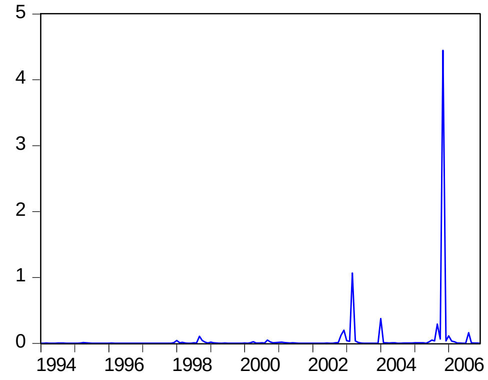
EGKUS$



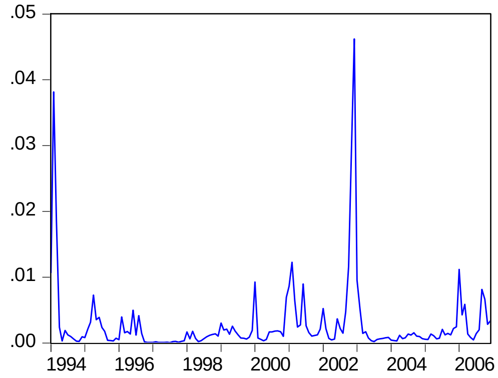
EGKYEN



EGKZIM$



EGNEER



EGNEERZIM$

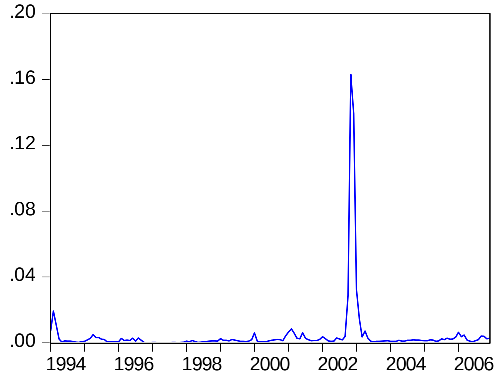
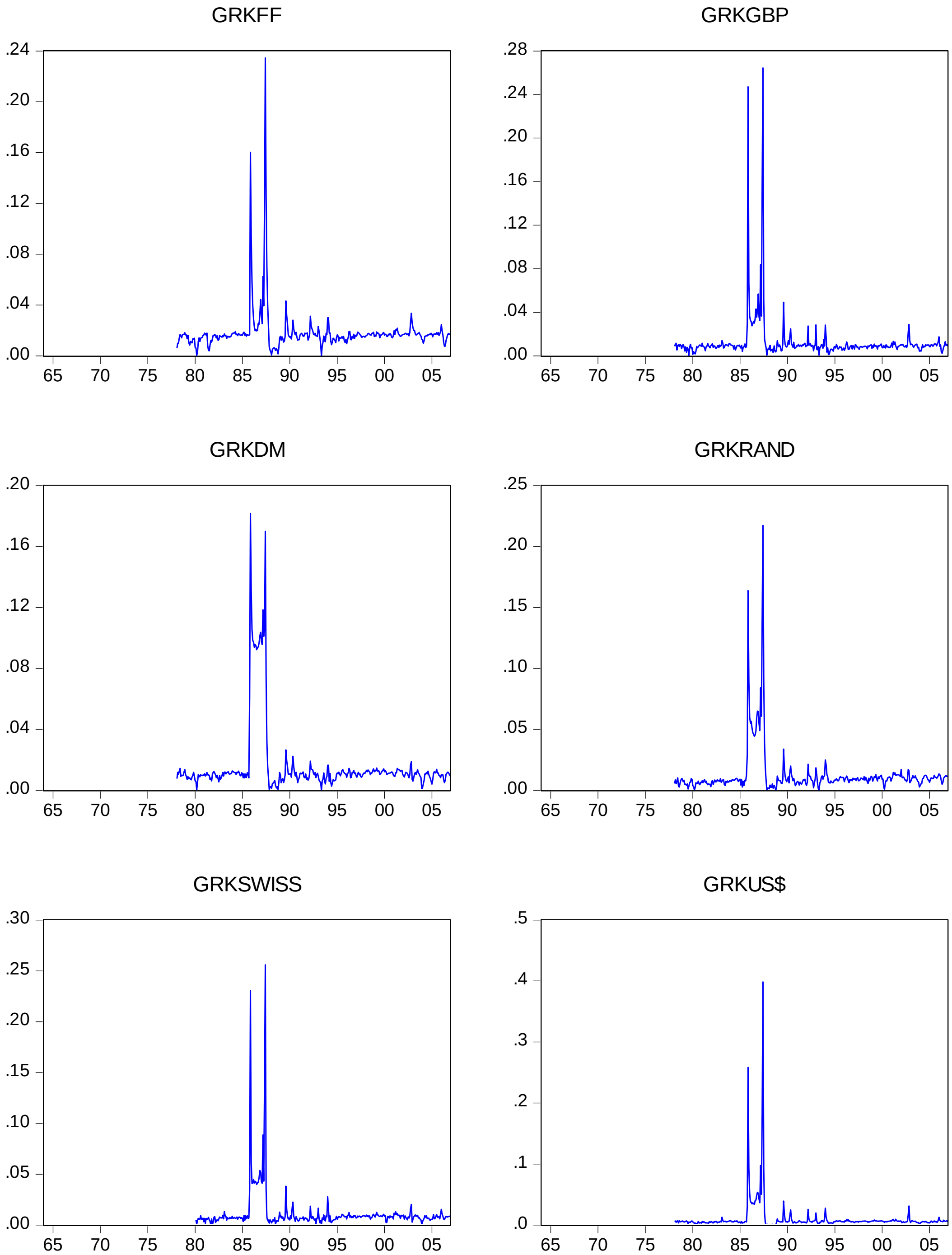
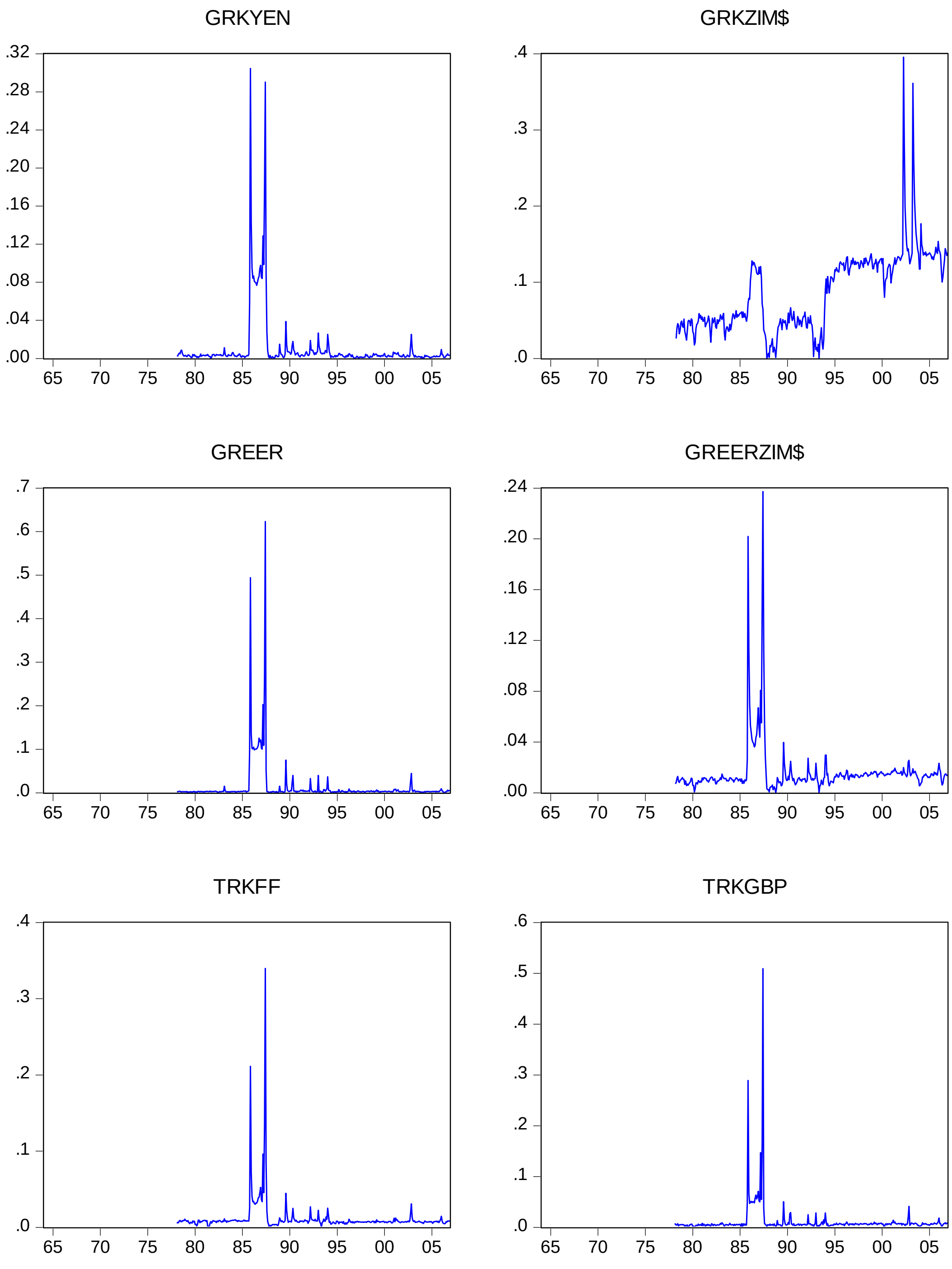
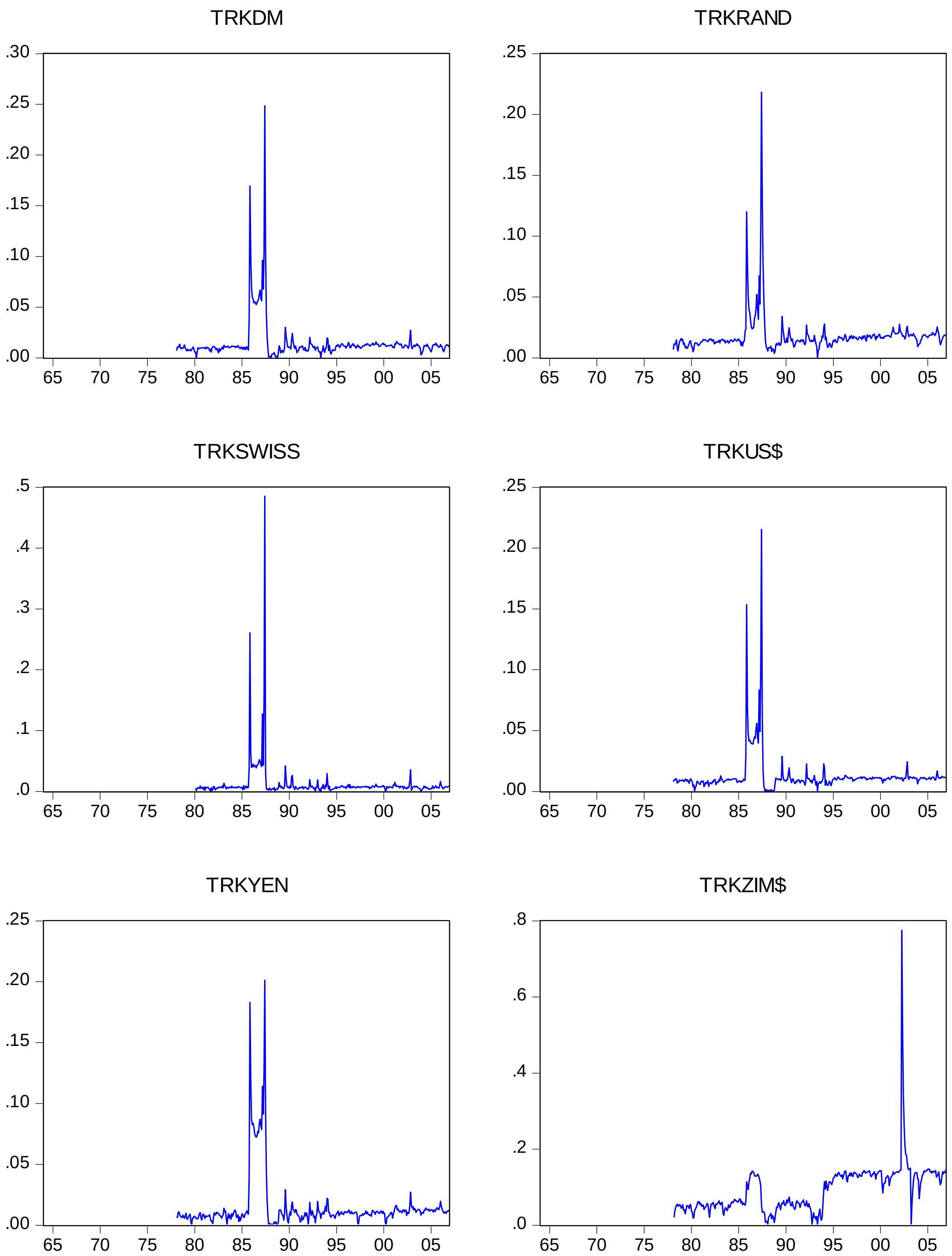


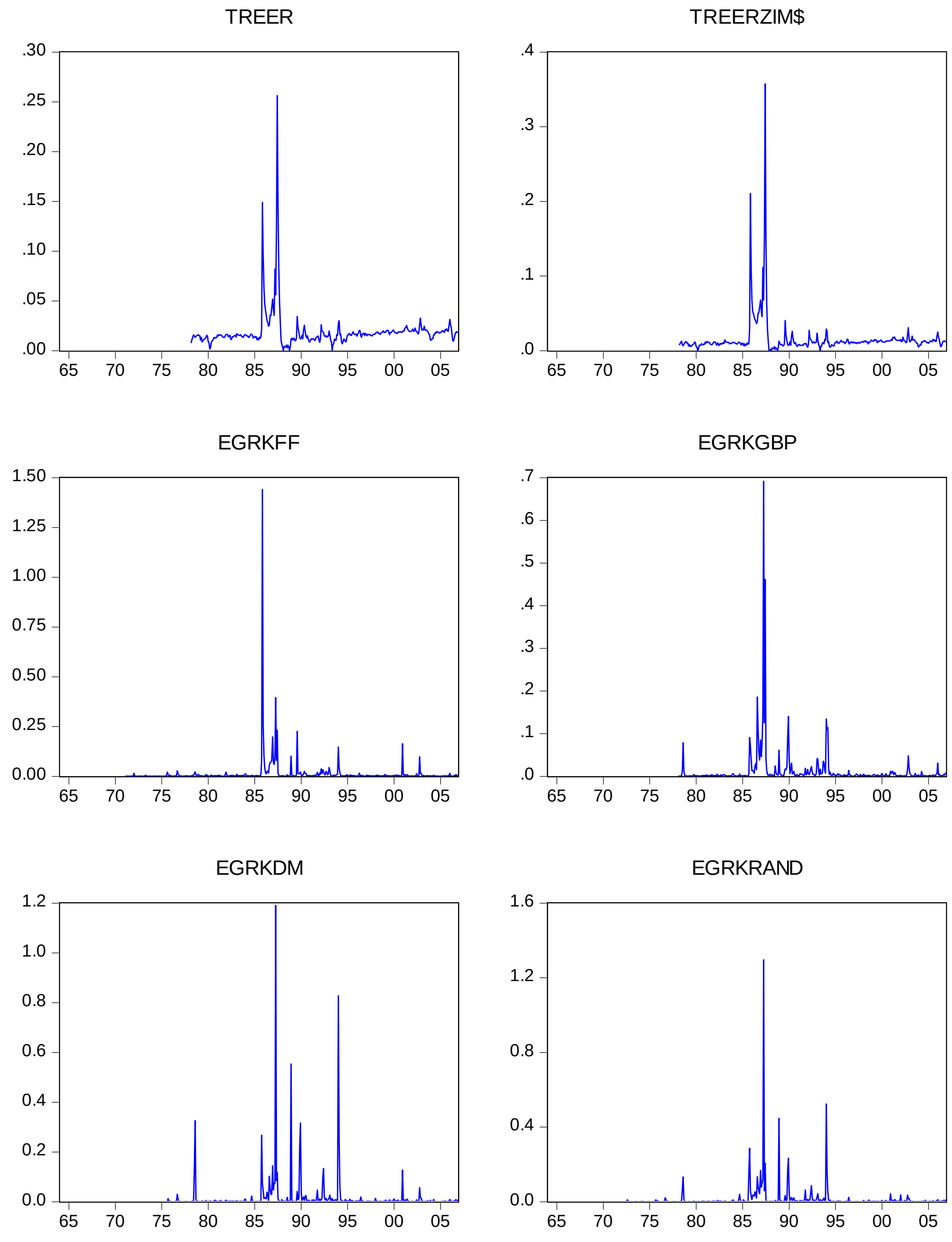
Figure 3.4 Estimated Conditional Variance In Real Exchange Rates

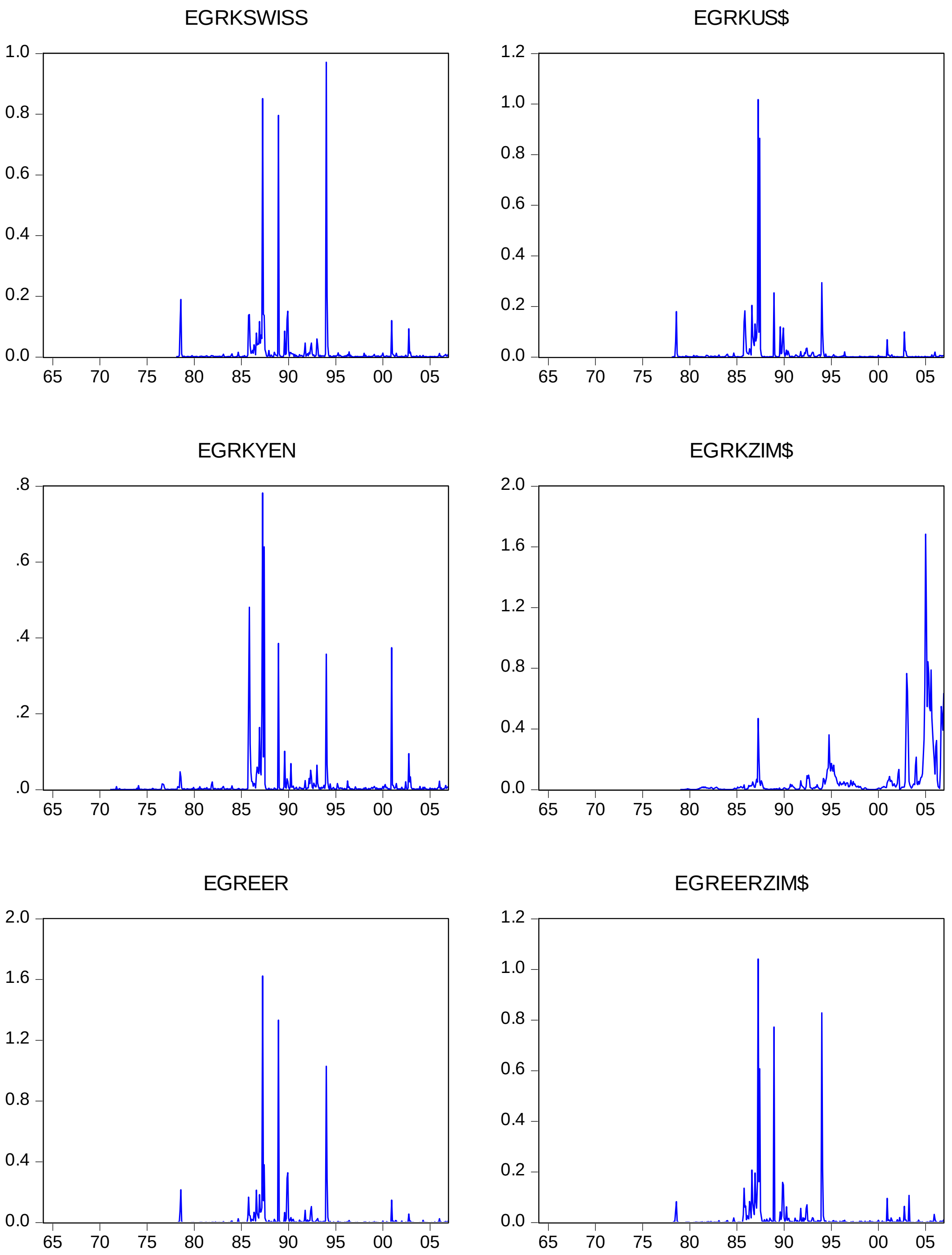




GRKYEN
.32
.28
.24
.20
.16
.12
.08
.04
.00
65 70 75 80 85 90 95 00 05
GRKZIM$
.4
.3
.2
.1
.0
65 70 75 80 85 90 95 00 05
GREER
.7
.6
.5
.4
.3
.2
.1
.0
65 70 75 80 85 90 95 00 05
GREERZIM$
.24
.20
.16
.12
.08
.04
.00
65 70 75 80 85 90 95 00 05
TRKFF
.4
.3
.2
.1
.0
65 70 75 80 85 90 95 00 05
TRKGBP
.6
.5
.4
.3
.2
.1
.0
65 70 75 80 85 90 95 00 05


TRKDM
.30
.25
.20
.15
.10
.05
.00
65 70 75 80 85 90 95 00 05
TRKRAND
.25
.20
.15
.10
.05
.00
65 70 75 80 85 90 95 00 05
TRKSWISS
.5
.4
.3
.2
.1
.0
65 70 75 80 85 90 95 00 05
TRKUS$
.25
.20
.15
.10
.05
.00
65 70 75 80 85 90 95 00 05
TRKYEN
.25
.20
.15
.10
.05
.00
65 70 75 80 85 90 95 00 05
TRKZIM$
.8
.6
.4
.2
.0
65 70 75 80 85 90 95 00 05


TREER
.30
.25
.20
.15
.10
.05
.00
65 70 75 80 85 90 95 00 05
TREERZIM$
.4
.3
.2
.1
.0
65 70 75 80 85 90 95 00 05
EGRKFF
1.50
1.25
1.00
0.75
0.50
0.25
0.00
65 70 75 80 85 90 95 00 05
EGRKGBP
.7
.6
.5
.4
.3
.2
.1
.0
65 70 75 80 85 90 95 00 05
EGRKDM
1.2
1.0
0.8
0.6
0.4
0.2
0.0
65 70 75 80 85 90 95 00 05
EGRKRAND
1.6
1.2
0.8
0.4
0.0
65 70 75 80 85 90 95 00 05


EGRKSWISS
1.0
0.8
0.6
0.4
0.2
0.0
65 70 75 80 85 90 95 00 05
EGRKUS$
1.2
1.0
0.8
0.6
0.4
0.2
0.0
65 70 75 80 85 90 95 00 05
EGRKYEN
.8
.6
.4
.2
.0
65 70 75 80 85 90 95 00 05
EGRKZIM$
2.0
1.6
1.2
0.8
0.4
0.0
65 70 75 80 85 90 95 00 05
EGREER
2.0
1.6
1.2
0.8
0.4
0.0
65 70 75 80 85 90 95 00 05
EGREERZIM$
1.2
1.0
0.8
0.6
0.4
0.2
0.0
65 70 75 80 85 90 95 00 05

The impact of some fundamental variables on conditional volatility of the exchange rates varies in sign and statistical significance across the three GARCH models. Thus, the analysis of the influence of fundamentals on exchange rate volatility that follows is based on the optimally chosen EGARCH model (tables 3.9 and 3.10) for all exchange rates except the real Kzim$ for which the TGARCH model (table 3.8) is used.

Money supply, foreign reserves and openness have a tendency to increase conditional volatility in exchange rates while inflation, domestic and foreign interest rates, terms of trade and real output reduce conditional volatility. Both real and nominal exchange rates including the trade-weighted measure[50] with and without the zim$ are practically affected by the same factors. Money supply, terms of trade, openness and real output are predominantly statistically significant (mostly at 1 percent level) in most (real) conditional variance equations. Generally, inflation (ϕ_2) and to some extent foreign reserves and the real interest rate have no statistical significant effects on conditional volatility in the majority of exchange rates.

In line with theoretical predictions and evidence from descriptive statistics in table 3.2, money supply (ϕ_1) has the expected positive sign in virtually all exchange rates (especially the real), similar to De Grauwe and Rosiers (1987), Jeong (2000) and Cady and Gonzalez-Garcia (2006). This highlights the importance of monetary policy in influencing exchange rate volatility especially in the short-run due to the existence of nominal rigidities (Edwards, 1987).[51]

The positive influence of foreign reserves (ϕ_3) on conditional variance suggests that changes in the former induce uncertainty in the foreign exchange market as

---

[50] The negligible impact of the zim$ could be due to the small weight (5.8 percent) in NEER and REER.

[51] The short-run effect is captured via the use of high frequency data at monthly interval over which nominal rigidities are expected to hold while money supply varies.

opposed to creating confidence as argued by Hviding et al. (2004). This result could be attributed to the measure of foreign reserves adopted which may not accurately capture what the conventional measure, adequate reserve ratio, postulates.

In contrast to other studies (e.g. Hau, 2000), openness (ϕ_7) has a positive effect on conditional volatility. Karras (2006) finds similar results. According to theory, closely integrated economies tend to experience lower volatility in exchange rates. The positive sign and insignificance of openness for some exchange rates suggests that the degree of openness (extent of trade link between Zambia and her trading partners) is low relative to that implied by theory. The results could also be affected by the interpolation of nominal GDP and use of aggregate as opposed to bilateral trade data as postulated by OCA theory (see Hau, 2002). Furthermore, trade could be concentrated in one or few goods in which case deviations from PPP are more likely than if trade is diversified.

While both domestic (ϕ_4) and foreign real interest rates (ϕ_5) tend to reduce conditional volatility, there are instances when the two impose opposite influence on conditional volatility (i.e. nominal KDM in table 3.9 and real KGP in table 3.10). In addition, both interest rates do not simultaneously enter significantly in any conditional variance equation. Thus, it would be restrictive to assume domestic and foreign interest rates to be of the same sign and magnitude by taking their difference (interest differential) in the conditional variance specification.

All else being equal, increases in copper output signal more foreign exchange inflows. This has the tendency to bolster confidence in the foreign exchange market and thus reduce volatility. Thus, the negative influence of changes in copper output (ϕ_8) could be attributed to this.

Conditional volatility in all kwacha exchange rates are significantly affected by exchange rate regime consistent with Hasan and Wallace (1996), Canales-Kriljenko and Habermeier (2004), Kočenda and Valachy (2006), Stančík (2007) and Schnabl (2009). In particular, the initial float of the kwacha (τ_3 in table 3.10) had a dominant positive effect on conditional volatility as it raised volatility considerably[52]. The fixed exchange rate period is generally associated with low conditional volatility (τ_1 and τ_2 in table 3.10) and for some exchange rates, conditional volatility during this period is not statistically different from conditional volatility experienced between 1994 and 2006. Thus, this result confirms the relevance of exchange rate regime in exchange rate management.

[52] Non-convergent and implausible GARCH parameter coefficients are obtained when the conditional variance equations is estimated without exchange rate regime dummies. This provides a justification for including exchange rate regime in the empirical model as GARCH models correctly capture the effect of exchange rate regime as displayed in the raw data.

Table 3.5 GARCH- Nominal bilateral and effective kwacha exchange rates: 1994.01-2006.12

	KFF	KGBP	KDM	Krand	Kswiss	KUS$	Kyen	Kzim$	NEERzim$	NEER
Mean eq.										
α_0	0.009** (2.23)	0.010* (2.79)	0.007** (2.12)	0.007 (1.14)	0.002* (2.81)	0.008+ (1.94)	0.011+ (1.71)	0.005 (0.18)	0.007 (1.31)	0.006* (1.37)
α_1	0.309 (3.46)	0.222** (2.49)	0.398* (5.30)	0.161 (1.41)	0.226* (2.55)	0.265* (2.82)	0.246** (2.47)	0.206 (1.24)	0.201** (2.21)	0.200* (2.36)
α_2	-0.028 (-0.35)									
ρ_1	0.060* (2.65)	0.086* (5.65)	0.080* (4.85)	0.049** (2.06)	0.044** (2.40)	0.081* (5.34)	0.010 (0.12)	-1.265* (-7.96)	0.049** (2.45)	0.059* (3.37)
ρ_2	-0.114* (-2.70)	-0.150* (-4.48)	-0.137* (-2.98)	-0.087** (-2.37)	-0.109* (-3.47)	-0.144* (-4.37)	-0.106 (-1.24)	0.208 (0.66)	-0.106* (-3.05)	-0.111* (-3.56)
Variance eq.										
α_0	0.002* (3.02)	0.001* (6.33)	0.002* (3.86)	0.002* (6.81)	0.002* (5.34)	0.001* (5.07)	0.002* (2.83)	0.020* (2.71)	0.002* (6.10)	0.002* (6.92)
α_1	0.281* (2.65)	0.259* (3.06)	0.426* (3.41)	0.130 (1.05)	0.156** (2.04)	0.270* (2.67)	0.147 (0.82)	0.003 (0.07)	0.143 (1.53)	0.148+ (1.79)
β	0.212 (1.03)	0.406* (5.16)	0.195 (1.23)	0.558* (3.34)	0.566* (4.38)	0.418* (3.99)	0.593* (2.91)	0.544** (2.03)	0.534* (5.80)	0.502* (6.16)
ρ_1							0.008 (0.51)	0.097* (2.81)		
ρ_2								-0.053 (-1.54)		
ϕ_1								-0.013 (-0.34)		
ϕ_2	-0.044* (-2.99)		-0.055* (-4.69)		-0.034** (-2.27)	-0.010 (-0.64)				
ϕ_3			-0.001* (-3.76)	-0.001* (-2.58)	-0.0005 (-1.22)	-0.001** (-2.13)	-0.001** (-2.46)	-0.012 (-1.26)	-0.001* (-3.80)	-0.001* (-3.80)
ϕ_4		-1.16^{-5*} (-4.70)		-2.01^{-5*} (-2.60)	-1.38^{-5*} (-4.69)	-9.61^{-6**} (-2.13)	-2.09^{-5+} (-1.73)	-0.0001 (-1.21)	-1.72^{-5*} (-3.96)	-1.27^{-5*} (-5.79)
ϕ_5	-3.87^{-5} (-1.45)	-6.73^{-5*} (-3.09)		-4.71^{-5} (-1.08)	-2.06^{-5} (-1.25)		-1.82^{-5} (-1.02)	-5.38^{-5} (-0.77)		
ϕ_6				-0.010** (-2.37)	-0.005 (-1.26)	-0.005* (-3.70)	-0.011 (-1.02)	-0.055 (-1.29)	-0.008* (-3.93)	-0.008* (-3.82)
ϕ_7	0.003 (1.33)							-0.015 (-0.55)		
ϕ_8	-0.0002+ (-1.70)	-7.11^{-5**} (-2.09)	-0.0001* (-4.01)	-0.0001 (-1.11)	-0.0002* (-5.35)	-0.0001* (-3.04)	-8.57^{-5} (-0.67)		-0.0001* (-2.97)	-0.0001* (-5.90)
υ_t Q(6)	2.0986 [0.835]	2.0844 [0.837]	2.8765 [0.719]	4.1643 [0.526]	1.3510 [0.930]	3.8841 [0.566]	3.9075 [0.563]	6.5979 [0.252]	2.5845 [0.764]	0.3866 [0.996]
υ_t^2 Q(6)	4.6773 [0.457]	5.1938 [0.393]	4.4269 [0.490]	3.4738 [0.627]	8.9090 [0.113]	7.5098 [0.185]	7.8509 [0.165]	4.8909 [0.429]	9.5518 [0.089]	10.731 [0.057]
J-B	4.613 [0.100]	10.500 [0.005]	11.525 [0.003]	12.623 [0.002]	9.568 [0.008]	47.795 [0.000]	1.445 [0.485]	607.882 [0.000]	19.006 [0.000]	16.363 [0.000]
ARCH LM	0.273 [0.602]	0.007 [0.934]	0.578 [0.448]	0.713 [0.400]	4.987 [0.027]	3.335 [0.070]	3.747 [0.055]	2.301 [0.131]	6.536 [0.012]	5.406 [0.021]
Log L	263.6	275.2	271.5	249.1	260.1	291.5	253.2	112.8	268.2	279.4
AIC	-3.226	-3.400	-3.353	-3.040	-3.167	-3.583	-3.079	-1.254	-3.297	-3.441
SBC	-2.991	-3.204	-3.158	-2.805	-2.913	-3.348	-2.825	-0.960	-3.082	-3.226

Source: Eviews 6. z-statistics are reported in parenthesis while p-values are in square brackets.
*,** and + indicate coefficient significance at the 1%, 5% and 10% probability level, respectively.

Mean eq.: α_0 =constant; α_1 and α_2 =lagged values of y_t; ρ_1 and ρ_2 = D and $D(-1)$.

Variance eq.: α_0 =constant; α_1 =ARCH term; β =GARCH term; ϕ_1 =money supply; ϕ_2 =inflation; ϕ_3 =forex reserves; ϕ_4 =domestic interest rate; ϕ_5 =foreign interest rate; ϕ_6 =terms of trade; ϕ_7 =openness; ϕ_8 =copper output.

Table 3.6 GARCH- Real bilateral and effective kwacha exchange rates: 1964.01-2006.12

	KFF	KGBP	KDM	Krand	Kswiss	KUS$	Kyen	Kzim$	NEERzim$	NEER
Mean eq.										
α_0	0.021+ (1.91)	0.021** (2.53)	0.011 (1.24)	0.016* (2.77)	0.014** (2.00)	0.009+ (1.78)	0.004 (1.16)	0.013 (0.58)	0.019+ (1.75)	0.009 (1.03)
α_1	0.078 (0.71)	0.108 (1.06)	0.273* (2.55)	0.122 (1.21)	0.257* (2.69)	0.373* (4.61)	0.213* (3.52)	0.009 (0.06)	0.003* (0.02)	0.431* (3.76)
α_2				0.130 (1.24)	0.080 (0.96)	0.114 (1.36)		0.046 (0.31)		
Variance eq.										
α_0	0.010* (5.13)	0.009* (11.16)	0.010* (8.91)	0.009* (5.53)	0.010* (10.71)	0.006* (7.53)	0.001+ (1.91)	0.065* (5.25)	0.010* (4.53)	0.009* (7.64)
α_1	0.189* (3.34)	0.267* (2.74)	0.114** (2.31)	0.178** (2.46)	0.221* (3.24)	0.287* (3.94)	0.245* (4.44)	0.033 (0.85)	0.166* (2.69)	0.245* (2.86)
β	0.523* (5.52)	0.168** (2.12)	0.395* (6.84)	0.409* (5.97)	0.111 (1.20)	0.197* (2.60)	0.283* (3.50)	0.574* (5.87)	0.546* (8.85)	0.373* (8.37)
τ_1	-0.005* (-3.71)		-0.003* (-3.17)	-0.002* (-3.27)	-0.002* (-3.20)	-0.004* (-8.50)	-0.002 (-0.22)	-0.043* (-3.13)	-0.005* (-2.98)	-0.004* (-3.85)
τ_2		0.001 (1.22)					0.001* (3.38)	-0.030* (-2.91)	-0.002 (-1.37)	
τ_3		0.018* (6.84)	0.050* (5.86)	0.023* (5.71)	0.030* (9.33)	0.024* (9.89)	0.057* (6.92)		0.004+ (1.88)	0.047* (5.77)
ϕ_1				0.004 (0.37)			0.021* (5.00)			
ϕ_2			-0.122+ (-1.61)	-0.135+ (-1.71)	-0.169* (-2.77)	-0.106* (-3.91)	-0.023 (-0.94)		-0.061 (-0.67)	
ϕ_3				-0.003* (-2.64)	-0.003* (-3.24)			-0.020* (-2.66)		-0.107 (-1.12)
ϕ_4	-5.38^{-5+} (-1.67)	-6.34^{-5*} (-4.00)	-6.34^{-5*} (-8.28)	-2.84^{-5*} (-3.02)	-6.48^{-5*} (-72.27)	-4.10^{-5*} (-11.49)	-6.35^{-5} (-0.59)	-0.0002* (-3.61)	-7.36^{-5*} (-3.28)	-5.63^{-5*} (-10.11)
ϕ_5	-0.0001* (-2.76)	-0.0001* (-2.61)	-0.0001+ (-1.71)	-9.25^{-5**} (-2.05)	-5.98^{-5*} (-5.14)	-4.33^{-5*} (2.93)	-2.14^{-5*} (-3.14)			
ϕ_6	-0.035* (-4.45)	-0.031* (-4.68)	-0.027* (-3.70)	-0.026* (-4.94)	-0.013* (-3.39)	-0.002 (-0.38)	-0.006 (-1.55)	-0.116** (-2.31)	-0.036* (-2.88)	-0.028* (-3.41)
ϕ_7				-0.003 (-0.87)		0.002 (1.44)	0.003* (3.25)	-0.020 (-1.57)		
ϕ_8				-0.0001 (-1.02)		-6.13^{-5} (-1.03)	-9.86^{-5**} (-2.03)			-0.0002 (-1.32)
υ_t Q(6)	2.8934 [0.822]	2.9425 [0.816]	2.7880 [0.835]	3.5806 [0.733]	5.4150 [0.492]	3.9519 [0.683]	8.8810 [0.180]	1.3604 [0.968]	6.0789 [0.414]	6.6453 [0.355]
υ_t^2 Q(6)	0.6266 [0.996]	1.3554 [0.969]	3.9757 [0.680]	2.4352 [0.876]	1.4795 [0.961]	2.2664 [0.894]	2.9326 [0.817]	0.2768 [1.000]	1.7518 [0.941]	3.9095 [0.689]
J-B	9218.914 [0.000]	2238.992 [0.000]	1287.581 [0.000]	1478.382 [0.000]	1060.6 [0.000]	1848.386 [0.000]	366.754 [0.000]	31220.01 [0.000]	6257.268 [0.000]	2303.225 [0.000]
ARCH LM	0.239 [0.625]	0.577 [0.448]	3.443 [0.064]	0.523 [0.470]	0.741 [0.390]	1.338 [0.248]	0.803 [0.371]	0.026 [0.873]	1.118 [0.291]	3.607 [0.058]
Log L	314.2	389.5	385.8	393.3	372.7	462.0	482.6	44.7	321.0	389.8
AIC	-1.759	-2.187	-2.160	-2.174	-2.227	-2.582	-2.695	-0.190	-1.792	-2.183
SBC	-1.659	-2.076	-2.038	-1.997	-2.075	-2.427	-2.529	-0.056	-1.670	-2.061

Source: Eviews 6. z-statistics are reported in parenthesis while p-values are in square brackets.
*,** and + indicate coefficient significance at the 1%, 5% and 10% probability level, respectively.

Mean eq.: α_0 =constant; α_1 and α_2 =lagged values of y_t ; ρ_1 and $\rho_2 = D$ and $D(-1)$.

Variance eq.: α_0 =constant; α_1 =ARCH term; β =GARCH term; τ_1 , τ_2 and $\tau_3 = D1$, $D2$ and $D3$;

ϕ_1 =money supply; ϕ_2 =inflation; ϕ_3 =forex reserves; ϕ_4 =domestic interest rate; ϕ_5 =foreign interest rate; ϕ_6 =terms of trade; ϕ_7 =openness; ϕ_8 =copper output.

Table 3.7 TGARCH- Nominal bilateral and effective kwacha exchange rates: 1994.01-2006.12

	KFF	KGBP	KDM	Krand	Kswiss	KUS$	Kyen	Kzim$	NEERzim$	NEER
Mean eq.										
α_0	0.011 (1.47)	0.011* (2.71)	0.009** (2.23)	0.004 (0.72)	0.011* (3.00)	0.009* (3.12)	0.011** (2.21)	0.003 (0.11)	0.008 (1.20)	0.011+ (1.79)
α_1	0.198 (1.36)	0.205+ (1.84)	0.251* (2.59)	0.167 (1.28)	0.235** (2.33)	0.261* (2.60)	0.246** (2.19)	0.107 (0.76)	0.202 (1.49)	0.192 (1.36)
α_2	0.053 (0.41)									
ρ_1	0.039 (1.12)	0.033 (0.24)	0.017 (0.13)	0.049 (0.96)	0.030 (0.27)	0.096* (4.73)	0.011 (0.08)	-1.484* (-16.3)	0.042 (0.83)	0.040 (0.78)
ρ_2	-0.112** (-2.42)	-0.109 (-0.94)	-0.089 (-0.78)	-0.085 (-1.56)	-0.104 (-1.09)	-0.139 (-1.37)	-0.106 (-0.86)	0.122 (0.35)	-0.106+ (-1.82)	-0.107+ (-1.84)
Variance Eq.										
α_0	0.002** (2.09)	0.002* (2.56)	0.002* (3.44)	0.003* (4.20)	0.002* (2.82)	0.002** (2.49)	0.002 (1.59)	0.020** (2.40)	0.002+ (1.84)	0.002+ (1.81)
α_1	0.136 (0.89)	0.121 (0.89)	0.125 (0.93)	0.125 (0.74)	0.145 (1.01)	0.142 (0.86)	0.147 (0.68)	0.046 (0.37)	0.136 (0.71)	0.136 (0.68)
γ	0.030 (0.11)	0.010 (0.05)	0.018 (0.12)	0.034 (0.12)	0.032 (0.16)	0.042 (0.19)	0.048 (0.16)	0.044 (0.30)	0.034 (0.12)	0.037 (0.12)
β	0.562** (2.26)	0.511* (2.84)	0.517* (2.67)	0.561* (4.83)	0.555* (3.30)	0.529* (3.57)	0.592* (2.70)	0.582** (2.19)	0.560** (2.37)	0.561** (2.45)
ρ_1		0.005 (0.39)	0.005 (0.42)	0.003 (0.59)	0.014 (0.43)		0.009 (0.33)	0.008 (0.90)	0.001 (0.27)	0.001 (0.24)
ρ_2	0.001 (0.13)	0.003 (0.11)	0.004 (0.13)			0.014 (0.54)	-0.002 (-0.04)	-0.031 (-1.48)		
ϕ_1	-0.004 (-0.38)	-0.001 (-0.13)	-0.002 (-0.69)	-0.005 (-0.60)	-0.002 (-0.32)	-0.002 (-0.30)	-0.004 (-0.35)	-0.036 (-0.58)	-0.005 (-0.61)	-0.004 (-0.58)
ϕ_2	-0.024 (-0.46)	-0.021 (-1.22)	-0.031+ (-1.72)	-0.020 (-0.56)	-0.039+ (-1.85)	-0.018 (-0.88)	-0.008 (-0.15)		-0.020 (-0.54)	-0.020 (-0.47)
ϕ_3	-0.0004 (-0.45)	-0.0002 (-0.24)		-0.001 (-1.06)	-0.0003 (-0.41)	-0.001 (-1.42)	-0.001 (-1.39)	-0.014+ (-1.75)	-0.001 (-0.87)	-0.0005 (-0.83)
ϕ_4	-1.70^{-5} (-1.15)	-1.05^{-5}+ (-1.68)	-1.18^{-5}** (-1.99)	-1.57^{-5}* (-2.62)	-1.21^{-5}+ (-1.78)	-1.00^{-5}+ (-1.61)	-1.76^{-5} (-1.18)	-0.002+ (-1.76)	-1.44^{-5} (-1.31)	-1.34^{-5} (-1.38)
ϕ_5	-3.37^{-5} (-0.69)	-3.46^{-5} (-0.82)	-1.27^{-5} (-0.42)	-3.13^{-5} (-0.58)	-1.75^{-5} (-1.03)		-1.53^{-5} (-0.81)	2.06^{-5} (0.39)		
ϕ_6		-0.005 (-0.82)	-0.007+ (-1.74)	-0.010** (-1.98)	-0.004 (-0.54)	-0.007* (-3.24)	-0.010 (-0.93)	-0.033 (-0.45)	-0.007 (-0.89)	-0.006 (-0.84)
ϕ_7	-0.001 (-1.05)	-0.001 (-0.79)	-0.001 (-0.60)	-0.001 (-0.49)	-0.001 (-0.55)	-0.001 (-0.54)	-0.001 (-0.28)		-0.001 (-0.51)	-0.001 (-0.51)
ϕ_8	-0.0001 (-0.99)	-0.0001 (-2.41)	-0.000** (-2.05)	-7.71^{-5} (-0.90)	-0.0001* (-2.72)	-0.0001+ (-1.73)	-7.72^{-5} (-0.61)		-9.88^{-5} (-1.22)	-9.19^{-5} (-1.19)
υ_t Q(6)	1.9268 [0.859]	2.0750 [0.839]	4.2879 [0.509]	4.8843 [0.430]	4.954 [0.422]	3.7909 [0.580]	3.8128 [0.577]	3.1362 [0.679]	2.1898 [0.822]	1.1711 [0.948]
υ_t^2 Q(6)	7.2777 [0.201]	7.0480 [0.217]	5.5707 [0.350]	2.6672 [0.751]	4.696 [0.454]	5.7051 [0.336]	7.7899 [0.168]	0.5702 [0.989]	10.453 [0.063]	12.107 [0.033]
J-B	27.824 [0.000]	9.037 [0.011]	8.086 [0.018]	20.057 [0.000]	5.779 [0.056]	44.160 [0.000]	2.161 [0.339]	2347.170 [0.000]	28.291 [0.000]	36.100 [0.000]
ARCH LM	5.218 [0.024]	2.46e-05 [0.996]	0.164 [0.686]	0.082 [0.775]	0.275 [0.601]	1.031 [0.312]	3.282 [0.072]	0.435 [0.511]	5.917 [0.016]	5.481 [0.021]
Log L	242.8	275.8	262.7	248.9	264.6	288.3	253.3	89.4	264.5	270.6
AIC	-2.894	-3.305	-3.150	-2.974	-3.175	-3.491	-3.017	-0.954	-3.186	-3.264
SBC	-2.562	-2.953	-2.818	-2.641	-2.842	-3.178	-2.665	-0.660	-2.873	-2.952

Source: Eviews 6. z-statistics are reported in parenthesis while p-values are in square brackets.

*,** and + indicate coefficient significance at the 1%, 5% and 10% probability level, respectively.

Mean eq.: α_0 =constant; α_1 and α_2 =lagged values of y_t ; ρ_1 and ρ_2 = D and $D(-1)$.**Variance eq.:** α_0 =constant; α_1 =ARCH term; γ =asymmetry term; β =GARCH term; ϕ_1 =money supply; ϕ_2 =inflation; ϕ_3 =forex reserves; ϕ_4 =domestic interest rate; ϕ_5 =foreign interest rate; ϕ_6 =terms of trade; ϕ_7 =openness; ϕ_8 =copper output.

Table 3.8 TGARCH- Real bilateral and effective kwacha exchange rates: 1964.01-2006.12

	KFF	KGBP	KDM	Krand	Kswiss	KUS$	Kyen	Kzim$	NEERzim$	NEER
Mean eq.										
α_0	0.009 (1.22)	0.013* (3.31)	0.012 (1.27)	0.022+ (1.80)	0.012+ (1.67)	0.004 (0.55)	0.011+ (1.91)	-0.004 (-0.42)	0.018+ (1.81)	0.007 (0.73)
α_1	0.232** (2.08)	0.363* (6.26)	0.221+ (1.68)	-0.037 (-0.34)	0.253** (2.29)	0.113 (0.88)	0.024 (0.23)	0.136 (0.95)	0.002 (0.01)	0.018 (0.13)
α_2				-0.073 (-0.56)	0.083 (0.94)	0.059 (0.55)		0.051 (0.41)		
Variance Eq.										
α_0	0.007* (5.64)	0.003* (3.19)	0.010* (8.15)	0.010* (3.17)	0.010* (6.36)	0.010* (5.41)	0.009* (63.79)	0.010* (4.75)	0.010* (4.86)	0.009* (6.53)
α_1	0.230* (3.00)	0.483* (3.88)	0.139** (2.40)	0.156+ (1.84)	0.195* (2.90)	0.156+ (2.42)	0.144+ (1.86)	0.162 (1.59)	0.172+ (1.64)	0.215+ (1.76)
γ	0.051 (0.25)	0.041 (0.19)	0.062 (0.38)	0.068 (0.51)	0.148 (0.54)	0.061 (0.29)	0.049 (0.29)	0.131 (0.41)	0.104 (0.61)	0.121 (0.56)
β	0.217+ (1.94)	0.051 (1.38)	0.393* (9.1)	0.566* (5.20)	0.135 (1.41)	0.278* (2.71)	0.462* (8.18)	0.448* (5.82)	0.547* (9.36)	0.417* (5.54)
τ_1	-0.003 (-1.47)	-0.001 (-0.45)	-0.005* (-3.62)	-0.003 (-1.12)	-0.002 (-1.27)	-0.007* (-4.85)	-0.004* (-7.22)	-0.006* (-5.09)	-0.005* (-3.41)	-0.003* (-2.94)
τ_2	0.001 (0.94)	0.001+ (1.93)	-0.001 (-0.76)	-0.001 (-0.66)	0.001 (0.73)	-0.001 (-0.48)	0.001 (0.99)		-0.002 (-1.29)	-0.001 (-0.60)
τ_3	0.019* (8.76)	0.086* (4.78)	0.025* (6.92)	0.001 (0.27)	0.029* (7.42)	0.022* (4.92)	0.037* (10.05)	0.038* (5.63)	0.008* (2.62)	0.014* (4.87)
ϕ_1		0.010 (1.46)		-0.006 (-0.23)	0.002 (0.19)			-0.011 (-0.66)		
ϕ_2		-0.045 (-1.16)	-0.083** (-2.44)	-0.064 (-0.43)	-0.180* (-4.64)	-0.046 (-0.46)		0.019 (0.14)	-0.058 (-0.48)	-0.127+ (-1.71)
ϕ_3		-0.001** (-2.43)			-0.003* (-3.08)	-0.002 (-0.62)	-0.004* (-16.15)	-0.001 (-0.40)		
ϕ_4	-2.93^{-5*} (-7.66)	-1.28^{-5} (-0.84)	-6.26^{-5*} (-8.27)	-6.23^{-5*} (-5.75)	-6.93^{-5*} (-8.64)	-6.84^{-5*} (-4.51)	-3.30^{-5} (-1.28)	-6.29^{-5} (-1.65)	-6.66^{-5*} (-5.52)	-6.16^{-5*} (-5.55)
ϕ_5	-0.0001* (-4.61)	-4.05^{-5} (-1.56)	-0.000** (-2.15)	-8.61^{-5} (-0.74)	-6.08^{-5*} (-3.51)	-8.95^{-5*} (-6.03)	-8.45^{-6*} (-3.82)	-8.9^{-6**} (-2.48)		
ϕ_6	-0.012 (-1.24)	-0.010** (-2.43)	-0.025* (-4.36)	-0.030 (-1.40)	-0.014+ (-1.89)		-0.011** (-2.15)	-0.011 (-1.07)	-0.034* (-4.24)	-0.029* (-5.44)
ϕ_7		0.003+ (1.88)		-0.003 (-0.41)		-0.001 (-0.49)	-0.004 (-1.32)		-0.002 (-0.40)	
ϕ_8	-4.92^{-5} (-0.26)	7.21^{-5} (0.93)				-9.49^{-5} (-0.88)	-0.0002* (-3.98)	-0.0003* (-3.74)	-0.0001 (-0.84)	-0.0001 (-1.18)
υ_t Q(6)	3.1598 [0.789]	4.9156 [0.555]	2.1267 [0.908]	12.455 [0.053]	5.7047 [0.457]	6.7250 [0.347]	2.1662 [0.826]	5.1865 [0.520]	8.7511 [0.188]	9.2702 [0.159]
υ_t^2 Q(6)	1.1337 [0.980]	0.5374 [0.997]	2.0777 [0.912]	9.3231 [0.156]	1.4594 [0.962]	3.3421 [0.765]	4.3615 [0.499]	1.7512 [0.941]	0.8210 [0.991]	0.6604 [0.995]
J-B	1650.4 [0.000]	786.073 [0.000]	1828.282 [0.000]	2385.494 [0.000]	1084.181 [0.000]	2319.714 [0.000]	1105.109 [0.000]	1570.396 [0.000]	5089.323 [0.000]	3565.428 [0.000]
ARCH LM	0.529 [0.468]	0.025 [0.875]	1.660 [0.199]	1.954 [0.163]	0.849 [0.358]	2.335 [0.127]	0.312 [0.577]	1.533 [0.217]	0.493 [0.4883]	0.288 [0.592]
Log L	405.7	488.7	376.8	316.4	373.2	401.6	385.8	360.1	332.5	381.7
AIC	-2.263	-2.719	-2.097	-1.731	-2.212	-2.223	-2.137	-1.983	-1.841	-2.125
SBC	-2.119	-2.530	-1.953	-1.554	-2.025	-2.045	-1.971	-1.806	-1.685	-1.981

Source: Eviews 6. z-statistics are reported in parenthesis while p-values are in square brackets.
*,** and + indicate coefficient significance at the 1%, 5% and 10% probability level, respectively.

Mean eq.: α_0 =constant; α_1 and α_2 =lagged values of y_t; ρ_1 and ρ_2 = D and $D(-1)$. **Variance eq.:** α_0 =constant; α_1 =ARCH term; γ =asymmetry term; β =GARCH term; τ_1, τ_2 and τ_3 = $D1$, $D2$ and $D3$; ϕ_1 =money supply; ϕ_2 =inflation; ϕ_3 =forex reserves; ϕ_4 =domestic interest rate; ϕ_5 =foreign interest rate; ϕ_6 =terms of trade; ϕ_7 =openness; ϕ_8 =copper output.

Table 3.9 EGARCH- Nominal bilateral and effective kwacha exchange rates: 1994.01-2006.12

	KFF	KGBP	KDM	Krand	Kswiss	KUS$	Kyen	Kzim$	NEERzim$	NEER
Mean eq.										
α_0	0.006 (1.38)	0.008** (2.49)	0.006+ (1.96)	0.001 (0.25)	0.007+ (1.75)	0.005* (3.33)	0.006+ (1.74)	-0.004 (-1.07)	0.003 (1.10)	0.003 (1.19)
α_1	0.340* (3.53)	0.316* (3.11)	0.423* (5.36)	0.310* (3.63)	0.384* (4.30)	0.461* (8.51)	0.325* (4.80)	0.163* (2.96)	0.373* (5.14)	0.369* (4.88)
α_2	-0.053 (-0.68)									
ρ_1	0.111* (3.94)	0.141* (6.85)	0.218 (0.78)	0.141** (2.43)	0.097* (3.39)	0.217 (0.67)	0.089* (2.38)	-1.210* (-3.53)	0.226 (0.67)	0.120* (3.35)
ρ_2	-0.171* (-3.71)	-0.201* (-4.51)	-0.378 (-1.09)	-0.191* (-3.36)	-0.156* (-3.02)	-0.450+ (-1.60)	-0.197* (-4.16)	0.179 (1.37)	-0.403 (-1.32)	-0.187* (-3.47)
Variance Eq.										
α_0	-3.362* (-2.89)	-3.772* (-4.02)	-3.109* (-2.56)	-2.439* (-4.89)	-2.951** (-2.35)	-2.532* (-4.87)	-2.910* (-3.04)	-2.091* (-6.00)	-1.933* (-4.07)	-2.533* (-4.14)
α	0.515* (2.87)	0.666* (4.10)	0.393** (2.00)	0.412** (2.01)	0.610* (2.78)	0.207 (1.37)	0.460* (3.41)	0.556* (4.69)	0.356** (2.32)	0.575* (3.19)
γ	-0.077 (-0.54)	-0.153 (-0.88)	-0.011 (-0.09)	-2.87** (-2.09)	-0.061 (-0.41)	0.189+ (1.81)	-0.142 (-1.24)	-0.317* (-3.44)	-0.024 (-0.25)	-0.090 (-0.76)
β	0.598* (3.72)	0.568* (4.77)	0.599** (3.56)	0.674* (8.95)	0.631* (3.71)	0.736* (14.63)	0.654* (5.05)	0.772* (20.52)	0.762* (15.91)	0.721* (9.97)
ρ_1								4.995* (4.03)		
ρ_2			2.447 (0.75)			2.798 (1.12)		-2.381** (-2.14)	1.823 (0.87)	
ϕ_1	5.872 (1.57)	9.971** (2.18)	5.721 (1.31)	7.446+ (1.94)	5.895 (1.44)	4.050 (1.33)	4.769 (1.17)	-5.238 (-1.37)	5.477 (1.55)	8.135** (2.00)
ϕ_2	3.991 (0.32)							24.106** (2.17)	6.696 (0.54)	
ϕ_3								1.315* (4.33)		
ϕ_4		-0.010 (-0.99)	-0.004 (-0.45)	-0.010+ (-1.75)	-0.005 (-0.55)				-0.005 (-1.01)	-0.006 (-1.12)
ϕ_5		0.048 (1.54)	0.007 (0.51)			0.073* (3.27)				
ϕ_6			-1.357 (-0.43)	-4.345** (-2.05)	-2.410 (-0.68)			-1.562 (-1.03)	-2.699 (-1.24)	-2.560 (-1.14)
ϕ_7	2.597** (2.47)		1.724+ (1.85)	2.783* (3.17)	2.096** (2.11)	2.710* (3.69)	3.809* (3.80)	4.348* (5.74)	2.654* (3.23)	3.717* (4.59)
ϕ_8	-0.073 (-1.22)	-0.073 (-1.33)	-0.102** (-2.02)	-0.134* (-2.88)	-0.100+ (-1.90)	-0.182* (-5.18)	-0.133* (-2.89)	-0.124* (-3.78)	-0.167* (-4.21)	-0.182* (-3.86)
υ_t Q(6)	0.8576 [0.973]	2.1312 [0.831]	7.1501 [0.210]	2.7457 [0.739]	1.6212 [0.899]	3.1709 [0.674]	3.5072 [0.622]	5.7262 [0.334]	3.6820 [0.596]	1.3625 [0.928]
υ_t^2 Q(6)	2.7758 [0.734]	1.6245 [0.898]	9.7194 [0.084]	1.8834 [0.865]	4.1753 [0.524]	7.5997 [0.180]	7.7107 [0.173]	2.5724 [0.766]	4.5991 [0.467]	5.6259 [0.344]
J-B	1.184 [0.553]	10.023 [0.007]	1.234 [0.540]	0.835 [0.659]	1.262 [0.532]	22.301 [0.000]	1.124 [0.570]	45.323 [0.000]	2.736 [0.255]	0.962 [0.618]
ARCH LM	0.056 [0.813]	0.388 [0.534]	0.248 [0.619]	0.442 [0.507]	0.002 [0.961]	0.005 [0.943]	1.073 [0.302]	0.251 [0.617]	0.003 [0.957]	0.317 [0.574]
Log L	265.5	282.8	280.4	270.9	270.4	325.9	264.5	208.4	296.4	303.0
AIC	-3.237	-3.471	-3.403	-3.306	-3.300	-4.012	-3.250	-2.467	-3.608	-3.718
SBC	-2.983	-3.237	-3.110	-3.052	-3.046	-3.757	-3.035	-2.154	-3.315	-3.464

Source: Eviews 6. z-statistics are reported in parenthesis while p-values are in square brackets.

*,** and + indicate coefficient significance at the 1%, 5% and 10% probability level, respectively.

Mean eq.: α_0 =constant; α_1 and α_2 =lagged values of y_t; ρ_1 and ρ_2 = D and $D(-1)$. **Variance eq.:** α_0 =constant; α =abs(resid(-1)/@sqrt(GARCH(-1))) term; γ =asymmetry term; β =GARCH term; ϕ_1 =money supply; ϕ_2 =inflation; ϕ_3 =forex reserves; ϕ_4 =domestic interest rate; ϕ_5 =foreign interest rate; ϕ_6 =terms of trade; ϕ_7 =openness; ϕ_8 =copper output.

Table 3.10 EGARCH- Real bilateral and effective kwacha exchange rates: 1964.01-2006.12

	KFF	KGBP	KDM	Krand	Kswiss	KUS$	Kyen	Kzim$	NEERzim$	NEER
Mean eq.										
α_0	0.002 (1.39)	0.006** (2.50)	0.003 (1.45)	0.003** (2.26)	0.003 (1.19)	0.006* (3.20)	0.0004 (0.22)	0.005 (1.55)	0.003+ (1.64)	0.001 (0.75)
α_1	0.320* (5.97)	0.225* (4.20)	0.326* (6.93)	0.192* (3.26)	0.403* (6.23)	0.435* (8.01)	0.370* (8.49)	0.129+ (1.82)	0.366* (7.49)	0.376* (8.83)
α_2				0.031 (0.60)	0.084 (1.53)	-0.008 (-0.16)		-0.041 (-0.57)		
Variance Eq.										
α_0	-4.310* (-12.85)	-3.826* (-11.53)	-5.139* (-14.02)	-4.752* (-17.08)	-5.113* (-11.18)	-4.975* (-14.69)	-4.609* (-14.42)	-2.143* (-10.79)	-4.919* (-12.04)	-5.481* (-13.88)
α	0.896* (8.41)	0.801* (7.96)	0.694* (8.11)	0.767* (9.98)	0.820* (7.66)	1.030* (9.27)	1.203* (13.12)	0.668* (6.46)	1.055* (10.00)	0.956* (8.37)
γ	**0.007** **(0.10)**	-0.432* (-6.35)	-0.175* (-2.78)	-0.241* (-4.27)	-0.004 (-0.05)	-0.273* (-3.23)	-0.172** (-2.50)	-0.057 (-0.86)	-0.313* (-3.84)	-0.229* (-2.96)
β	0.452* (11.71)	0.612* (15.82)	0.421* (10.06)	0.473* (14.61)	0.428* (6.95)	0.507* (12.08)	0.430* (10.69)	0.679* (36.65)	0.436* (8.34)	0.426* (9.02)
τ_1	-0.275** (-2.34)		-0.286 (-1.23)	-0.340** (-2.39)	0.479 (1.30)		-0.528* (-3.47)	-0.538* (-3.16)	0.896* (2.89)	0.819** (2.41)
τ_2	0.159 (1.25)			0.201+ (1.89)	-0.009 (-0.06)	0.197+ (1.92)	-0.218+ (-1.71)	-0.919* (-10.99)		0.222+ (1.70)
τ_3	1.191* (3.58)	0.747* (3.41)	0.737+ (1.85)	1.206* (2.67)	0.882** (1.97)	1.041* (2.92)	0.893* (3.02)	-0.614+ (-1.93)	1.002* (3.29)	1.106* (2.83)
ϕ_1	9.853* (6.29)	13.097* (9.26)	20.820* (14.78)	18.250* (13.02)	17.646* (9.01)	15.821* (10.19)	12.256* (8.00)	10.423* (7.27)	19.448* (16.42)	22.684* (15.25)
ϕ_2	-6.721 (-0.84)	-11.555 (-1.12)			-7.935 (-0.74)		-25.502* (-2.76)	98.910* (9.65)	-23.619+ (-1.85)	-25.06** (-1.96)
ϕ_3	0.990* (4.47)		0.496+ (1.87)		0.195 (0.66)	0.406+ (1.62)	1.080* (4.61)	-0.386** (-2.25)		
ϕ_4		0.005 (1.23)			-0.003 (-0.70)	-0.005 (-1.08)		-0.007** (-2.02)	-0.007 (-1.27)	-0.005 (-1.11)
ϕ_5	-0.031* (-4.69)	-0.008 (-1.16)	-0.019** (-2.31)	-0.009 (-1.54)			-0.001* (-2.74)			
ϕ_6	-2.828+ (-1.94)			-0.486 (-0.50)	-1.207 (-0.82)	-1.326 (-1.12)	-3.587* (-3.35)	-6.416* (-6.04)	-6.193* (-4.59)	-4.204* (-2.80)
ϕ_7	1.384* (3.45)	2.634* (7.83)	2.220* (5.37)	1.816* (4.77)	2.824* (6.21)	2.827* (7.77)	1.396* (3.74)	0.669 (1.59)	1.962* (5.41)	2.816* (6.31)
ϕ_8	-0.005 (-0.23)	0.023+ (1.62)			0.001 (0.05)			-0.051* (-3.86)	0.057* (3.19)	0.034 (1.50)
υ_t Q(6)	5.3222 [0.503]	3.2712 [0.774]	1.3057 [0.971]	2.4436 [0.875]	6.4825 [0.371]	2.3587 [0.884]	3.958 [0.682]	3.0587 [0.801]	2.7898 [0.835]	0.9849 [0.986]
υ_t^2 Q(6)	4.1286 [0.659]	3.3093 [0.769]	1.2463 [0.975]	2.2621 [0.894]	1.8582 [0.932]	2.1271 [0.908]	4.3863 [0.625]	0.7232 [0.994]	2.7281 [0.842]	1.5636 [0.955]
J-B	180.852 [0.000]	251.488 [0.000]	395.795 [0.000]	329.082 [0.000]	135.122 [0.000]	590.146 [0.000]	177.103 [0.000]	5119.834 [0.000]	591.439 [0.000]	323.302 [0.000]
ARCH LM	0.274 [0.601]	0.015 [0.904]	0.014 [0.908]	0.004 [0.951]	0.002 [0.967]	0.282 [0.596]	0.141 [0.708]	0.103 [0.749]	0.277 [0.599]	0.101 [0.751]
Log L	660.4	520.0	558.9	672.1	494.4	541.7	687.3	201.2	514.8	556.1
AIC	-2.990	-2.922	-2.901	-3.054	-2.752	-3.042	-3.120	-1.068	-2.895	-3.119
SBC	-2.839	-2.778	-2.776	-2.922	-2.563	-2.886	-2.978	-0.879	-2.739	-2.952

Source: Eviews 6. z-statistics are reported in parenthesis while p-values are in square brackets.

*,** and + indicate coefficient significance at the 1%, 5% and 10% probability level, respectively. **Mean eq.:** α_0 =constant; α_1 and α_2 =lagged values of y_t; ρ_1 and ρ_2 = D and $D(-1)$. **Variance eq.:** α_0 =constant; α =abs(resid(-1)/@sqrt(GARCH(-1))) term; γ =asymmetry term; β =GARCH term; τ_1, τ_2 and τ_3 = $D1$, $D2$ and $D3$; ϕ_1 =money supply; ϕ_2 =inflation; ϕ_3 =forex reserves; ϕ_4 =domestic interest rate; ϕ_5 =foreign interest rate; ϕ_6 =terms of trade; ϕ_7 =openness; ϕ_8 =copper output.

3.4.4 Principal Components Analysis

3.4.4.1 Motivation for using PCA

Underlying pattern(s) linking volatility in the eight kwacha bilateral exchange rates generated in the preceding section can be identified. The common pattern in these volatility series is governed by factors which, among others, include country-specific ones (Bauwens et al. 2006) as specified below

$$erv_{ijt} = f(zm_i, oc_j) \tag{20}$$

where erv_{ijt} is a measure of volatility in the bilateral exchange rate between currency i (kwacha) and currency j (Zambia's trading partners such that $j = 1,2,3,...,8$ as outlined in sub-section 3.4.3.1); and zm_i and oc_j refer to influences on erv_{ijt} emanating from Zambia and trading partner countries, respectively. For instance a devaluation of the kwacha affects all the kwacha bilateral exchange rates whereas policy changes or related events occurring specific to one of the foreign currencies may not necessarily affect other kwacha exchange rates, at least directly.

Equation 20 represents 24 equations (three for each of the eight bilateral exchange rates split into real and nominal bilateral exchange rates) relating to the eight kwacha bilateral exchange rate volatility series generated from the three GARCH models. These series are transformed into a new set of uncorrelated GARCH series called principal components (PCs) arranged in a descending order of importance in order to detect a common structure in conditional volatility series[53]. Notwithstanding the optimal GARCH model chosen in the previous section, all three GARCH models

[53] The PCs summarise volatility in kwacha bilateral exchange rates.

are used in PCA as each GARCH model is deemed to contain information about the underlying volatility in each exchange rate.

3.4.4.2 Brief Description of PCA

In general, PCA describes the underlying pattern of relationships that exists in a set of random series or data so that data with high dimensions can be reduced to dimensions that reflect the original data without loss of information. Specifically, PCA is concerned about the variance structure of a set of observed variables generated through a linear combination of the variables (Johnson and Wichern, 2007).

For a given dataset, through PCA, eigenvalues (variance) and eigenvectors (components)[54] are computed using either correlation or covariance matrices[55]. Eigenvectors represent the main patterns present in the dataset or how well data are summarised. Each PC represents a particular expression profile that is commonly found in the data. PCs are arranged in decreasing order of importance such that PCs with larger variances are desirable as they contain more information about the original dataset. Eigenvalues quantify the extent to which a particular component represents the data or the level of explained variance as a proportion of total variance such that the higher the value of the eigenvalue of the component the more important or representative the component is of the dataset.

PCs accounting for a large proportion of the total variance of the original dataset are chosen and components of less significance (low variance) can be ignored. However, the criteria for eliminating PCs with insignificant information tend to be ad

[54] The number of eigenvectors equals the number of variables in the dataset. Similarly, the number of eigenvalues corresponds to the number of variables with an average of 1.

[55] The correlation matrix is used when variables in the dataset are measured in different units whereas a covariance matrix is used in instances when variables are of the same scale (Kool and Koedijk, 1997; and Mazlum et al. 1999). If the variables used to generate principal components are measured differently, then a variable with a larger variance due to having a different scale of measurement from others dominates the first principal component (which describes the data well) as the principal components depend on the scaling of variables. In this chapter, correlation matrix is used as the conditional volatility series are of different dimensions.

hoc (Mazlum et al. 1999; and Klaassen, 1999). The practice in the literature is to discard PCs whose corresponding eigenvalues are less than 1 or PCs with variances larger than the average variance of the variables under study are retained. In line with Nellis (1982), the first criterion is employed in this chapter in choosing significant PCs.

Thus, let Z be a vector of random series $(z_1, z_2, ..., z_n)$ representing the original data

$$Z = \begin{pmatrix} z_1 \\ z_2 \\ z_3 \\ .. \\ .. \\ .. \\ z_n \end{pmatrix} \qquad (21)$$

where n is the number of elements constituting Z. Z has mean zero $(\mu_z = 0)$. Either a covariance matrix for Z denoted $\sum_z$ or correlation matrix denoted ρ_z can be constructed using elements of Z. The computed correlations reveal the interdependence between the elements of Z such that a high degree of interdependence given by coefficients close to 1 indicates the extent of $Z's$ multicollinearity.

To obtain PCs of Z, orthonormal eigenvectors[56] denoted v_i of $\sum_z$ are calculated and arranged as columns of a matrix[57]. The corresponding eigenvalues, λ_i [58], are also calculated. Since eigenvectors describe the modes of fluctuation of the random

[56] Eigenvectors are orthogonal and of unit length.
[57] The covariance matrix is used to illustrate the point.
[58] Eigenvalues are used to select significant principal components.

vector Z, Z is a linear combination of n $D_i s$ where $v_i s$ are the loadings or weights of each D_i

$$Z = D_1 v_1 + D_2 v_2 + D_3 v_3 + \ldots.. + D_n v_n = vD \tag{22}$$

where D_i is defined as

$$D_i = v_i^{'}(Z - \mu_Z), \forall_i = 0,1,2,\ldots n \tag{23}$$

$D_i s$ are PCs of Z, which are random variables that define the contribution of each v_i to Z. $D_i s$ are uncorrelated linear combinations of Z with variances equal to the eigenvalues of their corresponding eigenvectors. The statistical properties of vector D are that its mean $\mu_D = 0$ and its covariance matrix is

$$\sum_D = \begin{pmatrix} \lambda_1 & 0 & 0 & .. & .. & .. & 0 \\ 0 & \lambda_2 & 0 & .. & .. & .. & .. \\ 0 & 0 & \lambda_3 & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. & .. & 0 \\ 0 & 0 & 0 & .. & .. & .. & \lambda_n \end{pmatrix} \tag{24}$$

Each $v_i^{'}$ is selected to maximise the variance of each D_i by setting each $v_i^{'}$ equal to the normalised first eigenvector of $\sum_z$. Hence, the number of D_i will be equal to n corresponding to a normalised $v_i^{'}$ of $\sum_z$ such that

$$Z = D_1 v_1 + D_2 v_2 + D_3 v_3 + \ldots.. + D_n v_n = vD + \mu_z \qquad (25)$$

All D_i are completely unrelated to each other, with each D_i capturing additional dimensions in the data while explaining smaller and smaller proportions of the variations in the original data[59]. The proportion of the total variation in Z accounted for by each D is given by $\frac{\lambda_i}{n}$. $D_i s$ are ordered according to the values of λ_i with the highest first: $\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq \ldots \geq \lambda_n \geq 0$. For instance D_1 explains the largest possible amount of variation in the original data, Z, subject to the constraint that the sum of the squared weights (loadings) is equal to 1; i.e. $\sum v_{11}^2 + v_{12}^2 + v_{13}^2 + \ldots\ldots + v_{1n}^2 = 1$. The next, D_i, D_2, explains additional but less variation than D_1 subject to the same constraint. Nellis (1982) proposes that $D_i s$ with eigenvalues greater than 1 describe more of the data and should therefore be retained in PCA. In this way insignificant $D_i s$ whose contribution to the vector Z is trivial can be discarded. Hence, Z can be approximated by the most significant $D_i s$ for instance the first four whose contribution is significant such that equation 25 reduces to

$$\tilde{Z} = D_1 v_1 + D_2 v_2 + D_3 v_3 + D_4 v_4 \qquad (26)$$

---

[59] The first principal component is the single best summary of the linear relationship exhibited in the data while the second principal component is the linear combination of variables that accounts for the most residual variance after the effects of D_1 is removed from the data (Nellis, 1982). The process continues with subsequent $D_i s$ until the variance in the data is exhausted.

where $\tilde{Z}$ is the approximate of Z with $\mu_{\tilde{z}} = 0$ while $\sum_{\tilde{z}}$ is derived from $\tilde{Z}$ and $\sum_D$. $\sum_z$ and $\sum_{\tilde{z}}$ should look similar. If the degree of correlation among the original variables in the data is high, fewer components are required to capture common information.

3.4.4.3 PCA Results

Cross-currency correlations among conditional volatilities in the eight kwacha bilateral exchange rates are very high (not reported to conserve space). They average about 0.8, indicating a very close positive relationship. The only exception to this pattern is the zim$ which differs markedly to the rest. It has a low and negative coefficient value (0.1 on average). This provides more evidence of the zim$'s peculiarity.

While the 24 PCs generated from the GARCH volatility series reflect factors governing the underlying variance structure of the kwacha bilateral exchange rates as shown in equation 20, it is imperative to choose PCs with significant information content about the original volatility series. Thus, based on the criterion adopted in sub-section 3.4.4.2, only the first four eigenvalues shown in table 3.11 for nominal conditional variance estimates (PCAN) exceed 1 and account for most of the variability (about 89 percent) of the total variation in nominal exchange rate volatility. Similarly, only the first three eigenvalues exceed 1 with a cumulative proportion of about 87 percent in the case of the real conditional variance estimates (PCAR). Hence conditional volatility in real and nominal bilateral exchange rates can be described by PC1-3 and PC1-4, respectively. However, PC1 accounts for the bulk (77 percent and 72 percent) of the variation in conditional variance captured by PC1-3 and PC1-4 in PCAN and PCAR respectively and mimics the original conditional variance estimates in figures 3.3 and

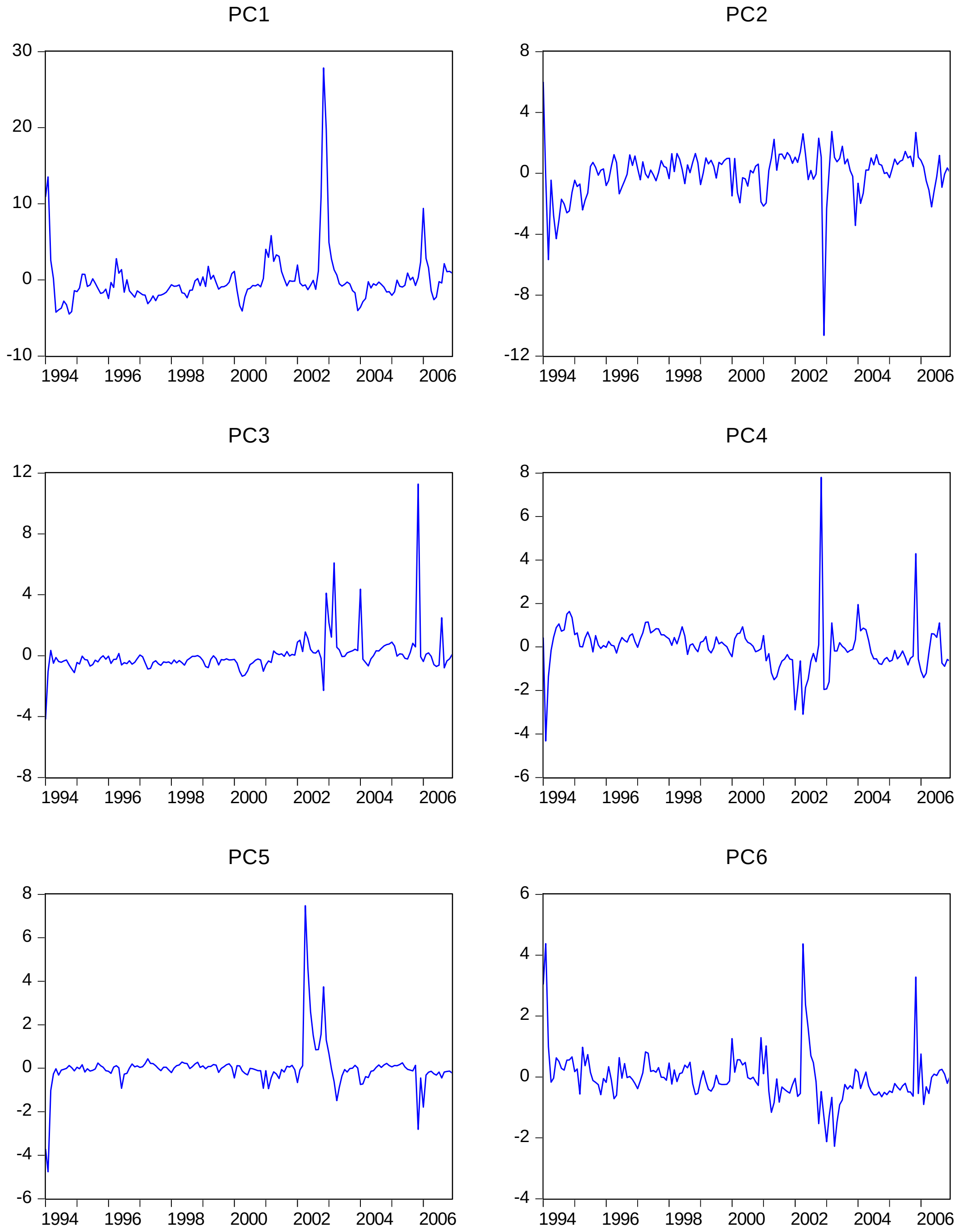
3.4. Consequently, PC1 (hereinafter denoted GARCH-PCA) is recommended for use in subsequent empirical work as an alternative measure of exchange rate volatility (more details follow). In contrast, as can be seen from table 3.12, the interpretation of the rest of the PCs is not clear-cut. This is confirmed by their modes of fluctuations depicted in figures 3.5 and 3.6 that vary considerably from the behaviour of the original exchange rate volatility series shown in figures 3.3 and 3.4.

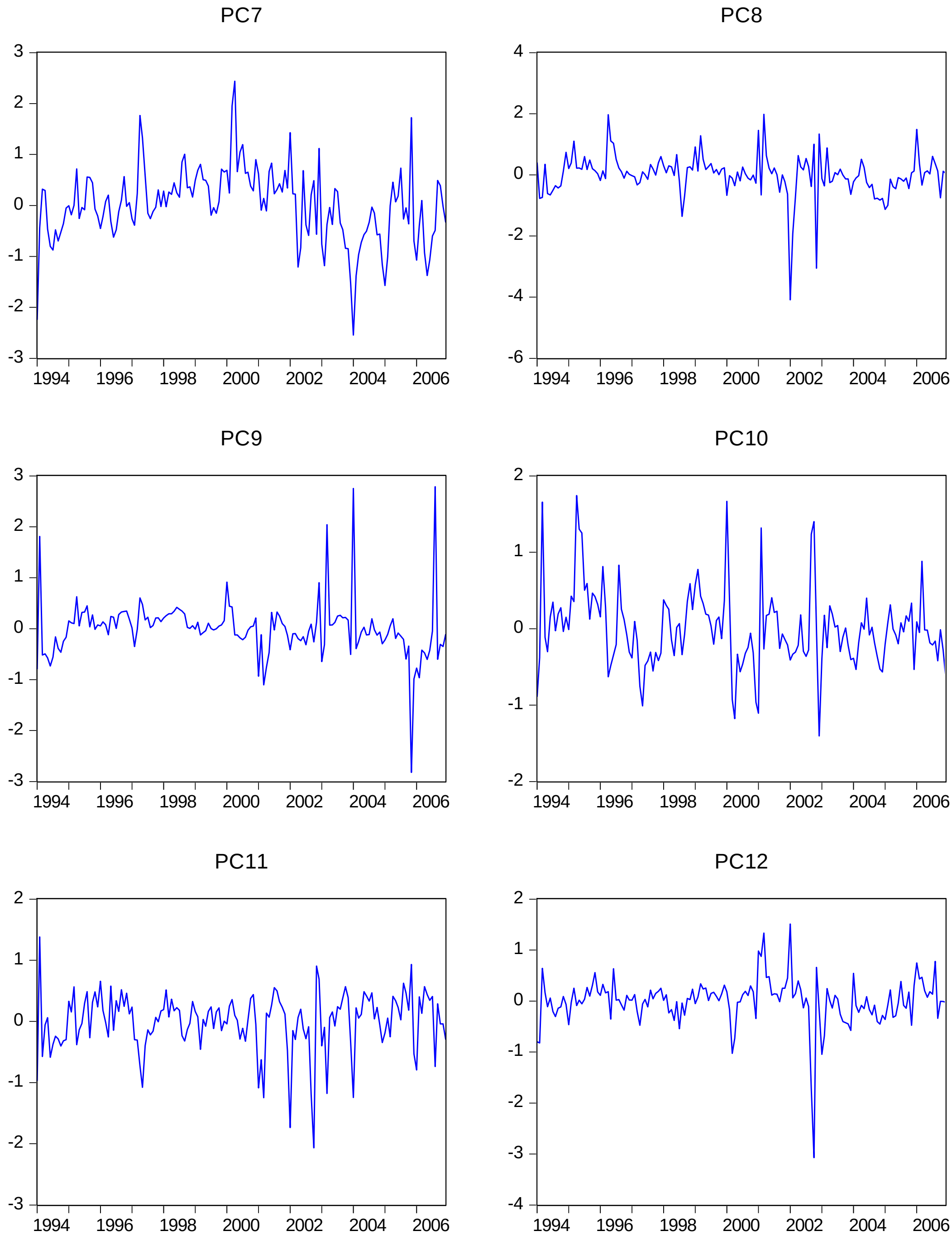
Table 3.11 Eigenvalues (sum=24, average=1)

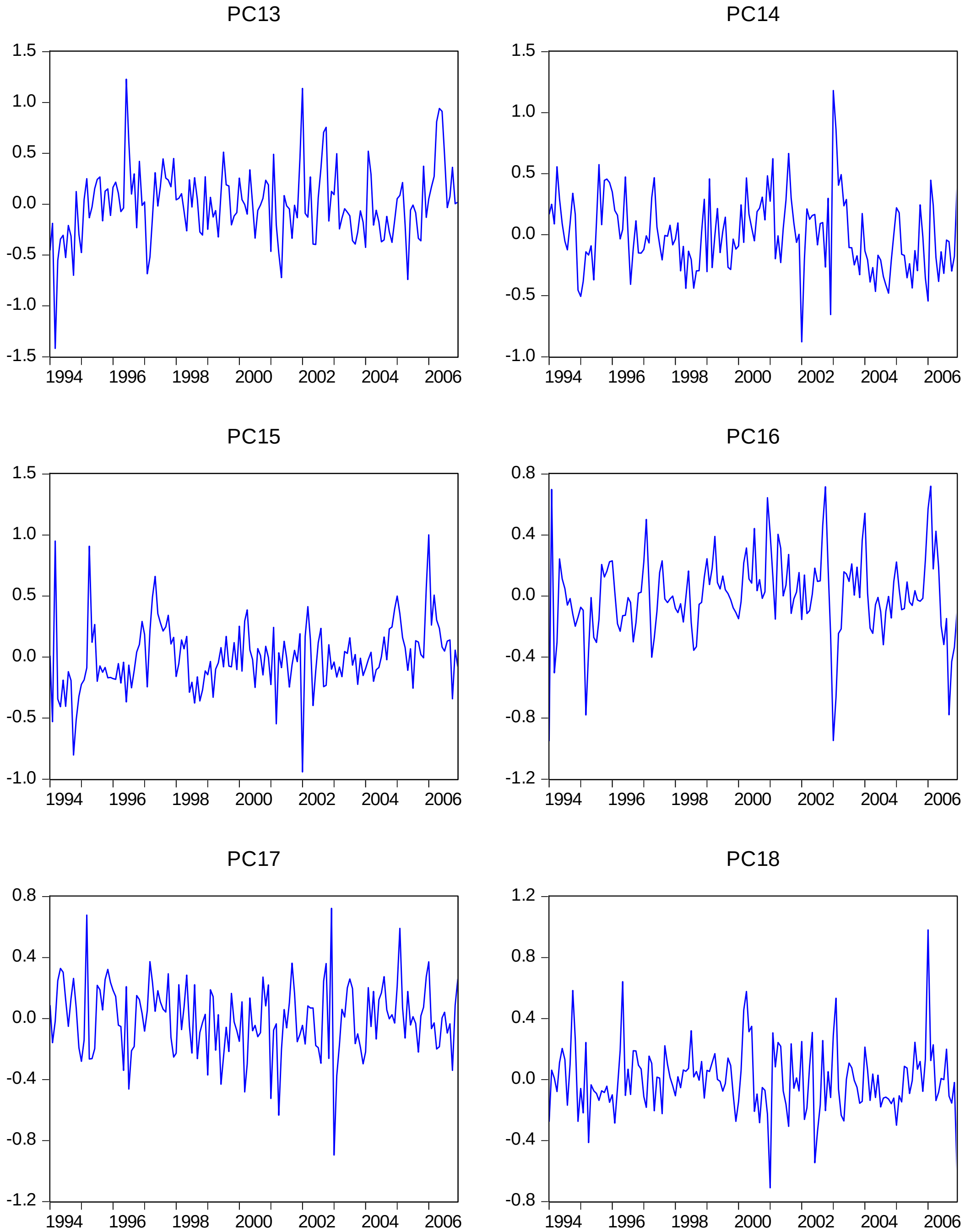
	PCAN					PCAR		
Number	value	proportion	Cumulative proportion		Number	value	proportion	Cumulative proportion
1	16.21	0.68	0.68		1	15.17	0.63	0.63
2	2.55	0.11	0.78		2	3.70	0.15	0.79
3	1.38	0.06	0.84		3	1.97	0.08	0.87
4	1.10	0.05	0.89		4	0.90	0.04	0.91
5	0.64	0.03	0.91		5	0.70	0.03	0.94
6	0.54	0.02	0.93		6	0.61	0.03	0.96
7	0.39	0.02	0.95		7	0.33	0.1	0.97
8	0.30	0.01	0.96		8	0.22	0.01	0.98
9	0.26	0.01	0.97		9	0.18	0.01	0.99
10	0.17	0.01	0.98		10	0.09	0.00	0.99
11	0.13	0.01	0.99		11	0.03	0.00	0.99
12	0.09	0.00	0.99		12	0.02	0.00	0.99
13	0.07	0.00	0.99		13	0.02	0.00	0.99
14	0.05	0.00	0.99		14	0.02	0.00	0.99
15	0.03	0.00	0.99		15	0.01	0.00	0.99
16	0.02	0.00	0.99		16	0.01	0.00	0.99
17	0.02	0.00	0.99		17	0.01	0.00	0.99
18	0.02	0.00	0.99		18	0.01	0.00	0.99
19	0.01	0.00	0.99		19	0.01	0.00	0.99
20	0.01	0.00	0.99		20	0.00	0.00	0.99
21	0.01	0.00	0.99		21	0.00	0.00	0.99
22	0.00	0.00	0.99		22	0.00	0.00	1.00
23	0.00	0.00	1.00		23	0.00	0.00	1.00
24	0.00	0.00	1.00		24	0.00	0.00	1.00

Source: Eviews6
PCAN=PCA for nominal kwacha bilateral exchange rates
PCAR=PCA for real kwacha bilateral exchange rates

Figure 3.5 Estimated Nominal PCA (PCAN) Conditional Variance




PC7
3
2
1
0
-1
-2
-3
1994 1996 1998 2000 2002 2004 2006
PC8
4
2
0
-2
-4
-6
1994 1996 1998 2000 2002 2004 2006
PC9
3
2
1
0
-1
-2
-3
1994 1996 1998 2000 2002 2004 2006
PC10
2
1
0
-1
-2
1994 1996 1998 2000 2002 2004 2006
PC11
2
1
0
-1
-2
-3
1994 1996 1998 2000 2002 2004 2006
PC12
2
1
0
-1
-2
-3
-4
1994 1996 1998 2000 2002 2004 2006


PC13
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
1994
1996
1998
2000
2002
2004
2006
PC14
1.5
1.0
0.5
0.0
-0.5
-1.0
PC15
1.5
1.0
0.5
0.0
-0.5
-1.0
PC16
0.8
0.4
0.0
-0.4
-0.8
-1.2
PC17
0.8
0.4
0.0
-0.4
-0.8
-1.2
PC18
1.2
0.8
0.4
0.0
-0.4
-0.8

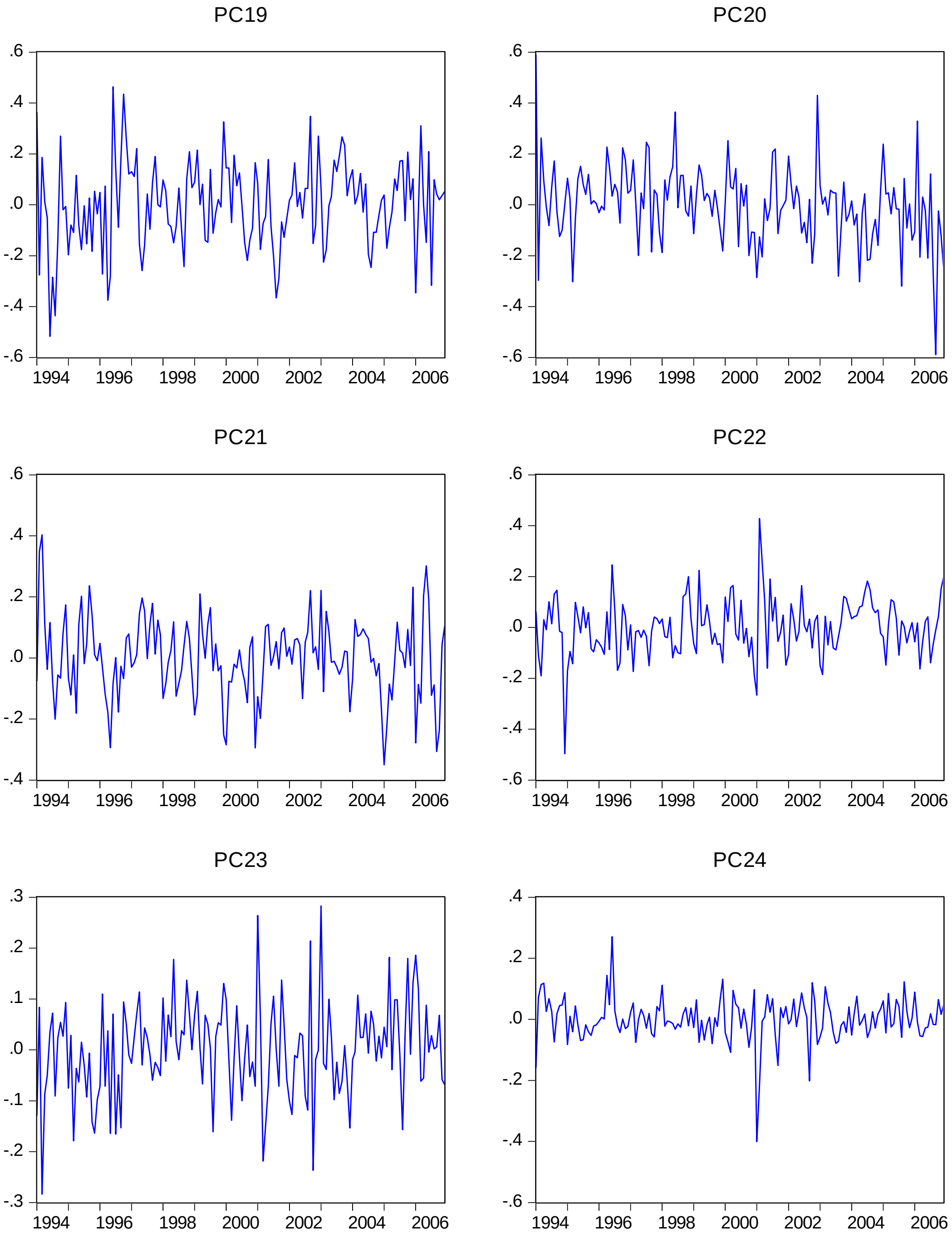
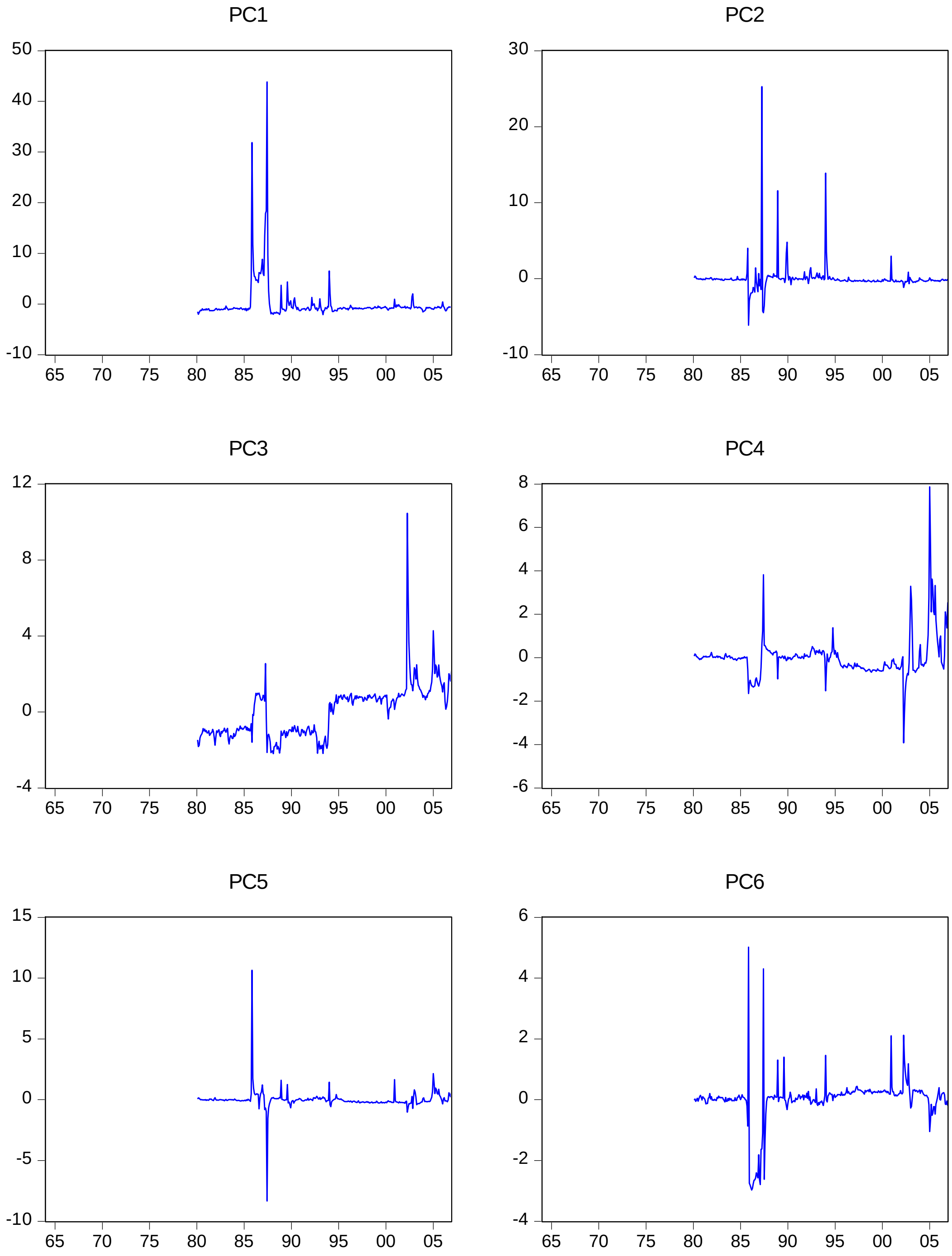
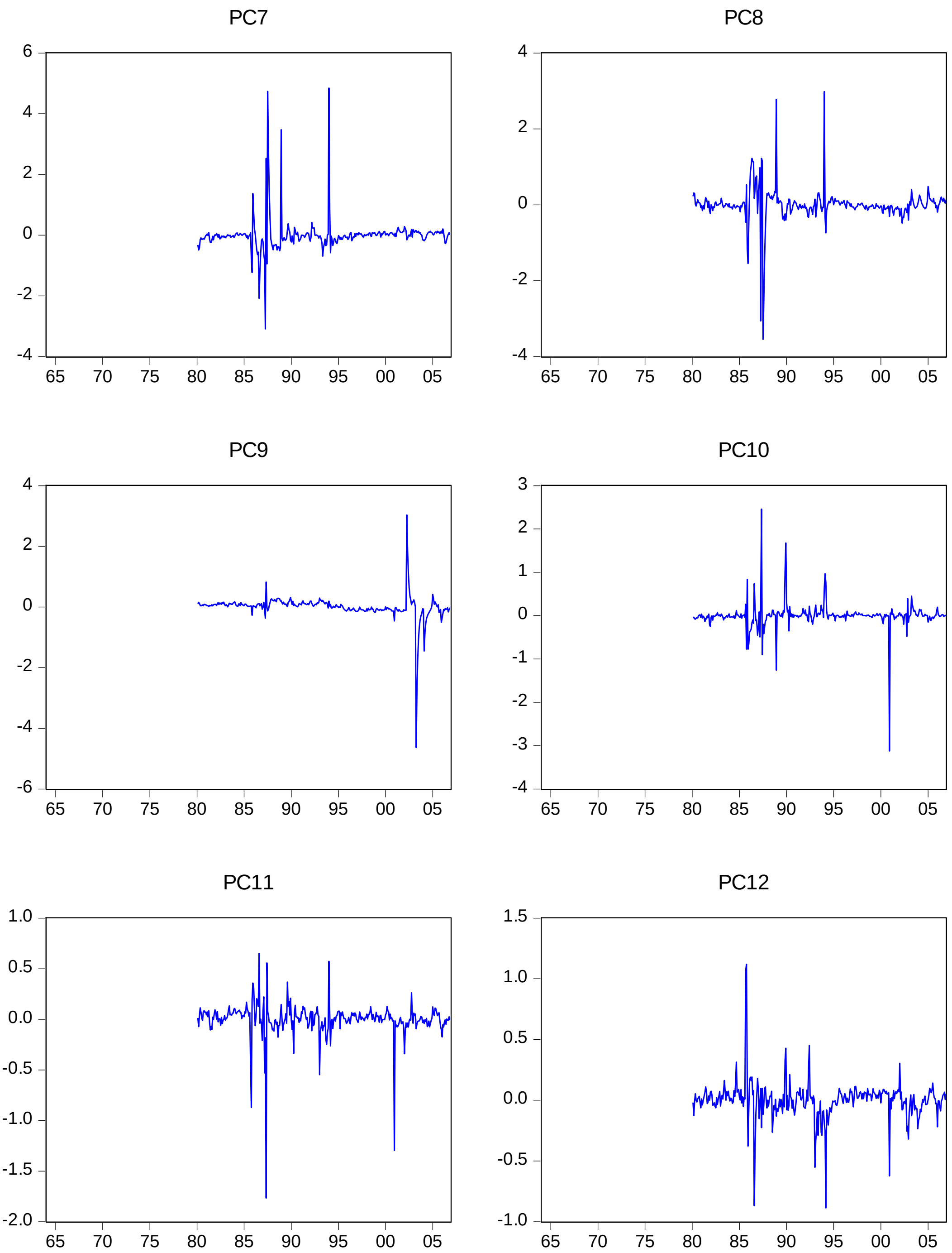
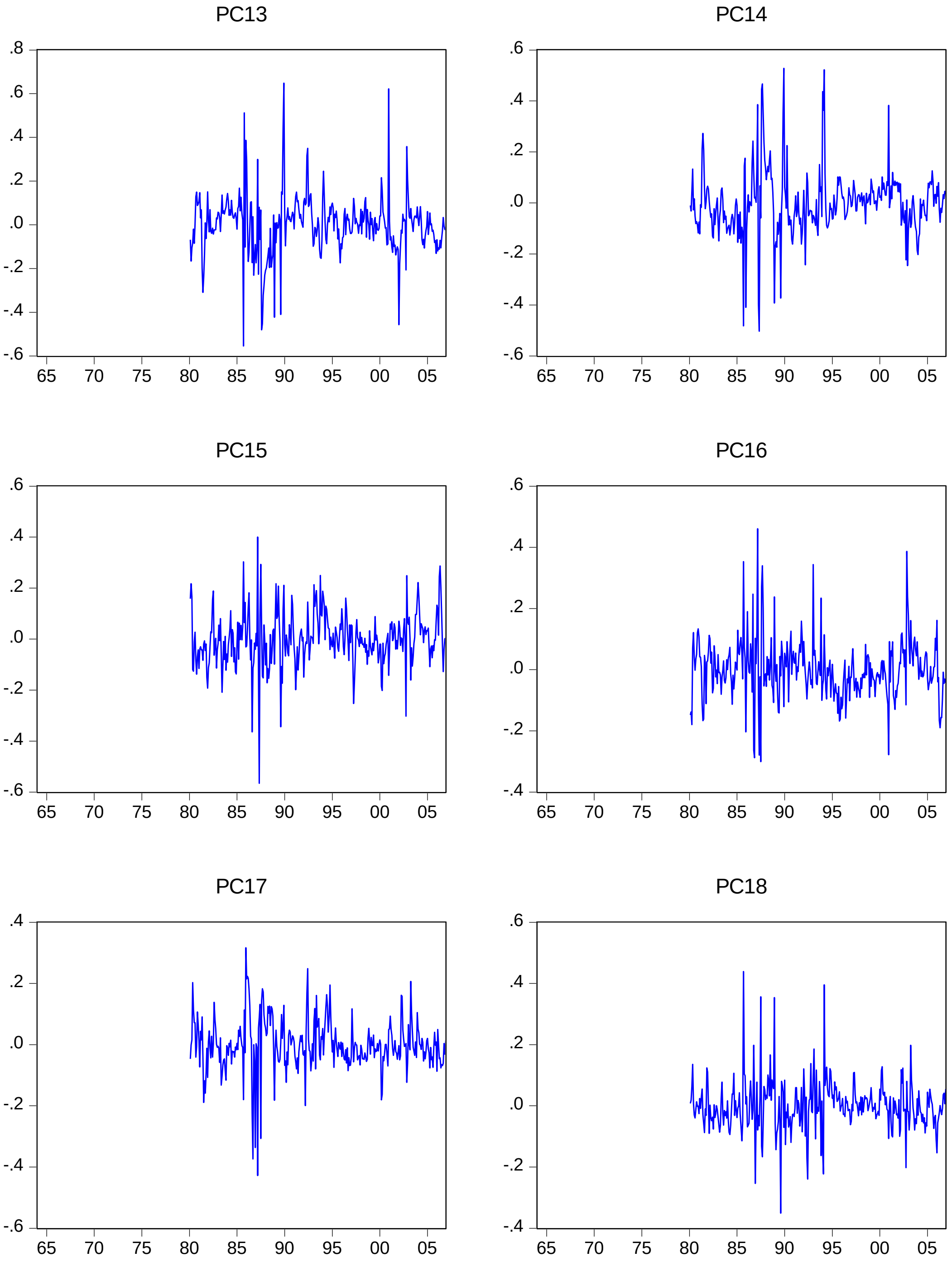
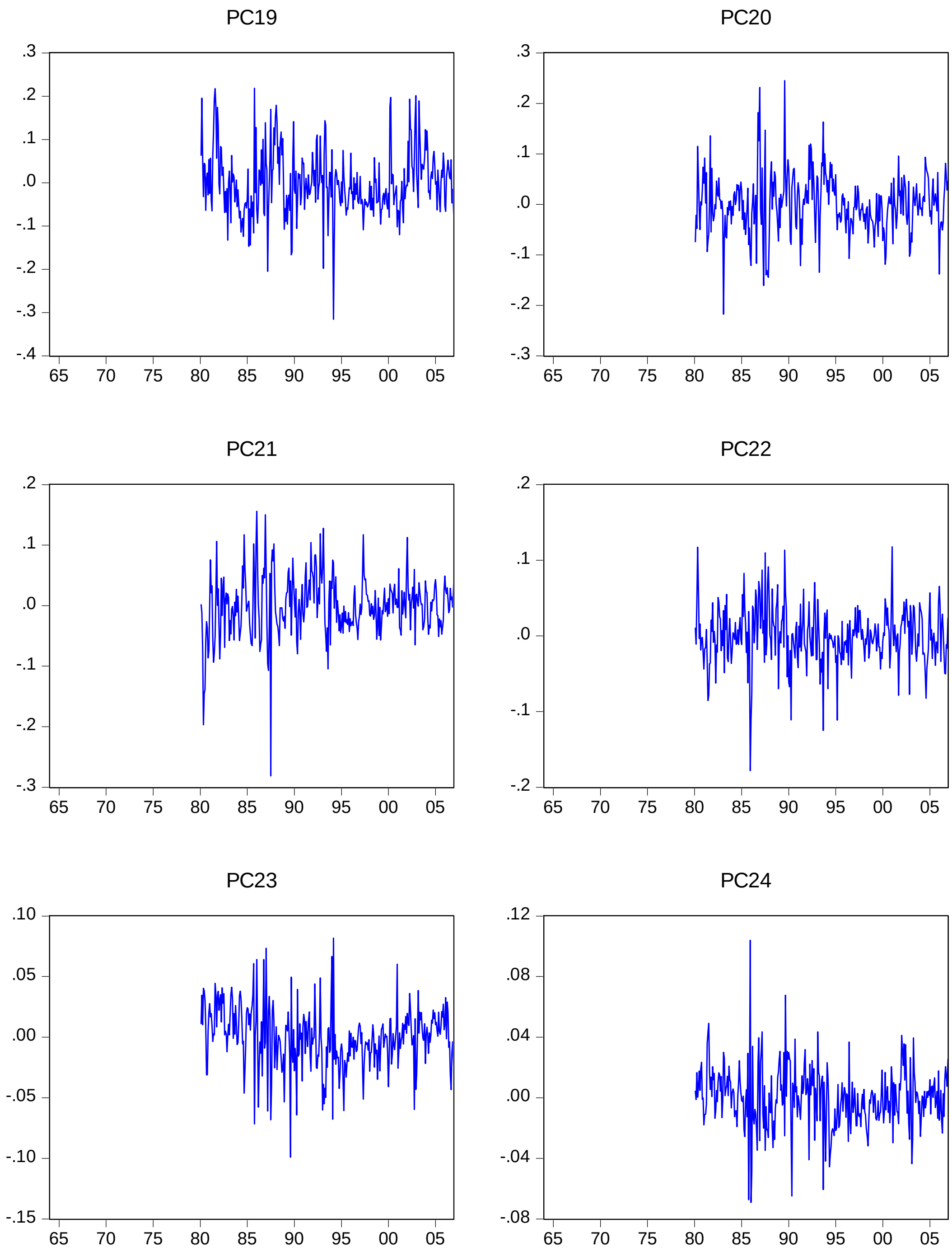

PC19
PC20
PC21
PC22
PC23
PC24
.6
.4
.2
.0
-.2
-.4
-.6
.3
.1
-.1
-.3
1994
1996
1998
2000
2002
2004
2006

Figure 3.6 Estimated Real PCA (PCAR) Conditional Variance




PC7
PC8
PC9
PC10
PC11
PC12
65 70 75 80 85 90 95 00 05


PC13
.8
.6
.4
.2
.0
-.2
-.4
-.6
65 70 75 80 85 90 95 00 05
PC14
.6
.4
.2
.0
-.2
-.4
-.6
65 70 75 80 85 90 95 00 05
PC15
.6
.4
.2
.0
-.2
-.4
-.6
65 70 75 80 85 90 95 00 05
PC16
.6
.4
.2
.0
-.2
-.4
65 70 75 80 85 90 95 00 05
PC17
.4
.2
.0
-.2
-.4
-.6
65 70 75 80 85 90 95 00 05
PC18
.6
.4
.2
.0
-.2
-.4
65 70 75 80 85 90 95 00 05



NOTE:
Exchange rate preceded by G refers to GARCH model measure of conditional volatility e.g. GKFF
Exchange rate preceded by T refers to TGARCH model measure of conditional volatility e.g. TKFF
Exchange rate preceded by EG refers to EGARCH model measure of conditional volatility e.g. EGKFF

The eigenvector results in table 3.12 indicate the weights of each GARCH series in the sample PC. In PC1, no conditional variance (GARCH) series for any of the eight exchange rates dominates. Instead all of them have relatively equal weights and move in the same direction except the zim$ which has a negligible weight and in one case (GKZIM) moves in opposition to the rest (in the case of PCAN). Thus, PC1 with the highest explanatory power can be described as an *index of exchange rate volatility* capturing influences specific to Zambia. It links volatility in all kwacha exchange rates as the kwacha displays similar pattern against all trading partner currencies except the zim$.

With respect to PC2-4, their interpretation varies slightly between PCAN and PCAR. In the case of PCAN, PC2 is dominated by zim$'s influence across the three GARCH models given the exceedingly large weight (GKZIM:0.48; TKZIM:0.50; EGKZIM:0.30) relative to other currencies while in PC3, despite the zim$ still dominating, its weight is significantly larger in two GARCH series: GKZIM (0.43) and EGKZIM (0.63). Thus, it can be concluded that while both PC2 and PC3 reflect the zim$ as the dominant source of variation in bilateral kwacha exchange rate volatility, its influence is more pronounced in PC2. This is evident in figure 3.5 where PC2 mimics the behaviour of zim$ series in figure 3.3 (GKZIM, TKZIM, and EGKZIM). In contrast, PC4 appears similar to PC1 but with low information content and with considerable variation in weights and sign across currencies and GARCH models. In essence, PC3 and PC4 reflect idiosyncrasies in the three GARCH models: they reflect differences in volatilities across exchange rates captured by the three GARCH models. For PCAR, similar to PCAN, PC3 reflects the influence of zim$ in bilateral kwacha exchange rate volatility while PC2 appears to reflect the influence of all bilateral currencies based on volatility derived from the EGARCH model i.e. non-linearities of the EGARCH process[60].

Table 3.12 Eigenvectors (Loadings)

	PCAN					PCAR		
Variable	PC1	PC2	PC3	PC4	Variable	PC1	PC2	PC3
GLKFF	0.23	-0.13	0.06	0.13	GLKFF	0.23	-0.12	-0.02
GLKGBP	0.23	-0.05	0.10	-0.05	GLKGBP	0.24	-0.11	-0.04
GLKDM	0.23	-0.09	0.05	0.20	GLKDM	0.22	-0.06	0.04
GLKRAND	0.20	0.17	0.01	-0.36	GLKRAND	0.25	-0.09	0.02
GLKSWISS	0.22	0.01	-0.01	-0.25	GLKSWISS	0.25	-0.10	-0.01
GLKUS$	0.24	-0.04	0.09	-0.07	GLKUS$	0.25	-0.10	-0.04
GLKYEN	0.23	0.19	-0.17	-0.01	GLKYEN	0.25	-0.07	-0.03
GLKZIM$	-0.00	0.48	0.43	0.07	GLKZIM$	0.01	-0.05	0.66
TLKFF	0.22	0.09	-0.03	-0.12	TLKFF	0.25	-0.10	-0.05
TLKGBP	0.23	0.11	-0.15	0.02	TLKGBP	0.25	-0.10	-0.03
TLKDM	0.23	0.11	-0.20	0.09	TLKDM	0.25	-0.09	0.02
TLKRAND	0.21	0.21	-0.11	-0.24	TLKRAND	0.23	-0.11	0.03
TLKSWISS	0.22	0.12	-0.25	0.06	TLKSWISS	0.24	-0.10	-0.04
TLKUS$	0.24	0.06	-0.07	0.21	TLKUS$	0.25	-0.09	0.03
TLKYEN	0.22	0.20	-0.20	-0.00	TLKYEN	0.24	-0.07	0.05
TLKZIM$	0.02	0.50	-0.04	-0.03	TLKZIM$	0.01	-0.05	0.65
EGLKFF	0.21	-0.24	0.20	-0.02	EGLKFF	0.18	0.03	-0.04
EGLKGBP	0.17	-0.22	0.23	-0.34	EGLKGBP	0.18	0.30	0.01
EGLKDM	0.20	-0.04	-0.02	0.47	EGLKDM	0.10	0.47	0.03
EGLKRAND	0.20	-0.12	0.16	-0.21	EGLKRAND	0.12	0.45	0.04
EGLKSWISS	0.23	-0.18	0.14	-0.01	EGLKSWISS	0.10	0.43	0.02
EGLKUS$	0.20	-0.05	0.04	0.45	EGLKUS$	0.19	0.30	0.01
EGLKYEN	0.20	-0.22	0.20	-0.02	EGLKYEN	0.20	0.28	-0.01
EGLKZIM$	0.01	0.30	0.63	0.15	EGLKZIM$	0.00	0.04	0.34

Source: Eviews6
PC1=principal component 1; PC2=principal component 2; and PC3=principal component 3
GLKFF, TLKFF and EGLKFF = conditional volatility estimate from GARCH, TGARCH and EGARCH models. This definition applies to the rest of the exchange rates as defined above

3.5 Conclusion

The conditional volatility characterising real and nominal kwacha bilateral as well as trade-weighted exchange rates plus the underlying sources of volatility in these exchange rates were investigated over the period 1964.01-2006.12 using three alternative GARCH models: GARCH (1, 1), TGARCH (1, 1) and EGARCH (1, 1).

[60] EGARCH weights are relatively larger than the GARCH and TGARCH ones which are all negative.

Evidence in support of EGARCH specification as the best fitting model and bilateral exchange rates exhibiting different conditional volatility dynamics is found. This underscores the importance of examining alternative GARCH model specifications when modelling exchange rate volatility as opposed to imposing a uniform GARCH model specification without testing the appropriateness of alternative specifications when a large sample of currencies is involved. Volatility persistence, although low in most exchange rates and the existence of asymmetric response to shocks are established. The Kzim$ exhibits a special feature in conditional volatility that is not common to conditional volatility in other exchange rates. This highlights the feature of an outlier currency (zim$) that must be considered in policy decisions. A GARCH-PCA series constructed from original conditional kwacha bilateral exchange rate series captures factors governing the underlying variance structure of the kwacha bilateral exchange rates. It mimics the original kwacha exchange rate series and reflects influences specific to Zambia.

Exchange rate regime imposed a significant positive effect on the volatility of the exchange rate in Zambia as volatility increased during the initial float of the kwacha relative to the fixed regime period. In addition, both real and monetary factors account for volatility in kwacha exchange rates. Generally, increases in conditional volatility in virtually all the exchange rate series are underpinned by money supply and openness. Conditional volatility in both real and nominal conditional variances is influenced by similar factors.

The empirical results are amenable for policy by revealing the nature of conditional volatility dynamics present in each exchange rate and potential sources of exchange rate volatility in Zambia. Specifically, the role for monetary policy and exchange rate stabilisation is identified. Thus, stable growth in money supply (reduction in trend rate in monetary expansion) would be appropriate in order to reduce volatility in the exchange rate especially in the short-term given nominal rigidities. This could entail adopting a predictable monetary policy rule that involves pre-announcement of targets, instruments and their timing. In the medium- to long-term, enhancing economic integration with trading partners and trade diversification underlies further volatility reduction given the predominant positive influence of openness on conditional volatility.

Finally, evidence of asymmetric response of conditional volatility in exchange rates to shocks suggests asymmetric central bank reaction to variations in volatility in exchange rates in order to mitigate the potential negative effects it may impose on the economy as noted earlier. The response may take the form of direct (asymmetric) intervention in the foreign exchange market depending on the nature of the shock affecting the exchange rate of policy concern. In particular, unexpected depreciations of the kwacha relative to trading partner currencies may be perceived as bad news with respect to inflation given the strong evidence of exchange rate pass-through to domestic prices in Zambia (Andersson and Sjöö, 2000; and Mutoti, 2006). Thus, this may prompt the central bank to sell foreign exchange to moderate the rate of depreciation. This is in contrast to unexpected appreciations which help in moderating inflationary pressures and thus may not prompt immediate reaction from the central bank.

Chapter 4 EXCHANGE RATE VOLATILITY AND TRADE FLOWS IN ZAMBIA

Useful comments on this chapter from participants at the University of Leicester Economics Department PhD Conference held on 4 and 11March 2009 are greatly appreciated.

4.1 Introduction

The exchange rate volatility-trade flow relationship continues to be actively investigated empirically. While the empirical focus is on verifying the theoretical validity of existing evidence, assessment of the size and direction of the impact of exchange rate volatility on trade remains inconclusive. Thus, the existence of ambiguous empirical results has motivated many researchers to undertake further examination of the relationship in an attempt to establish robust and systematic empirical evidence (see McKenzie, 1999; Clark et al. 2004; and Chit, 2008). While most empirical studies find support for exchange rate volatility reducing the level of trade, its impact is however, relatively small (Smith, 2004; and Choudhry, 2005). Theoretically, an ambiguous relationship is predicted as exchange rate volatility can either stimulate or depress trade (Bailey et al. 1987; and Côté, 1994). Consequently, original theoretical models by Clark (1973), Ethier (1973), Baron (1976) and Hopper and Kohlhagen (1978) have been extended by varying the underlying assumptions in an attempt to either refute or justify the predicted direction of the relationship. A comprehensive survey of the literature on exchange rate volatility-trade link is provided by Farrell et al. (1983), IMF (1984), Côté (1994), McKenzie (1999), UK Treasury (2003), Clarke et al. (2004) and Ozturk (2006).

Several factors account for variations in empirical results. They include underlying assumptions in various theoretical models, sample periods studied, level of disaggregation of trade data, estimation techniques employed, countries studied and the specification of the standard trade equation: whether in volume or value terms and choice of regressors (McKenzie, 1999; Clark et al. 2004; and Tenreyro, 2007). Lack of consensus on the appropriate proxy for exchange rate risk is another fundamental factor. Evidence suggests that empirical results are generally sensitive to the definition of exchange rate and measures of exchange rate volatility: real or nominal, bilateral or trade-weighted, short- or long-run and ex ante or ex post exchange rate volatility.

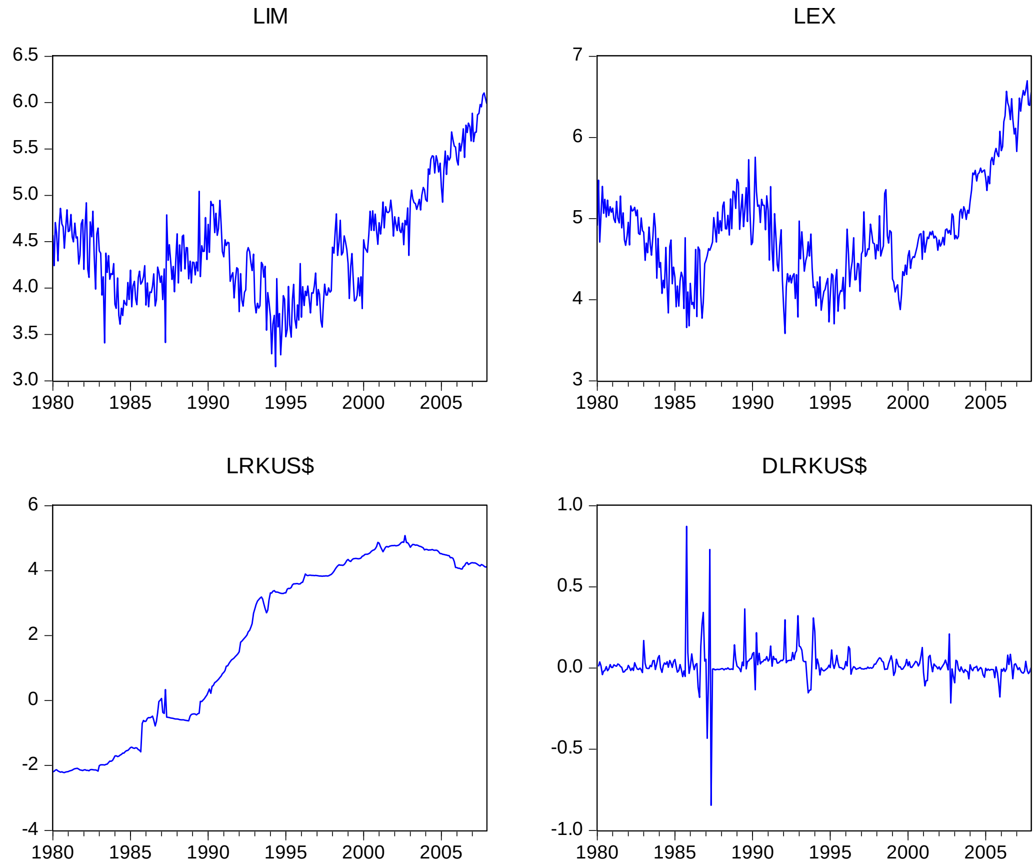
Nonetheless, improvements in measures of exchange rate volatility and the effectiveness of estimation techniques have contributed to the strength of empirical results in recent years. Increasingly, most studies analyse sectoral trade flows in line with theory as opposed to aggregate trade data, use high frequency data and alternative measures of exchange rate volatility, take into account time series properties of the data, focus on a number of industrial countries and extend empirical investigations to developing countries where the evidence is limited (McKenzie, 1999)[61]. To improve the quality of empirical results, McKenzie (1999) notes that attention must be paid to the way the proxy of the measure of exchange rate volatility (unobserved) is generated as this could potentially affect the consistency, efficiency and inference of the results.

From a policy point of view, evidence of exchange rate uncertainty adversely affecting trade flows especially in developing countries due to lack of hedging instruments may compel governments to intervene in foreign currency markets. This is done in order to stabilise exchange rates as severe fluctuations in currencies can potentially affect the design of appropriate trade policies and thus undermine the achievement of specific economic goals such as export promotion and growth (see Arize et al. 2000; Choudhry, 2005; and Bahmani-Oskooee and Hegerty, 2009).

[61] Arize et al. (2000, 2008), Bah and Amusa (2003) and Munyama and Todani (2005) provide evidence on developing countries.

In Zambia, while the exchange rate (LRKUS$ in figure 4.1) has exhibited a rising trend with considerable fluctuations (DLRKUS$ in figure 4.1), the value of trade has been on a rising trend especially after 2000 (see figure 4.1). However, insufficient empirical work has examined the exchange rate volatility-trade relationship in the context of Zambia. Notable studies undertaken include Tenreyro (2007) and Musonda (2008). Both studies use aggregate annual trade data. Utilising panel data that include Zambia over the period 1970-2004, Tenreyro finds nominal exchange rate variability to have no significant impact on trade flows. Conversely, Musonda employs the Johansen multivariate cointegration technique and finds a negative impact of volatility in the real effective exchange rate on NTEs over the period 1965-1999. Thus, the variation in empirical results partially motives this study.

Figure 4.1 Plots of imports (IM), exports (EX) and exchange rate (KUS$)



In line with Mckenzie (1999), this chapter seeks to contribute to the unsettled empirical debate by examining the impact of volatility in the kwacha exchange rate on trade flows in Zambia over the period 1980-2007. Firstly, import and export demand equations are estimated using monthly aggregate and disaggregated trade data. Evidence regarding sectoral response to exchange rate risk is lacking in Zambia. Disaggregrated trade data allow us to determine how specific commodities are affected by exchange rate volatility as aggregate data tend to obscure industry specific response (Bahmani-Oskooee and Hegerty, 2009). Notwithstanding the aggregation bias, the estimation of total import and export demand equations serves as a benchmark against which specific individual commodity effects can be evaluated.

Secondly, two cointegration techniques namely, the Johansen multivariate cointegration technique (herein after referred to as Johansen method) developed by Johansen (1988) and extended by Johansen and Juselius (1990) and the autoregressive distributed lag (ARDL) bounds testing procedure proposed by Pesaran et al. (2001) as well as the error-correction model are employed simultaneously similar to Rahmatsyah et al. (2002) to ensure robustness of results. The two techniques examine the same variables but treat their time series properties differently. Different estimation techniques have tended to give unclear and inconsistent pattern of results in previous studies. Almost all previous studies employ either the Johansen or ARDL bounds testing or related methods (see Bustaman and Jayanthakumaran, 2006; and Ozturk, 2006).

Finally, alternative measures of conditional exchange rate volatility derived from GARCH models in the previous chapter are employed to establish the robustness of exchange rate volatility effect on trade and also determine the measure of exchange rate volatility relevant for trade flow analysis[62]. Numerous measures of exchange rate volatility have been employed and yet none appears superior to others (Bahmani-Oskooee and Hegerty, 2008). In view of this, another measure of exchange rate volatility, GARCH-PCA, derived in the previous chapter is employed. To the best knowledge of the author, this measure of exchange rate risk has not been used in any empirical work on the relationship under study. Hence, the use of this measure is intended to determine its robustness as an alternative measure of exchange rate risk.

The results provide evidence of significant influence of exchange rate volatility on trade flows in Zambia. Aggregate trade tends to be depressed. While individual export commodities show mixed response to variations in exchange rate volatility, the latter tends to exert a positive impact on the former and matters most in the long- than short-run.

The rest of this chapter proceeds as follows. The next section presents a brief review of Zambia's trade policy since independence. In section 4.3, theory and evidence regarding exchange rate volatility and trade flows is reviewed while section 4.4 deals with the empirical model to be tested, estimation procedure and the results. Section 4.5 concludes.

4.2 Overview of Zambia's Trade Policy

Zambia adopted a liberal trade regime in 1991 in order to reduce the dependency of the economy on copper, the main export commodity, by diversifying and expanding the export base. Stimulating production and export of NTEs and inducing and enhancing the competitiveness of the economy was the focus of the new policy.

Prior to that, the trade regime was highly protective. The objective was to attain industrial import-substitution and a self-sufficient agricultural sector. Thus, various

[62] GARCH models are appropriate in measuring risk as they capture the predictable element in the exchange rate that reflect importers'/exporters' prediction of exchange rate risk (Choudhry, 2008).

policy instruments such as import and export license requirements, exchange controls with a fixed exchange rate system and tariff and non-tariff barriers were instituted. However, many of these policies were reversed in 1991. The key trade reforms undertaken included abolition of the fixed exchange rate system, tariff reductions, expansion of the number of open trade import licences and the promotion of trade liberalisation at bilateral, regional and multilateral levels through various trade agreements.

Trade and economic reforms begun in the mid-1980s, but were pursued more vigorously during the 1990s. Between 1964 and the mid-1970s, a fairly unrestricted trade regime with high tariffs varying between zero and 150 percent was adopted. However, the first attempt at tariff reform was done in 1985, but was interrupted between 1987 and 1989 when Zambia temporarily broke ties with the IMF. In 1991, the economic reform programme was launched and trade was fully liberalised making Zambia one of the most liberal economies (Mudenda, 2005; and Tussie and Aggio, 2006). The tariff rate structure narrowed from a range of 100-0 to 50-10 percent while import liberalisation eliminated non-tariff import measures between 1981 and 1985. From 1991, lowering of tariff rates commenced initially over a five-year period. Nominal tariff levels were reduced to a 0–50 percent range in 1991, 0–40 percent range in 1993 and 0–25 percent range in 1994. In 1992, quantitative import restrictions for 153 commodities were converted into their corresponding tariff protection measures while exchange controls were abolished in 1994.

Zambia has signed a number of bilateral and regional trade agreements with neighbouring countries and other trade partners in order to expand markets for her exports and receive preferential market access. Notable trade agreements signed include the African Growth and Opportunity Act (AGOA) in 2000 with the USA, the Cotonou

Agreement in 2000 and the Everything But Arms (EBA) Initiative in 2001 with the European Union (EU). Regionally, Zambia is a member of the African Union, Common Market for Eastern and Southern Africa (COMESA) and COMESA Free Trade Area launched in 2000 and SADC. The SADC Trade Protocol was signed in 1996. Multilaterally, Zambia is a member of the World Trade Organisation and grants Most Favoured Nation treatment to all its trading partners. In order to spur investment and promote exports, the Zambia Export Processing Zone Authority was established in 2003.

Zambia’s exports can be divided into traditional i.e. metal (copper and cobalt) and NTEs. NTEs consist of engineering products (copper rods, cables, wire, billets and brass ingots), textiles (cotton yarn, loomstate fabric, acrylic yarn, towelling and chitenge), processed foods (sugar, molasses, honey and beeswax), building materials (cement, pvc pipes and asbestos pipes), primary agricultural commodities, animal products (crocodile meat, poultry, fish and leather products), gemstones, floricultural products and electricity. Most of these are raw or processed raw materials with a relatively small amount of value-added. Major imports into Zambia include capital equipment for the mining sector, crude oil, fertiliser and consumer goods. Major markets for exports as shown in table 4.1 are the EU and SADC. South Africa is Zambia's major source for imports (see chapter 3 sub-section 3.4.3.1).

Exports have largely been dominated by copper and cobalt since independence, accounting for about 90 percent of total earnings. However, in recent years, the share of NTEs has substantially improved rising from about 10 percent in early 1990s to about 30 percent in 2008 (see figure 2.17). Despite a remarkable increase in NTEs over the years, full advantage of preferential treatment has not been utilised due to supply-side constraints reflected in high production and freight costs in addition to low productivity (Mudenda, 2005; and Tussie and Aggio, 2006).

4.3 Literature Review

4.3.1 Theoretical Framework

Exchange rate uncertainty affects the volume of trade by making prices and profits indeterminate as the future spot rate at which transactions are to be conducted is not known with certainty. In addition, exchange rate uncertainty alters investment decisions, structure of output and distorts the pattern of trade by changing relative prices of domestic and foreign goods in specific industries (Fang et al. 2006). Thus, in the absence of hedging instruments, risk-averse firms may respond by re-allocating resources towards the production of less risky non-tradeables resulting in the backward shift in the supply curve at a given price (Choudhry, 2005).

A brief outline of selected theoretical models is provided as numerous models on this subject have emerged over the years. Clark (1973), Ethier (1973) and Baron (1976) present early theoretical models describing the relationship between exchange rate volatility and trade for firms operating under uncertainty. Firms seek to maximise profits subject to the exchange rate risk, the sole source of risk faced in the course of trade. A number of other simplifying assumptions about utility functions, degree of risk-averseness, market structure and existence of hedging facilities among others are made. These assumptions lead to the conclusion that exchange rate volatility tends to reduce the level of trade.

Clark (1973) focuses on exchange rate variability and its effect on the level of exports. One of the key equations in Clark's model in which the firm's objective is to maximise the expected value of a quadratic utility function of profits derived from a combination of profit and quadratic utility functions under a number of simplifying assumptions is given by

$$U(\pi) = a\pi + b\pi^2 \tag{1}$$

$$\pi = fpq - C(q) \tag{2}$$

where π is profit, f is the forward rate, p is the price of exports in foreign currency, q is quantity of export produced, C is the cost function, a is the proportion of trade that is hedged through the forward exchange market and b captures the risk-averseness of the exporting firm. Equation 1 defines the utility function while the profit function is given by equation 2. π is stochastic (in domestic currency) given the unpredictability of f. The first order condition for equation 1 is that

$$MR - MC = \{-(\frac{2b}{a})p^2 q\sigma_f^2\}/\{1 + (\frac{2b}{a})E(\pi)\} \tag{3}$$

where MR is marginal revenue, MC is marginal cost, σ_f^2 is variance of f and $E(\pi)$ is expected profit. The right hand side is the risk premium. As p equals MR under perfect competition, the price for exports covers costs (MC) and compensates the exporting firm for the exchange risk it is exposed to. Thus, as σ_f^2 increases, the supply curve shifts to the left which in turn reduces q for a risk-averse firm ($b < 0$).

Ethier (1973) highlights the role of the forward exchange rate on imports. The firm's problem is to choose the amount of imports (M) and forward cover (α) as it maximises profits (π) expressed as

$$\pi(M,\alpha) = PM - V(M) - MQ[\alpha R_F + (1-\alpha)R] \quad (4)$$

where P is the price of M in domestic currency received by the firm for its imports, $V(M)$ is value-added cost in domestic currency, Q is foreign price of imports, R_F is the current forward rate and R is the applicable spot exchange rate when payment is due. Exchange rate uncertainty is reflected in P and $V(M)$ and P is defined as

$$P = P^0 + \gamma(R - \bar{R})Q \quad (5)$$

where P^0 is a constant, $\bar{R}$ is the expected value of R and $1 \geq \gamma \geq 0.$ Thus

$$E_\pi = P^0 M - V(M) - [(1-\gamma)R_F + \gamma \bar{R}]QM + (1-\alpha-\gamma)(R_F - \bar{R})QM \quad (6)$$

and

$$\sigma = (1-\alpha-\gamma)QM\sigma_R \quad (7)$$

The proportion of trade covered is $1-\gamma$. The extent to which M is affected by exchange rate uncertainty is given by the magnitude by which the forward rate exceeds the expected future spot rate regardless of the attitude towards risk and volatility of the spot rate. Thus, an increase in R_F depresses M.

Baron (1976) considers the price setting behaviour of a firm operating in an oligopolistic market. The firm could choose to invoice exports either in the own home currency or currency of the importer. Invoicing exports in the importer's currency exposes the exporting firm's revenue to exchange rate risk and consequently affects the level of exports. Demand is known with certainty as the importer faces a constant price.

If the firm is risk-averse, it seeks to reduce its exposure to exchange rate uncertainty by increasing the price of exports which in turn adversely affects output. On the other hand, the quantity demanded of exports is uncertain and so is revenue for the firm when exports are invoiced in the exporter's currency as the effective price paid by the importer in the future is unknown due to exchange rate risk. However, the full effect on exports depends on the properties of the demand function in the importing country: with a linear demand function, given the risk-averseness of the firm, the price falls which induces demand to rise while the margin between the price and cost decreases and ultimately reduces the variance of profits for the exporting firm.

Unlike Clark, Ethier and Baron who focus on one side of the market, Hooper and Kohlhagen (1978) consider both import and export demand functions to determine the impact of exchange rate risk on both equilibrium price (P^*) and quantity (q^*). The reduced form equations for P^* and q^* derived from the aggregation of individual firm supply and demand functions are given by

$$P^* = c_o + c_1UC^* + c_2UC + c_3PD + c_4Y + c_5CU + c_6EH^* + c_7EH +$$
$$c_8\delta^*{}_{1/R_1} + c_9\delta_{R_1} \tag{8}$$
$$q^* = d_o + d_1UC^* + d_2UC + d_3PD + d_4Y + d_5CU + d_6EH^* + d_7EH +$$
$$d_8\delta^*{}_{1/R_1} + d_9\delta_{R_1} \tag{9}$$

where $CU, PD, Y, UC, UC^*, EH, EH^*, \delta_{R_1}$ and $\delta_{1/R}$ are non-price rationing in the importing country proxied by capacity utilisation, price index for goods in the domestic economy, income in the importing country, unit cost representing labour and other material costs of production, domestic unit cost of production for exporters, weighted average exchange rate for importers, exchange rate risk for importers and exporters, respectively. The spot exchange rate is R_1. In this model, exchange rate risk enters the analysis to the extent that imports (exports) are invoiced in the exporters' (importers') currency and a proportion of foreign currency obligation for importers' and exporters' due is not fully hedged. The expected sign on $c_1, c_3, c_4, c_8, d_3, d_4$ and d_6 is positive while that on $c_2, c_5, c_6, c_7, c_9, d_1, d_2, d_5, d_7, d_8$ and d_9 is negative. The sign on c_0 and d_0 could either be positive or negative. The parameters of interest here are c_8, c_9, d_8 and d_9 and their effect on price and quantity. The effect of exchange rate risk on quantity is negative in line with Clark (1973). However, price is ambiguously affected by exchange rate risk depending on who bears the risk: importer or exporter. The price falls if importers bear the exchange rate risk as demand for imports falls while a rise in price results if exporters accept the exchange rate risk as they seek a risk premium in compensation.

The above models have been criticised for making rigid assumptions such that relaxing them has implications for the predicted direction of the relationship. For instance, the assumption of risk-aversion is not sufficient to obtain a negative relationship. Instead, the property of the utility function matters (Côté, 1994).

De Grauwe (1988) derives a simple model in which a firm operating under competitive market conditions maximises the expected utility of total income as it produces for both domestic and foreign markets. Limited restrictions on the utility function (concavity and separability) are assumed. Export proceeds in domestic currency are uncertain (source of risk) as pricing is in foreign currency while the exchange rate is random. This is in contrast to the domestic good which is priced in the domestic currency. Thus, the fall in expected marginal utility of export revenue depends on whether expected marginal utility is convex or concave in the random exchange rate subject to some degree of (relative) risk-aversion. Sufficiently risk-averse firms increase export volumes in response to an increase in exchange rate risk in order to avoid a drastic fall in revenue, as an increase in risk raises the expected marginal utility of export revenue. The opposite is true for less risk-averse firms: the level of export output falls as a rise in exchange rate risk induces a decline in expected marginal utility of export revenue as the exporter is not concerned about the worst outcome. Thus, an increase in exchange rate risk generates income and substitution effects with the net effect depending on which one dominates the other. Income effect exerts a positive effect on trade (more resources are employed to avoid a drastic fall in export revenue) while the substitution effect leads to a decline in the volume of trade as the attractiveness of the risky venture is reduced in preference to domestic production (De Grauwe, 1988). By and large, income effect tends to dominate substitution effect.

Theoretical support for a positive trade-exchange rate risk relationship is provided. Notably, Franke (1991) bases the argument on the assumption of a risk-neutral exporting firm operating under monopolistic competition whose objective is to maximise net present value of expected cash flows from exports. Cost-benefit analysis underpins the entry and exit of a foreign market by the exporting firm. Exchange rate volatility generates gains for a firm if the present value of cash flows exceeds the entry and exit costs as long as the cash flow function is convex in the exchange rate.

Industries react differently to exchange rate variability due to differences in profit objectives. Highly profitable firms may not reduce the volume of trade and instead absorb the exchange rate risk. Similarly, highly concentrated industries may have a relatively low response to exchange rate risk which also applies to multinational firms that are able to diversify and adjust production and trade patterns across countries.

The importance of internationally traded inputs to production, ability to reduce domestic costs of imports and exports, trade restriction structure and attitude towards risk are other crucial factors.

Forward markets for foreign exchange can mitigate exchange rate risk by providing a hedge against currency risk at which future transactions are conducted. Nonetheless, available evidence suggests that forward markets do not completely eliminate the exchange rate risk (Akhtar and Spence-Hilton, 1984; Arize et al. 2000, 2008; and Choudhry, 2005, 2008). This is due to the fact that the brokerage cost which is an increasing function of the fluctuation of the exchange rate is incurred through hedging. Further, hedging is affected by accessibility and availability of instruments especially in developing economies. Hedging is limited by large sizes and relatively short-term to maturity of contracts which impose additional cost on traders. Moreover, the forward rate is not the best predictor of the future spot rate that leaves firms exposed to the currency risk (Choudhry, 2005).

Further extensions to earlier models involve trade composition (see Kumar, 1992). In addition, models of hysteresis in international trade have demonstrated that foreign trade can be influenced by high uncertainty generated by highly volatile exchange rates especially if sunk costs exist or entry costs in international trade are huge.

The gravity model has also been used to analyse the effect of exchange rate volatility on trade (see Clark et al. 2004; and Tenreyro, 2007). It attempts to explain bilateral trade between countries as a function of their product of gross domestic product (positive effect), geographical distance between them which reflects transportation cost that can impede trade, country size approximated by population size and other factors that reflect common characteristics (i.e. common border, common language, membership in a free trade area and level of economic development between countries). Tenreyro specifies the gravity model as

$$T_{ij} = \alpha_0 Y_i^{\alpha_1} Y_j^{\alpha_2} D_{ij}^{\alpha_3} \exp(\alpha_4 s_i + \alpha_5 s_j + \alpha_6 \delta_{ij}) \varepsilon_{ij} \tag{10}$$

where T_{ij} is exports from country i to country j; Y_{ij} represents GDP for countries i and j; D_{ij} captures all factors that might impede trade while s_i and s_j are specific effects of the importers and exporters; δ_{ij} is exchange rate volatility; ε_{ij} is the error term assumed to be independent of regressors such that $E(\varepsilon_{ij} \mid Y_i, Y_j, D_{ij}, \delta_{ij} s_i, s_j) = 1$; and $\alpha' s$ are the parameters to be estimated.

4.3.2 Empirical Evidence

Empirical evidence regarding the impact of exchange rate volatility on trade is mixed. The impact differs across countries, sectors and commodities such that no consensus exists (Côté, 1994; McKenzie, 1999; and Clark et al. 2004).

Trade models are conducted on both aggregate and sectoral trade data mostly on developed countries. However, increasing interest in developing countries has emerged in recent years. Time-series and panel data techniques have been used. While the use of aggregate trade data is permissible due to data limitations, it however, contradicts the micro-foundations of theoretical models that focus on firm behaviour (see Clark, 1973; Ehtier, 1973; and Baron 1976). Aggregate trade data restrict elasticities of income, price and exchange rate to be equal across sectors/commodities which is empirically refuted (see Doyle, 2001; de Vita and Abbott, 2004; Munyama and Todani, 2005; and Ardalani and Bahmani-Oskooee, 2006).

Notable studies that have rendered support for exchange rate volatility depressing trade include Cushman (1983), Thursby and Thursby (1987), Koray and Lastrapes (1989), Bini-Smaghi (1991), Arize et al. (2000, 2008), Rahmatsyah et al. (2002), Fang et al. (2006), Baak et al. (2007), Ulugbek and Nishanbay (2008) and Byrne et al. (2008). On the contrary, Giovannini (1988), Asseery and Peel (1991), Franke (1991), Sercu and Vanhulle (1992), Dellas and Zillberfarb (1993) and Mckenzie and Brooks (1997) find empirical support for exchange rate volatility stimulating trade. Exchange rate uncertainty creates profit opportunities which firms view as an option that can be exercised in favourable times when exchange rate volatility rises. This in turn increases trade volumes.

Other studies have established a neutral result or no statistically significant impact at all of exchange rate volatility on trade volume due to relatively inelastic short-run export supply and considerable hedging of exchange rate risk. These include Hooper and Kohlhagen (1978), Gotur (1985), Bailey et al. (1986, 1987), Koray and Lastrapes (1989), Gagnon (1993), Aristotelous (2001), Klassen (2004) and Tenreyro (2007). Mixed results are also established (see Doyle, 2001; de Vita and Abbott, 2004; Bustaman and Jayanthakumaran, 2006; and Baum and Mustafa, 2008).

Recent studies have tended to focus on sectoral data analysis and the results reveal mixed response to exchange rate volatility. For instance, Chit (2008) focuses on the impact of exchange rate volatility on the ASEAN-China Free Trade Area and finds a negative effect albeit small on trade based on the gravity model analysed using panel data. Bahmani-Oskooee and Hegerty (2009) use ARDL method to analyse sectoral data for 102 imports and exports between the USA and Mexico over 1962-2004. Exchange rate volatility is found to affect only a few industries.

In conclusion, the extent to which exchange rate volatility affects trade depends critically on underlying model assumptions. Key among the assumptions include the type of market structure in which firms operate, their attitude towards risk, currencies in which prices of exports and imports are denominated and the existence of hedging facilities to cover exchange rate risk. It is suggested that to obtain desired empirical results, a sectoral approach must be employed in line with theory as opposed to aggregation of data to avoid aggregation bias. In addition, the marginal contribution of exchange rate risk relative to the overall measure of risk faced by firms needs to be examined to meaningfully determine the extent of exchange rate volatility effect on trade.

4.4 Model Specification, Data, Estimation Methodology and Empirical Results

4.4.1 Model Specification

The choice of a trade model is not clear-cut as many variables can potentially influence trade. The standard trade equation mostly specifies the volume (value) of imports/exports as a function of a proxy for income, relative prices and a measure of exchange rate risk (Mckenzie, 1998). This specification has been extended in an attempt to improve empirical results. Additional regressors include tariff levels, transport costs, capacity utilisation, distance between countries, consumer tastes and a hedge variable. Nonetheless, the inclusion of additional variables does not change the results substantially.

The empirical model employed here is similar to Arize et al. (2000, 2008), Choudhry (2005, 2008) and Baum and Mustafa (2008). It incorporates most of the recent developments in the literature noted by Mckenzie (1999)

$$\ln EX_{ijt} = \alpha_0 + \alpha_1 \ln Y_{jt} + \alpha_2 \ln P_{ijt} + \alpha_3 erv_{ijt} + \varepsilon_{ijt} \tag{11}$$

$$\ln IM_{ijt} = \alpha_0^{'} + \alpha_1^{'} \ln Y_{jt} + \alpha_2^{'} \ln P_{ijt} + \alpha_3^{'} erv_{ijt} + \varepsilon_{ijt}^{'} \tag{12}$$

Equations 11 and 12 are standard reduced form long-run solutions of the behavioural demand and supply functions for exports and imports, respectively (see Goldstein and Khan, 1978; and Gotur, 1985). EX_{ijt} is exports (total exports/disaggregated or individual export commodities) from country i to country j during period t; IM_{ijt} is total imports from country i to country j during period t; Y_{jt} is real foreign (domestic) income; P_{ijt} is a measure of relative price level - import/export prices: price of country $i's$ export/import relative to country $j's$ goods; erv_{ijt} is a measure of exchange rate risk faced by exporters/importers due to fluctuations in the exchange rate between country i and country j; and ε_{ijt} and $\varepsilon_{ijt}^{'}$ are white noise disturbance terms.

Y_{jt} is a scale variable that captures demand conditions in trading partner (domestic) countries. Thus, the expected sign on Y_{jt} is positive (i.e. elasticities $\alpha_1 > 0$ and $\alpha_1^{'} > 0$). The coefficients α_1 and $\alpha_1^{'}$ can exceed unity as income picks up the effects of other factors related to it that cannot be easily disentangled but influence imports/exports as well.

P_{ijt} is usually represented by terms of trade or real exchange rate in the absence of actual relative export/import price data (Bahmani-Oskooee and Hegerty, 2009). An increase in the foreign price relative to the domestic price of the competing good tends to increase exports but depress imports. In this chapter, P_{ijt} is approximated by the real exchange rate due to lack of data on imports/exports prices in Zambia. The real exchange rate is defined as nominal domestic currency price of one unit of the foreign currency adjusted for the inflation differential between the two countries (see sub-section 3.4.3.1). Thus, an increase in the real exchange rate represents depreciation while a decrease refers to real appreciation. Real depreciation lowers (increases) the foreign currency price of exports (imports) and consequently tends to increase (lower) the volume of exports (imports) and export revenue in domestic currency terms. Conversely, real appreciation lowers export competitiveness, reduces the volume and return on exports in value terms expressed in domestic currency. The oppositive is true for imports: volume of imports increase as their domestic currency value reduces. Hence, the coefficient sign on P_{ijt} in the export and import demand equations are positive (elasticity $\alpha_2 > 0$) and negative (inelasticity $\alpha_2^{'} < 0$), respectively.

In line with theoretical arguments, the expected sign on erv_{ijt} is ambiguous (i.e. α_3 and $\alpha_3^{'} > 0$ or < 0 – semi-elasticity). Further, there is a huge debate in the literature on whether real or nominal exchange rate should be used to measure exchange rate volatility (see Akhtar and Spence-Hilton, 1984; and Mckenzie and Brooks, 1997)[63]. While the two are conceptually different, in practice, the difference is negligible (Clark et al. 2004). Both real and nominal exchange rates are practically the same given the stickiness of domestic goods prices in the short-run. The difference between the two is noticeable during periods of high inflation when nominal exchange rate volatility tends to exceed real exchange rate volatility. If real and nominal exchange rates are highly correlated, their effect on trade will be similar. Empirically, the difference in coefficient estimates between the two is negligible (Rahmatsyah et al. 2002). Nonetheless, both real

[63] Real exchange rate depicts the influence of the nominal exchange rate as well as relative prices which makes it difficult to disentangle the effect of the former. Nominal exchange rates are more relevant to firms undertaking individual transactions over shorter horizons while for longer horizons, the real exchange rate matters (Clark et al. 2004). In the long-run, short-run fluctuations in the exchange rate may offset each other such that in the long-run, the major source of uncertainty becomes divergence of the real exchange rate from its equilibrium level as opposed to changes from one period to the next.

and nominal exchange rate volatility are examined in this chapter similar to Choudhry (2008).

4.4.2 Data

Monthly data from 1980 to 2007 are used to estimate equations 11 and 12.

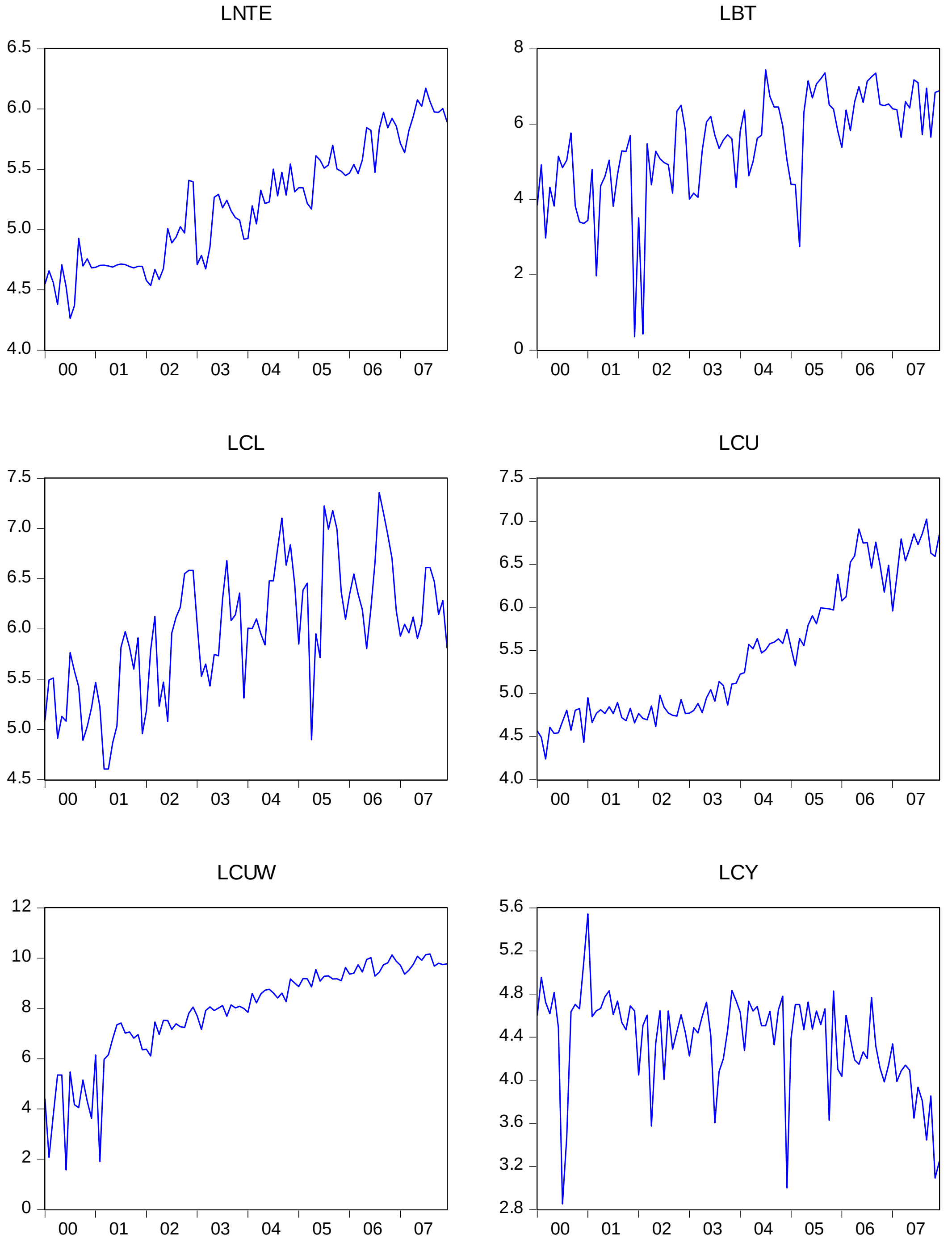
Similar to the practice in the literature (see Doyle, 2001; Baum and Caglayan, 2008; and Arize et al. 2008), real import (IM) and export (EX) values expressed in kwacha are used in the absence of volume data suggested by theory[64]. Real IM and EX kwacha values are obtained by deflating nominal values by the CPI for Zambia. Nominal IM and EX data originally expressed in US dollars are converted into kwacha using the monthly KUS$ exchange rate (IFS series ae.zf). Total import and export data available from 1980 to 2007 are obtained from Datastream, Bank of Zambia and the Central Statistics Office - Zambia Monthly Digest of Statistics. Only aggregate imports are examined due to gaps in individual import commodity data series. In contrast, disaggregated export data, obtained from the Bank of Zambia, are available but only from 2000 to 2007. Thus, total NTEs and some export commodities that make up NTEs are examined. They include burley tobacco (BT), cotton lint (CL), copper wire (CUW), cotton yarn (CV), electricity (E), electrical cables (EC), fresh flowers (FF), fresh fruit vegetables (FFV), gemstones (G), gasoil/petroleum oils (GPO) and white spoon sugar (WSS). In addition copper (CU) is examined over the period 2000-2007.

In terms of graphical plots, total imports and exports display a cyclical pattern between 1980 and 2000 (see figure 4.1 above). However, a rising trend is vivid in both series from 2000 onwards. Conversely, individual export commodities display an erratic pattern with large swings, reflecting periods of no exports (see figure 4.2). The

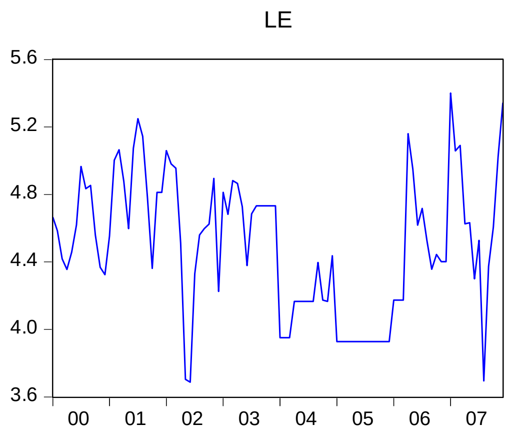
[64] Attempts to derive volume from value data by deflating values by prices (prices are usually proxied by contractual export prices, unit value prices and wholesale price indices) often yield biased elasticity estimates. Moreover, whenever available, the coverage of commodities in these price indices is not uniform especially in developing countries (Onafowora and Owoye, 2008).

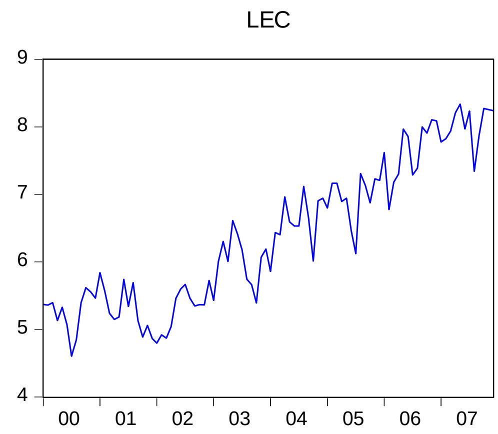
exception to this pattern is total NTEs, CU and CUW which exhibit a somewhat smooth pattern similar to IM and EX post-2000[65].

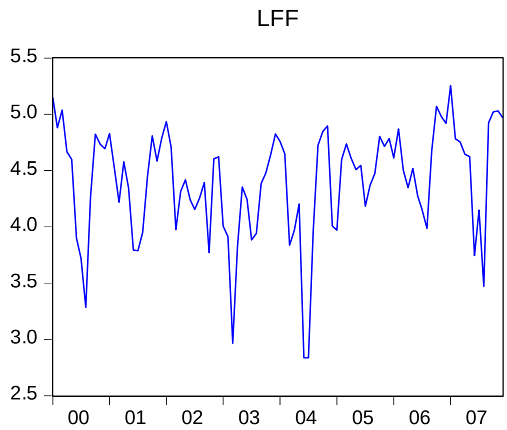
Figure 4.2 Logarithm of total NTEs and individual Export Commodities

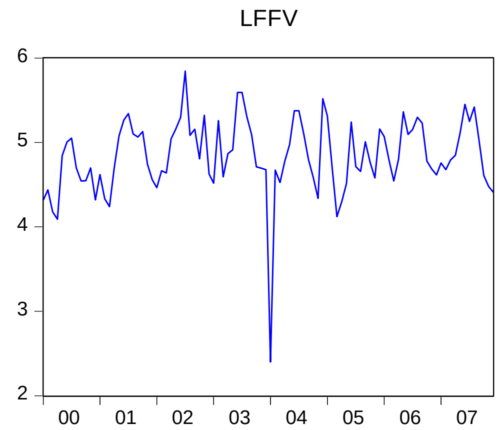


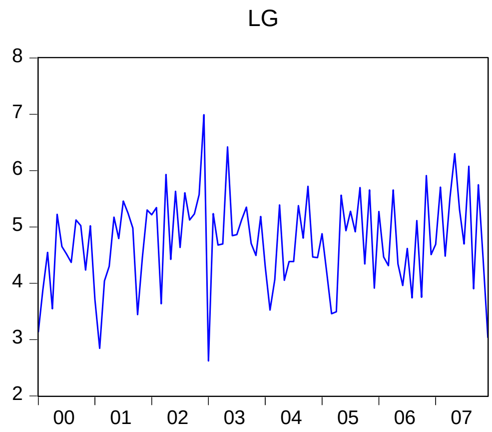
[65] The smooth pattern in import and export data series could be attributed to aggregation of individual items.

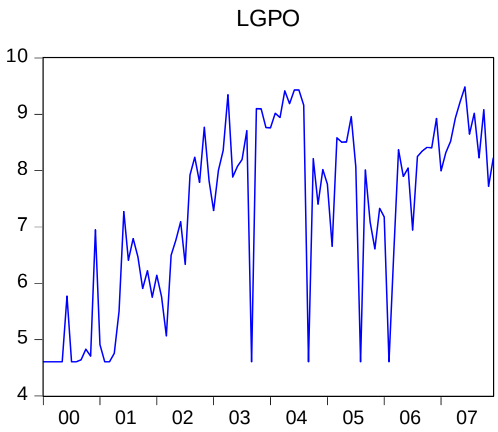

LE
5.6
5.2
4.8
4.4
4.0
3.6
00 01 02 03 04 05 06 07


LEC
9
8
7
6
5
4
00 01 02 03 04 05 06 07


LFF
5.5
5.0
4.5
4.0
3.5
3.0
2.5
00 01 02 03 04 05 06 07


LFFV
6
5
4
3
2
00 01 02 03 04 05 06 07


LG
8
7
6
5
4
3
2
00 01 02 03 04 05 06 07


LGPO
10
9
8
7
6
5
4
00 01 02 03 04 05 06 07

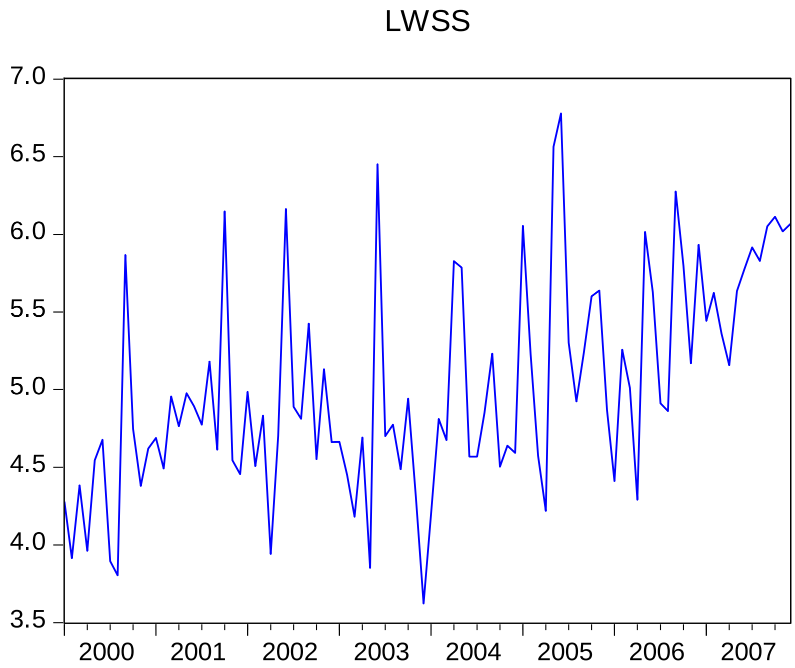


Figure 4.3 displays the measure of income. LYAGG and LYBT…LYWSS represent foreign income used in the total exports/total NTEs and individual export commodity demand equations, respectively. Foreign income is measured as trade-weighted real gross domestic product (GDP) for countries to which Zambia's exports are destined[66]. LYAGG includes income for all trading partner countries captured from Datastream over the period 1980-2007 whereas for individual export commodities, foreign income represents GDP for countries as shown in Table 4.1. LYZGDP is domestic income (real GDP for Zambia) used in the import demand equation.

As data on GDP are not available at monthly frequency and since industrial production index, the widely used proxy for real GDP, is not available in many countries (in particular developing countries), to ensure data compatibility across countries in the sample, real monthly GDP estimates are interpolated from annual real GDP series using the cubic-match-last method similar to previous empirical studies (e.g.

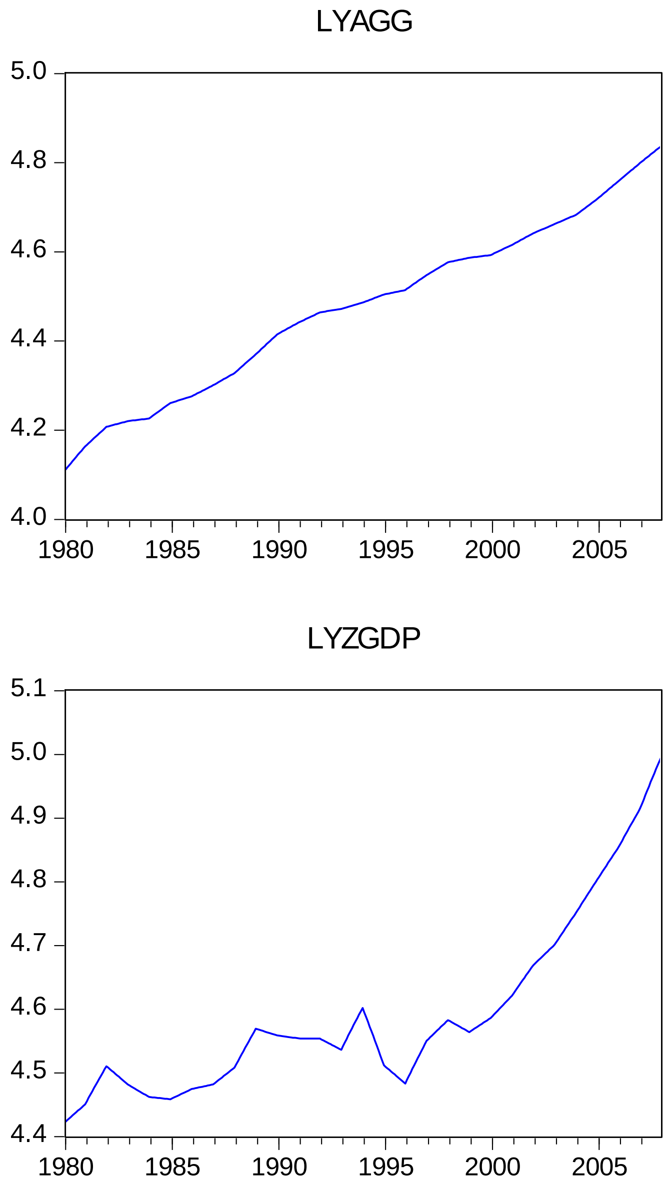
[66] Trade-weighted income is computed as a sum of the product of each country's trade weight and real GDP for each commodity at time *t*.

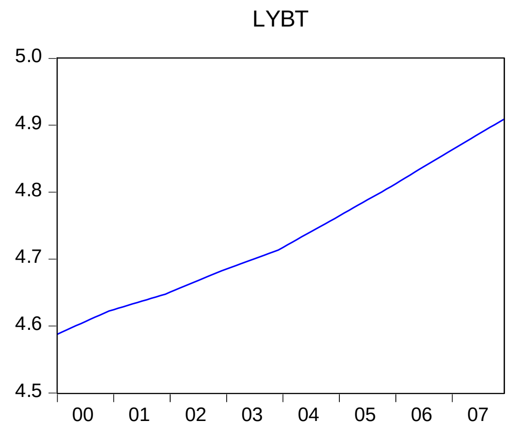
Caglayan, 2008). Real GDP is obtained by deflating nominal GDP by GDP deflator for each country. The trade-weighted income approach is used to avoid assigning equal importance to all markets. Trade weights for individual export commodities are based on 2007 trade data[67] while for aggregate trade flows (total imports, exports and NTEs), trade data from 1980 to 2007 obtained from Datastream are used to derive trade weights. Nominal annual GDP (expressed in local currency unit) and GDP deflator (index with 2000 as base year) data for each country are taken from the IFS of IMF series 99b.czf and 99birzf, respectively. However, for DRC and Zambia, GDP in local currency at market prices and GDP deflator are respectively obtained from the World Bank Development Indicators series NY.GDP.MKTP.CN and NY.GDP.DEFL.ZS.

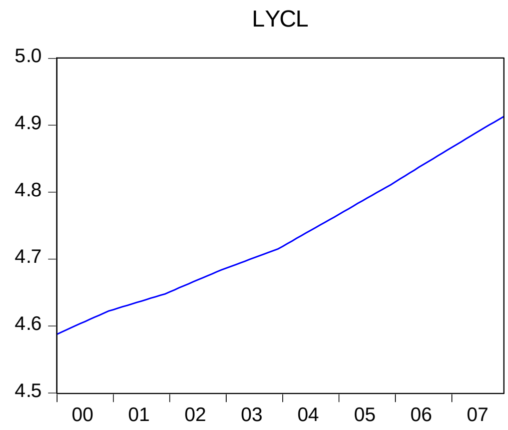
All income series in figure 4.3 exhibit a rising trend, with real GDP for Zambia (LYZGDP) exhibiting a drastic increase after 2000 after a sustained period of low and negative growth as alluded to in chapter 2.

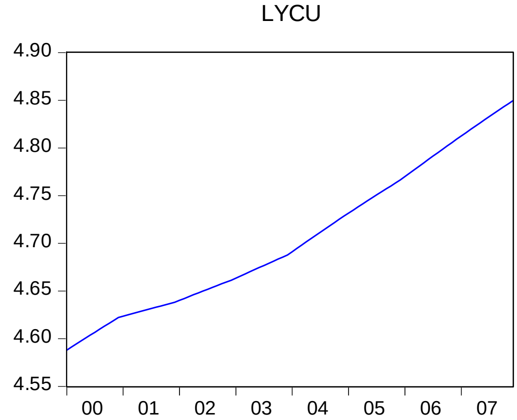
[67] Data on export destinations for individual commodities obtained from Zambia Development Agency are only available for one year, 2007. Nonetheless, the computed weights are not likely to change substantially with the sample covering more years as trade pattern has not changed considerably since trade reforms commenced.

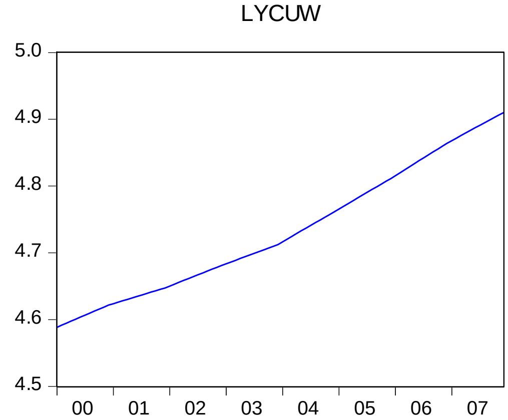
Figure 4.3 Logarithm of Income

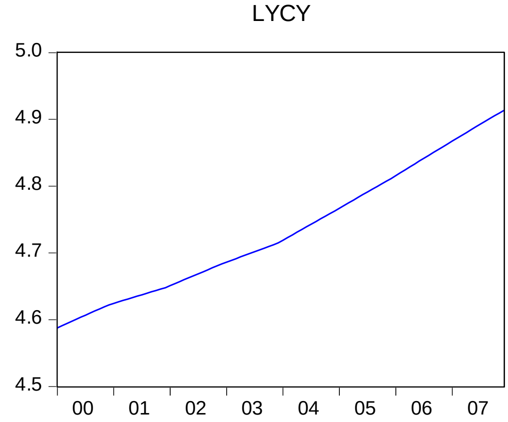


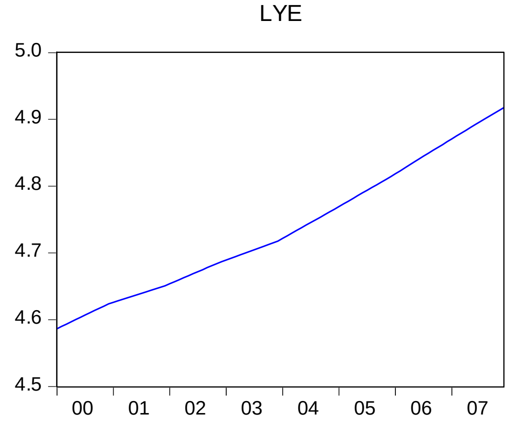

LYBT
5.0
4.9
4.8
4.7
4.6
4.5
00 01 02 03 04 05 06 07


LYCL
5.0
4.9
4.8
4.7
4.6
4.5
00 01 02 03 04 05 06 07


LYCU
4.90
4.85
4.80
4.75
4.70
4.65
4.60
4.55
00 01 02 03 04 05 06 07


LYCUW
5.0
4.9
4.8
4.7
4.6
4.5
00 01 02 03 04 05 06 07


LYCY
5.0
4.9
4.8
4.7
4.6
4.5
00 01 02 03 04 05 06 07


LYE
5.0
4.9
4.8
4.7
4.6
4.5
00 01 02 03 04 05 06 07

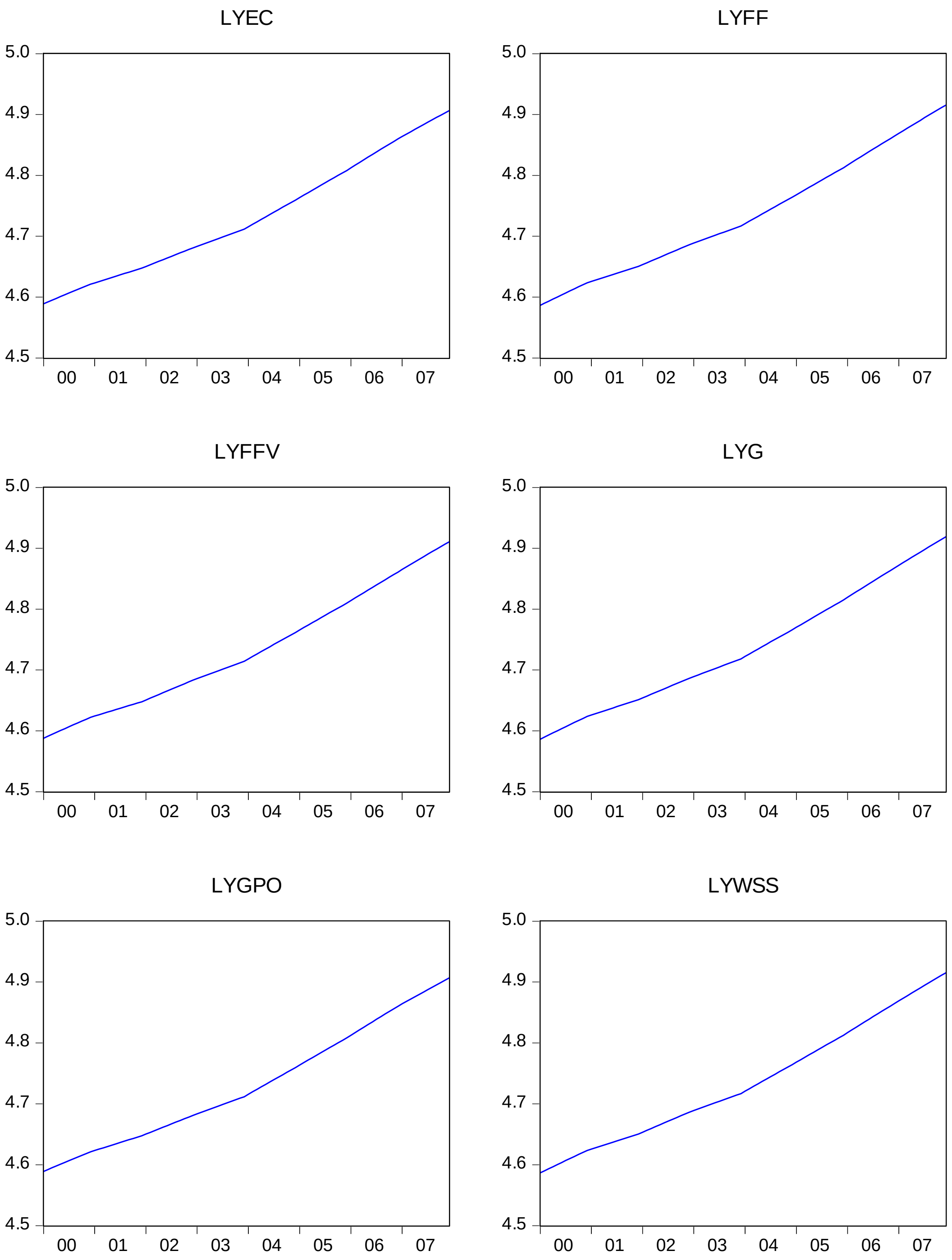

LYEC
LYFF
LYFFV
LYG
LYGPO
LYWSS
5.0
4.9
4.8
4.7
4.6
4.5
00
01
02
03
04
05
06
07

Table 4.1 Export commodity by destination (trade weights in brackets)

Commodity	Country of destination(trade weight)
Burley tobacco	Belgium(0.02), Botswana(0.01), Bulgaria(0.00), Canada(0.00), Denmark(0.00), France(0.19), Germany(0.14), Israel(0.00), Malawi(0.05), Phillipines(0.00), Poland(0.00), South Africa(0.22), Ireland(0.00), Russia(0.00), Spain(0.02), Switzerland(0.22), Thailand(0.06), Ukraine(0.00), United Arab Emirates(0.00), Zimbabwe(0.06).
Cotton lint	Botswana(0.01), Canada(0.00), China(0.08), DRC(0.05), UK(0.36), Lesotho(0.00), Malawi(0.04), South Africa(0.20), Swaziland(0.00), Switzerland(0.20), Zimbabwe(0.05).
Copper	Switzerland(0.13), China(0.05), Egypt(0.01), SaudiArabia(0.04), Netherlands(0.04), Malaysia(0.02), Thailand(0.04),Taiwan(0.00), India(0.08), United Kingdom(0.37), Japan(0.35).
Copper wire	Botswana(0.01), Kenya(0.02), Malawi(0.05), South Africa(0.25), Swaziland(0.00), Tanzania(0.07), Uganda(0.00), DRC(0.07), Zimbabwe(0.07), Kuwait(0.00), Hong Kong(0.01), Singapore(0.04), India(0.15), Switzerland(0.25), Canada(0.00).
Cotton yarn	Belgium(0.02), Botswana(0.01), DRC(0.04), Germany(0.10), UK(0.28), India(0.10), Italy(0.11), Malawi(0.03), South Africa(0.16), Switerland(0.15).
Electricity	Namibia(0.10), Tanzania(0.17), South Africa(0.52), Botswana(0.02), DRC(0.14), Zimbabwe(0.14).
Electrical cables	Botswana(0.01), DRC(0.09), Italy(0.25), Kenya(0.03), Malawi(0.07), South Africa(0.34), Tanzania(0.11), UAE(0.00), Zimbabwe(0.09).
Fresh flowers	Germany(0.12), UK(0.35), Netherlands(0.05), New Zealand(0.00), Norway(0.00), South Africa(0.19), Switzerland(0.19), USA(0.10).
Fresh fruit vegetables	Botswana(0.01), DRC(0.05), UK(0.32), Malawi(0.04), Namibia(0.00), Netherlands(0.05), New Zealand(0.00), Nigeria(0.00), South Africa(0.17), Switzerland(0.17), Tanzania(0.06), UAE(0.00), USA(0.10), Zimbabwe(0.05).
Gemstones	Australia(0.00), Bangladesh(0.00), Belgium(0.01), Canada(0.00), China(0.04), DRC(0.03), France(0.09), Germany(0.07), UK(0.19), Greece(0.02), Hong Kong(0.00), India(0.07), Israel(0.00), Italy(0.08), Kuwait(0.00), Netherlands(0.03), South Africa(0.11), Sri Lanka(0.00), Swaziland(0.00), Switzerland(0.11), Taiwan(0.00), Tanzania(0.03), Thailand(0.03), UAE(0.00), USA(0.06), Zimbabwe(0.03).
Gasoil/petroleum oils	DRC(0.12), Kenya(0.04), Malawi(0.10), Mozambique(0.00), South Africa(0.46), Tanzania(0.14), Zimbabwe(0.12).
White spoon sugar	Botswana(0.01), South Africa(0.28), Tanzania(0.09), DRC(0.07), Belgium(0.03), Burundi(0.01), UK(0.50), Namibia(0.01), Portugal(0.01).

Source: Zambia Develpoment Agency and author computations

Consistent with previous studies (i.e. Ardalani and Bahmani-Oskooee, 2006; Baak et al. 2007; and Bahmani-Oskooee and Hegerty, 2009), relative price is proxied by the real exchange rate (CPI-based with 2000 as base year) due to non-availability of data on import and export prices in Zambia. Thus, the real KUS$ exchange rate (LRKUS$) plotted in figure 4.1 above is used as most exports and imports are predominantly invoiced and settled in US$ (BoZ unpublished report dated 2006).

Eight alternative measures of exchange rate volatility are employed[68]. These are volatility in real and nominal KUS$ (widely used exchange rates in trade as explained above), Krand and trade-weighted exchange rates plus GARCH-PCA generated in the previous chapter but re-estimated over the sample period 1980-2007. The EGARCH (1, 1) model is used as an optimal model to generate volatility in KUS$, Krand and trade-weighted series (refer to chapter 3). The Krand is included in the estimation due to the prominence of South Africa as a major destination for most of Zambia's exports as shown in table 4.1[69]. Both trade-weighted and GARCH-PCA exchange rate volatility are used in individual export commodity demand functions to capture the effects of other currencies rather than the KUS$ and Krand in which some trade transactions are conducted[70].

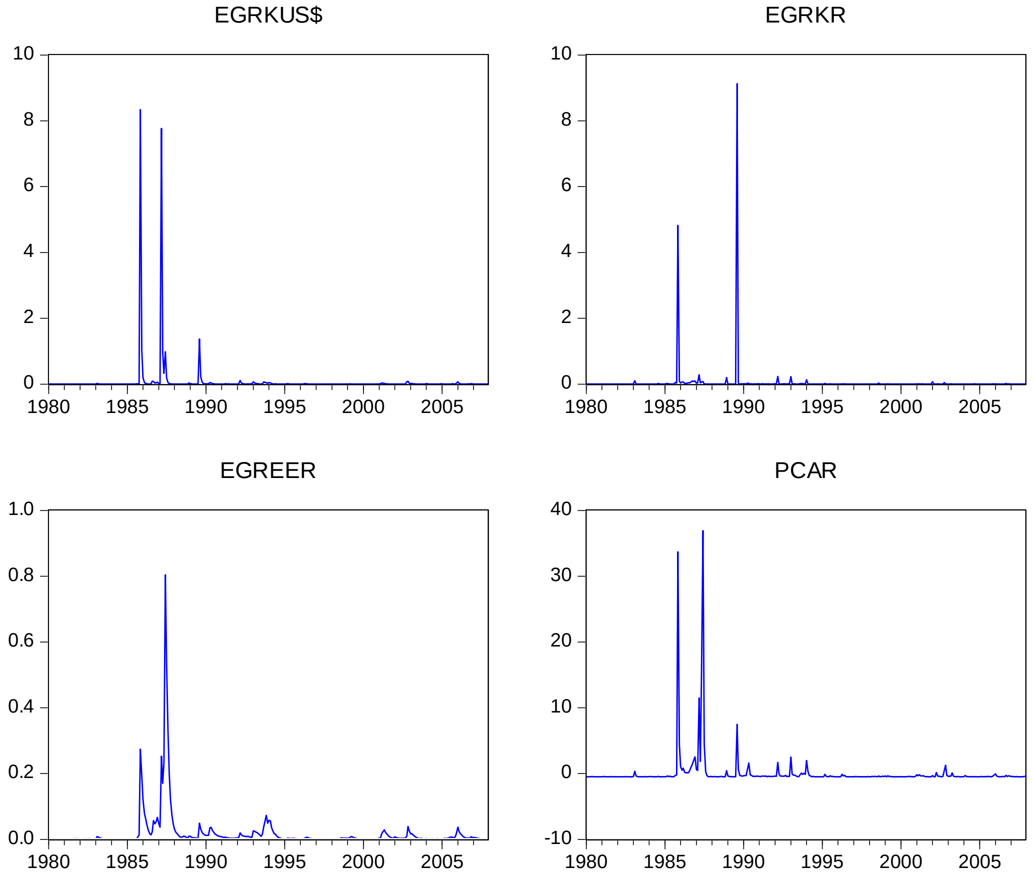
Plots of exchange rate volatility series are in figure 4.4 for real and nominal KUS$ denoted as EGRKUS$ ($erv_{rkus\$}$) and EGNKUS$ ($erv_{nkus\$}$), real and nominal Krand denoted as EGRKR (erv_{rkr}) and EGNKR (erv_{nkr}), real and nominal trade-weighted

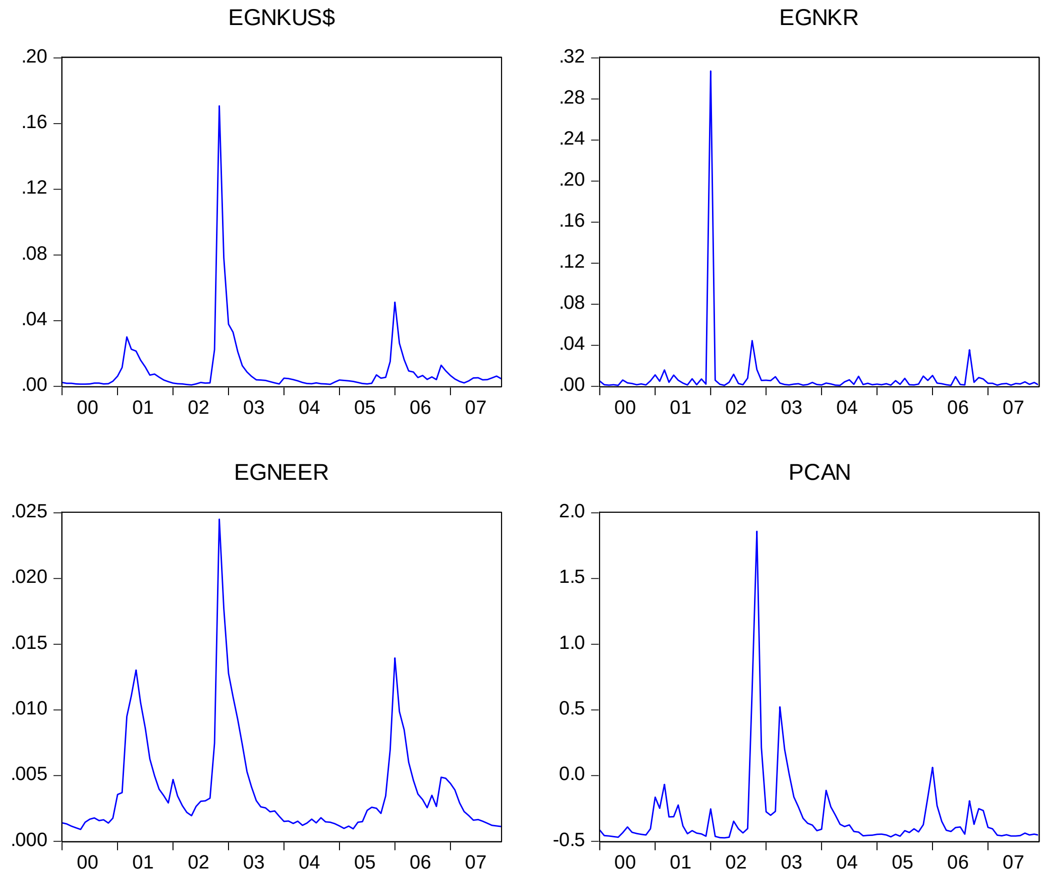
[68] This implies that eight versions of equations 11 and 12 are estimated for each import and export demand equation corresponding to total import/export and individual export commodities.
[69] South Africa has a relatively larger trade share with Zambia than any country. Some trade transactions (invoicing and settlement) are conducted in South African rand. Invoicing exports in foreign currency has the effect of importing economic shocks from abroad (Doyle, 2001). Further, South Africa is a major source of most imports for Zambia with a share of just under two-thirds in Zambia's total trade as reported in the previous chapter.
[70] The bilateral exchange rate is relevant if analysing firm behaviour or currency of invoicing and receipting involved for individual commodities (Côte, 1994). Conversely, the appropriate measure of exchange rate risk for aggregate trade involving a country/firm or trade transactions in different currencies with possibility of exchange rate moving in offsetting direction to mitigate the risk is the effective exchange rate (Côte, 1994; and Clark et al. 2004).

denoted as EGREER (erv_{reer}) and EGNEER (erv_{neer}) and real and nominal GARCH-PCA denoted as PCAR (erv_{rpca}) and PCAN (erv_{npca}), respectively.

As the estimation period for total imports and exports covers the fixed exchange rate regime, only volatility in the real exchange rate is employed in total import and export demand equations.

Figure 4.4 Plots of Exchange Rate Volatility Series





4.4.3 Estimation Method

Several estimation techniques have been employed in the analysis of exchange rate volatility-trade flow relationship. They include ordinary least squares, instrumental variable, vector autoregressive (VAR) based cointegration and error-correction models, ARDL and GARCH-in-Mean simulation analysis (see Ozturk, 2006). The use of the VAR technique has increased in recent years as it accommodates general dynamic relationships among variables[71].

Underlying the concept of cointegration or long-run equilibrium analysis is that in many cases, time series variables are non-stationary, but move together over time and hence share a common stochastic trend.

---

[71] Failure to take into account dynamism in relationships is cited as a contributing factor for obtaining weak results in most earlier studies (Doyle, 2001).

As mentioned earlier, the underlying equilibrium relationship among variables in equations 11 and 12 are examined using the Johansen and ARDL cointegration methods. However, the two methods differ in terms of estimation procedure and underlying assumptions as well as the way time series properties of variables under study are treated. Unlike the Johansen method, the ARDL bounds test does not require the pre-testing of variables for non-stationarity. While it is noted that variables must be of the same order of integration to undertake cointegration analysis, the Johansen method can still be employed despite variables being of different integration order[72]. However, the validity of the Johansen and ARDL methods is questionable with respect to the distribution of the test statistic when estimated time series variables such as conditional variance are used instead of the observed ones. The use of estimated time series adds to the degree of uncertainty resulting in a larger variance (hence a degree of error) such that the test statitistic no longer follows the original distribution under the null hypothesis. The test statistics would be different from the standard Johansen and ARDL ones when conditional variance is used as an endogenous variable. Notwithstanding this, the Johnasen and ARDL methods are used in line with prrevious studies as the possibility of the error-in-variable is noted but assumed to be negligible. A brief description of the two methods follows.

[72] de Vita and Abbott (2004) argue that mixing I(0) and I(1) regressors in cointegration analysis can render standard statistical inference based on conventional cointegration tests invalid: spurious cointegration relations are generated as trace and maximum eigenvalue tests are difficult to interpret and nuisance parameters are likely to be generated by I(0) regressors. A counter argument is provided by Enders (2004) and Asteriou and Hall (2007). They argue that cointegrating relationship among groups of variables of different orders of integration may exist in that the trend in one variable can be expressed as a linear combination of the trends in the other variable(s). However, mixing I(0) and I(1) series tends to generate many cointegrating vectors as each stationary variable forms each vector and also with others. The system becomes complex as many cointegrating vectors are possible as each I(0) forms a vector on its own and also combines with other I(0) resulting from linear combination of I(1) series.

4.4.3.1 Johansen Method

The Johansen maximum likelihood system-based reduced-rank regression approach determines the presence of cointegration in non-stationary time series using the trace trace (λ_{trace}) and maximal eigenvalue ($\lambda_{\max}$) statistical ratio tests. The non-stationary time series are set up as VAR in general form

$$\Delta z_t = \phi D_t + \Pi z_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta z_{t-i} + \varepsilon_t \qquad (13)$$

where Δ is the difference operator; z_t is an $(nx1)$ vector of non-stationary variables (n) in levels such that variables in equations 11 and 12 constitute elements of z_t i.e. $z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$; D_t is an $(nx1)$ vector of deterministic variables: intercept, time trend, seasonal dummy variables or other intervention dummies; ϕ is a matrix of coefficients on deterministic variables; $\Pi = -(\Pi_1 - \Pi_2 - ....\Pi_p - I)$ is an (nxn) impact matrix of unknown coefficients with I being an (nxn) identity matrix; n is the number of variables constituting z_t; $\Gamma_i = (I - \Gamma_1 - \Gamma_2 - .... - \Gamma_p)$, the short-run response matrix with $i = 1,2,3,..., p$, is a matrix of parameter coefficients on lagged first difference of z_t variables; ε_t is an $(nx1)$ vector of Gaussian innovations; p is the lag length for the VAR; and $t = 1,2,......,T$.

The $\prod$ matrix is a product of two matrices α and β' that contains information about the long-run relationship among z_t variables. α is an (nxr) matrix of coefficients reflecting how quickly each variable in z_t adjusts towards the equilibrium once a disequilibrium occurs while β' is an (rxn) matrix representing cointegrating vector(s) with long-run coefficients among z_t. The rows of $\beta^{'}$ also known as the cointegrating rank (r) of $\prod$ form the r distinct cointegrating vectors such that the elements in $\beta^{'} z_t$ are stationary even though z_t is itself non-stationary.

To detect the presence of cointegration in the unrestricted VAR, the rank of $\prod$ must be determined through its eigenvalues (λ_i) using λ_{trace} and $\lambda_{\max}$[73]. The rank of $\prod$ is equal to the number of non-zero $\lambda_i s$ arranged in ascending order: $\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq ..... \geq \lambda_n$. The number of significant eigenvalues in the estimated matrix defines the rank of $\prod$. The condition for cointegration is for the $\prod$ matrix to have a reduced rank i.e. $0 < r \leq (n-1)$. Otherwise a cointegrating relationship will not exist among z_t variables if the rank of $\prod$ is either equal to n[74] or zero[75].

The number of r is confirmed by comparing the test statistic with the critical values such that the null of the number of r present is rejected in favour of the alternative if the test statistic exceeds the critical value for a given λ_i. A non-zero vector indicated by the two tests implies a stationary long-run relationship between z_t variables and the larger the number of non-zero vectors the more stable is the system. It is possible for the two tests to lead to different conclusions about the number of cointegrating vectors. The choice between λ_{trace} and $\lambda_{\max}$ depends on the economic

---

[73] The trace test is defined as $\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln(1-\hat{\lambda}_i)$ while the maximal eigenvalue test is $\lambda_{\max}(r, r+1) = -T \ln(1-\hat{\lambda}_{r+1})$ with $\hat{\lambda}_i$ representing the estimated value of the $i-th$ ordered eigenvalue from the $\prod$ matrix. As an example, for a four variable VAR, the null hypothesis for λ_{trace} is $r = 0$, $r \leq 1$, $r \leq 2$, $r \leq 3$ while the corresponding alternative is $r \geq 1$, $r \geq 2$, $r \geq 3$, $r = 4$. On the other hand, the null hypothesis for $\lambda_{\max}$ is $r = 0$, $r \leq 1$, $r \leq 2$, $r \leq 3$ while the corresponding alternative is $r = 1$, $r = 2$, $r = 3$, $r = 4$.

[74] This is a case of a full rank such that all z_t variables are I(0).

[75] In this case all z_t sequences are unit root processes with linearly independent columns.

interpretation of the cointegrating vectors. Generally, $\lambda_{\max}$ is preferred to λ_{trace} due to the precise formulation of the alternative hypothesis in determing the rank of Π (Enders, 2004)[76].

Once cointegration is confirmed, a VECM that incorporates both short-run and long-run effects is estimated such that $\beta' z_{t-1}$ is the error-correction as $\beta' z_{t-1} \sim I(0)$ through cointegration and defines the stability condition for the VECM. This is in line with the postulation by the Granger representation theorem that a dynamic error-correction representation of a given data set exists if a cointegrating relationship exists among them (Engel and Granger, 1987). If cointegration is not detected, a VAR in first differences of z_t is estimated as there is no stationary linear combination of the z_t variables and thus no error-correction representation.

Residuals are assumed to be Gaussian. Thus an optimal lag length for the unrestricted VAR and subsequently VECM that ensures serially uncorrelated residuals is chosen based on an appropriate Lagrange-Multiplier (LM) test and information criteria (AIC, SBC). The adequacy of the estimated VECM can be checked based on equation residuals using various diagnostic tests such as serial correlation, normality and heteroskedasticity. Further, the deterministic term can enter either the VAR or the cointegrating equation or both. The decision on this kind of specification is empirical. The Pantula principle[77] is usually employed to select the appropriate deterministic trend specification in a cointegrating VAR (Asteriou and Hall, 2007).

---

[76] To the contrary those who prefer the λ_{trace} argue that the trace test is robust to skewness and excess kurtosis in residuals and that it is more powerful when eigenvalues are evenly distributed (Choudhry, 2005).

[77] The Pantula principle refers to the process of choosing the appropriate model with respect to deterministic terms entering the cointegration specification. The test starts with the most restrictive case to the least restrictive one using the trace test statistic for the null of no cointegrating. The process stops (hence optimal model determined) when the null is rejected for the first time.

The Johansen tests allows for hypothesis testing on the elements of the $\prod$ matrix informed by theoretical predictions or model restrictions. Thus, linear restrictions are imposed on α and β to obtain an economically interpretable relationship among z_t variables once cointegration is confirmed. This involves determining whether the cointegrating vectors are identified and check for parameter constancy in the long-run cointegrating vector. Thus tests such as weak exogeneity and causality using χ^2 statistics as well as innovation accounting (impulse response and variance decomposition) can be performed.

With cointegration confirmed, causality must exist in at least one direction (Choudhry, 2005). If β for a variable in any cointegrating vector is insignificant, then this confirms absence of causality among variables under study[78]. If however, α for any of z_t is equal to zero, the corresponding variable is characterised as weakly exogenous with respect to β (refer to subsection 4.4.4.1 for more details)[79]. The significance of α_i implies rejection of weak exogeneity corresponding to variable i in a given cointegrating vector, implying long-run causality running from variable i to other variable(s). Conversely, the insignificance of α_i means variable i is weakly exogenous, and thus no causality exists. Bi-directional long-run causality exists when weak exogenity is rejected for two variables.

[78] This test corresponds to short-run Granger non-causality whereby given two variables X and Y the causality test is set up as $X \rightarrow Y$ with the $H_0 : \beta_{1X} = 0$ against $H_1 : \beta_{1X} \neq 0$ such that the rejection of H_0 implies absence of causality from X to Y.

[79] All the discrepancy from long-run equilibrium take places through other variables and hence does not provide any useful information regarding the inference based on the estimated parameters.

4.4.3.2 ARDL Bounds Testing Procedure

The ARDL bounds testing procedure to cointegration examines the long-run equilibrium relationship between a dependent variable and a set of regressors in levels irrespective of the order of integration of the regressors: whether I(0), I(1) or mutually/fractionally cointegrated. As equations 11 and 12 above state the long-run relationship among z_t variables, short-run dynamics can be incorporated using the ARDL method by expressing the two equations in error-correction modelling form as follows (see Bahmani-Oskooee and Goswami, 2004; and Ardalani and Bahmani-Oskooee, 2006)

$$\Delta \ln EX_t = \alpha_0 + \phi D_t + \sum_{k=1}^{n1} \alpha_1 \Delta \ln EX_{t-k} + \sum_{k=1}^{n2} \alpha_2 \Delta \ln Y_{t-k} + \sum_{k=1}^{n3} \alpha_3 \Delta \ln P_{t-k} + \sum_{k=1}^{n4} \alpha_4 \Delta erv_{t-k}$$
$$+ \alpha_5 \ln EX_{t-1} + \alpha_6 \ln Y_{t-1} + \alpha_7 \ln P_{t-1} + \alpha_8 erv_{i-1} + \varepsilon_t \qquad (14)$$

$$\Delta \ln IM_t = \alpha_0^{'} + \phi D_t + \sum_{k=1}^{n1^{'}} \alpha_1^{'} \Delta \ln IM_{t-k} + \sum_{k=1}^{n2^{'}} \alpha_2^{'} \Delta \ln Y_{t-k} + \sum_{k=1}^{n3^{'}} \alpha_3^{'} \Delta \ln P_{t-k} + \sum_{k=1}^{n4^{'}} \alpha_4^{'} \Delta erv_{t-k}$$
$$+ \alpha_5^{'} \ln IM_{t-1} + \alpha_6^{'} \ln Y_{t-1} + \alpha_7^{'} \ln P_{t-1} + \alpha_8^{'} erv_{i-1} + \varepsilon_t^{'} \qquad (15)$$

where $n1, n2,\ n3,$ and $n4$ denoted as ARDL ($n1, n2,\ n3, n4$) and the counterparts for the import demand equation are lags on first difference of z_t chosen on the basis of certain information criterion (SBC, AIC). The rest of the variables are as defined earlier.

The long-run effects normalised on EX_t are captured by the estimated $\alpha_5, \alpha_6, \alpha_7$ and α_8 coefficients (the same applies to the import demand equation). The short-run effects are reflected in statistically significant $\alpha_1, \alpha_2, \alpha_3$ and α_4 coefficients (and corresponding parameter coefficients in the import demand equation). The error-correction term is captured by a linear combination of the lagged level of all variables in z_t. Deterministic terms may be restricted or unrestricted (see Pesaran et al. 2001 for details regarding the five possible cases).

To detect the presence of cointegration among z_t, a decision must be made whether lagged levels of z_t should be retained or not. The idea is to test for the absence of the level relationship between trade flows and their determinants by excluding lagged level z_t variables in equations 14 and 15. This is an explicit test for cointegration among z_t variables. Thus, a joint null hypothesis involving coefficients on lagged levels of z_t i.e. $H_0 : \alpha_5 = \alpha_6 = \alpha_7 = \alpha_8 = 0$ against the alternative $H_1 : \alpha_5 \neq 0$, $\alpha_6 \neq 0$, $\alpha_7 \neq 0$, $\alpha_8 \neq 0$ is tested using the Wald or F-test statistic with critical values provided by Pesaran et al. (2001). The same applies to equation 15. The F-test has non-standard distribution.

Two asymptotic critical values are used to detect the presence of cointegration: one set corresponding to lower values purely for I(0) regressors and the other set for upper values purely for I(1) regressors while mutually cointegrated cases are also catered for by the bounds created by the two critical values. A conclusive decision about the null is made when the calculated F-statistic falls outside the critical value bounds. An inconclusive inference about the null exists when the calculated F-statistic falls within the critical value bounds. Thus, knowledge of the order of integration of the regressors in z_t is required in order to further examine the relationship in the inconclusive case. Cointegration is confirmed among z_t variables if the F-statistic exceeds the upper critical value while the null of no cointegration cannot be rejected if the F-statistic falls below the lower critical value. The F-test statistic is sensitive to the lag length for each differenced variable in z_t.

Once cointegration is established, estimates of the long-run coefficients can be obtained and the ECM associated with the long-run estimates can also be estimated. The optimal lag length for each of the first differenced z_t variables is chosen based on the AIC and/or SBIC. Coefficient stability can be tested by undertaking cumulative sum (CUSUM) and CUSUMSQ tests on residuals of the ARDL model. Stability is achieved if the plots of CUSUM and CUSUMSQ fall within a defined significance level such as the conventional 95 percent.

4.4.4 Empirical Results

The unit root test results conducted using the ADF and P-P methods reveal that trade, income and real exchange rate data series are I(1) as they are level non-stationary but first difference stationary (see table 4.2.). On the other hand, all measures of exchange rate volatility are level stationary or I(0) consistent with the convergent GARCH model results obtained in chapter 3. Rahmatsyah et al. (2002) and Bahmani-Oskooee and Hegerty (2009) also found exchange rate volatility to be I(0).

Table 4.2 Unit root tests

	ADF Level	First Diff	lags	Determ included	P-P level	First Diff	Determ included
LIM	-1.6	-16.3*	2	C&T	-3.3	-43.8*	C&T
LEX	-1.5	-16.4*	2	C&T	-3.4	-39.7*	C
LNTEs	-1.7	-12.4*	1	C	-1.2	-21.6*	C
LVBT	-2.9	-16.7*	0	C	-0.5	-27.6*	None
LVCL	-0.2	-11.8*	0	None	0.2	-18.3*	None
LVCU	-0.1	-6.9*	8	C&T	-1.7	-22.9*	C&T
LVCUW	-3.6	-6.4*	11	C&T	-2.2	-23.5*	C
LVCY	-2.9	-11.6*	1	C	-0.8	-21.3*	None
LVE	-3.7	-10.8*	0	C&T	-3.7	-13.1*	C&T
LVEC	-0.5	-9.6*	1	C	-0.6	-18.6*	C
LVFF	-0.5	-10.4*	0	None	-0.3	-15.0*	None
LVFFV	-0.3	-13.3*	1	None	-0.1	-20.4*	None
LVG	-0.4	-11.8*	2	None	-0.6	-30.0*	None
LVGPO	-3.9	-10.9*	1	C&T	0.1	-25.6*	None
LVWSS	0.6	-10.7*	3	None	0.2	-31.2*	None
LZGDP	-0.5	-3.7**	0	C&T	1.1	-4.0**	C&T
LYAGG	-2.5	-3.2+	0	C&T	-1.9	-3.2+	C&T
LYBT	-0.9	-3.5**	1	C&T	0.7	-3.6**	C&T
LYCL	-0.9	-3.5**	0	C&T	0.7	-3.6**	C&T
LYCU	-2.5	-3.2+	0	C&T	-1.4	-3.3+	C&T
LYCUW	-1.2	-3.4**	0	C&T	0.4	-3.5**	C&T
LYCY	-0.9	-3.5**	0	C&T	0.7	-3.6**	C&T
LYE	-0.9	-3.5**	0	C&T	0.7	-3.6**	C&T
LYEC	-1.1	-3.4**	0	C&T	0.5	-3.5**	C&T
LYFF	-0.9	-3.5**	0	C&T	0.7	-3.6**	C&T
LYFFV	-1.0	-3.5**	0	C&T	0.6	-3.6**	C&T
LYG	-0.8	-3.5**	0	C&T	0.7	-3.6**	C&T
LYGPO	-1.1	-3.4**	0	C&T	0.5	-3.5**	C&T
LYWSS	-0.9	-3.5**	0	C&T	0.7	-3.6**	C&T
LRKUS$	0.2	-19.1*	0	C&T	0.3	-19.2**	C&T
LRKRAND	-0.2	-18.8*	0	C&T	-0.2	-18.8**	C&T
erv_{neer}	-7.3*		0	C	-7.1*		C
erv_{reer}	-3.7*		1	C	-3.6*		C
$erv_{rkus\$}$	-6.9*		0	C	-6.7*		C
$erv_{nkus\$}$	-8.5*		0	C	-8.4*		C
erv_{rkr}	-9.1*		0	C	-9.1*		C
erv_{nkr}	-5.3*		3	C	-9.3*		C
erv_{npca}	-9.3*		0	C	-9.0*		C
erv_{rpca}	-8.2*		0	C	-8.1*		C

Source: Eviews6

Critical values for unit root tests are Mackinnon (1996) one-sided p-values. All variables are expressed in natural logarithm except exchange rate volatility. *, ** and + imply 1%, 5% and 10% levels of significance, respectively. Determ=deterministic, C is constant while T stands for trend.

Exchange rate volatility can still impose level effects on trade flows despite being I(0). Hence, it is included in the cointegration test in line with Pattichis et al. (2004) and Asteriou and Hall (2007).

The existence of a stable long-run equilibrium relationship between trade flows, income, relative prices and exchange rate volatility is confirmed by both ARDL and Johansen methods. Both λ_{trace} and $\lambda_{\max}$ tests reject the null of no cointegration for import and all export demand equations at the 5 percent significance level and indicate the existence of either one or two cointegrating relationships (see tables 4.3-4.17). This result is consistent with Baak et al. (2007), Onafowora and Owoye (2008) and Choudhry (2005, 2008) but is in contrast to Doyle (2001). Doyle discounted the long-run effects of exchange rate volatility on exports on account of being I(0) without formally conducting the cointegration test in the Johansen method employed. Similarly, the ARDL F-test reported in table 4.18 rejects the null hypothesis of no cointegration at 10 percent significance level similar to Rahmatsyah et al. (2002), Bahmani-Oskooee and Goswami (2004), Munyama and Todani (2005) and Ardalani and Bahmani-Oskooee (2006) as the calculated F-values exceed the upper bound F-critical values[80].

[80] There are cases where the decision for existence of cointegration for some measures of exchange rate volatility is inconclusive as the calculated F-values fall within the critical value band: erv_{neer} for copper wire and electricity; erv_{reer} for total imports and exports and GPO; $erv_{rk\$}$ for total exports and copper wire; erv_{nkr} for cotton yarn and electricity; erv_{rpca} total imports and cotton yarn. However, cointegration was detected in all the above when the intercept was restricted with no trend at 10 percent level as the F-critical values are 2.37-3.20.

Table 4.3 Cointegration Test for Total Imports (1980-2007)

	95% critical values	erv_{neer}	erv_{reer}	$erv_{rkus\$}$	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace}/No. of CE			1	1		1			1
$r=0$	69.8		98.4**	81.2**		99.2**			84.2**
$r=1$	47.9		45.7	46.6		43.3			42.9
$r=2$	29.8		13.0	13.3		11.4			13.4
$r=3$	15.5		3.6	3.5		3.3			3.2
$\lambda_{\max}$			2	2		2			2
$r=0$	33.9		52.7**	34.6**		55.9**			41.3**
$r=1$	27.6		32.7**	33.3**		31.9**			29.5**
$r=2$	21.1		9.4	9.8		8.1			10.1
$r=3$	14.3		3.5	3.4		3.3			3.2
Optimal lag			2	2		2			2

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.4 Cointegration Test for Total Exports (1980-2007)

	Critical values-95%	erv_{neer}	erv_{reer}	$erv_{rkus\$}$	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace}/No. of CE			2	2		1			1
$r=0$	47.9		66.4**	67.1**		56.6**			64.1**
$r=1$	29.8		30.0**	30.8**		26.1			28.8
$r=2$	15.5		7.4	8.4		8.2			7.6
$r=3$	3.8		1.4	1.6		1.9			1.4
$\lambda_{\max}$ / No. of CE			2	2		1			2
$r=0$	27.6		36.4**	36.2**		30.5**			35.3**
$r=1$	21.1		22.6**	21.9**		17.9			21.3**
$r=2$	14.3		6.0	7.3		6.3			6.2
$r=3$	3.8		1.4	1.6		1.9			1.4
Optimal lag			3	4		4			3

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.5 Cointegration Test for NTES (2000-2007)

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace}/No. of CE		1	1	2	1	2	2	2	2
$r = 0$	47.9	71.0**	67.6**	75.4**	68.5**	80.6**	87.2**	76.1**	79.4**
$r = 1$	29.8	29.3	28.8	33.6**	27.6	36.4**	34.4**	34.1**	40.4**
$r = 2$	15.5	15.6	16.1	15.3	14.6	10.0	10.6	12.4	12.8
$r = 3$	3.8	5.3	4.2	2.2	2.6	3.9	3.6	2.4	2.3
$\lambda_{\max}$ / No. of CE		1	1	2	1	2	2	2	2
$r = 0$	27.6	41.7**	38.8**	41.9**	41.0**	44.2**	52.8**	42.0**	39.0**
$r = 1$	21.1	13.7	12.7	18.2**	13.0	26.3**	23.8**	21.7**	27.6**
$r = 2$	14.3	10.4	11.9	13.2	11.9	6.1	7.0	10.1	10.4
$r = 3$	3.8	5.3	4.2	2.1	2.6	3.9	3.6	2.4	2.3
Optimal lag		2	2	2	2	2	3	2	2

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.6 Cointegration Test for Burley tobacco

	Critical values-95%	erv_{neer}	erv_{reer}	$erv_{rkus\$}$	erv_{nkus}	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace}/No. of CE		1	1	2	1	2	2	1	2
$r = 0$	47.9	61.8**	58.9**	70.5**	66.4**	75.1**	73.5**	66.7**	69.1**
$r = 1$	29.8	27.7	26.1	33.6**	26.8	38.6**	37.4**	28.6	37.1**
$r = 2$	15.5	15.0	11.2	13.4	15.1	8.5	8.2	11.6	11.9
$r = 3$	3.8	3.3	3.3	3.9	3.7	1.6	1.5	2.4	2.6
$\lambda_{\max}$ / No. of CE		1	1	1	1	2	2	1	2
$r = 0$	27.6	34.2**	32.8**	37.0**	39.6**	36.5**	36.1**	36.2**	32.0**
$r = 1$	21.1	12.6	14.9	20.2	11.7	30.0**	29.2**	19.0	25.3**
$r = 2$	14.3	11.7	7.9	9.4	11.4	6.9	6.7	9.2	9.3
$r = 3$	3.8	3.3	3.3	3.9	3.7	1.6	1.5	2.4	2.6
Optimal lag		2	2	2	3	2	2	3	2

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.7 Cointegration Test for Cotton lint

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace} /No. of CE		1	1	2	1	1	1	1	2
$r=0$	47.9	56.0**	67.2**	64.5**	59.8**	65.3**	68.6**	62.2**	67.2**
$r=1$	29.8	26.9	35.9	34.3**	28.1	28.6	27.8	29.2	35.9**
$r=2$	15.5	11.7	12.0	13.2	13.5	8.4	7.8	12.1	12.0
$r=3$	3.8	4.0	2.5	3.5	3.5	1.7	1.5	2.6	2.5
$\lambda_{\max}$ / No. of CE		1	2	2	1	1	2	1	2
$r=0$	27.6	29.7**	31.3**	30.2**	31.7**	36.7**	37.8**	33.0**	31.3**
$r=1$	21.1	15.2	23.9**	21.2**	14.5	20.3	23.0**	17.1	23.9**
$r=2$	14.3	7.7	9.5	9.6	10.1	6.7	6.3	9.5	9.5
$r=3$	3.8	4.0	2.5	3.5	3.5	1.7	1.5	2.6	2.5
Optimal lag		3	2	2	2	2	2	2	3

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.8 Cointegration Test for Copper

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace} /No. of CE		1	2	2	1			2	2
$r=0$	47.9	48.1**	64.8**	68.3**	50.8**			80.4**	87.9**
$r=1$	29.8	20.3	36.8**	36.8**	20.5			39.0**	39.1**
$r=2$	15.5	7.1	7.5	6.6	6.6			6.7	6.7
$r=3$	3.8	0.9	0.9	0.9	0.9			0.9	0.9
$\lambda_{\max}$ / No. of CE		1	1	1	1			1	1
$r=0$	27.6	27.7**	27.8**	31.4**	30.3**			40.4**	47.8**
$r=1$	21.1	13.3	14.7	15.2	13.9			17.8	17.7
$r=2$	14.3	6.2	6.6	5.8	5.7			5.8	5.8
$r=3$	3.8	0.9	0.9	0.9	0.9			0.9	0.9
Optimal lag		2	2	2	2			2	2

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.9 Cointegration Test for Copper wire

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace}/No. of CE		1	1	2	1	1	1	1	2
$r=0$	47.9	49.8**	59.1**	57.3**	49.5**	57.6**	55.1**	47.9**	63.1**
$r=1$	29.8	25.6	27.1	31.3**	26.0	19.4	18.8	26.8	35.4**
$r=2$	15.5	10.5	9.0	13.1	12.8	5.2	5.1	12.7	12.8
$r=3$	3.8	0.4	0.3	0.1	0.2	0.3	0.2	0.1	0.1
$\lambda_{\max}$ / No. of CE		1	1	1	1	1	1	1	1
$r=0$	27.6	24.2**	32.0**	26.0**	23.4**	38.3**	36.4**	21.1**	27.6**
$r=1$	21.1	15.1	18.1	18.2	13.2	14.2	13.7	14.1	15.9
$r=2$	14.3	10.0	8.7	13.0	12.6	4.9	4.9	12.6	12.8
$r=3$	3.8	0.4	0.3	0.1	0.2	0.3	0.2	0.1	0.1
Optimal lag		3	2	3	3	3	3	3	5

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.10 Cointegration Test for Cotton yarn

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace}/No. of CE		1	1	1	1	1	1	1	1
$r=0$	47.9	48.5**	50.7**	54.6**	49.1**	67.3**	65.2**	49.1**	56.4**
$r=1$	29.8	24.8	24.9	29.0	25.5	28.6	29.0	28.0	28.7
$r=2$	15.5	12.7	9.8	12.0	12.0	9.2	8.7	10.8	10.8
$r=3$	3.8	3.3	3.1	3.1	3.4	2.4	2.3	2.2	2.2
$\lambda_{\max}$ / No. of CE		1	1	1	1	2	2	1	1
$r=0$	27.6	22.6**	25.9**	25.6**	23.6**	35.8**	35.2**	21.2**	27.7**
$r=1$	21.1	12.1	15.1	17.0	13.5	22.3**	21.3**	17.2	17.9
$r=2$	14.3	9.5	6.7	8.9	8.7	6.9	6.5	8.5	8.6
$r=3$	3.8	3.3	3.1	3.1	3.4	2.4	2.3	2.2	2.2
Optimal lag		2	2	2	2	2	2	2	4

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.11 Cointegration Test for Electricity

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace} /No. of CE		1	1	2	1	1	1	1	2
$r=0$	47.9	59.6**	62.0**	75.1**	61.9**	60.4**	57.1**	63.7**	69.7**
$r=1$	29.8	26.8	28.0	34.1**	29.6	27.2	24.1	29.3	40.0**
$r=2$	15.5	12.5	10.7	13.4	15.1	12.0	9.9	14.6	15.3
$r=3$	3.8	3.7	1.4	3.5	2.7	2.5	2.2	5.0	4.8
$\lambda_{\max}$ / No. of CE		1	1	1	1	1	1	1	2
$r=0$	27.6	32.7**	33.9**	41.0**	30.3**	33.3**	33.0**	32.4**	29.7**
$r=1$	21.1	14.3	17.4	20.7	16.0	15.2	14.2	16.7	24.6**
$r=2$	14.3	8.8	9.2	10.0	10.9	9.5	7.6	9.6	10.5
$r=3$	3.8	3.7	1.4	3.5	4.8	2.5	2.2	5.0	4.8
Optimal lag		3	3	2	3	4	4	3	3

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.12 Cointegration Test for Electrical cables

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace} /No. of CE		1	1	1	1	2	2	1	2
$r=0$	47.9	54.2**	53.4**	60.4**	54.1**	58.1**	69.5**	56.9**	67.5**
$r=1$	29.8	25.7	25.9	28.7	26.4	30.9**	36.6**	28.9	34.2**
$r=2$	15.5	13.4	10.9	10.5	11.0	10.6	7.3	10.2	10.2
$r=3$	3.8	2.7	2.8	1.3	1.5	2.0	1.2	0.9	0.9
$\lambda_{\max}$ / No. of CE		1	1	2	1	1	2	1	2
$r=0$	27.6	28.4**	27.5**	28.7**	27.7**	27.3**	32.9**	26.9**	33.2**
$r=1$	21.1	12.3	14.9	21.2**	15.4	20.2	29.3**	19.7	24.0**
$r=2$	14.3	10.6	8.2	9.2	9.5	8.6	6.1	9.2	9.3
$r=3$	3.8	2.7	2.8	1.3	1.5	2.0	1.2	0.9	0.9
Optimal lag		2	2	2	2	3	2	2	2

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.13 Cointegration Test for Fresh flowers

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace} /No. of CE		1	1	2	1	2	2	1	2
$r=0$	47.9	68.9**	67.8**	61.2**	72.7**	82.1**	81.3**	74.5**	78.8**
$r=1$	29.8	21.7	28.5	34.5**	28.9	44.5**	43.8**	27.3	42.3**
$r=2$	15.5	15.2	13.7	15.5	14.9	10.5	9.9	13.4	13.3
$r=3$	3.8	3.1	4.6	5.7	4.2	1.8	1.7	3.1	2.9
$\lambda_{\max}$ / No. of CE		1	1	1	1	2	2	1	2
$r=0$	27.6	37.2**	39.2**	26.6**	40.7**	37.6**	37.4**	41.2**	36.6**
$r=1$	21.1	15.5	14.8	19.1	17.0	33.9**	33.9**	19.8	28.9**
$r=2$	14.3	12.1	9.1	9.8	10.7	8.7	8.3	10.3	10.4
$r=3$	3.8	4.1	4.6	5.7	4.2	1.8	1.7	3.1	2.9
Optimal lag		2	2	2	2	2	2	2	2

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.14 Cointegration Test for Fresh fruit vegetables

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace} /No. of CE		1	1	2	1	2	2	1	2
$r=0$	47.9	62.6**	62.4**	59.9**	58.3**	71.0**	69.9**	58.9**	66.5**
$r=1$	29.8	28.4	28.2	33.3**	28.8	34.0**	36.4**	28.4	35.7**
$r=2$	15.5	13.3	12.5	14.4	14.9	9.8	9.3	12.2	12.5
$r=3$	3.8	3.5	3.4	4.6	4.1	1.8	1.6	2.6	2.7
$\lambda_{\max}$ / No. of CE		1	1	1	1	2	2	1	2
$r=0$	27.6	34.2**	34.2**	26.6**	29.5**	37.0**	33.4**	26.5**	30.8**
$r=1$	21.1	15.2	15.8	18.8	13.8	24.1**	27.2**	20.2	23.2**
$r=2$	14.3	9.7	9.1	9.9	10.8	8.1	7.6	9.6	9.8
$r=3$	3.8	3.5	3.4	4.6	4.1	1.8	1.6	2.6	2.7
Optimal lag		3	2	2	2	2	2	2	2

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.15 Cointegration Test for Gemstones

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace} /No. of CE		1	1	1	1	2	2	1	1
$r=0$	47.9	53.1**	56.9**	60.7**	54.4**	74.5**	68.7**	56.2**	61.3**
$r=1$	29.8	29.2	28.6	28.7	29.6	36.5**	34.1**	27.6	27.6
$r=2$	15.5	15.1	14.1	13.9	14.2	9.7	9.5	11.8	12.0
$r=3$	3.8	3.6	4.1	4.4	4.3	1.7	1.6	2.7	2.6
$\lambda_{\max}$ / No. of CE		0	1	1	0	1	1	1	1
$r=0$	27.6	24.0	28.3**	28.0**	24.8	38.0**	34.6**	28.6**	29.7**
$r=1$	21.1	14.1	14.5	18.8	15.4	26.8	24.6	15.8	19.5
$r=2$	14.3	11.5	10.0	9.5	9.9	8.1	7.9	9.2	9.4
$r=3$	3.8	3.6	4.1	4.4	4.3	1.7	1.6	2.7	2.6
Optimal lag		2	2	2	2	2	2	2	2

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.16 Cointegration Test for Gasoil/petroleum oils

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace} /No. of CE		1	1	1	1	1	1	1	2
$r=0$	47.9	52.9**	50.2**	68.5**	58.7**	59.3**	58.9**	63.0**	63.0**
$r=1$	29.8	24.5	24.5	27.1	22.1	24.4	26.1	23.8	32.7**
$r=2$	15.5	11.5	9.8	9.0	9.1	8.1	7.9	8.3	8.9
$r=3$	3.8	0.7	0.6	0.9	0.9	1.3	1.2	0.7	0.8
$\lambda_{\max}$ / No. of CE		1	0	1	1	1	1	1	1
$r=0$	27.6	28.5**	25.6	41.4**	36.6**	34.9**	32.8**	39.2**	30.2**
$r=1$	21.1	13.0	14.7	18.1	13.0	16.3	18.2	15.5	23.8
$r=2$	14.3	10.7	9.2	8.1	8.2	6.7	6.7	7.5	8.1
$r=3$	3.8	0.7	0.6	0.9	0.9	1.3	1.2	0.7	0.8
Optimal lag		2	2	2	2	4	4	2	2

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.17 Cointegration Test for White spoon sugar

	Critical values-95%	erv_{neer}	erv_{reer}	erv_{rkus}	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
λ_{trace}/No. of CE		1	1	2	1	2	2	1	2
$r=0$	47.9	76.9**	71.2**	72.7**	71.6**	62.8**	77.0**	62.2**	60.9**
$r=1$	29.8	28.6	27.7	35.4**	27.2	34.4**	41.4**	25.6	33.7**
$r=2$	15.5	15.4	13.2	13.6	13.7	11.9	8.3	12.9	13.8
$r=3$	3.8	4.2	4.9	4.2	4.2	2.4	1.6	3.8	3.5
$\lambda_{\max}$ / No. of CE		1	1	2	1	2	2	1	1
$r=0$	27.6	48.3**	43.5**	37.3**	41.4**	28.4**	35.6**	36.6**	27.3**
$r=1$	21.1	13.2	14.5	21.8**	16.5	22.5**	33.2**	12.8	19.9**
$r=2$	14.3	11.1	8.3	9.4	9.5	9.5	6.6	9.1	10.3
$r=3$	3.8	4.2	4.9	4.2	4.2	2.4	1.6	3.8	3.5
Optimal lag		2	2	2	2	3	2	3	4

Source: Eviews 6.

The variables entering the unrestricted VAR ($z_t = (EX_{ijt} / IM_{ijt}, Y_{jt}, P_{ijt}, erv_{ijt})'$) used to test for cointegration are those shown in equations 11 and 12 for alternative measures of exchange rate volatility.

Table 4.18 ARDL Bounds test (for alternative measure of exchange rate volatility)

	F-critical values (Lower-Upper Bounds)	erv_{neer}	erv_{reer}	$erv_{rkus\$}$	$erv_{nkus\$}$	erv_{rkr}	erv_{nkr}	erv_{npca}	erv_{rpca}
Total imports	**2.72-3.77**		3.56	4.07		4.41			3.52
Total exports	**2.72-3.77**		3.56	3.43		3.80			3.84
NTEs	**2.72-3.77**	5.82	5.94	5.87	5.42	5.35	5.84	4.93	4.73
Burley tobacco	**2.72-3.77**	4.77	4.69	4.95	5.31	4.66	4.63	5.73	4.91
Cotton lint	**2.72-3.77**	5.64	6.20	4.09	4.70	5.39	3.97	4.23	3.80
Copper	**2.72-3.77**	6.22	6.35	5.50	6.07	5.61	4.98	6.00	5.81
Copper wire	**2.72-3.77**	3.61	4.00	3.27	4.29	5.05	4.40	4.30	4.13
Cotton yarn	**2.72-3.77**	3.93	4.34	4.20	3.80	3.94	3.72	3.80	3.62
Electricity	**2.72-3.77**	3.52	3.79	4.22	4.68	3.79	3.60	4.64	5.27
Electrical cables	**2.72-3.77**	5.94	5.18	6.25	6.19	5.59	5.54	5.94	5.76
Fresh flowers	**2.72-3.77**	8.46	7.98	9.67	8.98	8.35	7.19	9.07	9.14
Fresh fruit vegetables	**2.72-3.77**	6.86	6.93	4.63	5.10	6.73	5.18	5.01	6.17
Gemstones	**2.72-3.77**	4.51	4.45	4.82	4.71	4.34	4.01	4.62	4.87
Gasoil/petroleum oils	**2.72-3.77**	4.17	3.49	4.42	4.51	5.32	5.31	4.65	4.85
White spoon sugar	**2.72-3.77**	6.88	6.35	7.31	7.49	6.13	6.40	8.07	6.89

Source: Microfit 4.1. F-critical values from Pesaran et al (2001) and calculated F-statistics are from Microft4.1. The F-statistic test for each commodity above is formulated as $F(x_t | y_t, rp_t, erv_t)$ where x_t denotes imports/exports (both total and disaggregated) and the rest of the variables are as defined earlier.

The inclusion of exchange rate volatility in equations 11 and 12 is thus appropriate, evidenced by the existence of cointegration among the VAR variables reported above. The error-correction term (*ecm*) in the dynamic model reported in table 4.41 in sub-section 4.4.4.2 below displays an appropriate and statistically significant negative sign thereby providing further evidence of the validity of cointegration. The intercept is unrestricted while the trend is excluded in both cointegration tests. A dummy denoted D, taking the value of 1 from 2000 to 2007 and zero otherwise capturing a spike in both imports and domestic income is included in the import demand function in order to detect the existence of cointegration. Initial lags in the ARDL model vary between 4 and 12 for different equations to ensure residuals are serially uncorrelated while maintaining degrees of freedom with reasonable margin. The optimal lag (ARDL lag specification) for the estimated long-run coefficients (see Tables 4.19-4.26) are selected based on SBC. Similarly, SBC is used in the Johansen method to select the optimal lag length in the unrestricted VAR when determining the number of cointegrating vectors for each trade series.

The ARDL and Johansen multivariate cointegration equations fit reasonably well and pass the diagnostic tests against serial correlation but fail the normality and heteroskedasticity tests in most cases similar to Doyle (2001) and Choudhry (2005, 2008). Nonetheless, cointegration results are still robust despite residuals being non-normal (Gonzalo, 1994)[81].

[81] No assumption about any particular distribution of the error is made in the approach employed (i.e. reduced rank simultaneous least squares) when generating parameter coefficients. Gonzalo further argues that the performance of the Johansen method is still comparable to OLS, non-linear least squares, principal components and canonical correlations used to estimate cointegrating vectors.

4.4.4.1 Long-Run Estimates

The long-run estimates for income, relative price and exchange rate volatility from the ARDL and Johansen method are reported in tables 4.19-4.26 and tables 4.33-4.40, respectively for alternative measures of exchange rate volatility. The cointegration results for total imports and exports by both methods indicate that income, real exchange rate and exchange rate volatility are statistically significant with expected signs in virtually all the trade equations. The statistical significance of the real exchange rate (capturing level effects) and exchange rate volatility (capturing risk) in the majority of the estimated trade equations confirms overall influence of the exchange rate in trade.

While there are some differences in the size and statistical significance of coefficients generated by the two methods, the direction of the relationship is mostly consistent. Accounting for the observed differences are underlying estimation procedures and assumptions. Firstly, the estimated sample periods for each import/export demand equation is slightly different as the determination of required initial and subsequently optimal lags that ensure efficient parameter estimates differs in each method as indicated earlier. Secondly, the ARDL method is a single equation technique that assumes only one cointegrating relationship for a group of variables. This is not always the case as the Johansen multivariate method results in tables 4.3-4.17 illustrate. Finally, the ARDL assumes all but one variable in the relationship to be exogenous. The weak exogeneity test results reported in tables 4.27-4.30 demonstrate that this is not always the case. Moreover, results from the ARDL method indicate that exchange rate volatility does not bear a statistically significant effect on trade in the majority of equations contrary to the results from the Johansen method. In view of the above, the analysis that follows below is based on the Johansen method results.

Table 4.19 ARDL Long-run estimates ($\alpha_{3,neer}$)

Commodity/ ARDL lag specification	α_0	α_1	α_2	$\alpha_{3,neer}$	χ^2_{SC}	χ^2_{FF}	χ^2_{Nor}	χ^2_{Het}
NTEs 1,0,0,1	-38.5* (-6.1)	8.8* (7.8)	0.5** (2.1)	0.02 (0.5)	9.6 [0.66]	2.2 [0.14]	0.1 [0.95]	0.02 [0.88]
Burley tobacco 3,0,0,0	-47.2** (-2.4)	10.8* (3.4)	0.4 (0.3)	0.04 (0.2)	10.7 [0.56]	3.8 [0.05]	107.2 [0.00]	3.1 [0.08]
Cotton lint 1,1,0,0	-35.5** (-2.5)	6.3** (2.5)	2.5* (3.0)	0.3+ (1.9)	17.5 [0.13]	0.1 [0.72]	9.3 [0.00]	0.06 [0.81]
Copper 9,1,4,0	-15.7* (-4.2)	5.6* (8.2)	-1.2* (-8.1)	0.02 (1.0)	16.0 [0.19]	2.8 [0.09]	0.9 [0.65]	0.004 [0.95]
Copper wire 3,0,0,0	-36.1 (-0.5)	11.2 (1.0)	-0.7 (-0.2)	0.8 (1.6)	14.8 [0.25]	17.5 [0.00]	317.6 [0.00]	11.6 [0.00]
Cotton yarn 1,0,0,0	18.8** (2.2)	-2.9** (-2.0)	-0.1 (-0.3)	0.01 (0.1)	13.9 [0.31]	1.6 [0.20]	48.0 [0.00]	0.03 [0.85]
Electricity 1,1,3,0	6.2 (0.6)	1.3 (0.8)	-1.1** (-1.9)	0.2+ (1.9)	20.5 [0.06]	0.3 [0.60]	11.1 [0.00]	0.04 [0.84]
Electrical cables 1,0,0,0	-38.4* (-5.5)	9.9* (8.7)	-0.5 (-1.2)	-0.05 (-0.6)	8.5 [0.74]	1.7 [0.19]	0.4 [0.84]	0.1 [0.70]
Fresh flowers 1,0,0,0	3.8 (0.4)	0.4 (0.3)	-0.4 (-0.6)	-0.04 (-0.3)	18.6 [0.10]	0.9 [0.34]	23.2 [0.00]	5.0 [0.03]
Fresh fruit vegetables 1,2,0,3	11.6 (1.2)	-1.4 (-0.8)	0.1 (0.2)	0.3** (2.5)	18.0 [0.12]	13.9 [0.00]	3.3 [0.20]	3.9 [0.05]
Gemstones 0,0,0,0	-15.0+ (-1.7)	3.3** (2.3)	1.1** (2.1)	0.2+ (1.8)	9.6 [0.65]	2.6 [0.11]	2.6 [0.27]	1.2 [0.27]
Gasoil/petroleum oils 1,0,0,0	-121.2* (-7.7)	22.1* (8.5)	5.3* (5.7)	-0.03 (-0.2)	18.8 [0.09]	0.6 [0.98]	59.0 [0.00]	0.8 [0.37]
White spoon sugar 0,0,0,0	-20.2* (-2.9)	4.9* (4.4)	0.4 (1.0)	-0.03 (-0.3)	9.6 [0.65]	3.9 [0.05]	7.2 0.03]	0.2 [0.7]

Source: Microfit4.1 LM based diagnostic tests where χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

*,**,+ refer to statistical significance at 1%, 5% and 10%, respectively.

t-statistics are reported in parenthesis while p-values are in square brackets.

Table 4.20 ARDL Long-run estimates ($\alpha_{3,reer}$)

Commodity/ ARDL lag Specification	α_0	α_1	α_2	$\alpha_{3,reer}$	D	χ^2_{SC}	χ^2_{FF}	χ^2_{Nor}	χ^2_{Het}
Total imports 3,0,0,0	-12.4* (-4.9)	3.7* (6.6)	-0.1* (-4.6)	-0.1 (1.0)	0.5 (3.3)	20.7 [0.05]	0.04 [0.84]	15.5 [0.00]	12.1 [0.00]
Total exports 4,0,1,0	-31.3* (-6.7)	8.3* (7.7)	-0.5* (-6.3)	0.01 (0.2)		16.9 [0.16]	0.0 [0.97]	6.7 [0.03]	7.2 [0.01]
NTEs 1,0,0,0	-41.0* (-5.8)	9.2* (7.4)	0.7** (2.3)	0.04 (1.3)		9.1 [0.69]	1.8 [0.19]	1.5 [0.48]	0.2 [0.68]
Burley tobacco 3,0,0,0	-47.6** (-2.4)	10.9* (3.4)	0.4 (0.4)	0.04 (0.3)		11.2 [0.52]	3.6 [0.06]	108.8 [0.00]	3.1 [0.08]
Cotton lint 1,1,0,0	-37.9** (-2.6)	6.7** (2.6)	2.5* (3.1)	0.2** (2.0)		19.3 [0.08]	0.08 [0.78]	15.8 [0.00]	0.2 [0.64]
Copper 9,1,4,0	-15.7* (-3.9)	5.6* (7.8)	-1.2* (-7.6)	0.01 (0.7)		16.7 [0.16]	3.4 [0.07]	0.7 [0.69]	0.02 [0.89]
Copper wire 3,0,0,0	-67.6 (-1.5)	16.1** (2.1)	0.9 (0.4)	0.7** (2.3)		13.7 [0.32]	17.7 [0.00]	373.3 [0.00]	10.1 [0.00]
Cotton yarn 1,0,0,0	15.7+ (1.9)	-2.3+ (-1.7)	0.02 (0.05)	0.06 (1.1)		12.7 [0.39]	2.4 [0.12]	33.4 [0.00]	0.1 [0.70]
Electricity 1,1,0,0	5.7 (0.5)	1.3 (0.7)	-1.1+ (-1.8)	-0.002 (-0.03)		12.2 [0.43]	0.6 [0.45]	19.2 [0.00]	0.00 [0.94]
Electrical cables 1,0,0,0	-38.8* (-5.7)	9.9* (8.9)	-0.5 (-1.2)	-0.06 (1.0)		8.3 [0.76]	2.3 [0.13]	0.3 [0.88]	0.2 [0.67]
Fresh flowers 1,0,0,0	3.6 (0.3)	0.5 (0.3)	-0.4 (-0.6)	-0.04 (-0.4)		19.1 [0.09]	0.8 [0.36]	23.7 [0.00]	4.8 [0.03]
Fresh fruit vegetables 1,2,0,0	3.3 (0.4)	0.2 (0.1)	0.1 (0.3)	0.06 (0.8)		20.6 [0.06]	6.6 [0.01]	0.4 [0.82]	12.3 [0.00]
Gemstones 0,0,0,0	-14.3 (-1.6)	3.1** (2.1)	1.1** (2.1)	0.1+ (1.7)		7.8 [0.80]	4.1 [0.04]	1.9 [0.38]	0.7 [0.41]
Gasoil/ Petroleum oils 1,0,0,0	-121.6* (-7.7)	22.1* (8.6)	5.3* (5.7)	-0.05 (-0.4)		18.4 [0.10]	0.03 [0.87]	58.1 [0.00]	0.8 [0.38]
White spoon sugar 0,0,0,0	-20.3* (-2.9)	4.9* (4.4)	0.4 (1.0)	-0.02 (-0.3)		9.6 [0.65]	4.3 [0.04]	7.6 [0.02]	0.2 [0.65]

Source: Microfit4.1 LM based diagnostic tests where χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

*,**,+ refer to statistical significance at 1%, 5% and 10%, respectively.
t-statistics are reported in parenthesis while p-values are in square brackets.

Table 4.21 ARDL Long-run estimates ($\alpha_{3,rkus\$}$)

Commodity/ ARDL lag Specification	α_0	α_1	α_2	$\alpha_{3,rkus\$}$	D	χ^2_{SC}	χ^2_{FF}	χ^2_{Nor}	χ^2_{Het}
Total imports 3,0,0,0	-12.4* (-4.9)	3.7* (6.5)	-0.1* (-4.6)	-0.02 (-0.9)	0.5 (3.4)	19.8 [0.07]	0.04 [0.84]	16.7 [0.00]	12.6 [0.00]
Total exports 4,0,1,0	-31.5* (-6.9)	8.3* (7.9)	-0.5* (-6.5)	-0.02 (-0.5)		16.5 [0.17]	0.8 [0.98]	7.8 [0.02]	7.4 [0.01]
NTEs 1,0,0,0	-37.8* (-6.4)	8.6* (8.3)	0.5** (2.2)	0.02 (0.9)		13.4 [0.34]	2.2 [0.14]	0.9 [0.62]	0.09 [0.77]
Burley tobacco 3,0,0,0	-47.1** (-2.5)	10.8* (3.4)	0.4 (0.4)	0.04 (0.3)		11.0 [0.53]	3.9 [0.05]	103.9 [0.00]	3.1 [0.08]
Cotton lint 1,1,0,0	-25.5** (-2.1)	4.6** (2.1)	1.8** (2.6)	0.06 (0.7)		15.1 [0.23]	0.3 [0.59]	16.2 [0.00]	0.2 [0.68]
Copper 4,0,0,0	-17.9* (-3.2)	6.1* (6.3)	-1.2* (-4.7)	-0.03 (-1.2)		20.1 [0.07]	0.005 [0.94]	0.1 [0.95]	7.1 [0.01]
Copper wire 3,0,0,0	-4.7 (-0.1)	5.3 (0.4)	-1.8 (-0.4)	0.6 (1.2)		19.3 [0.08]	16.5 [0.00]	332.5 [0.00]	12.4 [0.00]
Cotton yarn 1,0,0,0	18.6** (2.2)	-2.9** (-2.1)	-0.1 (-0.3)	0.01 (0.2)		13.8 [0.31]	1.5 [0.22]	49.5 [0.00]	0.03 [0.85]
Electricity 1,1,0,0	6.1 (0.5)	1.2 (0.6)	-1.2+ (-1.9)	-0.02 (-0.2)		11.9 [0.46]	0.6 [0.43]	19.2 [0.00]	0.00 [0.94]
Electrical cables 1,0,0,0	-38.3* (-5.4)	9.9* (8.6)	-0.5 (-1.2)	0.01 (0.3)		9.4 [0.67]	1.6 [0.20]	0.3 [0.84]	0.2 [0.69]
Fresh flowers 1,0,0,0	3.9 (0.4)	0.5 (0.3)	-0.4 (-0.6)	-0.01 (-0.1)		18.4 [0.10]	0.9 [0.33]	22.2 [0.00]	5.2 [0.02]
Fresh fruit vegetables 1,0,0,0	-3.2 (-0.4)	1.3 (1.0)	0.4 (0.8)	-0.02 (-0.3)		15.5 [0.21]	5.6 [0.02]	571.3 [0.00]	0.8 [0.36]
Gemstones 0,0,0,0	-15.6+ (-1.7)	3.2** (2.2)	1.1* (2.1)	-0.01 (-0.10)		5.9 [0.92]	0.6 [0.45]	1.1 [0.58]	0.8 [0.38]
Gasoil/petroleum oils 1,0,0,0	-121.2* (-7.7)	22.1* (8.6)	5.3* (5.7)	0.06 (0.5)		18.7 [0.10]	0.1 [0.72]	55.3 [0.00]	0.7 [0.42]
White spoon sugar 0,0,0,0	-20.1* (-2.9)	4.9* (4.4)	0.4 (1.0)	-0.01 (-0.2)		9.7 [0.64]	3.6 [0.06]	7.3 [0.03]	0.2 [0.69]

Source: Microfit4.1 LM based diagnostic tests where χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.
*,**,+ refer to statistical significance at 1%, 5% and 10%, respectively.
t-statistics are reported in parenthesis while p-values are in square brackets.

Table 4.22 ARDL Long-run estimates ($\alpha_{3,nkus\$}$)

Commodity/ ARDL lag specification	α_0	α_1	α_2	$\alpha_{3,nkus\$}$	χ^2_{SC}	χ^2_{FF}	χ^2_{Nor}	χ^2_{Het}
NTEs 1,0,0,2	-35.8* (-6.6)	8.3* (8.7)	0.5** (2.0)	-0.00 (-0.2)	21.0 [0.06]	3.2 [0.08]	1.4 [0.49]	0.002 [0.99]
Burley tobacco 3,0,0,0	-46.8** (-2.4)	10.7* (3.4)	0.4 (0.3)	0.03 (0.2)	10.6 [0.56]	3.9 [0.05]	107.1 [0.00]	3.1 [0.08]
Cotton lint 1,1,0,0	-24.8** (-2.0)	4.4** (2.0)	1.8** (2.6)	0.06 (0.7)	16.0 [0.19]	0.3 [0.57]	16.6 [0.00]	0.2 [0.68]
Copper 9,1,4,0	-13.1* (-3.4)	5.1* (7.3)	-1.3* (-8.9)	0.01 (0.5)	11.5 [0.49]	9.0 [0.00]	1.0 [0.60]	0.4 [0.55]
Copper wire 3,0,0,0	-1.2 (-0.01)	4.6 (0.3)	-2.1 (-0.5)	0.5 (1.1)	18.7 [0.09]	15.0 [0.00]	348.3 [0.00]	11.9 [0.00]
Cotton yarn 1,0,0,0	19.1** (2.2)	-3.0** (-2.1)	-0.1 (-0.3)	-0.2 (-0.0)	13.8 [0.31]	1.6 [0.21]	49.9 [0.00]	0.02 [0.88]
Electricity 1,1,0,0	10.5 (1.3)	0.4 (0.3)	-1.2** (-2.3)	0.03 (0.4)	14.8 [0.26]	0.9 [0.35]	18.8 [0.00]	0.01 [0.93]
Electrical cables 1,0,0,0	-38.3* (-5.4)	9.9* (8.6)	-0.5 (-1.2)	0.01 (0.1)	8.9 [0.71]	1.7 [0.20]	0.4 [0.83]	0.1 [0.71]
Fresh flowers 1,0,0,0	3.7 (0.4)	0.5 (0.3)	-0.4 (-0.6)	-0.02 (-0.3)	18.8 [0.10]	1.0 [0.32]	22.5 [0.00]	5.2 [0.02]
Fresh fruit vegetables 1,0,0,0	-3.1 (-0.4)	1.3 (1.0)	0.4 (0.9)	0.02 (0.3)	18.0 [0.12]	5.2 [0.02]	611.4 [0.00]	0.5 [0.46]
Gemstones 0,0,0,0	-15.4+ (-1.7)	3.2** (2.1)	1.2** (2.1)	0.03 (0.4)	6.8 [0.87]	1.3 [0.26]	1.6 [0.44]	1.7 [0.19]
Gasoil/petroleum oils 1,0,0,0	-120.6* (-7.7)	22.1* (8.6)	5.3* (5.8)	0.09 (0.7)	17.5 [0.13]	0.3 [0.61]	52.8 [0.00]	0.6 [0.45]
White spoon sugar 0,0,0,0	-20.2* (-2.9)	4.9* (4.4)	0.4 (1.0)	-0.01 (-0.1)	9.7 [0.64]	3.6 [0.06]	7.5 [0.02]	0.2 [0.68]

Source: Microfit4.1 LM based diagnostic tests where χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.
*,**,+ refer to statistical significance at 1%, 5% and 10%, respectively.
t-statistics are reported in parenthesis while p-values are in square brackets.

Table 4.23 ARDL Long-run estimates ($\alpha_{3,rkr}$)

Commodity/ ARDL lag specification	α_0	α_1	α_2	$\alpha_{3,rkr}$	D	χ^2_{SC}	χ^2_{FF}	χ^2_{Nor}	χ^2_{Het}
Total imports 3,0,1,1	-12.9* (-4.7)	3.7* (6.2)	-0.1* (-4.2)	-0.02 (-0.8)	0.5 (2.8)	21.3 [0.10]	0.4 [0.51]	5.5 [0.06]	9.9 [0.00]
Total exports 4,0,1,0	-30.0* (-5.5)	8.0* (6.4)	-0.5* (-5.1)	-0.01 (-0.3)		18.3 [0.11]	0.4 [0.51]	6.8 [0.03]	7.8 [0.01]
NTEs 4,0,0,0	-30.3* (-21.7)	7.2* (28.6)	0.4* (4.7)	0.03** (2.6)		16.7 [0.16]	0.1 [1.00]	2.6 [0.27]	0.03 [0.87]
Burley tobacco 3,0,0,0	-54.1* (-5.6)	11.3* (7.0)	1.4+ (1.8)	0.07 (0.6)		12.5 [0.41]	3.0 [0.08]	65.3 [0.00]	4.1 [0.04]
Cotton lint 1,0,0,0	-23.2* (-3.1)	5.1* (4.2)	1.2** (2.1)	0.2 (1.6)		9.9 [0.62]	0.1 [0.73]	7.5 [0.02]	0.00 [0.99]
Copper									
Copper wire 3,0,0,0	-58.9** (-2.3)	13.7* (3.2)	1.1 (0.6)	0.4 (1.3)		22.5 [0.06]	8.7 [0.00]	348.8 [0.00]	13.0 [0.00]
Cotton yarn 1,0,0,0	12.4* (3.0)	-2.0* (-2.9)	0.4 (1.3)	0.05 (1.0)		15.6 [0.21]	0.4 [0.53]	51.8 [0.00]	0.1 [0.71]
Electricity 1,1,0,0	2.0 (0.3)	1.7 (1.4)	-0.8** (-2.0)	0.03 (0.4)		12.7 [0.39]	0.9 [0.33]	25.7 [0.00]	0.09 [0.76]
Electrical cables 1,0,0,0	-50.2* (-11.4)	11.5* (15.6)	0.5 (1.4)	-0.01 (-0.2)		8.9 [0.74]	0.1 [0.74]	0.9 [0.63]	0.4 [0.54]
Fresh flowers 2,0,0,0	3.6 (0.7)	0.8 (1.0)	-0.6+ (1.7)	0.00 (0.1)		18.8 [0.09]	0.03 [0.87]	35.8 [0.00]	2.1 0.15]
Fresh fruit vegetables 2,0,0,0	3.5 (0.7)	0.4 (0.4)	-0.07 (-0.2)	0.01 (0.1)		17.6 [0.13]	6.5 [0.01]	527.8 [0.00]	1.4 [0.23]
Gemstones 0,0,0,0	0.5 (0.1)	0.9 (0.9)	0.1 (0.3)	0.07 (0.9)		4.8 [0.96]	0.3 [0.61]	0.5 [0.79]	0.1 [0.81]
Gasoil/petroleum oils 1,0,1,0	-65.8* (-5.1)	12.2* (5.6)	3.4* (3.5)	0.02 (0.2)		20.8 [0.06]	1.6 [0.21]	88.2 [0.00]	0.6 [0.44]
White spoon sugar 0,0,0,0	-11.8* (-2.8)	3.8* (5.4)	-0.3 (-0.7)	0.03 (0.6)		9.8 [0.63]	0.3 [0.58]	12.4 [0.00]	0.4 [0.51]

Source: Microfit4.1 LM based diagnostic tests where χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

*,**,+ refer to statistical significance at 1%, 5% and 10%, respectively.

t-statistics are reported in parenthesis while p-values are in square brackets.

Table 4.24 ARDL Long-run estimates ($\alpha_{3,nkr}$)

Commodity/ ARDL lag specification	α_0	α_1	α_2	$\alpha_{3,nkr}$	χ^2_{SC}	χ^2_{FF}	χ^2_{Nor}	χ^2_{Het}
NTEs 4,0,0,0	-29.8* (-21.7)	7.1* (28.6)	0.4* (4.5)	0.03** (2.1)	13.8 [0.31]	0.05 [0.82]	3.9 [0.14]	0.3 [0.57]
Burley tobacco 3,0,0,0	-54.0* (-5.7)	11.4* (7.0)	1.4+ (1.9)	0.09 (0.7)	13.6 [0.33]	3.7 [0.06]	61.4 [0.00]	4.2 [0.04]
Cotton lint 1,0,0,0	-22.4* (-3.2)	5.0* (4.3)	1.2** (2.2)	0.2+ (1.7)	7.5 [0.82]	0.1 [0.80]	8.5 [0.01]	0.01 [0.94]
Copper								
Copper wire 3,0,0,0	-52.5** (-2.0)	12.5* (2.8)	0.6 (0.3)	0.2 (0.6)	23.8 [0.06]	7.0 [0.01]	319.1 [0.00]	14.0 [0.00]
Cotton yarn 1,0,0,0	13.2* (3.2)	-2.2* (-3.1)	0.3 (1.1)	0.02 (0.4)	14.6 [0.27]	0.8 [0.37]	64.0 [0.00]	0.00 [0.95]
Electricity 1,1,0,0	2.1 (0.4)	1.7 (1.4)	-0.8** (-2.1)	0.03 (0.4)	12.6 [0.40]	0.9 [0.34]	26.7 [0.00]	0.08 [0.78]
Electrical cables 1,0,0,0	-50.1* (-11.6)	11.4* (15.8)	0.5 (1.4)	-0.03 (-0.5)	8.4 [0.75]	0.1 [0.79]	1.0 [0.61]	0.5 [0.48]
Fresh flowers 2,0,0,0	3.9 (0.8)	0.7 (0.9)	-0.7+ (-1.7)	-0.02 (-0.3)	20.4 [0.06]	0.01 [0.92]	32.6 [0.00]	2.0 [0.16]
Fresh fruit vegetables 1,0,0,0	3.8 (0.7)	0.3 (0.4)	-0.1 (-0.2)	-0.02 (-0.2)	16.3 [0.18]	6.7 [0.01]	542.0 [0.00]	1.4 [0.24]
Gemstones 0,0,0,0	0.8 (0.1)	0.8 (0.8)	0.1 (0.2)	0.08 (0.9)	4.8 [0.97]	0.7 [0.40]	0.4 [0.82]	0.03 [0.85]
Gasoil/petroleum oils 1,0,1,0	-65.4* (-5.1)	12.1* (5.6)	3.4* (3.4)	0.01 (0.1)	20.8 [0.06]	1.6 [0.21]	88.0 [0.00]	0.6 [0.44]
White spoon sugar 0,0,0,0	-11.9* (-2.8)	3.9* (5.4)	-0.2 (-0.7)	0.06 (1.0)	9.7 [0.64]	0.8 [0.37]	14.5 [0.00]	0.7 [0.41]

Source: Microfit4.1 LM based diagnostic tests where χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

*,**,+ refer to statistical significance at 1%, 5% and 10%, respectively.
t-statistics are reported in parenthesis while p-values are in square brackets.

Table 4.25 ARDL Long-run estimates ($\alpha_{3,npca}$)

Commodity/ ARDL lag specification	α_0	α_1	α_2	$\alpha_{3,npca}$	χ^2_{SC}	χ^2_{FF}	χ^2_{Nor}	χ^2_{Het}
NTEs 1,1,4,0	-32.0* (-6.2)	7.5* (8.3)	0.4+ (1.7)	0.3 (3.5)	22.6 [0.08]	2.3 [0.13]	1.1 [0.57]	0.2 [0.64]
Burley tobacco 3,0,0,0	-43.2** (-2.3)	10.4* (3.4)	-0.003 (-0.003)	0.9+ (1.8)	17.3 [0.14]	3.5 [0.06]	96.4 [0.00]	3.6 [0.06]
Cotton lint 1,1,0,0	-23.5+ (-1.9)	4.3** (2.0)	1.6** (2.4)	0.3 (1.0)	16.6 [0.17]	0.5 [0.48]	14.4 [0.00]	0.09 [0.76]
Copper 9,1,4,0	-12.8* (-3.3)	5.1* (7.1)	-1.3* (-9.1)	0.02 (0.3)	12.4 [0.42]	9.4 [0.00]	1.2 [0.56]	0.3 [0.57]
Copper wire 3,0,0,0	23.5 (0.2)	1.0 (0.1)	-4.0 (-0.8)	2.4 (1.3)	16.4 [0.17]	13.4 [0.00]	367.4 [0.00]	12.5 [0.00]
Cotton yarn 1,0,0,0	19.2** (2.3)	-3.0** (-2.2)	-0.2 (-0.4)	0.05 (0.3)	13.6 [0.33]	1.5 [0.23]	47.3 [0.00]	0.05 [0.83]
Electricity 1,1,0,0	11.1 (1.4)	0.4 (0.3)	-1.3** (-2.5)	0.2 (0.6)	15.6 [0.21]	0.7 [0.42]	19.5 [0.00]	0.2 [0.99]
Electrical cables 1,0,0,0	-37.4* (-5.2)	9.8* (8.5)	-0.6 (-1.4)	0.2 (0.8)	10.0 [0.62]	1.4 [0.23]	0.4 [0.81]	0.1 [0.72]
Fresh flowers {1,0,0,0}	4.5 (0.4)	0.4 (0.2)	-0.4 (-0.7)	0.1 (0.4)	16.9 [0.16]	0.7 [0.39]	21.4 [0.00]	5.1 [0.02]
Fresh fruit vegetables 1,0,0,0	-1.5 (-0.2)	1.1 (0.8)	0.3 (0.5)	0.3 (1.1)	18.0 [0.11]	4.7 [0.03]	586.5 [0.00]	0.7 [0.40]
Gemstones 0,0,0,0	-13.7 (-1.5)	3.0** (2.0)	1.0+ (1.8)	0.3 (1.1)	8.2 [0.77]	1.5 [0.22]	1.4 [0.49]	0.9 [0.34]
Gasoil/petroleum oils 0,0,0,0	-117.6* (-9.3)	21.7* (10.7)	4.9* (6.6)	0.7+ (1.7)	18.9 [0.09]	0.6 [0.43]	24.5 [0.00]	0.07 [0.80]
White spoon sugar 0,0,0,0	-20.7* (-3.0)	5.0* (4.4)	0.5 (1.1)	-0.1 (-0.4)	9.8 [0.63]	3.2 [0.07]	7.4 [0.02]	0.2 [0.69]

Source: Microfit4.1 LM based diagnostic tests where χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

*,**,+ refer to statistical significance at 1%, 5% and 10%, respectively.

t-statistics are reported in parenthesis while p-values are in square brackets.

Table 4.26 ARDL Long-run estimates ($\alpha_{3,rpca}$)

Commodity/ ARDL lag specification	α_0	α_1	α_2	$\alpha_{3,rpca}$	D	χ^2_{SC}	χ^2_{FF}	χ^2_{Nor}	χ^2_{Het}
Total imports 3,0,0,1	-12.2* (-4.8)	3.6* (6.4)	-0.1* (-4.5)	-0.04 (-0.6)	0.5* (3.3)	22.0 [0.04]	0.1 [0.78]	8.3 [0.01]	13.0 [0.00]
Total exports 4,0,1,0	-31.8* (-6.5)	8.4* (7.5)	-0.5* (-6.2)	0.1 (0.8)		18.7 [0.09]	0.03 [0.86]	5.7 [0.05]	7.0 [0.01]
NTEs 1,0,0,0	-37.1* (-6.4)	8.6* (8.4)	0.5** (2.0)	0.2+ (1.7)		12.9 (0.38)	2.1 [0.15]	0.2 [0.89]	0.09 [0.76]
Burley tobacco 3,0,0,0	-46.3** (-2.4)	10.8* (3.4)	0.2 (0.2)	0.9 (1.4)		15.3 [0.23]	3.7 [0.05]	99.6 [0.00]	3.4 [0.07]
Cotton lint 1,1,0,0	-25.4** (-2.0)	4.6** (2.1)	1.7** (2.5)	-0.1 (-0.01)		12.9 [0.37]	0.2 [0.64]	16.8 [0.00]	0.3 [0.59]
Copper 9,1,4,0	-13.0* (-3.4)	5.1* (7.3)	-1.3* (-9.3)	0.03 (0.6)		12.4 [0.41]	8.8 [0.00]	1.2 [0.55]	0.4 [0.52]
Copper wire 3,0,0,0	35.5 (0.3)	-0.9 (-0.1)	-4.5 (-0.7)	3.3 (1.1)		16.0 [0.19]	13.3 [0.00]	340.5 [0.00]	12.6 [0.00]
Cotton yarn 1,0,0,0	19.3** (2.3)	-3.0** (-2.2)	-0.1 (-0.3)	-0.1 (-0.6)		13.5 [0.34]	1.6 [0.21]	51.5 [0.00]	0.03 [0.86]
Electricity 1,1,0,0	10.5 (1.3)	0.5 (0.3)	-1.3** (-2.5)	0.1 (0.5)		15.8 [0.20]	0.7 [0.42]	20.2 [0.00]	0.00 [0.99]
Electrical cables 1,0,0,0	-38.4* (-5.4)	9.9* (8.6)	-0.5 (-1.2)	-0.01 (-0.1)		8.7 [0.73]	1.7 [0.20]	0.4 [0.83]	0.1 [0.71]
Fresh flowers 1,0,0,0	4.6 (0.4)	0.4 (0.3)	-0.5 (-0.7)	0.4 (0.9)		16.4 [0.17]	0.5 [0.49]	20.8 [0.00]	5.1 [0.02]
Fresh fruit vegetables 1,0,0,0	-2.4 (-0.3)	1.3 (0.9)	0.3 (0.7)	0.3 (1.0)		19.7 [0.07]	5.0 [0.03]	595.6 [0.00]	0.7 [0.39]
Gemstones 0,0,0,0	-14.5 (-1.6)	3.1** (2.1)	1.0+ (1.9)	0.4 (1.3)		8.7 [0.73]	0.7 [0.40]	1.3 [0.51]	0.6 [0.45]
Gasoil/petroleum oils 1,0,0,0	-120.4* (-7.6)	22.0* (8.5)	5.2* (5.6)	0.3 (0.5)		17.8 [0.12]	0.1 [0.79]	55.8 [0.00]	0.7 [0.42]
White spoon sugar 0,0,0,0	-20.6* (-3.0)	5.0* (4.4)	0.4 (1.1)	-0.2 (-0.6)		9.6 [0.65]	3.1 [0.08]	6.7 [0.03]	0.09 [0.76]

Source: Microfit4.1 LM based diagnostic tests where χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

*,**,+ refer to statistical significance at 1%, 5% and 10%, respectively.

t-statistics are reported in parenthesis while p-values are in square brackets.

Johansen Method Results based on Identifying Restrictions

Identifying restrictions are imposed on the estimated unrestricted long-run VAR (Johansen method) in order to uniquely determine the underlying structural relationship among the z_t variables[82]. In this chapter, the estimated equations are exactly-identified (see Pesaran and Shin, 2002)[83].

Weak Exogeneity Test

Weak exogeneity test underpins identifying restrictions (Burke and Hunter, 2005)[84]. The results in tables 4.27-4.30 reveal that the null hypothesis of weak exogeneity for all trade data (total imports/exports and all individual export commodities) is rejected at both 1 and 5 percent significance levels irrespective of the measure of exchange rate volatility employed[85]. On the contrary, weak exogeneity test for income and relative price is sensitive to the measure of exchange rate volatility used in individual export commodity demand equations. In general, exchange rate volatility

---

[82] Identifying restrictions provide a link between economic behaviour and economic data.

[83] The three formal identifying conditions suggested by Pesaran and Shin through the tests of $r^2 + k(k \geq 1)$ are: under-identified when $k < r^2$; exactly-identified when $k = r^2$; and over-identified when $k > r^2$ where r^2 is the just-identifying restriction proposed by Johansen (1991) while k is over-identifying restrictions to be imposed in the cointegrating space. One of the restrictions in each cointegrating vector should at least be a normalisation on the variable of interest among the r restrictions required.

[84] Weak exogeneity test is a likelihood ratio test distributed as $\chi^2(r)$ where $r = rank$. The null is that each of the variables in the VAR (x_t, y_t, p_t, erv_t) is weakly exogenous to the system against the alternative that that it is not. The test is set up as $H_o : \alpha_{1i} = 0$ against $H_1 : \alpha_{1i} \neq 0$ for relationships with rank equal to 1 and $H_o : \alpha_{1i} = \alpha_{1i} = 0$ against $H_1 : \alpha_{1i} = \alpha_{1i} \neq 0$ for relationships with rank equal to 2. H_o is rejected if the calculated p-value for the calculated $\chi^2 < 0.05$ significance level and not rejected if p-value for the calculated $\chi^2 > 0.05$. Weak exogeneity restrictions are maintained and imposed in further estimations of the relationship under study. The system is defined as a VAR consisting of (x_t, y_t, p_t, erv_t) and the test is for individual variables in the VAR. Further, weak exogeneity test helps in identifying variables on which the normalisation restriction is imposed. Normalisation restriction is imposed on endogeneous as opposed to (weakly) exogenous variables. Further, if a variable is found to be weakly exogenous, it implies that once disequilibrium from long-run occurs, the adjustment back to equilibrium does not take place through that variable.

[85] The null of weak exogeneity is rejected at 10 percent significance level for electricity (table 4.29).

is not weakly exogenous (i.e. is endogenous) while income and relative price are not consistently weakly exogeneous across all alternative measures of exchange rate volatility as the null of weak exogeneity cannot be rejected in the majority of cases. Thus z_t variables have differential response to shocks. Further, as the focus of the chapter is on the sensitivity of trade flows to exchange rate volatility, weak exogeneity test results indicate that the direction of long-run causality is from imports/exports to their determinants. This is supported by the statistically significant *ecm* term in the import and export equations consistent with Choudhry (2005, 2008) (see table 4.41). Thus, adjustment to equilibrium once the system is shocked takes place through changes in imports/exports. Nonetheless, changes in exchange rate volatility complement the adjustment process in cases where the weak exogeneity test for exchange rate volatility is rejected for a particular measure of exchange rate volatility[86].

[86] In particular, weak exogenity is rejected for $erv_{rkus\$}$, $(erv_{rkr}$, $erv_{nkr})$ and erv_{rpca} in Tables 4.28, 4.29 and 4.30, respectively in some trade equations.

Table 4.27 Test for weak exogeneity (erv_{neer} and erv_{reer})

	x_t	y	p_t	erv_{neer}			x_t	y	p_t	erv_{reer}
Total imports						Total imports	18.1 [0.00]	9.3 [0.01]	9.9 [0.01]	2.5 [0.28]
Total exports						Total exports	5.9 [0.02]	0.1 [0.78]	4.2 [0.04]	7.5 [0.00]
NTEs	16.3 [0.00]	16.7 [0.00]	1.3 [0.26]	0.4 [0.55]		NTEs	17.7 [0.00]	15.2 [0.00]	0.79 [0.37]	0.8 [0.38]
Burley tobacco	19.1 [0.00]	0.6 [0.45]	0.2 [0.65]	0.2 [0.64]		Burley tobacco	17.1 [0.00]	0.1 [0.73]	0.5 [0.48]	0.04 [0.84]
Cotton lint	14.0 [0.00]	1.0 [0.32]	1.7 [0.19]	1.0 [0.31]		Cotton lint	13.0 [0.00]	0.4 [0.50]	4.6 [0.03]	0.5 [0.49]
Copper	4.4 [0.00]	0.4 [0.53]	1.7 [0.19]	5.4 [0.02]		Copper	15.7 [0.00]	2.7 [0.26]	12.1 [0.00]	2.7 [0.06]
Copper wire	5.9 [0.01]	3.7 [0.05]	0.01 [0.94]	0.3 [0.59]		Copper wire	11.7 [0.00]	4.8 [0.03]	0.1 [0.77]	1.7 [0.19]
Cotton yarn	7.2 [0.01]	1.5 [0.22]	2.2 [0.14]	2.8 [0.09]		Cotton yarn	8.7 [0.00]	1.1 [0.29]	0.5 [0.49]	4.5 [0.03]
Electricity	13.4 [0.00]	2.0 [0.15]	2.5 [0.12]	6.0 [0.01]		Electricity	16.5 [0.00]	1.7 [0.19]	3.5 [0.06]	2.7 [0.09]
Electrical cables	13.9 [0.00]	1.9 [0.17]	0.1 [0.83]	0.4 [0.55]		Electrical cables	11.4 [0.00]	2.6 [0.11]	0.01 [0.92]	0.4 [0.53]
Fresh flowers	21.0 [0.00]	0.01 [0.89]	0.4 [0.54]	0.7 [0.41]		Fresh flowers	23.7 [0.00]	0.04 [0.83]	0.3 [0.59]	3.8 [0.05]
Fresh fruit vegetables	18.3 [0.00]	1.0 [0.32]	0.1 [0.73]	0.02 [0.89]		Fresh fruit vegetables	17.8 [0.00]	1.0 0.33]	0.1 [0.75]	0.0 [0.97]
Gemstones	8.8 [0.00]	0.8 [0.36]	0.1 [0.80]	2.0 [0.16]		Gemstones	11.9 [0.00]	0.6 [0.42]	0.7 [0.40]	4.9 [0.03]
Gasoil/ petroleum oils	10.2 [0.00]	5.1 [0.02]	1.6 [0.19]	0.4 0.51]		Gasoil/ petroleum oils	7.8 [0.01]	3.8 [0.05]	1.9 [0.16]	0.2 [0.63]
White spoon sugar	17.8 [0.00]	1.9 [0.16]	7.3 [0.01]	1.2 [0.27]		White spoon sugar	12.4 [0.00]	0.9 [0.35]	6.0 [0.01]	4.0 [0.04]

Sources: Eviews6

x_t represents trade data. p-values are in [ ] brackets.

Table 4.28 Test for weak exogenity ($erv_{rkus\$}$ and $erv_{nkus\$}$)

	x_t	y	p_t	$erv_{rkus\$}$			x_t	y	p_t	$erv_{nkus\$}$
Total imports	7.3 [0.03]	5.1 [0.08]	2.1 [0.36]	18.3 [0.00]		Total imports				
Total exports	4.7 [0.09]	0.06 [0.97]	4.4 [0.11]	14.0 [0.00]		Total exports				
NTEs	21.4 [0.00]	16.0 [0.00]	2.9 [0.24]	5.8 [0.05]		NTEs	17.7 [0.00]	17.8 [0.00]	1.2 [0.28]	2.1 [0.15]
Burley tobacco	23.0 [0.00	6.5 [0.04]	1.3 [0.53]	8.4 [0.02]		Burley tobacco	21.4 [0.00]	0.6 [0.46]	0.24 [0.63]	3.2 [0.07]
Cotton lint	16.1 [0.00]	6.3 [0.04]	5.6 [0.06]	8.5 [0.01]		Cotton lint	11.1 [0.00]	2.0 [0.16]	4.3 [0.04]	2.4 [0.12]
Copper	7.8 [0.02]	1.4 [0.49]	10.4 [0.01]	13.7 [0.00]		Copper	3.9 [0.04]	0.5 [0.83]	3.7 [0.05]	8.3 [0.00]
Copper wire	5.6 [0.05]	10.4 [0.01]	4.6 [0.10]	4.5 [0.01]		Copper wire	4.8 [0.02]	4.7 [0.03]	0.5 [0.48]	0.04 [0.85]
Cotton yarn	4.3 [0.03]	5.3 [0.02]	0.03 [0.85]	5.5 [0.02]		Cotton yarn	7.0 [0.01]	2.5 [0.11]	2.7 [0.10]	3.3 [0.07]
Electricity	30.6 [0.00]	8.2 [0.01]	2.3 [0.32]	7.2 [0.02]		Electricity	8.4 [0.00]	1.4 [0.23]	4.5 [0.03]	2.9 [0.01]
Electrical cables	5.9 [0.01]	0.0 [0.96]	0.8 [0.37]	0.6 [0.45]		Electrical cables	10.8 [0.00]	0.4 [0.54]	0.1 [0.82]	0.0 [0.95]
Fresh flowers	11.6 [0.00]	5.4 [0.06]	1.7 [0.43]	6.8 [0.03]		Fresh flowers	22.9 [0.00]	0.4 [0.52]	0.8 [0.37]	0.04 [0.83]
Fresh fruit vegetables	11.6 [0.00]	5.0 [0.08]	1.6 [0.44]	7.3 [0.02]		Fresh fruit vegetables	14.8 [0.00]	1.9 [0.17]	0.4 [0.53]	1.4 [0.24]
Gemstones	8.4 [0.00]	4.7 [0.03]	0.5 [0.47]	0.9 [0.34]		Gemstones	9.3 [0.00]	1.7 [0.19]	0.01 [0.90]	0.0 [0.93]
Gasoil/ petroleum oils	12.6 [0.00]	8.3 [0.00]	6.2 [0.01]	0.01 [0.92]		Gasoil/ petroleum oils	13.2 [0.00]	8.6 [0.00]	2.8 [0.09]	0.04 [0.84]
White spoon sugar	21.6 [0.00]	8.8 [0.01]	2.5 [0.29]	6.1 [0.04]		White spoon sugar	18.8 [0.00]	3.0 [0.08]	2.5 [0.11]	0.0 [0.97]

Sources: Eviews6

x_t represents trade data. p-values are in [ ] brackets.

Table 4.29 Test for weak exogenity (erv_{rkr} and erv_{nkr})

	x_t	y	p_t	erv_{rkr}			x_t	y	p_t	erv_{nkr}
Total imports	15.2 [0.00]	6.1 [0.05]	9.8 [0.01]	19.0 [0.00]		Total imports				
Total exports	5.9 [0.05]	0.2 [0.90]	3.7 [0.16]	8.7 [0.01]		Total exports				
NTEs	23.7 [0.00]	19.2 [0.00]	2.3 [0.31]	16.3 [0.00]		NTEs	30.4 [0.00]	18.3 [0.00]	0.5 [0.78]	14.0 [0.00]
Burley tobacco	25.4 [0.00]	4.6 [0.10]	0.5 [0.77]	22.3 [0.00]		Burley tobacco	24.8 [0.00]	1.2 [0.54]	0.3 [0.85]	24.0 [0.00]
Cotton lint	14.6 [0.00]	4.0 [0.14]	1.3 [0.52]	21.3 [0.00]		Cotton lint	16.7 [0.00]	1.5 [0.47]	1.2 [0.56]	26.5 [0.00]
Copper						Copper				
Copper wire	4.0 [0.04]	8.5 [0.00]	0.6 [0.44]	14.4 [0.00]		Copper wire	3.9 [0.04]	2.9 [0.09]	0.3 [0.57]	17.7 [0.00]
Cotton yarn	9.3 [0.00]	0.8 [0.36]	6.7 [0.01]	1.9 [0.16]		Cotton yarn	7.6 [0.01]	0.1 [0.76]	6.4 [0.01]	2.3 [0.13]
Electricity	2.7 [0.09]	0.7 [0.40]	1.2 [0.27]	8.4 [0.00]		Electricity	3.0 [0.08]	1.8 [0.18]	0.9 [0.35]	13.6 [0.00]
Electrical cables	11.6 [0.00]	10.9 [0.00]	0.6 [0.73]	6.8 [0.03]		Electrical cables	15.6 [0.00]	8.2 [0.16]	0.4 [0.83]	23.6 [0.00]
Fresh flowers	23.4 [0.00]	5.6 0.06]	2.9 [0.23]	21.9 [0.00]		Fresh flowers	24.1 [0.00]	1.8 [0.39]	3.0 [0.22]	24.0 [0.00]
Fresh fruit vegetables	16.3 [0.00]	4.9 [0.08]	0.5 [0.77]	22.1 [0.00]		Fresh fruit vegetables	13.2 [0.00]	1.3 [0.51]	0.6 [0.74]	24.3 [0.00]
Gemstones	17.3 [0.00]	6.3 [0.04]	2.4 [0.30]	23.6 [0.00]		Gemstones	14.2 [0.00]	2.2 [0.33]	2.3 [0.31]	24.5 [0.00]
Gasoil/ petroleum oils	7.7 [0.01]	0.01 [0.96]	1.7 [0.19]	15.3 [0.00]		Gasoil/ petroleum oils	14.4 [0.00]	0.3 [0.61]	2.3 [0.13]	1.0 [0.31]
White spoon sugar	8.9 [0.00]	7.8 [0.02]	0.9 [0.64]	11.8 [0.00]		White spoon sugar	18.9 [0.00]	7.9 [0.02]	1.7 [0.43]	26.4 [0.00]

Sources: Eviews6

x_t represents trade data. p-values are in [ ] brackets.

Table 4.30 Test for weak exogenity (erv_{npca} and erv_{rpca})

	x_t	y	p_t	erv_{npca}			x_t	y	p_t	erv_{rpca}
Total imports						Total imports	6.5 [0.04]	3.3 [0.19]	0.4 [0.81]	13.3 [0.00]
Total exports						Total exports	5.3 [0.07]	0.5 [0.78]	3.5 [0.17]	12.6 [0.00]
NTEs	23.1 [0.00]	26.1 [0.00]	2.8 [0.24]	6.5 [0.04]		NTEs	21.2 [0.00]	23.8 [0.00]	2.6 [0.27]	9.6 [0.01]
Burley tobacco	12.9 [0.00]	2.0 [0.16]	0.1 [0.70]	0.3 [0.60]		Burley tobacco	21.9 [0.00]	7.3 [0.03]	0.6 [0.74]	13.5 [0.00]
Cotton lint	9.7 [0.00]	2.3 [0.13]	4.4 [0.04]	4.0 [0.04]		Cotton lint	14.5 [0.00]	8.8 [0.01]	5.6 [0.06]	14.7 [0.00]
Copper	4.4 [0.00]	0.4 [0.53]	1.7 [0.19]	5.4 [0.02]		Copper	15.7 [0.00]	2.7 [0.26]	12.1 [0.00]	2.7 [0.02]
Copper wire	4.8 [0.02]	5.6 [0.01]	0.3 [0.57]	0.0 [0.95]		Copper wire	6.1 [0.04]	12.3 [0.00]	0.6 [0.74]	9.0 [0.01]
Cotton yarn	3.6 [0.05]	11.0 [0.00]	0.4 [0.52]	1.6 [0.21]		Cotton yarn	4.2 [0.03]	0.6 [0.42]	12.2 [0.00]	0.8 [0.36]
Electricity	9.7 [0.00]	0.7 [0.39]	3.6 [0.06]	4.2 [0.04]		Electricity	17.4 [0.00]	5.1 [0.07]	5.0 [0.08]	11.8 [0.00]
Electrical cables	6.3 [0.01]	0.2 [0.63]	0.1 [0.81]	0.2 [0.63]		Electrical cables	15.3 [0.00]	13.3 [0.00]	0.7 [0.71]	13.9 [0.00]
Fresh flowers	17.6 [0.00]	1.6 [0.20]	1.4 [0.24]	2.1 [0.15]		Fresh flowers	24.4 [0.00]	9.7 [0.01]	1.5 [0.47]	15.8 [0.00]
Fresh fruit vegetables	5.8 [0.01]	1.4 [0.24]	0.6 [0.44]	0.2 [0.63]		Fresh fruit vegetables	16.6 [0.00]	8.7 [0.01]	0.9 [0.65]	14.5 [0.00]
Gemstones	6.3 [0.01]	4.4 [0.03]	0.0 [0.96]	7.2 [0.01]		Gemstones	2.0 [0.01]	7.0 [0.01]	0.1 [0.72]	9.3 [0.00]
Gasoil/ petroleum oils	7.2 [0.01]	14.4 [0.00]	4.2 [0.04]	0.7 [0.40]		Gasoil/ petroleum oils	7.5 [0.02]	12.5 [0.00]	4.2 [0.12]	16.1 [0.00]
White spoon sugar	11.9 [0.00]	10.9 [0.00]	0.3 [0.59]	1.4 [0.23]		White spoon sugar	10.6 [0.00]	8.7 [0.01]	5.2 [0.07]	5.2 [0.07]

Sources: Eviews6

x_t represents trade data. p-values are in [ ] brackets.

β_2

Identifying Restrictions

For equilibrium relationships with one cointegrating vector, one restriction, normalisation on import/export, is imposed while the rest are left as free parameters as shown in table 4.31 below.

Table 4.31 Rank=1: Identifying Restrictions

	x_t	y_t	p_t	erv_t
β_1	1	β_{12}	β_{13}	β_{14}

In the case of trade relationships with two cointegrating vectors (table 4.32), four identifying restrictions are imposed and variables in the VAR are ordered as they appear in the table below. In the first cointegrating vector, β_1, in addition to the normalisation restriction, long-run proportionality is imposed between x_t and y_t as the latter is treated as a scale variable such that changes in y_t are directly linked to changes in x_t. In the second cointegrating vector, β_2, the normalisation restriction is imposed on exchange rate volatility while zero is imposed on foreign income, signifying no direct contemporaneous relationship between erv_t and foreign income. This is despite the fact that in open economies, the transmission of price changes between trading countries is captured through the volatility-trade relation (Doyle, 2001).

Table 4.32 Rank=2: Identifying Restrictions

	x_t	y_t	p_t	erv_t
β_1	1	-1	β_{13}	β_{14}
β_2	β_{21}	0	β_{23}	1

The long-run estimates for income, relative price and exchange rate volatility of the restricted long-run matrix from the Johansen method are reported in tables 4.33-4.40. They correspond to the Π matrix reflecting the total effect of the identifying restrictions discussed above on the variables in the sytem.

Income

Consistent with existing evidence (see Arize et al. 2000, 2008 and Munyama and Todani, 2005) income (α_1 coefficient in the tables 4.33-4.40) exerts very strong positive influence on both imports and exports. It is highly statistically significant at 1 percent level in virtually all the trade equations with (high) elasticities ranging from 0.1 to 13.8. This signifies the importance of foreign and domestic income in Zambia's trade. The only exception is cotton yarn where the impact is negative and statistically significant across all exchange rate volatility measures contrary to theoretical predictions[87]. GPO has the highest long-run income elasticity of 13.8.

Some possible explanations for the large income coefficients include adaptation of exports to local taste in trading partner countries (Arize et al. 2000, 2008; and Munyama and Todani, 2005). In addition, export demand depends on economic conditions obtaining in trading partner countries. Moreover, most of Zambia's export commodities examined are semi-finished with relatively small amount of value-added. They are used as raw material for the production of final goods in trading partner countries. Thus, their demand varies according to prevailing economic conditions in trading partner countries. In the case of cotton yarn, fresh fruit vegetables and fresh flowers, the negative income coefficient reflects the reduction in demand for these

[87] Fresh fruit vegetables and fresh flowers in the erv_{neer} and erv_{rpca} specifications only (tables 4.33 and 4.40, respectively) also have negative income coefficients.

commodities as foreign income grows due to the substitution of imported goods for domestic ones. Alternatively, the contribution of foreign income growth to the demand for these commodities is lower than demand for other commodities (Bahmani-Oskooee and Hegerty, 2008).

Relative Prices

The influence of the real exchange rate (α_2 coefficient in tables 4.33-4.40) on trade varies across alternative measures of exchange rate volatility similar to Bahmani-Oskooee and Hegerty (2008, 2009). The long-run price elasticity ranges from 0.004 to 4 (in absolute terms). In line with theoretical predictions, real depreciation of the exchange rate depresses imports. Contrary to theoretical predictions, total exports are depressed by the real depreciation of the kwacha exchange rate. NTEs increase as expected in response to the real depreciation of the kwacha. However, individual export commodities show varied response to the real depreciation of the kwacha: cotton lint, copper wire, gemstones and GPO (with the largest coefficient in excess of 1) increase while copper, electricity, fresh flowers and white spoon sugar decrease in all the specifications under alternative measures of exchange rate volatility. Despite exhibiting mixed response, positive coefficients dominate in burley tobacco, cotton yarn and fresh fruit vegetables. Thus, in general, it can be concluded that the real depreciation of the KUS$ imposes a positive influence on individual export commodities and thus have the tendency to improve the trade balance.

Exchange Rate Volatility

Both imports and exports are sensitive to movements in exchange rate volatility (α_3 coefficient in tables 4.33-4.40) with varied response across individual export commodities under alternative measures of exchange rate risk.

All measures of exchange rate volatility unambiguously depress total imports and total exports (including total NTEs as statistically significant negative coefficients dominate) predominantly at 1 percent significance level. The above result is similar to Choudhry (2005, 2008), Arize et al. (2008), Musonda (2008), Onafowora and Owoye (2008) and Ulugbek and Nishanbay (2008). Individual export commodities exhibit different sensitivity to variations in exchange rate volatility across alternative measures similar to McKenzie (1999) and Bustaman and Jayanthakumaran (2006).

By and large, exchange rate volatility exerts a direct effect on individual export commodities as positive coefficients are in the majority. Specifically, exports of burley tobacco, cotton lint, copper, copper wire, cotton yarn, electrical cables, fresh fruit vegetables, gemstones and GPO increase in response to the rise in exchange rate volatility[88]. Thus, exchange rate risk re-enforces the effect of real income for these exports except cotton yarn. Exporters of these commodities may construe exchange rate volatility as an opportunity rather than as a trading risk. In addition, the positive response could reflect their degree of risk-averseness in line with De Grauwe (1988) that exports increase to avoid a drastic fall in export revenue. In contrast, exports of fresh flowers and white spoon sugar reduce as exchange rate volatility increases[89]. The

[88] Exports of copper wire and cotton yarn and cotton lint (with the exception of real KUS$ risk measure) increase irrespective of the measure of exchange rate risk employed. However, the response of burley tobacco, electricity, gemstones and gas oils/petroleum oils exports to increases in exchange rate volatility is mixed, but statistically significant positive coefficients dominate.

[89] The response to exchange rate volatility by these two commodities is mixed, but statistically significant negative coefficients dominate across alternative measures of exchange rate risk.

response of electricity exports to variations in exchange rate risk is not easily discernible: it depends on the measure of exchange rate risk in question.

Thus, aggregation bias is evident from the foregoing as individual commodity exports that make up total exports reveal different response to exchange rate risk while total exports and NTEs respond negatively.

While an assessment of the underlying differences in the response of individual export commodities to exchange rate volatility is industry-specific and falls outside the scope of this chapter, it is noteworthy to mention that most, if not all exporters from Zambia are too small to influence the price in the export markets. In addition, most exporters have long-term contractual commitments either through the trade agreements discussed in section 4.2 or through bilateral arrangements. Thus, exporters cannot renege on contractual obligations without facing severe financial consequences. Accordingly, firms continue exporting despite facing substantial currency fluctuations as long as variable costs are met in the short-run with the expectation that the turnaround in the exchange rate would offset total costs to ensure continuity in business. Finally, the foreign exchange market in Zambia is largely underdeveloped with virtually non-existent hedging instruments which, although have their own shortcomings, could mitigate the negative effects of exchange rate risk.

The performance of the GARCH-PCA measure is comparable to the other measures of exchange rate volatility examined. The sign on the coefficient and statistical significance predominantly at 1 percent level (for erv_{npca} in Table 4.39) is broadly consistent with other measures especially erv_{neer} (table 4.33) and $erv_{nkus\$}$ (table 4.36). For instance, erv_{npca} in table 4.39 is statistically significant in 11 out of 13 trade equations which compares favourably with $erv_{nkus\$}$ in table 4.36 and erv_{neer} in table 4.33 (12 out of 13). Further, GARCH-PCA, in particular erv_{rpca}, exhibits a more stable cointegrating relationship (reported in tables 4.3-4.17) than the rest, as the rank for virtually all export demand equations is 2 with the exception of cotton yarn and gemstones while other measures of exchange rate risk indicate a rank of 1. Finally, the coefficient magnitude on GARCH-PCA measures is relatively larger (reported in {} brackets in tables 4.33-4.40 below t-values), thus revealing a slightly greater impact on trade flows than other measures[90].

A comparison of bilateral exchange rates shows that volatility in the KUS$ matters more for trade than volatility in the Krand exchange rate as the coefficient on the latter is insignificant in the majority of export demand equations (only 5 out of total 12 in table 4.38 are significant) compared with the former (12 out of total 13 in table 4.36). Nominal and real measures of exchange rate volatility exert similar impact in magnitude on trade flows consistent with Clark et al. (2004) and Tenreyro (2007). However, the number of statistically significant coefficients for the nominal measure dominates the real measure counterpart in all trade equations except the trade-weighted measure (tables 4.33 and 4.34) where the two are almost equally statistically significant. This highlights the importance of the nominal measure of exchange rate risk in trade flows and justifies the practical arguments about the relationship between real and nominal measures pointed out earlier. Thus, in order to conserve space, the trade-weighted measure of exchange rate risk is used in estimating the short-run dynamic model (subsection 4.4.4.2) as it has slightly more statistically significant coefficients in the trade equations.

[90] The size of the coefficient on exchange rate volatility is multiplied by the standard error of the corresponding exchange rate volatility measure in order to compare the extent of the impact of each alternative measure on trade. The reason for doing this is that the dimension of the GARCH-PCA measure is different from the rest: GARCH-PCA is pooled from three GARCH models (EGARCH and GARCH plus TGARCH are a mixture of log and non-log linear specification of conditional variance, respectively) while the rest are estimated from the EGARCH model which is specified in log-linear form.

Table 4.33 Johansen Cointegration test: Long-run estimates ($\alpha_{3,neer}$)

Commodity	α_1	α_2	$\alpha_{3,neer}$	$F(sc)$	χ^2_{Nor}	$F(Het)$
NTEs	5.4* (6.4)	0.2* (7.0)	-0.02* (-6.3) {7.6^{-5}}	0.8 [0.89]	701.1 [0.00]	1.6 [0.00]
Burley tobacco	4.0* (4.7)	0.2* (4.7)	0.10* (4.7) {4.0^{-4}}	0.7 [0.95]	208.0 [0.00]	1.8 [0.00]
Cotton lint	1.0* (4.5)	0.5* (4.6)	0.15 (4.5) {6.0^{-4}}	1.0 [0.54]	133.2 [0.00]	1.0 [0.53]
Copper	4.3* (5.4)	-0.5* (-5.4)	0.04* (5.4) {1.5^{-4}}	0.9 [0.60]	379.7 [0.00]	1.7 [0.00]
Copper wire	10.5* (4.0)	2.0* (4.1)	0.37* (4.1) {1.5^{-3}}	1.1 [0.22]	292.2 [0.00]	1.3 [0.02]
Cotton yarn	-2.8* (-5.7)	0.2* (6.3)	0.16* (5.7) {6.4^{-4}}	0.6 [0.99]	195.9 [0.00]	1.3 [0.02]
Electricity	0.7* (5.8)	-0.7* (-5.8)	-0.01* (-8.0) {3.2^{-5}}	0.8 [0.85]	166.0 [0.00]	0.9 [0.82]
Electrical cables	5.8* (5.8)	-0.1* (-6.3)	0.03* (5.0) {1.2^{-4}}	0.9 [0.79]	428.1 [0.00]	1.4 [0.00]
Fresh flowers	0.8* (6.7)	-0.5* (-6.3)	-0.06* (-6.7) {2.4^{-4}}	0.8 [0.91]	188.0 [0.00]	1.2 [0.05]
Fresh fruit vegetables	-0.4* (-6.7)	0.2* (5.0)	0.20* (5.3) {8.0^{-4}}	0.5 [1.00]	175.3 [0.00]	0.8 [0.95]
Gemstones	3.5* (6.1)	1.3* (6.5)	0.14* (7.0) {5.6^{-4}}	0.7 [0.94]	161.8 [0.00]	1.6 [0.00]
Gasoil/petroleum oils	13.3* (4.8)	4.2* (4.7)	0.07* (7.0) {2.8^{-4}}	0.7 [0.95]	361.7 [0.00]	1.3 [0.02]
White spoon sugar	6.5* (7.1)	-0.2* (-7.0)	-0.11* (-7.3) {4.4^{-4}}	0.8 [0.94]	200.7 [0.00]	1.4 [0.01]

Source: PcGive10.0 . χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.
t-values are in parenthesis while p-values are in square brackets.
*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.
Numbers in {} are re-scaled exchange rate volatility coefficients obtained by multiplying the coefficient by the standard deviation corresponding to the GARCH measure of exchange rate volatility to facilitate comparison.

Table 4.34 Johansen Cointegration test: Long-run estimates ($\alpha_{3,reer}$)

Commodity	α_1	α_2	$\alpha_{3,reer}$	D	$F(sc)$	χ^2_{Nor}	$F(Het)$
Total imports	1.3* (6.5)	-0.03* (-6.0)	-0.01* (-10.0) $\{1.6^{-2}\}$	0.1* (5.0)	0.6 [1.00]	85737.0 [0.00]	2.2 [0.00]
Total exports	1.4* (3.5)	-0.1* (-4.0)	-0.004* (-0.4) $\{6.4^{-3}\}$		1.0 [0.62]	2731.6 [0.00]	1.7 [0.00]
NTEs	5.3* (6.4)	0.2* (7.3)	-0.02* (-6.7) $\{1.6^{-4}\}$		0.8 [0.86]	627.2 [0.00]	1.4 [0.00]
Burley tobacco	0.2* (4.1)	-0.1* (-4.5)	-0.01* (-4.6) $\{4.8^{-5}\}$		0.7 [0.96]	206.0 [0.00]	1.6 [0.00]
Cotton lint	0.1* (4.7)	0.4* (4.4)	0.04* (4.0) $\{3.2^{-4}\}$		0.9 [0.72]	165.8 [0.00]	1.0 [0.35]
Copper	4.1* (4.7)	-0.6* (-4.9)	0.03* (2.6) $\{2.1^{-4}\}$		0.9 [0.79]	404.8 [0.00]	1.5 [0.00]
Copper wire	13.6* (5.4)	2.6* (5.3)	0.28* (5.6) $\{2.2^{-3}\}$		1.2 [0.15]	278.6 [0.00]	1.7 [0.00]
Cotton yarn	-2.7* (-5.9)	0.2* (6.6)	0.13* (6.5) $\{1.0^{-3}\}$		0.8 [0.90]	184.3 [0.00]	1.3 [0.01]
Electricity	0.8* (5.7)	-0.7* (-5.8)	-0.04* (-6.7) $\{3.2^{-5}\}$		0.7 [0.95]	186.3 [0.00]	0.8 [0.93]
Electrical cables	6.1* (5.5)	-0.03* (-5.0)	0.01* (3.3) $\{8.0^{-5}\}$		0.8 [0.92]	366.1 [0.00]	1.3 [0.02]
Fresh flowers	1.2* (6.3)	-0.5* (-6.3)	-0.04* (-6.7) $\{3.2^{-4}\}$		0.9 [0.72]	195.0 [0.00]	1.1 [0.29]
Fresh fruit vegetables	1.0* (5.1)	0.4* (5.7)	0.08* (5.3) $\{6.4^{-4}\}$		0.8 [0.87]	189.0 [0.00]	1.3 [0.02]
Gemstones	2.4* (6.3)	1.2* (6.1)	0.08* (8.0) $\{6.4^{-4}\}$		0.9 [0.80]	174.4 [0.00]	1.3 [0.01]
Gasoil/petroleum oils	12.2* (4.5)	3.9* (4.3)	-0.01* (-5.0) $\{8.0^{-5}\}$		0.8 [0.89]	318.5 [0.00]	1.3 [0.03]
White spoon sugar	6.3* (7.0)	-0.1* (-13.0)	-0.03* (-6.3) $\{2.4^{-4}\}$		0.8 [0.84]	214.5 [0.00]	1.2 [0.09]

Source: PcGive10.0 . χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

t-values are in parenthesis while p-values are in square brackets.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Numbers in {} are re-scaled exchange rate volatility coefficients obtained by multiplying the coefficient by the standard deviation corresponding to the GARCH measure of exchange rate volatility to facilitate comparison.

Table 4.35 Johansen Cointegration test: Long-run estimates ($\alpha_{3,rkus\$}$)

Commodity	α_1	α_2	$\alpha_{3,rkus\$}$	D	$F(sc)$	χ^2_{Nor}	$F(Het)$
Total imports	1.2* (6.0)	-0.03* (-6.0)	-0.01* (-5.0) {1.5^{-2}}	0.1 (10.0)	0.7 [0.99]	89419.0 [0.00]	2.6 [0.00]
Total exports	1.1* (2.8)	-0.1* (-3.5)	-0.01 (-0.5) {7.5^{-3}}		0.9 [0.71]	3150.8 [0.00]	1.6 [0.00]
NTEs	5.1* (6.3)	0.2* (3.4)	-0.01 (-0.7) {1.4^{-4}}		1.1 [0.21]	744.1 [0.00]	1.3 [0.01]
Burley tobacco	4.3* (4.7)	-0.02 (-0.1)	-0.05 (-0.5) {7.3^{-4}}		1.1 [0.23]	219.5 [0.00]	1.6 [0.00]
Cotton lint	1.2* (4.4)	0.4* (3.0)	-0.004 (-0.1) {5.6^{-5}}		1.1 [0.35]	175.2 [0.00]	1.1 [0.18]
Copper	4.1* (5.0)	-0.7* (-4.8)	-0.01 (-0.3) {8.4^{-5}}		1.1 [0.25]	414.9 [0.00]	1.2 [0.03]
Copper wire	9.8* (3.1)	2.0* (3.0)	0.11 (1.2) {1.5^{-3}}		1.2 [0.15]	343.8 [0.00]	1.0 [0.40]
Cotton yarn	-2.2* (-6.3)	0.5* (6.7)	0.17* (5.7) {2.4^{-3}}		0.8 [0.90]	201.3 [0.00]	1.4 [0.01]
Electricity	0.7* (4.1)	-0.4* (-3.1)	0.03 (0.9) {3.6^{-4}}		1.0 [0.42]	202.6 [0.00]	1.1 [0.22]
Electrical cables	5.2* (5.2)	0.1* (4.7)	0.10* (5.0) {1.4^{-3}}		0.9 [0.63]	395.2 [0.00]	1.2 [0.04]
Fresh flowers	-0.1* (-5.0)	-0.5* (-4.2)	-0.01 (-0.2) {1.3^{-4}}		1.1 [0.34]	203.1 [0.00]	1.1 [0.30]
Fresh fruit vegetables	1.4* (4.2)	0.2 (1.6)	-0.04 (-0.9) {5.6^{-4}}		0.9 [0.80]	224.2 [0.00]	1.4 [0.00]
Gemstones	3.9* (6.2)	0.8* (6.2)	-0.06* (-6.0) {8.4^{-4}}		0.9 [0.74]	185.4 [0.00]	1.3 [0.02]
Gasoil/petroleum oils	13.8* (4.3)	4.2* (4.4)	0.19* (4.8) {2.7^{-3}}		1.0 [0.52]	321.2 [0.00]	1.3 [0.03]
White spoon sugar	5.3* (6.9)	-0.1 (-0.7)	-0.04 (-0.6) {5.6^{-4}}		0.9 [0.64]	192.7 [0.00]	1.0 [0.40]

Source: PcGive10.0 . χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

t-values are in parenthesis while p-values are in square brackets.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Numbers in {} are re-scaled exchange rate volatility coefficients obtained by multiplying the coefficient by the standard deviation corresponding to the GARCH measure of exchange rate volatility to facilitate comparison.

Table 4.36 Johansen Cointegration test: Long-run estimates ($\alpha_{3,nkus\$}$)

Commodity	α_1	α_2	$\alpha_{3,nkus\$}$	$F(sc)$	χ^2_{Nor}	$F(Het)$
NTEs	5.3* (6.8)	0.2* (6.8)	-0.02* (-5.7) {4^{-4}}	1.2 [0.18]	602.3 [0.00]	1.6 [0.00]
Burley tobacco	2.9* (5.4)	0.5* (5.4)	0.30* (5.4) {5.9^{-3}}	1.1 [0.34]	201.3 [0.00]	1.1 [0.32]
Cotton lint	0.1* (2.8)	0.3** (2.4)	0.10** (2.5) {2^{-3}}	1.1 [0.24]	165.4 [0.00]	1.3 [0.01]
Copper	3.4* (4.4)	-0.4* (-4.5)	0.04* (4.5) {7.2^{-4}}	1.1 [0.35]	371.7 [0.00]	1.7 [0.00]
Copper wire	9.7* (3.6)	2.0* (3.6)	0.22* (3.7) {4.4^{-3}}	1.3 [0.09]	283.4 [0.00]	1.1 [0.23]
Cotton yarn	-2.8* (-5.6)	0.3* (5.5)	0.16* (5.3) {3.2^{-3}}	0.8 [0.87]	181.4 [0.00]	1.5 [0.00]
Electricity	0.4* (6.7)	-0.7* (-7.0)	0.07* (7.0) {1.4^{-3}}	1.0 [0.57]	197.3 [0.00]	0.8 [0.99]
Electrical cables	4.9* (5.1)	0.1* (6.0)	0.09* (5.0) {1.8^{-3}}	1.0 [0.41]	323.6 [0.00]	1.5 [0.00]
Fresh flowers	0.7* (5.9)	-0.7* (-5.8)	-0.14* (-7.0) {2.8^{-3}}	1.0 [0.48]	194.3 [0.00]	1.3 [0.02]
Fresh fruit vegetables	1.4* (4.8)	0.3* (5.0)	0.02* (4.0) {4^{-4}}	0.9 [0.77]	197.6 [0.00]	1.8 [0.00]
Gemstones	4.0* (5.7)	0.9* (6.4)	0.0001 (0.0) {2^{-6}}	0.8 [0.83]	178.2 [0.00]	1.9 [0.00]
Gasoil/petroleum oils	12.3* (4.6)	4.1* (4.6)	0.30* (5.0) {6^{-3}}	1.0 [0.41]	261.3 [0.00]	1.4 [0.01]
White spoon sugar	5.6* (7.2)	-0.4* (-6.7)	-0.14* (-7.0) {2.8^{-3}}	0.9 [0.70]	185.2 [0.00]	1.4 [0.00]

Source: PcGive10.0 . χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

t-values are in parenthesis while p-values are in square brackets.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Numbers in {} are re-scaled exchange rate volatility coefficients obtained by multiplying the coefficient by the standard deviation corresponding to the GARCH measure of exchange rate volatility to facilitate comparison.

Table 4.37 Johansen Cointegration test: Long-run estimates ($\alpha_{3,rkr}$)

Commodity	α_1	α_2	$\alpha_{3,rkr}$	D	$F(sc)$	χ^2_{Nor}	$F(Het)$
Total imports	0.1** (2.5)	-0.004* (-4.0)	-0.03* (-3.3) $\{3.8^{-2}\}$	0.02 (2.2)	0.8 [0.97]	86408.0 [0.00]	1.9 [0.00]
Total exports	0.2** (2.0)	-0.01 (-1.4)	-0.02** (-2.0) $\{2.5^{-2}\}$		0.9 [0.83]	2096.9 [0.00]	1.3 [0.00]
NTEs	5.7* (6.3)	0.3* (5.9)	0.01 (0.8) $\{1.0^{-4}\}$		0.9 [0.71]	449.9 [0.00]	1.0 [0.49]
Burley tobacco	4.8* (4.9)	0.6* (3.2)	0.06 (0.6) $\{5.1^{-4}\}$		0.8 [0.94]	113.3 [0.00]	1.4 [0.01]
Cotton lint	0.5* (2.9)	0.3* (2.9)	0.13** (2.6) $\{1.0^{-3}\}$		0.9 [0.73]	85.7 [0.00]	1.0 [0.38]
Copper							
Copper wire	2.0** (2.7)	0.5* (2.7)	0.24* (2.7) $\{1.9^{-3}\}$		1.3 [0.06]	159.5 [0.00]	1.1 [0.25]
Cotton yarn	-1.6* (-4.6)	0.3* (4.6)	0.15* (5.0) $\{1.2^{-3}\}$		0.9 [0.73]	112.0 [0.00]	0.9 [0.78]
Electricity	0.2 (1.5)	-0.2 (-1.5)	-0.06 (-1.5) $\{4.8^{-4}\}$		0.8 [0.93]	140.1 [0.00]	0.8 [0.93]
Electrical cables	6.5* (4.6)	0.3* (4.3)	-0.002 (-0.05) $\{1.6^{-5}\}$		0.8 [0.89]	118.1 [0.00]	0.8 [0.98]
Fresh flowers	0.5* (6.3)	-0.3* (-3.8)	-0.001 (-0.0) $\{8^{-6}\}$		1.1 [0.36]	110.5 [0.00]	1.0 [0.35]
Fresh fruit vegetables	0.6* (4.3)	-0.1 (-1.3)	-0.006 (-0.1) $\{4.8^{-5}\}$		0.9 [0.79]	116.8 [0.00]	1.1 [0.18]
Gemstones	2.2* (5.9)	0.1 (1.0)	0.13 (1.4) $\{1.0^{-3}\}$		0.8 [0.86]	100.2 [0.00]	1.1 [0.17]
Gasoil/petroleum oils	4.9** (2.0)	1.2** (2.0)	0.30+ (1.8) $\{2.4^{-3}\}$		1.0 [0.57]	89.0 [0.00]	0.5 [0.63]
White spoon sugar	4.7* (4.9)	-0.2+ (-1.7)	0.03 (0.4) $\{2.4^{-4}\}$		1.0 [0.53]	129.3 [0.00]	0.9 [0.90]

Source: PcGive10.0 . χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

t-values are in parenthesis while p-values are in square brackets.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Numbers in {} are re-scaled exchange rate volatility coefficients obtained by multiplying the coefficient by the standard deviation corresponding to the GARCH measure of exchange rate volatility to facilitate comparison.

Table 4.38 Johansen Cointegration test: Long-run estimates ($\alpha_{3,nkr}$)

Commodity	α_1	α_2	$\alpha_{3,nkr}$	$F(sc)$	χ^2_{Nor}	$F(Het)$
NTEs	5.4* (4.9)	0.3* (4.3)	-0.02 (-0.6) {4.7^{-4}}	1.1 [0.36]	518.9 [0.00]	0.8 [0.97]
Burley tobacco	4.7* (5.0)	0.5** (2.4)	0.01 (0.1) {3.1^{-4}}	0.7 [0.99]	113.4 [0.00]	1.7 [0.00]
Cotton lint	0.7* (3.1)	0.4* (3.0)	0.19* (3.2) {5.9^{-3}}	0.9 [0.68]	93.6 [0.00]	1.0 [0.41]
Copper						
Copper wire	2.2* (2.8)	0.5* (2.8)	0.34* (2.8) {1.1^{-2}}	1.3 [0.06]	259.2 [0.00]	1.1 [0.19]
Cotton yarn	-1.2* (-4.3)	0.3* (4.7)	0.20* (4.0) {6.2^{-3}}	0.7 [0.99]	138.6 [0.00]	1.0 [0.56]
Electricity	0.2* (1.8)	-0.3** (-2.3)	-0.11** (-2.2) {3.4^{-3}}	0.7 [0.96]	131.3 [0.00]	0.8 [0.97]
Electrical cables	6.5* (5.4)	0.2* (3.3)	-0.02 (-0.4) {6.2^{-4}}	0.9 [0.78]	371.9 [0.00]	0.9 [0.77]
Fresh flowers	0.5* (5.6)	-0.3* (-3.3)	0.02 (0.3) {6.2^{-4}}	1.0 [0.53]	119.1 [0.00]	1.1 [0.17]
Fresh fruit vegetables	0.6* (3.8)	-0.2** (-2.5)	-0.07 (-1.2) {2.2^{-3}}	0.9 [0.80]	127.2 [0.00]	1.2 [0.12]
Gemstones	2.5* (6.0)	0.1 (0.4)	0.07 (0.6) {2.2^{-3}}	0.7 [0.95]	105.1 [0.00]	1.2 [0.12]
Gasoil/petroleum oils	5.4+ (1.7)	1.4+ (1.8)	0.40** (2.0) {0.2}	1.2 [0.16]	105.0 [0.00]	0.5 [1.00]
White spoon sugar	4.6* (6.8)	-0.5* (-4.1)	-0.12 (-1.3) {3.7^{-4}}	0.9 [0.77]	112.7 [0.00]	1.1 [0.22]

Source: PcGive10.0 . χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.
t-values are in parenthesis while p-values are in square brackets.
*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.
Numbers in {} are re-scaled exchange rate volatility coefficients obtained by multiplying the coefficient by the standard deviation corresponding to the GARCH measure of exchange rate volatility to facilitate comparison.

Table 4.39 Johansen Cointegration test: Long-run estimates ($\alpha_{3,npca}$)

Commodity	α_1	α_2	$\alpha_{3,npca}$	$F(sc)$	χ^2_{Nor}	$F(Het)$
NTEs	5.0* (5.7)	0.2* (5.8)	0.06 (0.9) {1.8^-2}	0.9 [0.76]	689.7 [0.00]	1.9 [0.00]
Burley tobacco	3.2* (5.3)	-0.2* (-6.7)	1.36* (5.2) {0.40}	1.3 [0.09]	206.2 [0.00]	1.3 [0.01]
Cotton lint	0.7* (4.1)	0.2* (5.3)	0.50* (4.2) {0.15}	0.8 [0.83]	153.3 [0.00]	1.1 [0.18]
Copper	4.3* (5.3)	-0.7* (-5.0)	-0.02 (-0.3) {5.9^-3}	0.9 [0.78]	446.7 [0.00]	1.7 [0.00]
Copper wire	3.6** (2.3)	0.4** (2.1)	0.71** (2.2) {0.21}	1.1 [0.21]	353.9 [0.00]	1.3 [0.01]
Cotton yarn	-1.4* (-3.3)	-0.1* (-3.3)	0.54* (3.4) {0.16}	0.6 [1.00]	218.5 [0.00]	1.4 [0.00]
Electricity	0.2* (6.3)	-0.9* (-6.9)	0.43* (7.2) {0.13}	0.8 [0.85]	195.8 [0.00]	0.9 [0.90]
Electrical cables	2.3* (3.3)	-0.2* (-3.6)	0.44* (3.4) {0.13}	0.8 [0.91]	414.2 [0.00]	1.5 [0.00]
Fresh flowers	0.5* (4.2)	-0.1* (-5.0)	-0.60* (-4.3) {-0.18}	0.8 [0.93]	204.3 [0.00]	1.6 [0.00]
Fresh fruit vegetables	0.7* (4.4)	0.1* (3.9)	0.4* (3.6) {0.12}	0.7 [0.96]	211.1 [0.00]	1.7 [0.00]
Gemstones	3.2* (5.3)	0.7* (5.8)	1.02** (2.1) {0.21}	0.7 [0.96]	195.6 [0.00]	1.8 [0.00]
Gasoil/petroleum oils	5.1** (2.2)	1.2** (2.0)	0.98** (2.2) {0.29}	0.7 [0.95]	334.4 [0.00]	1.6 [0.00]
White spoon sugar	6.4* (5.4)	0.3* (5.0)	-0.90* (-5.4) {-0.27}	1.0 [0.51]	163.5 [0.00]	1.1 [0.27]

Source: PcGive10.0 . χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

t-values are in parenthesis while p-values are in square brackets.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Numbers in {} are re-scaled exchange rate volatility coefficients obtained by multiplying the coefficient by the standard deviation corresponding to the GARCH measure of exchange rate volatility to facilitate comparison.

Table 4.40 Johansen Cointegration test: Long-run estimates ($\alpha_{3,rpca}$)

Commodity	α_1	α_2	$\alpha_{3,rpca}$	D	$F(sc)$	χ^2_{Nor}	$F(Het)$
Total imports	0.4* (4.0)	-0.01** (-2.5)	-0.09* (-4.5) $\{5.1^{-2}\}$	0.1 (10.0)	0.8 [0.97]	92453.0 [0.00]	2.6 [0.00]
Total exports	0.3+ (1.8)	-0.02** (-2.0)	-0.04** (-2.0) $\{2.3^{-3}\}$		1.0 [0.47]	2931.7 [0.00]	1.9 [0.00]
NTEs	5.0* (5.8)	0.2* (6.0)	0.05 (0.6) $\{1.1^{-2}\}$		1.0 [0.50]	694.9 [0.00]	2.1 [0.00]
Burley tobacco	4.3* (4.6)	0.2** (2.2)	0.26 (0.5) $\{5.9^{-2}\}$		0.8 [0.84]	220.6 [0.00]	2.2 [0.00]
Cotton lint	1.1* (4.2)	0.4* (4.0)	0.09 (0.4) $\{2.0^{-2}\}$		1.1 [0.22]	224.7 [0.00]	1.6 [0.00]
Copper	4.3* (5.3)	-0.6* (-5.3)	-0.03 (-0.3) $\{6.8^{-3}\}$		1.0 [0.44]	473.8 [0.00]	1.6 [0.00]
Copper wire	8.4* (2.9)	1.2** (2.4)	0.83 (1.4) {0.19}		1.2 [0.11]	211.8 [0.00]	0.8 [0.98]
Cotton yarn	-1.4** (-2.2)	-0.2+ (-1.8)	0.6** (2.4) {0.14}		1.1 [0.30]	200.1 [0.00]	0.8 [0.98]
Electricity	0.5* (3.4)	-0.8* (-6.3)	0.48* (2.7) {0.11}		0.9 [0.74]	229.5 [0.00]	0.9 [0.67]
Electrical cables	5.9* (5.4)	-0.02 (-1.0)	0.08 (0.4) $\{1.8^{-2}\}$		0.9 [0.66]	449.1 [0.00]	1.5 [0.00]
Fresh flowers	-0.1** (-2.0)	-0.5* (-5.6)	-0.09 (-0.5) $\{-2.0^{-2}\}$		1.0 [0.56]	223.2 [0.00]	1.6 [0.00]
Fresh fruit vegetables	1.3* (4.5)	0.3* (4.3)	0.01 (0.02) $\{1.1^{-3}\}$		0.9 [0.61]	248.0 [0.00]	1.6 [0.00]
Gemstones	0.6** (2.0)	0.1** (2.5)	0.7* (5.8) {0.23}		0.9 [0.67]	208.5 [0.00]	1.9 [0.00]
Gasoil/petroleum oils	14.1* (4.4)	4.1* (4.6)	-0.49 (-0.8) {-0.11}		1.0 [0.48]	383.8 [0.00]	1.6 [0.00]
White spoon sugar	4.5* (3.5)	-0.2 (-1.3)	0.07 (0.2) $\{1.6^{-2}\}$		1.1 [0.33]	156.4 [0.00]	0.8 [0.95]

Source: PcGive10.0 . χ^2_{SC} =lagrange multiplier test of residual serial correlation; χ^2_{FF} =Functional form Ramsey's RESET test; χ^2_{Nor} =Normality test based on skewness and kurtosis of residuals; and χ^2_{Het} =Heteroskedasticity test.

t-values are in parenthesis while p-values are in square brackets.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Numbers in {} are re-scaled exchange rate volatility coefficients obtained by multiplying the coefficient by the standard deviation corresponding to the GARCH measure of exchange rate volatility to facilitate comparison.

4.4.4.2 Short-run Estimates

The results for the parsimonious dynamic import and export demand specifications obtained by imposing statistically insignificant coefficient restrictions on the parameter space are reported in table 4.41 below. The absence of serial correlation provides statistical support for the appropriateness of the short-run model as capturing the underlying dynamic structure of the variables in the VAR. However, residuals are found to be non-normal and heteroskedastic in some equations. To ensure accurate statistical inference, heteroskedasticity-robust standard errors are constructed using the Newey-West method and are reported in table 4.41 similar to Arize et al. (2008).

In general, changes in trade flows are driven by own past changes, with past changes in income and relative price having a very limited role in the short-run. About 60 percent of individual export commodities are affected by exchange rate volatility in the short-run.

Changes in total imports and exports are insensitive to changes in exchange rate volatility as their short-run behaviour is mostly influenced by own past changes with the tendency to reduce their values. Changes in total exports are affected by changes in past foreign income and real exchange rate with a positive influence. Total NTEs, cotton lint, copper, copper wire, cotton yarn and electrical cables are not affected by past changes in exchange rate volatility. Only current changes in burley tobacco, electricity, fresh fruit vegetables, GPO (with negative effect), fresh flowers, gemstones and white spoon sugar (with positive influence) are affected by past changes in exchange rate volatility.

The insensitivity of some export commodities to exchange rate volatility could be attributed to the existence of contractual obligations exporters enter into which cannot be breached without severe legal and financial consequences. For imports, the notion that a month or there about is too short a time for people to adjust consumption patterns by switching to alternative products and/or markets appears plausible. As observed by Hooper and Kohlhagen (1978), relatively inelastic short-run export supply could also contribute. In addition, firms do not respond instantaneously to price changes (Demers, 1991).

The error-correction term (ecm) indicates very high speed of adjustment per month for individual commodities (0.22 to 0.80), in some cases indicating almost complete adjustment in a month (0.80 for white spoon sugar) similar to Bustaman and Jayanthakumaran (2006). Moderate speed of adjustment is observed for aggregate trade data: 0.12 for total imports and 0.20 for total exports. Total exports and imports take about five and eight months, respectively to adjust to changes in income, relative price and exchange rate volatility once disequilibrium occurs. However, the majority of individual export commodities take about one to three months to adjust to equilibrium except cotton yarn and copper wire which take slightly longer, about five and seven months, respectively. The significance of the error-correction term indicates that market forces ensure equilibrium is restored once disequilibrium occurs. High volatility characterising individual export commodities whereby the series return to the mean value quite frequently with interchange periods of high and low export values accounts for the high speed of adjustment.

Table 4.41 ECM Results Adjusted by Newey-West HAC Standard Errors and Covariance

	c	Δx_{t-1}	Δx_{t-2}	Δx_{t-3}	Δy_{t-1}	Δp_{t-1}	Δp_{t-2}	Δp_{t-3}	Δerv_{t-1}	Δerv_{t-2}	D_{t-1}	ecm	adj R^2	$LM(sc)$	Nor	$Hert$
Total imports	0.01 (0.6)	-0.4* (-7.8)									0.2* (5.8)	-0.12* (-3.2)	0.29	0.2 [0.82]	17.2 [0.00]	1.4 [0.21]
Total exports	-0.03 (-1.0)	-0.6* (-7.8)	-0.4* (-5.7)	-0.2* (-2.9)	1.6* (3.5)			0.4* (2.6)				-0.20+ (-1.7)	030	1.7 [0.19]	4.7 [0.09]	1.2 [0.32]
NTEs	-0.1** (-2.4)				5.4* (5.2)							-0.61* (-7.6)	0.33	0.6 [0.57]	4.8 [0.09]	1.1 [0.32]
Burley tobacco	-1.8** (-2.5)		0.3** (2.2)			2.9** (2.0)				-0.9** (-2.1)		-0.71* (-6.5)	0.40	1.8 [0.17]	33.2 [0.00]	1.8 [0.13]
Cotton lint	-0.7* (-3.2)					1.5* (2.9)						-0.42* (-5.5)	0.22	1.6 [0.21]	8.0 [0.02]	0.2 [0.88]
Copper	-0.1* (-2.9)	-0.3* (-3.0)			5.7* (3.0)							-0.46* (-4.8)	0.34	2.4 [0.10]	7.0 [0.03]	3.3 [0.02]
Copper wire	0.1** (2.5)	-0.7* (-3.9)	-0.4** (-2.3)									-0.14** (-2.4)	0.45	2.3 [0.11]	219.6 [0.00]	6.7 [0.00]
Cotton yarn	-0.02 (-0.5)	-0.2** (-2.4)										-0.22* (-2.8)	0.18	5.1 [0.10]	60.7 [0.00]	0.1 [0.92]
Electricity	1.1* (5.7)	0.2** (2.2)	0.3* (3.4)			1.5* (3.6)	2.8* (5.6)		-0.5* (-4.0)	-0.4* (-3.9)		-0.46* (-3.6)	0.34	0.3 [0.76]	8.1 [0.02]	0.3 [0.98]
Electrical cables	-0.4* (-2.9)				5.4* (5.0)							-0.56* (-6.2)	0.28	0.9 [0.40]	1.6 [0.46]	2.7 [0.07]
Fresh flowers	0.5 (3.0)				0.4* (2.9)				0.6* (5.0)	0.4* (3.0)		-0.47* (-7.3)	0.27	0.5 [0.62]	17.5 [0.00]	2.2 [0.08]
Fresh fruit vegetables	0.00 (0.04)	0.1* (2.8)								-0.6** (-2.5)		-0.60* (-5.4)	0.30	0.4 [0.65]	554.9 [0.00]	0.2 [0.88]
Gemstones	1.0** (2.4)	-0.3* (-3.4)			3.0** (2.0)				1.2** (2.1)			-0.56* (-4.3)	0.47	2.9 [0.06]	1.6 [0.44]	1.0 [0.40]
Gasoil/petroleum oils	.1 (0.6)	-0.4* (-4.5)	-0.2* (-2.7)							-1.4* (-3.1)		-0.30** (-2.3)	0.32	1.8 [0.18]	150.2 [0.00]	0.3 [0.89]
White spoon Sugar	0.01 (0.3)					1.5** (2.1)			0.2* (2.7)			-0.80* (-8.3)	0.41	0.9 [0.40]	22.8 [0.00]	1.4 [0.23]

Source: Eviews6: x =trade data; LM(sc)=Breusch-Godfrey serial correlation test; Nor=J-B test for normality of residuals, Hert=Breusch-Pagan-Godfrey test for heteroskedasticity; *,**,+=1%,5%,10% significance level, respectively. t-statistics are reported in parenthsis while p-vales are in square brackets.

4.5 Conclusion

Import and export demand equations for Zambia were analysed over the period 1980.01-2007.12 with emphasis on exchange rate volatility as one of the key determinants. Alternative measures of exchange rate volatility for real and nominal bilateral and trade-weighted exchange rates generated from ARCH-type models were used in the empirical model in line with McKenzie (1999). Additionally, a GARCH-PCA measure which has not been used in the literature was employed as an alternative measure of exchange rate risk. Cointegration tests by Johansen (1988) and Pesaran et al. (2001) as well as the error-correction model were used to examine the underlying long-run equilibrium relationship between trade flows and their determinants. In line with theory and recent trends in the literature, individual export commodities were analysed in addition to aggregate exports and imports.

The results reveal the existence of a stable long-run equilibrium relationship between trade flows, income, relative price and exchange rate volatility. Both imports and exports are sensitive to the volatility in the kwacha exchange rates: value of total imports and exports reduces. While individual export commodities exhibit varied sensitivity to exchange rate volatility across alternative measures employed, by and large, the value of individual export commodities increases, suggesting that exporters of these commodities are not necessarily deterred by exchange rate fluctuations. Hence, the positive influence of exchange rate volatility on some exports should, all else being equal, improve the trade balance. In addition, the varied response of individual exports underscores the importance of disaggregating trade data, which has been lacking in Zambia thus far.

Exchange rate volatility tends to matter most in the long-run while in the short-run, some of trade flows especially aggregate imports and exports are insensitive to exchange rate volatility.

The GARCH-PCA measure performs reasonably well compared with other measures of exchange rate volatility employed and thus provides a useful alternative measure in trade analysis. The sign of the coefficient is broadly consistent with other measures and the extent of statistical significance is comparable. It also exhibits a more stable cointegrating relationship than other measures.

Finally, the study thus confirms that exchange rate volatility exerts influence on trade in line with existing evidence especially for developing countries. This therefore suggests that exchange rate volatility is an essential part of exchange rate and trade policy formulation as it might influence the allocation of resources between tradeable and non-tradeable sectors in Zambia. Overall a stable exchange rate is inevitable to ensure a positive effect on the trade balance.

Chapter 5 MONETARY POLICY RULES, FOREIGN EXCHANGE INTERVENTION AND EXCHANGE RATE VOLATILITY IN ZAMBIA

This chapter was partially written whilst at the IMF as an AERC/IMF Visiting Scholar from 30 March to 8 May 2009

5.1 Introduction

In recent years, the focus of monetary policy has narrowed down to one or two goals unlike in the past when multiple objectives were pursued (Poole, 1999; and Maria-Dolores, 2005). Most central banks define price stability as the primary objective of monetary policy, supported by the monetarist view that monetary policy only imposes long-run effects on the price level and not on real variables. Monetary policy however exerts short-run effects on output (Poole, 1999; and Rasche and Williams, 2007). Consequently, some central banks pay attention to short-term output stabilisation. As noted by Taylor (1981) and Leper and Zha (2001), attempts to stabilise both inflation and output generate a trade-off between the[se] two goals. For instance, a rise in the real interest rate constrains aggregate demand and consequently stabilises inflation at the expense of output growth.

Central banks also intervene in foreign exchange markets for various reasons. They include countering market disorderliness, correcting misalignment of exchange rates away from fundamental values, off-setting volatility in the exchange rate, resisting short-term trends in exchange rates, accumulating official reserves and limiting exchange rate pass-through to domestic prices (Dominguez, 1998; and Neely, 2000). Smoothing out excessive fluctuations and not influencing the level of the exchange rate is widely cited as the main objective for central bank intervention in foreign exchange markets. Nevertheless, intervention parameters are not explicitly stated. There is a tendency for central banks to pursue a range of objectives and evidence about the effectiveness of intervention is mixed (Özlü and Prokhorov, 2008). By and large, continued intervention actions by central banks reflect the importance of exchange rate in monetary policy transmission mechanism and its effect on the domestic price level. It is noted that central banks respond to exchange rate movements to smooth relative prices for domestic and foreign goods that could potentially affect international competitiveness and aggregate demand for domestic and foreign goods (Bjørnland and Jørn Halvorsen, 2008). This underscores the motivation for central banks paying attention to exchange rate volatility (Vonnák, 2005; Bjørnland, 2008; and Bjørnland and Jørn Halvorsen, 2008).

Underlying monetary policy and foreign exchange interventions are rules designed to guide central banks in decision-making in a consistent and predictable way (see Poole, 1999; and Svensson, 1999). They involve adjusting the policy instrument[91] in response to changes in economic conditions popularly referred to as central bank reaction function (Özlü and Prokhorov, 2008). This is against the background that central banks cannot influence desired goal(s) directly. Rather their actions have a direct influence on the policy instrument that bears a relatively predictable relationship with intermediate variables that in turn affect desired goals (McCallum, 1988; and Clarida and Gertler, 1998). Central bank actions could influence either the money stock, nominal short-term interest rate or the exchange rate (Rasche and Williams, 2007).

Policy rules may be followed rigidly as stipulated in an algebraic formula for instance or could serve as a guide to allow monetary authorities to respond to unanticipated events (shocks) that impact the economy[92]. An extensive discussion of whether monetary policy rules should be followed as formulated or whether discretion should be exercised is provided in the literature (see Dwyer Jr., 1993; and Taylor,

[91] A policy instrument refers to the variable that the central bank manipulates in order to achieve the desired goal(s). The policy instrument is linked to the state of the economy i.e. inflation, unemployment/output fluctuations among other indicators.
[92] This is referred to as feedback rules whereby policy instruments respond to variations in policy goal(s) such as inflation and output.

1993). The key attribute of policy rules is that they should be simple to implement and for the public to understand, comprehensive enough to reflect the structure of the economy and also incorporate a systematic approach of responding to shocks (Hall and Nixon, 1997; and Nelson, 2008).

Empirical support and the practical usefulness of monetary policy rules exists (Eleftheriou et al. 2006). Most empirical work especially in developed countries (i.e. US, Germany, Japan, France, Italy and the UK) is dominated by the estimations of the interest rate rule proposed by Taylor (1993) as most central banks typically use the nominal short-term interest rate as the main operating policy instrument (see Clarida et al. 1998 for the USA; Adam et al. 2005 for the UK; and Eleftheriou et al. 2006 for evidence on Euro area for instance). In this regard, central banks mostly adjust the nominal short-term interest rate in response to deviations of output and inflation from potential level and target, respectively. The application of the Taylor rule-type to developing countries, particularly African countries is limited but growing. For example Aron and Muellbauer (2000), Rotich et al. (2008) and Ngalawa (2009) have conducted studies on South Africa, Kenya and Malawi, respectively. Similarly, extensive empirical work on central bank intervention has been undertaken on Japan, Germany, the USA and the UK based on Edison's (1993) intervention rule version (see Edison, 1993; and Kamil, 2008). Empirical work on developing countries is also expanding.

Monetary policy setting in Zambia involves using base money as an operating target. A changing money supply growth rate rule was adopted in early 1990s as the central bank believes that inflation is historically - and continues to be - driven by money supply (UNDP, 2006)[93]. Thus, price stability is the primary objective of

[93] Andersson and Sjoo (2000) find evidence of money supply driving prices during the implementation of the structural adjustment programme: 1987-93. Thus, constraining money supply growth is recommended in order to contain inflationary pressures. Theoretically, it is predicted that money supply bears a steady

monetary policy in Zambia (Bank of Zambia Act of 1996). The Bank of Zambia (BoZ, central bank) adjusts base money (monetary base or reserve money) on a day-to-day basis in order to achieve and maintain price stability. In addition, the BoZ conducts foreign exchange interventions (hereinafter called intervention) in the spot market to smooth out fluctuations in the exchange rate without influencing its underlying trend (UNDP, 2006). By and large, foreign exchange interventions can be used to support monetary policy: sell (buy) foreign exchange to tighten (ease) monetary policy as desired by authorities. However, interventions can potentially conflict with monetary policy if the objectives of the two policies are not appropriately aligned (Mohanty and Turner, 2005; and Kamil, 2008)[94].

Structural models constitute an essential part of monetary policy rule formulation (Nelson, 2008). While the SVAR approach is widely used to study the transmission mechanisms of monetary policy, the approach is also used to estimate the reaction function of the central bank. This involves analysing the dynamic interaction between monetary and macroeconomic variables (see Clarida and Gertler, 1996; and Bjørnland and Jørn Halvorsen, 2008). Another approach used to model monetary policy rules is GMM (see Clarida et al., 1998; Adam et al., 2005; and Eleftheriou et al., 2006). In the case of foreign exchange, several techniques are employed in estimating the intervention reaction function. They include binary choice dependent variable method (probit, logit and friction models) due to data gaps in intervention series, ordinary least squares (OLS), GMM and Markov switching-VAR (see Özlü and Prokhorov, 2008; and Humala and Rodriguez, 2009).

---

long-run relationship with inflation as long as the velocity of money is fairly predictable (Judd and Motley, 1991 and Leeper and Zha, 2001).

[94]For instance, in response to excessive appreciation of the currency (which moderates inflationary pressures), the central bank might ease monetary policy to avoid output loss, but this action may lead to money supply overshooting the target. The opposite is true for a depreciation shock: monetary policy is tightened causing money supply to fall below the target in line with the desired monetary policy objective while interest rates rise and consequently lead to output loss.

In this chapter, both SVAR and GMM are used to estimate monetary policy and foreign exchange intervention reaction functions for Zambia during the post-liberalisation period (1995-2008)[95] to ensure robustness of results to alternative estimation techniques. In fact, the two estimation techniques yield non-conflicting results in this chapter. Virtually all previous empirical studies employ either technique but not both. The SVAR approach establishes the dynamic interaction between policy instruments and policy goals (response of policy instrument to shocks to policy goals) while the GMM determines the empirical weights attached to policy goals in a reaction function.

Two modified monetary policy (feedback) rules, namely McCallum (1988) and Taylor (1993) are estimated to describe monetary policy in Zambia and also determine the policy rule that best characterises the behaviour of the BoZ. With respect to the McCallum rule, the BoZ's monetary reaction function is modelled as adjusting base money in response to output gap, inflation gap and changes in exchange rate volatility. In the case of the Taylor rule, the presumption is that the BoZ follows the interest rate rule according to the Taylor rule specification such that the 3-month Treasury bill (T-bill) rate adjusts in response to output gap, inflation gap and changes in exchange rate volatility. The 3-month T-bill rate is used for both monetary and fiscal management in Zambia. It is frequently used by the central bank for liquidity management besides fiscal policy management[96].

A version of Edison's (1993) foreign exchange intervention rule that controls for the same factors as those specified in the monetary policy reaction function is estimated. The rationale is to establish the extent to which monetary and foreign exchange policies

[95] Monetary policy underwent significant structural changes from 1995 that could potentially affect the estimation and identification of a stable monetary regime if the period prior to 1995 was included in the sample in line with Bjørnland and Halvorsen (2008).
[96] A number of studies use the T-bill rate in the Taylor rule estimation where the interest rate is not explicitly adopted as an operating policy instrument, for instance Rotich et al. (2008).

are synchronised. Intervention is split into purchases and sales to allow for the possibility of central bank asymmetric response to changes in policy goal variables. The empirical results in this chapter support this conjecture. Further, monetary and foreign exchange intervention rules are examined under three policy settings to determine the type of information used to adjust policy instruments: whether policy decisions are based on past (backward-looking), current (contemporaneous) or future (forward-looking) information[97] in line with other studies i.e. Maria-Dolores (2005) and Eleftheriou et al. (2006). Hall and Nixon (1997) recommend a forward-looking policy strategy to avoid output loss arising from large policy changes induced by delayed actions.

To the knowledge of the author, no empirical modelling of monetary and foreign exchange intervention rules has been conducted in Zambia. This study therefore provides empirical evidence ever on Zambia. Not only does this study consider interaction among the macroeconomic variables traditionally studied in the monetary reaction functions but extends the SVAR specification to incorporate intervention data to capture the interaction between monetary and exchange rate policies. The author is not aware of any study that has done this. Similar to Clarida and Gertler (1996), Vdovichenko and Voronina (2004) and Eleftheriou et al. (2006), the study does not ascertain how the central bank reacts to economic conditions exactly or designs and implements the rules on a daily basis, but rather determines the extent to which factors in the reaction functions are considered in adjusting the policy instrument. Finally, as the focal point of the study, the role of exchange rate volatility, in particular the GARCH-PCA alternative measure of conditional volatility in the two central bank reaction functions, is examined. The GARCH-PCA alternative measure has not been

[97] Information relates to deviations of output and inflation from trend and target, respectively, as well as movements in exchange rate volatility.

employed in this kind of empirical work. This is achieved by estimating the augmented version of the reaction function that includes exchange rate volatility in addition to output and inflation gaps and compare with the baseline (benchmark) model. The objective is to determine the statistical significance of exchange rate volatility in the estimated reaction functions. The rationale for emphasising exchange rate volatility in the reaction functions is that the exchange rate imposes strong positive effects on inflation dynamics in Zambia (Andersson and Sjöö, 2000; and Mutoti, 2006). Thus, higher exchange rate volatility implies higher uncertainty which in the context of monetary policy affects inflation expectations and thus key in altering monetary policy decisions. Previous studies examine the level of the exchange rate for example Clarida et al. (1998) and Eichengreen (2007).

The results indicate that exchange rate volatility is an essential component of monetary policy decision (especially in the base money rule) and also motivates foreign exchange intervention. The performance of the GARCH-PCA measure is comparable to the trade-weighted measure while the bilateral exchange rate measure is statistically insignificant in the majority of the specifications. Monetary policy is inflation stabilising and output accommodating albeit low empirical weight placed on the former suggesting that monetary policy does not tighten enough when inflation exceeds the target. Nonetheless, monetary policy tends to accommodate output deviations from trend. Further, monetary policy in Zambia tends to be backward-looking and is best characterised by the base money rather than the presumed interest rate reaction function. The interaction between monetary policy and exchange rate policy is also established.

The rest of the chapter is structured as follows. Theoretical arguments relating to monetary and foreign exchange intervention rules and associated empirical evidence are presented in section 5.2. Section 5.3 provides the main features of the monetary policy framework for Zambia. Data analysis of foreign exchange intervention operations is covered in Section 5.4 that presents the estimation methodology and empirical results as well. Finally, section 5.5 concludes the chapter.

5.2 Literature Review

5.2.1 Monetary Policy Rules

5.2.1.1 Theoretical Framework

Money supply and the interest rate are extensively discussed as alternative monetary policy rules (see Orphanides, 2007)[98]. The money supply rule is simple to design and implement and is less demanding in terms of data requirements than the interest rate rule[99]. However, due to the instability in the demand for money function caused by financial innovations and the existence of various shocks to which economies are exposed, the assumption of a stable money demand function that underlies the money supply rule cannot hold continually, at least in the short-run (Judd and Motley, 1991; and Leeper and Zha, 2001). In addition, broad monetary aggregates such as M2/M3 can be difficult to control (Cecchetti, 2000). Thus, a reactive interest rate rule is considered as an alternative whereby monetary policy is adjusted via the interest rate in response to the behaviour of specific policy variables. A widely applied interest rate rule is the Taylor rule proposed by Taylor (1993). Notwithstanding this, some central banks especially in developing countries including Zambia continue to use money supply as a nominal anchor due to the difficulty of setting the interest rate consistent with the inflation target and the high volatility of the expected inflation (Leeper and

---

[98] Monetary policy cannot simultaneously target both the interest rate and stock of money.

[99] To develop a monetary policy rule that describes the reaction function of the central bank via the interest rate instrument requires rigorous knowledge of the paths of the state variables that influence the interest rate decision (Cecchetti, 2000).

Zha, 2001)[100]. Under monetary targeting, interest rates are expected to fluctuate widely due to money demand shocks.

A constant rate of growth of money policy rule (*k* percent) for central banks in particular the Federal Reserve (Fed) was proposed by Milton Friedman during the 1950s irrespective of the state of the economy (see Asso et al. 2007). Under this rule, shifts in money demand are accommodated by money supply changes. Friedman favoured monetary targeting as opposed to prices because inflation is appropriately anchored and above all, it is easy for the public to understand. In addition, it is flexible as it accommodates changes in the velocity of base money due to technological innovations. With high inflation rate, Friedman advocated a progressive reduction in money supply until inflation reaches near zero, after which a constant growth rate of money stock is maintained (Nelson, 2008). However, this proposal was criticised on the basis that structuring monetary policy in such a manner would obviate output stabilisation role and hence discretion was counter-proposed to stabilise cyclical fluctuations in output.

Consequently, modifications to the Friedman rule were made by Meltzer and McCallum to allow for a change in the growth rate of money stock. McCallum (1988) proposed a monetary targeting rule in which the long-run equilibrium growth rate of the monetary base, the operating policy instrument, is periodically adjusted (quarterly) as past values of the desired policy factors deviate from set targets while long-run nominal GDP is accommodated

$$\Delta b_t = (\Delta p_t^* + \Delta y_t^f) - \Delta \bar{v}_t + \lambda (z_{t-1}^* - z_{t-1}) \tag{1}$$

[100] In the short-term, the relationship between money and inflation is obscured by many factors.

where Δ, b_t, p_t, y_t, $\bar{v}_t$ and z_t denote the difference operator, monetary base, price level, real GDP, average velocity of the monetary base over 16 quarters[101] and targeted policy variables, respectively. Long-term changes in base money demand related to technological and/or regulatory changes in the economy are captured by $\bar{v}_t$. Variables with asterisks refer to desired values by the central bank while Δy_t^f is the steady-state value for y_t. All variables are expressed in logarithmic form. The feedback parameter, λ, specifies the extent to which the central bank adjusts base money when a gap arises in the variable of policy interest corresponding to the previous quarter. McCallum preferred the monetary base to broader money supply aggregates because the former is under the control of the central bank and thus easy to monitor.

The McCallum rule, however, suffers from the instability in the monetary base induced by financial innovations and changes to the regulatory framework. Nonetheless, volatility in the monetary base is automatically offset by the corresponding change in the monetary base: an increase (decrease) in velocity leads to a corresponding increase (decrease) in nominal GDP resulting in the latter exceeding the target. In order to bring nominal GDP back to target, the monetary base must fall (rise).

Notwithstanding arguments for monetary base targeting, nominal GDP targeting was proposed as an alternative (Judd and Motley, 1991). The relationship between inflation and GDP is expressed as

$$p_t \approx x_t - y_t \tag{2}$$

[101] 16 quarters was considered long-run enough to smooth out cyclical conditions and instability in velocity and reflects long-run trends in nominal GDP relative to the monetary base. $\bar{v}_t = 1/16[(x_{t-1} - b_{t-1}) - (x_{t-17} - b_{t-17})]$ where x_t is nominal GDP $(\Delta p_t^* + \Delta y_t^f)$.

where p_t is the logarithm of the price, x_t is the logarithm of nominal income and y_t is the logarithm of real GDP. Equation 2 asserts that predictability in real GDP underpins the relationship between nominal GDP and the price level. Under nominal GDP framework, money supply accommodates changes in velocity, an equivalent of 'velocity-adjusted money targeting'. Svensson (1999) argues that it is ideal for the central bank to achieve nominal GDP growth target than its components (inflation and real output separately) as the underlying factors governing inflation and real GDP are not known with certainty. However, nominal GDP targeting suffers from volatility in real GDP that inevitably translates into instability in prices. Real GDP is driven by long-run supply factors such as productivity, labour force participation and changes in the natural rate of unemployment (Taylor, 1993). Hence, supply shocks could have long lasting effects on real GDP which in turn affects the price level. Consequently, Taylor (1993) proposed to target prices directly.

Taylor proposed the following simple rule (that typically reflected the Fed's short-term rate setting behaviour) in which the nominal short-term interest rate is adjusted in response to output and inflation gaps (see Clarida et al. 1998)

$$i^* = \bar{i} + \gamma y + \phi(\pi - \pi^*) \tag{3}$$

where i is the nominal short-term interest rate, $\bar{i}$ is the long-run equilibrium real interest rate (assumed or estimated), y is the output gap defined as the percent deviation of actual real GDP from potential or natural output, π is actual rate of inflation, π^* is the inflation target and γ and ϕ are respectively, parameters or weights on output and inflation gaps to be estimated. According to Taylor, the trend for real

GDP was estimated at 2.2 percent for the USA over the period 1984-92 while the inflation target was set at 2 percent and the base rate for i is the sum of the estimated equilibrium real interest rate and the inflation target rate. The equilibrium real interest rate was estimated to be 2 percent and $\gamma = \phi = 0.5$ such that Taylor's approximation of the Fed's behaviour was[102]

$$i = p + 0.5y + 0.5(p-2) + 2 \tag{3.1}$$

Central banks tend to adjust the interest rate gradually to the desired level as shown in equation 4 below. Hence, a smoothing parameter is added to equation 3 to ensure orderly adjustment in the policy rate (see Vdovichenko and Voronina, 2004; Maria-Dolores, 2005; and Eleftheriou et al. 2006)[103].

$$i_t = \rho i_{t-1} + (1-\rho) i_t^* + \varepsilon_t \tag{4}$$

where $\rho \in [0,1]$ is the smoothing parameter, i_t^* is the desired rate and ε_t is the shock to the interest rate. Re-wrtiting equation 3 yileds

$$i^* = \bar{i} - \phi(\pi) + \gamma y + \phi(\pi) \tag{3.2}$$

$$i^* = \alpha + \gamma y + \phi(\pi) \tag{3.3}$$

[102] The parameter values in equation 3 were not estimated but presupposed by Taylor to describe the US interest rate policy over the period 1987-1992.

[103] In a reduced-form setting, the smoothing parameter also picks up the dynamic misspecification errors in the equation (Adam et al. 2005). Other than minimising interest rate volatility, Sack and Wieland (1999) argue that interest rate smoothing generates forward-looking expectations by agents, reduces uncertainty and thus adverse reaction by agents to larger and frequent interest rate changes. In addition, it helps to maintain financial sector soundness and central bank reputation. Further, central banks may adjust interest rates slowly due to data uncertainty and the general state of the economy.

where $\alpha = \bar{i} - \phi(\pi)$

Substituting equation 3.3 into equation 4 yields

$$i_t = (1-\rho)\alpha + \rho i_{t-1} + (1-\rho)\gamma y_t + (1-\rho)\phi\pi_t + \varepsilon_t \qquad (5)$$

where α, γ and ϕ are respectively constant term, output and inflation gap coefficients to be estimated. In each period, the central bank adjusts the interest rate in order to eliminate a proportion $(1-\rho)$ of the gap in interest rate between the current target level and its past level. The central bank could react to observed or expected inflation (forward-looking). A dummy variable could be included in equation 5 to capture extraordinary events such as supply shocks.

According to the Taylor rule predictions, for the policy rate to be effective, the coefficient on inflation gap should be greater than 1. This ensures that the change in the nominal policy rate is high enough to contain inflationary pressures as the rise in the real interest rate constrains aggregate demand. If the coefficient on the inflation gap is less than 1, a rise in inflation will result in a fall in the real interest rate which in turn boosts aggregate demand and consequently induces inflationary pressures resulting in never-ending rise in inflation (Hall and Nixon, 1997; and Leeper and Zha, 2001). With respect to output gap, its inclusion in the policy rule captures the extent of monetary policy stabilisation: a large coefficient might generate cycles in output while a small coefficient may deviate output from its long-run trend permanently and subsequently undermine the sustainability of inflation on the desired path (Hall and Nixon, 1997; and Poole, 1999).

The absence of the role of money and other variables such as the exchange rate in the standard Taylor rule has dominated the literature and led to its extension. Money supply exerts short-run effects on output and hence justifies its inclusion in the policy rule (Poole, 1999; and Rasche and Williams, 2007). The exchange rate tends to have strong and fastest effect on inflation via import prices (Ball, 1999). In view of this, Ball (1999) argues that in an open economy setting, monetary policy affects the economy through the interest rate and exchange rate channels as follows

$$y = -\beta r_{-1} - \delta e_{-1} + \lambda y_{-1} + \varepsilon \tag{6}$$

$$\pi = \pi_{-1} + \alpha y_{-1} - \gamma(e_{-1} - e_{-2}) + \eta \tag{7}$$

$$e = \theta r + v \tag{8}$$

where y, r, e and π are real output, real interest rate, real exchange rate and inflation while ε, η and v are demand, inflation and exchange rate white noise shocks. All the variables are expressed in logarithmic form and represent deviations from average levels and parameters preceding the variables are either empirically estimated or imposed.

Equations 6 and 7 are open economy IS and Phillips curves while equation 8 provides a link between the exchange rate and interest rate and captures the behaviour of asset markets. A monetary contraction causes interest rates to increase relative to foreign interest rates, attracts capital flows that lead to the appreciation of the exchange rate (domestic currency price of one unit of foreign currency) which in turn reduces inflation and output within one period via γ and δ, respectively. However, output affects inflation in the next period given by one lag on y in equation 7. Hence, the policy effect on inflation is immediate while output effect on inflation is not contemporaneous (Ball, 1999). The interaction of exchange rate with inflation and in turn output underscores its importance in macroeconomic management and thus justifies its inclusion in a monetary policy rule. Exchange rate gap has been suggested as an additional inclusion in the Taylor rule (Adam et al. 2005)[104].

Consequently, the Taylor rule has been extended and takes the general form

$$i = i^{*} + \gamma(E[y_{t+m}|\Omega_t] - y_t^{*}) + \phi(E[\pi_{t+n}|\Omega_t] - \pi^{*}) + \delta E[z_{t+i}|\Omega_t] + \varepsilon_t \qquad (9)$$

where z_t is a vector of additional variables such as foreign interest rate, money supply and real exchange rate (Aron and Muellbauer, 2000; and Björksten et al. 2004), E is the mathematical expectation operator, Ω_t is the information set available to the central bank when setting interest rate at time t, y_{t+m} and π_{t+n} are forecasted real output and inflation between time t and $t+m$ and t and $t+n$, respectively while γ, ϕ and δ are respectively weights placed on output, inflation and other variables of policy interest. The rest of the variables are as defined earlier.

5.2.1.2 Empirical Evidence

While consensus exists regarding the functional form and sign on the coefficients in the Taylor rule, the magnitude by which the interest rate should be adjusted remains a matter of empirical debate. There is a high degree of variation of these coefficients across empirical studies (see Adam et al. 2005; and Eleftheriou et al. 2006). Adjusting the policy at shorter interval (i.e. monthly) makes the policy more responsive and the decision to adjust the policy rate with respect to size and timing is

---

[104] The counter-arguments to this are provided by Taylor (2001) that indirect effects of exchange rate on inflation and output are captured in the standard rule and thus no explicit inclusion of the exchange rate in the rule is required.

influenced by the forecasted inflation rate over a certain period of time usually one or two years (Hall and Nixon, 1997). The interest rate could be adjusted based on either past, current or forecasted policy variables.

A huge amount of evidence on the empirical validity of monetary rules exists. Therefore, only selected studies are reported. Most of the empirical studies are influenced by Clarida et al. (1998). The estimated Taylor rule, especially the augmented version, captures the interest rate setting behaviour of most central banks such as the Fed, Bundesbank, Bank of Japan, Bank of England and the European Central Bank (ECB) (Eleftheriou et al. 2006).

Clarida and Gertler (1996) estimate the modified version of the Taylor rule for Germany over the period 1973-94 using the SVAR model. The empirical results reveal that, contrary to the announced policy of monetary targeting, the Bundesbank followed the interest rate rule similar to the Fed. While the Bundesbank focused on inflation stabilisation, especially anticipated as opposed to past inflation, its adjustment of short-term interest rates also took into account output shocks. However, its response to exchange rate shock was countercyclical.

Clarida et al. (1998) estimate the Taylor rule for Germany, Japan, the US, the UK, France and Italy using GMM from 1979 to 1993 using both forward- and backward-looking specifications. They find monetary policy to be inflation stabilising while attention is also paid to output stabilisation similar to Clarida and Gertler (1996). In addition monetary policy is found to be forward-looking as opposed to backward-looking as the lagged inflation coefficient is statistically insignificant in the specifications.

Aron and Muellbauer (2000) analyse the Taylor rule for South African under different monetary policy regimes over the period 1986-1997 using GMM. They establish that an appropriate interest rate (discount rate) rule describing monetary policy in South Africa should include deviations of money growth from target and the effects of financial liberation in addition to output and inflation gaps and the foreign interest rate (US short-term interest rate). Monetary policy is found to be output stabilising in the base line specification.

Vdovichenko and Voronina (2004) examine the monetary policy rule using both Taylor and McCallum rule type specifications for Russia over the period 2000-2003 using GMM, OLS and TSLS. They establish that monetary policy response to output, inflation gaps and exchange rate is low, less than 1 in absolute terms and that monetary policy is biased towards exchange rate stabilisation.

Maria-Dolores (2005) analyses monetary policy setting in some accession countries to the EU over the period 1998-2003 using GMM. The Taylor rule is found to more adequately describe monetary policy in the Czech Republic, Poland, and Hungary with a floating exchange rate regime and inflation-targeting framework than in Slovakia which had not moved to inflation-targeting. Inflation coefficients range from 0.11 to 1.27 while output gap coefficients are broadly below unity. The estimated reaction function for the ECB is also in line with the Taylor rule prediction with inflation gap coefficient above 1 and output gap coefficient around 0.60. Adam et al. (2005) estimate an interest rate reaction function for the UK incorporating institutional arrangements relating to the way monetary policy was formulated and how decision-making was affected during the pre-ERM (1985-90), post-ERM (1992-97) and monetary policy committee (MPC) period, 1997-2002. The reaction function includes US and German influences in addition to UK output and inflation gaps. The GMM estimator is employed. They conclude that US and German influences were important during the pre- and post-ERM periods in adjusting UK interest rates while under the MPC period, domestic factors (output and inflation) play a dominant role in the UK interest rate reaction function. In line with previous studies on the UK interest rate reaction function, evidence of interest rate smoothing is found. Eleftheriou et al. (2006) focus on EMU countries' monetary policy setting during pre-EMU era (1993-98) based on the Taylor rule. The GMM estimator is used and the results reveal that each country followed a distinct Taylor rule type policy.

Koivu et al. (2008) estimate the McCallum rule for China over the period 1994-2007 and generally find the values implied by the estimated McCallum rule to track actual base money and M2 closely and thus conclude that the rule offers a good description of monetary policy and inflationary pressures in China.

Bjørnland and Halvorsen (2008) employ the SVAR methodology in analysing the interaction between monetary policy and exchange rate movements for six open inflation targeting countries with floating exchange rates over the period 1983q1-2004q4. Interest rates rose systematically in response to a positive (depreciation) exchange rate shock across countries.

Finally, Rotich et al. (2008) use the GMM to estimate the Taylor rule type for Kenya over the period 1997-2006. While monetary policy in Kenya is found to be inflation stabilising, the central bank is also concerned about output and exchange rate stabilisation. Similarly, in Malawi, the central bank pursues both output and inflation stabilisation objectives simultaneously based on SVAR model evidence (Ngalawa, 2009). Interest rates fall in response to output shock but rise when inflation increases unexpectedly. However, the response of base money to output and inflation shocks is in direct opposition to the interest rate response.

5.2.2 Foreign Exchange Intervention Rule

5.2.2.1 Theoretical Framework

Foreign exchange market intervention is narrowly defined as any official sale or purchase of foreign assets against domestic assets in the foreign exchange market (Dominguez, 1998). Interventions can be sterilised (no effect on the monetary base) or non-sterilised (affect the monetary base). Nonetheless, both have the potential to affect the exchange rate. Unsterilised interventions affect the exchange rate via the money-stock effect i.e. in proportion to the change in the relative supplies of domestic and foreign money. Sterilised interventions affect the exchange rate through signaling and portfolio balance channels. The signaling hypothesis predicts a currency appreciation when the central bank buys its currency in the foreign exchange market (Lewis, 1995). Interventions provide a signal of future monetary policy which influences market traders' expectations of future monetary policy and consequently affect the exchange rate as most models of exchange rate determination include monetary variables as key determinants. Conversely, currency depreciation is predicted by the portfolio balance hypothesis following the central bank sale of its currency.

According to Edison (1993), a foreign exchange intervention reaction function is typically specified as

$$I_t = \alpha_0 + \alpha_1(s - s^*) + \alpha_2 \Delta s + \delta X + u_t \qquad (10)$$

where I_t is intervention data, s is the logarithm of the exchange rate defined as the domestic currency price of one unit of foreign currency, s^* is the logarithm of the target exchange rate, Δ is the first difference operator, X is a vector of macroeconomic variables and institutional factors such as intervention regimes (Rogers and Siklos,

2003) and u_t is the error term. In terms of the expected coefficient signs, α_1 captures the extent to which the central bank targets the exchange rate such that $\alpha_1 < 0$ implies leaning-against-the-wind as monetary authorities intervene whenever the exchange rate exceeds the target level; α_2 is ambiguous (irrespective of the direction of the exchange rate trend (up or down): $\alpha_2 < 0$ implies leaning-against-the-wind as the central bank resists depreciation (appreciation) of the domestic currency by selling (buying) foreign currency while $\alpha_2 > 0$ implies leaning-with-the-wind and thus increases exchange rate volatility, highly exceptional to central bank behaviour (Edison, 1993); and δ depends on the variables concerned.

5.2.2.2 Empirical Evidence

The empirical specification of equation 10, in particular elements of X , varies considerably across studies. For instance, in addition to some measure of exchange rate deviation from target/trend and exchange rate volatility, X includes *inter alia*, interest rate differential, profitability of intervention and reserve inventory or accumulation (Kim and Sheen, 2002 and Kamil, 2008); stock market prices, commodity prices, interest rate spread, market sentiments captured via kurtosis of exchange rate and implied volatilities of foreign currency futures, intervention regime and influence of adopting inflation targeting regime (Rogers and Siklos, 2003); inflation targeting indicator: a composite indicator that includes inflation and output gaps (Horváth, 2007); regime change vis-à-vis intervention strategy (Ito and Yabu, 2007); and news on or surprises in inflation announcement (Kamil, 2008).

Many empirical studies have overwhelmingly found exchange rate considerations especially the leaning-against-the-wind proposition to be a key determinant of intervention (see Edison, 1993 who reports studies for Germany, Japan and Australia; and Almekinders and Eijffinger, 1994, 1996 for the Bundesbank and the Fed). Most of these studies exclude X variables in the specification and only focus on the exchange rate: deviation from target/trend and the first difference. In addition, evidence of intervention persistence or occurring in clusters exists as the lagged value of intervention in the reaction function is positive and highly statistically significant.

Other studies have estimated versions of equation 10 and found similar results. Binary models such as probit, logit and friction are used to take care of the inactive periods of intervention as intervention does not occur continuously. For instance, Kim and Sheen (2002) estimate an intervention reaction function for the Reserve Bank of Australia (RBA) over the period 1983-1997 using daily data and employ probit and friction models. They find trends and volatility in exchange rate, foreign currency reserve inventory and interest rate differential between Australia and the US, profitability and reserves accumulation as key factors in influencing the RBA intervention decision. Employing the Heckman's two-stage procedure[105], Rogers and Siklos (2003) estimate an intervention reaction function for the Bank of Canada and the RBA for the period 1989-1998 using daily data. Changes in conditional volatility influence intervention decisions (reduction in net purchases) in both countries and the period of inflation targeting is associated with higher interventions.

Horváth (2007) analyses the determinants of intervention by the Czech National Bank (CNB) during the period 1998-2002 using daily data under the inflation targeting (IT) regime in a specification that includes actual intervention data in US$ amounts and dummy, lagged intervention, exchange rate misalignment and an IT consistency

[105] This method addresses the selectivity bias associated with data gaps in intervention series. In the first step, the intervention reaction equation is estimated using a probit model. In the second step, residuals from step one are included in the least squares intervention reaction equation as a regressor (see Rogers and Siklos, 2003). A statistically significant coefficient on selectivity bias implies adjusting the mean degree of intervention depending on the sign.

indicator[106]. The probit negative binomial model is used. Evidence of exchange rate changes influencing intervention decisions of the CBN is found while inflation targeting constrain CBN intervention.

Evidence from the Bank of Japan resisting yen appreciation/depreciation and intervention persistence is reported by Ito and Yabu (2007) using daily data over the period April 1991-December 2002. A probit model is employed. Similarly, Hassan (2009) establishes that Japanese monetary authorities intervene in response to exchange rate deviation from trend, increases in conditional volatility and interest rate differential between Japan and the USA. The ordered probit model[107] is used on daily data from January 1992 to March 2004.

Özlü and Prokhorov (2008) focus on deviations from trend and excess volatility in the exchange rate and find them to be key drivers for intervention decision in Turkey. A threshold regression approach is used over 1 November 1993-15 May 2006 period. Finally, Humala and Rodriguez (2009) find exchange rate volatility (currency pressures) and deviations of the exchange rate from trend/target as motivating the Central Reserve Bank of Peru to intervene in the currency market. A Markov switching-VAR model is employed over the period 1994-2007.

5.3 Overview of Monetary Policy in Zambia

Monetary policy in Zambia was conducted in the context of general controls of the economy prior to 1990. Multiple objectives without clearly defined targets were pursued and direct instruments of monetary policy were typically employed (Simatele, 2004). The cash reserve ratio was frequently adjusted to control the stock of money and

---

[106] An IT consistency indicator is constructed as a composite variable capturing the deviation of inflation and output from their respective targets to represent X variables.
[107] It captures three intervention outcomes: buying, selling and no intervention (for which a different threshold is set as a trigger for intervention).

interest rates. Credit ceilings with selective and limited bank lending to preferred sectors (SOEs) were implemented while the exchange rate was fixed. In addition, fiscal deficit financing was mainly done through central bank borrowing and consequently led to excessive monetary expansion. Accordingly, inflation accelerated during the 1970s and 1980s (refer to chapter 2). Thus, a non-accommodative (inflation) monetary policy regime was adopted in early 1990s with base money as the nominal anchor for inflation.

Inflation control is formalised in the Bank of Zambia Act of 1996 as the main objective of monetary policy. The Act states that "*the Bank of Zambia shall formulate and implement monetary and supervisory policies that will ensure the maintenance of price and financial systems stability so as to promote balanced macro-economic development"* (Bank of Zambia Act of 1996). Thus, monetary policy seeks to reduce inflation to a single digit and sustain it at that level by drastically reducing the growth rate of money supply (UNDP, 2006).

Interest rates were fully decontrolled in 1993 and auctions of government securities introduced in the same year, daily open market operations adopted in 1995 and repurchase (repo) operations launched in 2002. All these measures were taken as part of monetary policy reform to support the inflation objective. Besides debt management, auction of government securities is used for liquidity management (Simatele, 2004). The T-bill rate serves as a benchmark for credit price determination and also for setting the discount rate[108]. While the cash reserve ratio continues to be used, the level has however remarkably reduced compared to the pre-liberalisation period to avoid direct regulation of the financial system (Simatele, 2004).

[108] In setting the discount rate, the BoZ adds some percentage points on the 3-month T-bill rate.

Currently, monetary policy is conducted in the context of a managed float exchange rate regime[109]. The path for the exchange rate is not pre-determined, but the central bank undertakes foreign exchange interventions in the spot market to smooth out fluctuations in the exchange rate without influencing its underlying trend (UNDP, 2006). Interventions are also used to accumulate international reserves. Such intervention actions have the potential to generate inconsistencies between the inflation and exchange rate stability objectives if not properly co-ordinated (Mohanty and Turner, 2005).

The quantity equation of exchange linking money (M), prices (P), velocity of money (V) and real output (y) underpins the current monetary policy framework[110]

$$MV = Py \tag{11}$$

The path for money supply growth is derived consistent with nominal GDP (set inflation target plus forecasted real GDP growth) and an estimated trend in velocity as shown in equation 12 below expressed in logarithmic form

$$\Delta \ln M = \Delta \ln P + \Delta \ln y - \Delta \ln V \tag{12}$$

According to equation 12, changes in M accommodate nominal GDP at a non-inflationary rate. The conduct of monetary policy is guided by the path for M. Subsequently, the monetary base is derived from M according to equation 13 on the assumption that the money multiplier, m, grows at a certain rate

[109] The exchange rate regime in Zambia was originally classified as independently floating, but was changed to a floating regime in February 2009.

[110] Reserve money programming is embedded in the financial programming model of the IMF in which annual targets for both P and y are set by the government in consultation with the central bank.

$$M = mB \tag{13}$$

However, given the substantial proportion of currency in circulation in base money in Zambia (about 60 percent at end-2008), stability of the demand for currency is critical for base money targeting to be successful (Adam, 1995).

Individual components of base money are determined next

$$\Delta B = \Delta NDA + E\Delta NFA \tag{14}$$

where NDA, E and NFA are respectively net domestic assets[111], exchange rate defined as domestic currency per unit of foreign currency and net foreign assets. The change in B is expressed in domestic currency terms.

Equation 14 is a flow identity that links foreign exchange interventions and monetary policy. For instance, a foreign exchange purchase increases NFA and consequently base money by the same amount if the central bank accommodates NFA. Alternatively, the BoZ can offset the increase in NFA by reducing NDA.

Quantitative targets for NDA and NFA are derived from base money target taking into account projected developments in the external sector. These are strictly monitored as part of conditionality under the IMF-PRGF (Poverty Reduction and Growth Facility). A ceiling on NDA is imposed to ensure that base money target is achieved. In order to ensure consistency between monetary and fiscal policy, a ceiling is imposed on net domestic financing of the government. This also ensures that the central bank retains control of money supply while allowing for adequate credit expansion to

[111] NDA is defined as central bank credit to both public and private plus net worth or other items net (a balancing item between assets and liabilities).

the private sector to support real GDP growth. In addition, a floor is imposed on gross international reserves of the BoZ, a component of NFA[112].

The central bank can accumulate reserves in excess of what is stipulated in the programme provided monetary policy is not eased as this can potentially generate inflationary pressures[113]. This implies that the BoZ must routinely undertake bond sterilisation of liquidity arising from reserves accumulation to ensure that base money remains within the programme path. Such operations have the potential to adjust monetary policy for the purpose of achieving the exchange rate objective as significant reserves accumulation can alter the path for the exchange rate. Moreover, there is evidence to suggest that most central banks especially in developing countries do not fully sterilise foreign exchange intervention operations due to the small size and low depth of the financial markets (Lee, 1997).

On a day-to-day basis, the BoZ manages the monetary base by keeping it closer to the desired path so as to dampen inflationary pressures. In addition, monetary policy actions ensure that the deviations of actual NDA and NFA paths from targets are minimised. This is achieved by undertaking open market operations. The BoZ supplies (withdraws) bank reserves when base money is projected to be lower (higher) than the target. Bank reserves are supplied via credit auctions (collateralised loans), reverse repurchase agreements and outright purchase of government securities from banks. On the other hand, bank reserves are withdrawn using BoZ deposit auctions, repurchase agreements and outright sale of government securities on the BoZ trading portfolio. Foreign exchange sales and purchase may also be used. Direct instruments are used

[112] A floor serves as a minimum amount of international reserves the country must hold.
[113] This gives authorities some discretion (Simatele, 2004; and Easterley, 2006). Foreign reserves can be accumulated from aid flows and/or direct market purchases of foreign exchange mainly to raise the import cover of reserves to the set minimum.

albeit infrequently to supplement open market operations. They include cash reserve ratio[114] and liquid asset ratio[115].

5.4 Model Specification, Estimation Methodology, Data and Empirical Results

In line with the description of the monetary policy framework in section 5.3, the behaviour of the monetary base should at least reflect changes in nominal GDP and inflation. Thus, it is hypothesised that changes in base money are designed to accommodate the projected real GDP growth and to contain inflation. Similarly, the T-bill rate is presumed to behave in the same way.

Central bank intervention reaction functions are assumed rather than derived in most empirical studies as motivations for interventions are either not uniquely defined by central banks or guided by theory (Ito and Yabu, 2007; and Özlü and Prokhorov, 2008). A similar approach is adopted here. A version of Edison's (1993) intervention rule is estimated in which intervention is modelled as a function of its lagged value, output gap, inflation gap and movements in conditional volatility of the exchange rate derived from GARCH models. This is a slight departure from the practice in the intervention literature where the level and volatility of the exchange rate are simultaneously included in the specification (see Edison, 1993; and Kamil, 2008) without controlling for monetary policy goal variables. The rationale is to establish the extent to which monetary and foreign exchange polices are synchronised by considering monetary policy and intervention goals in reaction functions in the GMM and SVAR specifications.

---

[114] A prescribed ratio of kwacha and foreign currency deposits that commercial banks are required to keep with the BoZ. Currently, reserves are not remunerated.
[115] A prescribed ratio on kwacha deposits banks are required to hold in specified kwacha interest yielding assets plus cash.

5.4.1 SVAR Model

VARs were introduced to deal with the shortcomings embedded in large-scale simultaneous equations (Sims, 1980). Simultaneous equations models could not explain the dynamic structure of time series variables while the identification process of equations and the exogeneity assumption in the underlying relationship among variables are questionable (Lütkepohl, 2005).

The dynamic interactions of variables in which all variables are treated *a priori* as endogenous and theoretically motivated restrictions imposed on contemporaneous relations among variables are examined using SVAR[116] such that the marginal effect of a shock to any of the variables in the system and on itself can be traced out over time using impulse response analysis[117].

The relationship among variables entering the policy rule can be set up in VAR form of order p consisting of a system of equations equal to the number of variables (see Clarida and Gertler, 1996)

$$AX_t = A_0 + \sum_{i=1}^{p} A_1 X_{t-1} + B\varepsilon_t \tag{15}$$

where A is an invertible (nxn) matrix capturing contemporaneous relations among X_t variables; X_t is an $(nx1)$ vector of macroeconomic (endogenous) variables that includes central bank policy instruments and goals; A_0 is a vector of constants; A_1 to A_p is (nxn) matrix of unknown parameters on lagged values of X_t to be estimated; B

---

[116] SVAR models treat every variable as endogenous due to the difficulty of finding exogenous variables in macroeconomics (Gottschalk, 2001).

[117] Impulse response functions are calculated from the estimates of the VAR. They show how current and future values of each variable in the VAR respond to a one-off unit increase in the current value of one of the structural shocks in the VAR holding other shocks constant.

is an (nxn) matrix reflecting direct effects of some ε_t on more than one X_t variable; ε_t is an $(nx1)$ vector of uncorrelated structural innovations or shocks corresponding to each element of X_t with covariance matrix $E(\varepsilon_t \varepsilon_t^{'}) = \Sigma_\varepsilon$; $t = 1,2,......,T$; and n is the number of variables in the system.

Pre-multiplying equation 15 by A^{-1} yields

$$X_t = \Psi_0 + \sum_{i=1}^{p} \Psi_1 X_{t-1} + e_t \tag{16}$$

where $\Psi_0 = A^{-1}A_0$; $\Psi_1 = A^{-1}A_1, \Psi_2 = A^{-1}A_2,..., \Psi_p = A^{-1}A_p$; and $e_t = A^{-1}B\varepsilon_t$ is an $(nx1)$ vector of white noise error term with zero mean and constant variance $E(e_t e_t^{'}) = \Sigma_e$.

Equation 16 is a reduced form representation of equation 15 as the latter cannot be estimated directly since the structural model cannot be identified. Structural shocks are orthogonal to each other while the reduced form errors, e_t, are not. e_t are a linear combination of orthogonalised structural shocks. In order to recover individual structural shocks from VAR residuals, additional information is required. This takes the form of identifying restrictions imposed on A and B (A-B model).

Underlying SVAR is the moving average representation of the structural model in which each variable in X_t is expressed as a function of current and past innovations corresponding to each element of X_t. Denoting

$$e_t = A^{-1}B\varepsilon_t = H\varepsilon_t \tag{17}$$

where $H = A^{-1}B$, then

$$E(e_t e_t^{'}) = HE[\varepsilon_t \varepsilon_t^{'}]H^{'} = H\Sigma_\varepsilon H^{'} \tag{18}$$

The relationship between e_t and ε_t is captured by equations 17 and 18. Thus, equation 16 can be re-stated (without the constant term) as

$$X_t = \Phi(L)X_{t-1} + e_t \tag{19}$$

where $\Phi(L) = \sum_{i=1}^{p} \Psi_1$.

From equation 19, e_t can be expressed as

$$e_t = [I - \Phi(L)L]X \tag{20}$$

Or

$$X_t = [I - \Phi(L)L]^{-1} e_t \tag{21}$$

such that the moving average representation of the VAR model is

$$X_t = [I - \Phi(L)L]^{-1} e_t \tag{22}$$

Equivalently

$$X_t = C(L)H\varepsilon_t \tag{23}$$

where $C(L) = [I - \Phi(L)L]^{-1}$ is the infinite polynomial in lag operator $\Phi(L) = C(L)^{-1}$ (if p is replaced by ∞ in equation 15 and defines matrices for impulse response functions of shocks to X_t variables)[118].

From the foregoing, the relationship between ε_t and e_t can be expressed as

---

[118] $C(L)$ takes the general form $C(L) = c_1 L + c_1 L^2 + ... + c_n L^n$

$$Ae_t = B\varepsilon_t \tag{24}$$

A total of $2n^2$ unknown elements are to be identified as both A and B are nxn matrices. Thus, at least $2n^2 - n(n+1)/2$ additional restrictions are required in order to identify A and B and thus generate impulse response functions (Enders, 2004). Full or exact identification of structural shocks is equal to the imposition of $n(n-1)/2$ restrictions on A in addition to n normalisation restrictions.

Various identification strategies exist by imposing *a priori* restrictions on the covariance matrix of the structural errors (see Vonnák, 2005)[119]. Short- and long-run approaches are employed. In the short-run approach (also known as structural factorisation), non-recursive and direct restrictions on the contemporaneous interactions among X_t variables are imposed (see Bernanke, 1986; and Sims, 1986). Alternatively, restrictions on the long-run dynamic effect of shocks on particular variables in the system can be imposed and this is referred to as the long-run approach (see Shapiro and Watson, 1988; Blanchard and Quah, 1989; and Astley and Garrat, 1996).

A non-recursive (structural factorisation) identifying structure is adopted in this chapter similar to Bjørnland and Halvorsen (2008). *A priori* restrictions are imposed on contemporaneous interactions among X_t variables in order to identify the coefficient matrix A. Once A is estimated, the dynamic impact of ε_t can be traced on the path of any element in X_t (Bjørnland and Halvorsen, 2008)[120]. Thus, the response of X_t to

---

[119] In the absence of coherent theorectical structure, the Cholesky decomposition is used whereby the A matrix is converted into a lower (upper) triangular by setting all coefficients above (below) the diagonal to zero and variables ordered recursively (Dickinson and Liu, 2007).

[120] Matrix A must be identified in order to derive impulse response functions and variance decomposition (Bjørnland and Halvorsen, 2008).

any ε_t defines the policy reaction function of the central bank (Clarida and Gertler, 1996).

In line with Brischetto and Voss (1999), the following identification scheme is employed

$$X_t^{'} = (y_t, p_t, i_{t,} m_t, erv_t, I_t(fxp_t, fxs_t)) \tag{25}$$

such that elements of $X_t^{'}$ are expressed in equation 24 relation as follows

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & a_{34} & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & 1 & 0 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & 0 \\ a_{71} & a_{72} & a_{73} & a_{74} & a_{75} & 0 & 1 \end{pmatrix} \begin{pmatrix} e_t^y \\ e_t^p \\ e_t^i \\ e_t^m \\ e_t^{erv} \\ e_t^{I(fxp)} \\ e_t^{I(fxs)} \end{pmatrix} = \begin{pmatrix} b_{11} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & b_{33} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & b_{44} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & b_{55} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & b_{66} & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & b_{77} \end{pmatrix} \begin{pmatrix} \varepsilon_t^y \\ \varepsilon_t^p \\ \varepsilon_t^i \\ \varepsilon_t^m \\ \varepsilon_t^{erv} \\ \varepsilon_t^{I(fxp)} \\ \varepsilon_t^{I(fxs)} \end{pmatrix}$$

y_t is real output, p_t is the price level, i_t is the interest rate, m_t is money supply, erv_t is a measure of exchange rate volatility and I_t is foreign exchange intervention split into purchases (fxp_t) and sales (fxs_t). Output, inflation, interest rate, money supply, exchange rate volatility, foreign exchange purchase and foreign exchange sales shocks are denoted as $\varepsilon_t^y, \varepsilon_t^{\inf}$, $\varepsilon_t^{tbr}, \varepsilon_t^b$, $\varepsilon_t^{erv}, \varepsilon_t^{fxp}$ and ε_t^{fxs}, respectively. According to our specification, y_t, p_t and erv_t constitute policy goals while policy instruments are split into monetary policy (i_t and m_t) and foreign exchange intervention (fxp_t and fxs_t). Diagonal elements of A are normalised to 1 while zero (zero exclusion restriction) implies no contemporaneous relationship between X_t variables[121]. The study focuses on identifying the feedback policy rule relating to the policy instruments: ε_t^i, ε_t^m, ε_t^{fxp} and ε_t^{fxs} which define the policy reaction function of the BoZ.

The assumptions underlying the restrictions imposed on A above are as follows. Prices are sticky in the short-run and hence do not respond instantaneously to monetary policy shocks while shocks to monetary policy are contemporaneously transmitted to the exchange rate and vice-versa (Vonnák, 2005). Further, output adjusts sluggishly with a lag to financial and monetary variables (Brischetto and Voss, 1999; and Bjørnland and Halvorsen, 2008). Thus zero exclusion restriction is imposed on all variables in A corresponding to the y_t row. Similarly, zero exclusion restriction is imposed on all variables corresponding to the p_t row except y_t. Prices adjust slowly to all variables except movements in output to which they react contemporaneously (Brischetto and Voss, 1999). The interest rate (i_t) responds contemporaneously to base money and (level) nominal exchange rate (Brischetto and Voss, 1999). However, a zero exclusion restriction is imposed on exchange rate volatility as the level of the exchange rate is not used. This is effectively a money supply function (see Enders, 2004). With respect to m_t, a standard money demand equation specification is invoked in which base money depends on output, price level and the interest rate (Brischetto and Voss, 1999).

Further, the exchange rate depends upon innovations in macroeconomic variables as it reacts almost instantaneously to all information. Hence there is no zero exclusion in the row corresponding to erv_t except intervention (Brischetto and Voss,

[121] a_{ij} = variable j affects variable i instantaneously.

1999; and Bjørnland and Halvorsen, 2008)[122]. It is assumed that foreign exchange interventions like exchange rate respond contemporaneously to all available information. However, due to nominal rigidities it takes a while for the effects of foreign exchange intervention and exchange rate to affect other variables (Bjørnland and Halvorsen, 2008). Thus, foreign exchange sales are assumed to respond to all variables except foreign exchange purchases on which a zero exclusion restriction is imposed since both purchases and sales are policy instruments in this regard. Similarly, foreign exchange purchases are assumed to respond to all variables except foreign exchange sales.

5.4.2 GMM Approach

5.4.2.1 Model Specification

The specification of the three policy rules is as follows.

5.4.2.1.1 McCallum Rule

Baseline Model

$$\Delta b_t = \alpha_0 + \alpha_1 \Delta b_{t-1} + \gamma ygap + \phi \pi + \varepsilon_t \quad (26)$$

Contemporaneous Augmented McCallum Rule

$$\Delta b_t = \alpha_0 + \alpha_1 \Delta b_{t-1} + \gamma ygap + \phi \pi + \delta erv_t + \varepsilon_t \quad (27)$$

Backward-Looking Augmented McCallum Rule

$$\Delta b_t = \alpha_0 + \alpha_1 \Delta b_{t-1} + \gamma ygap_{t-1} + \phi \pi_{t-1} + \delta erv_{t-1} + \varepsilon_t \quad (28)$$

[122] Allowing fxp_t and fxs_t to contemporaneously affect erv_t is rejected.

Forward-Looking (Lead Inflation Gap) Augmented McCallum Rule

$$\Delta b_t = \alpha_0 + \alpha_1 \Delta b_{t-1} + \gamma ygap + \phi \pi_{t+1} + \delta erv_t + \varepsilon_t \qquad (29)$$

Forward-Looking (Lead T-bill Rate) Augmented McCallum Rule

$$\Delta b_t = \alpha_0 + \alpha_1 \Delta b_{t-1} + \alpha_2 \Delta b_{t+1} + \gamma ygap + \phi \pi + \delta erv_t + \varepsilon_t \qquad (30)$$

where Δb_t is change in nominal base money[123]; $ygap$ is current output gap defined as the deviation of real output from the potential level; π is the current inflation gap defined as the deviation of actual inflation rate from target; erv_t is a measure of current exchange rate volatility; and ε_t is the error term[124].

The expected signs on parameter coefficients are $\alpha_1, \alpha_2 > 0$; $\gamma < 0$ (tighten base money when output exceeds its potential level and vice-versa); ϕ determines the extent to which the central bank deals with inflationary pressures such that $\phi < 0$ (stabilising: monetary policy is tightened for a positive inflation gap or when inflation is forecasted to exceed the target and eased for a negative inflation gap); and $\delta < 0$: base money is adjusted to dampen excessive fluctuations (volatility) in the exchange rate, a case of leaning-against-the-wind by the central bank as observed by Rogers and Siklos (2003). A positive δ is possible but considered an exception to the rule as it implies central

[123] A number of studies (i.e. Koivu et al. 2008; and Rotich et al. 2008) use broad money measures as an alternative policy instrument to base money. There is no marked difference in results. Base money is used here as it is the operating target adopted by the BoZ.

[124] The error term refers to monetary policy shocks defined as the unexpected deviations from the systematic behaviour of monetary policy or the extent to which actual values of base money/T-bill rate deviate from the stated policy rule due to deliberate actions by monetary authorities (Vdovichenko and Voronina, 2004; and Vonnák, 2005).

bank increasing base money when exchange rate volatility increases. α_0 represents the desired value of the policy instrument when policy variables are at their respective target levels. A lagged value of b_t captures central bank reaction to past base money dynamics or partial adjustment of base money to the desired path (Tagaki, 1991).

Two versions of forward-looking policy setting are examined: lead (one-period ahead) inflation gap defined as the difference between actual current inflation rate and projected inflation rate one month ahead; and lead (one-period ahead) policy instrument in the reaction function to signify pre-emptive behaviour by the central bank.

5.4.2.1.2 Taylor Rule

Baseline Model

$$i_t = \alpha_0 + \alpha_1 i_{t-1} + \gamma ygap + \phi\pi + \varepsilon_t \tag{31}$$

Contemporaneous Augmented Taylor Rule

$$i_t = \alpha_0 + \alpha_1 i_{t-1} + \gamma ygap + \phi\pi + \delta erv_t + \varepsilon_t \tag{32}$$

Backward-Looking Augmented Taylor Rule

$$i_t = \alpha_0 + \alpha_1 i_{t-1} + \gamma ygap_{t-1} + \phi\pi_{t-1} + \delta erv_{t-1} + \varepsilon_t \tag{33}$$

Forward-Looking (Lead Inflation Gap) Augmented Taylor Rule

$$i_t = \alpha_0 + \alpha_1 i_{t-1} + \gamma ygap + \phi\pi_{t+1} + \delta erv_t + \varepsilon_t \tag{34}$$

Forward-Looking (Lead T-bill Rate) Augmented Taylor Rule

$$i_t = \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 i_{t+1} + \gamma ygap + \phi\pi + \delta erv_t + \varepsilon_t \qquad (35)$$

where $\alpha_1, \alpha_2 > 0$ (interest rate smoothing or persistence); $\gamma > 0$ (the interest rate is raised when output exceeds its potential level or trend); $\phi > 0$ but greater 1 for policy to be inflation stabilising (raise nominal and subsequently real short-term interest rate when inflation exceeds target) otherwise changes in inflation are accommodated (real interest rate falls) when ϕ is less than 1; and $\delta < 0$: adjustment of the interest rate ensures that considerable fluctuations in the exchange rate are minimised. Central bank interest rate smoothing is captured by a lagged value of i_t similar to Clarida et al. (1998).

5.4.2.1.3 Foreign Exchange Intervention Rule (Modified Edison's Model)

Baseline Model

$$I_t = \alpha_0 + \alpha_1 I_{t-1} + \gamma ygap + \phi\pi + \varepsilon_t \qquad (36)$$

Contemporaneous Model

$$I_t = \alpha_0 + \alpha_1 I_{t-1} + \gamma ygap + \phi\pi + \delta erv_t + \varepsilon_t \qquad (37)$$

Backward-Looking Model

$$I_t = \alpha_0 + \alpha_1 I_{t-1} + \gamma ygap_{t-1} + \phi\pi_{t-1} + \delta erv_{t-1} + \varepsilon_t \qquad (38)$$

Forward-Looking (Lead Inflation Gap) Model

$$I_t = \alpha_0 + \alpha_1 I_{t-1} + \gamma ygap + \phi \pi_{t+1} + \delta erv_t + \varepsilon_t \qquad (39)$$

Forward-Looking (Lead Intervention) Model

$$I_t = \alpha_0 + \alpha_1 I_{t-1} + \alpha_2 I_{t+1} + \gamma ygap + \phi \pi + \delta erv_t + \varepsilon_t \qquad (40)$$

where $\alpha_1, \alpha_2 > 0$; $\gamma < 0$ and $\phi < 0$ in line with Horváth (2007) implying the central bank is less likely to intervene in the market when the domestic currency is appreciating (even with some volatility) despite inflation and output exceeding their targets[125]; and $\delta < 0$ as above.

The underlying theoretical justification for $\delta < 0$ is not provided. The present study does not distinguish conditional volatility associated with depreciation and appreciation but rather examines whether the central bank responds to a rise in conditional volatility or not. As different specifications of the policy are considered in the literature, the emphasis here is on monetary policy response to future inflation in line with the BoZ monetary policy stance holding output and exchange rate volatility at current values, hence specifications or equations 29, 34 and 39[126].

Interventions tend to be correlated (Hassan, 2009). They follow each other in succession: intervention in one period is likely to be followed by another intervention in the next period and a period of no intervention is likely to be followed by another period of no intervention as can be deduced from the data in figures 5.1n and 5.1o below (see

[125] The rationale is that the pass-through effects of exchange rate appreciation moderate inflationary pressures and eventually inflation is aligned with the target. Similarly, an appreciation results in output loss due to loss of competiveness and thus output eventually returns to steady-state.

[126] For instance, Doménech et al. (2001) focus only on interest rate response to lead output and inflation gaps.

Kim and Sheen, 2002; Horváth, 2007; Ito and Yabu, 2007; and Kamil, 2008). Thus, a lagged value of intervention captures persistence of intervention as interventions usually occur in clusters. According to Kim and Sheen (2002), $0 < \alpha_1 < 1$ in equations 36-40, implying that the likelihood of intervention occurring the next day following intervention the previous day is given by the coefficient size of α_1.

5.4.2.2 Brief Description of the GMM Approach

OLS and instrumental variable (IV) methods are generally used to estimate variants of monetary policy and intervention rule equations such as 26-40 above (Leeper and Zha, 2001). However, the IV method is preferred to OLS as the former addresses a variety of classical linear model assumption violations typically classified under endogeneity and substantially reduces the biases associated with the latter.

Under OLS, the orthogonality assumption is assumed to hold[127]. However, OLS estimates of parameter coefficients are biased and inconsistent rendering model statistical inference invalid if some regressors are correlated with ε_t, relevant regressors are omitted and measurement errors-in-variables exist. Further, the inclusion of the lagged dependent variable among the set of regressors makes ε_t serially correlated[128]. A potential simultaneity problem exists between the dependent variable and regressors

---

[127] All the regressors are assumed to be exogenous (orthogonality assumption) such that $Cov(X_{it}, \varepsilon_{it}) = 0$ where X is a vector of regressors. The violation of the orthogonality assumption could be attributed to, among many factors, omitted variable(s), simultaneous causality and errors-in-variables biases.

[128] For instance given

$$\Delta b_t = \alpha_0 + \alpha_1 \Delta b_{t-1} + \alpha_2 \pi + \alpha_3 ygap + \varepsilon_t \qquad \text{(a)}$$

Supposing

$$\varepsilon_t = \psi \varepsilon_{t-1} + \upsilon_t \qquad \text{(b)}$$

By substituting equation (b) into (a) shows that b_{t-1} is correlated with ε_t and thus equation (a) has a serially correlated ε_t on assumption that υ_t are i.i.d., $|\psi| < 1, |\alpha_1| < 1, E(\upsilon_t) = 0$ and υ_t is independent of b_t, π and $ygap$.

with respect to foreign exchange intervention as noted by Edison (1993), Kim and Sheen (2002), Rogers and Siklos (2003) and Kamil (2008)[129].

Thus, an estimation technique requiring the use of instrumental variables is used to correct the potential endogeneity problem. In this chapter, the generalised method of moments (GMM) estimator is employed[130].

Expressing equations 26-40 in matrix form

$$G = X\beta + \varepsilon \tag{41}$$

where G is an $nx1$ vector of observations on the dependent variable; X is an nxn matrix containing observations on regressors; β is a $nx1$ vector of unknown parameters for regressors; ε is $nx1$ vector of error terms; n is the number of variables. Then

$$\hat{\beta}_{OLS} = (X^{'}X)^{-1}X^{'}g \tag{42}$$

Due to the problems associated with $\hat{\beta}_{OLS}$ as highlighted above, β is estimated using IV or GMM. The IV (GMM) estimator requires that instrumental variables denoted Z satisfy certain conditions for them to be relevant and valid: IVs must be

[129] There is a high possibility of feedback loop whereby regressors and the dependent variable are simultaneously determined. In particular, the decision to intervene in the foreign exchange market may be induced by increases in exchange rate volatility and the latter may be triggered by past, current or expected intervention (see Hassan, 2009).

[130] GMM is more general than the standard instrumental (IV) and the two stage least sqauares (TSLS) estimators. In the standard IV estimator, a special case of a GMM estimator, it is assumed that the errors are homoskedastic and not serially correlated. However, GMM is used when these assumptions fail especially the homoskedasticity one (Wooldridge, 2001). The GMM employs a weighting matrix (W) expressed in quadratic form "obtained by inverting a consistent estimator of the variance-covariance matrix of the moment conditions" (Wooldridge, 2001: 90). A quadratic form in the sample moment conditions are minimised by the GMM estimator. GMM accounts for heteroskedasticity (and serial correlation in time series data) in the errors of unknown form.

strongly correlated with X variables but bear no direct relationship with G except through X [131]

$$G = X\beta + \varepsilon \tag{41}$$

$$X = Z\Psi + \vartheta \tag{43}$$

where Z is a matrix of IVs; Ψ, defined as $\Psi = (Z^{'}Z)^{-1}Z^{'}X$, captures the impact of Z on X; ϑ is a vector containing error terms; and $Cov(Z,\varepsilon) = 0$ and $Cov(Z,X) \neq 0$ refer to instrument validity and instrument relevance, respectively. Further, at least one element of Ψ should be non-zero i.e. $\Psi \neq 0$. A problem of weak instruments[132] might arise when all elements of Ψ are close but not equal to zero even if all elements of Ψ are non-zero. In addition, having many instruments relative to the number of endogenous regressors can result in over-fitting and loss of degrees of freedom when X is regressed on Z. In this regard, asymptotic approximations are poor approximations and inference is wrong as standard errors on IV estimates are larger than OLS estimates. Further, GMM estimates will be biased and inconsistent with less precision with consequences exceeding OLS estimates in the presence of endogeneity thus rendering statistical inference invalid. In addition, GMM estimate converges to OLS estimate with

[131] This is a subject of empirical contention. The chosen instrumental variable may have a direct impact on both the instrumented regressor and the dependent variable thus making finding valid instruments difficult. The choice of IVs is based on data availability, underlying theory or pure assumption. Most importantly, IVs must be determined outside the regression model and be uncorrelated with ε. A constant term is also an IV.

[132] Weak instruments refer to a situation when the chosen instruments do not account for much of the variability in the endogenous variables i.e. instruments are poorly correlated with endogenous variables. Thus, their inclusion in the estimation renders statistical inference unreliable: the standard errors on IV estimates are larger than OLS estimates such that IV estimates are as biased as OLS estimates in the same direction, inconsistent with incorrect size for tests of significance.

a larger set of instruments relative to the sample size and parameters to be estimated such that if OLS is biased, GMM estimates will be biased too.

GMM is preferred to TSLS in the presence of heteroskedasticity (Wooldridge, 2001). In addition, while both the GMM and the TSLS estimators involve choosing the weighting matrix, the former generates more efficient estimates than the latter through the specification of the optimal weighting matrix. Hence, the GMM estimator is employed in this study as it addresses the inherent endogeneity of all or some regressors evident from our model specification above.

Thus, on assumption of instrument availability, a consistent IV (GMM) estimator for β can be constructed as

$$\hat{\beta}_{IV/GMM} = (X^{'}W_z X)^{-1} X^{'}W_z g \tag{44}$$

where $W_z = Z(Z^{'}Z)^{-1}Z^{'}$, the projection or weighting matrix for Z, is consistent and its distribution approximates normal when the sample size is large[133]. An ideal weighting matrix is given by $W = \Omega^{-1}$ where $\Omega = \text{var}(Z^{'}[G - X\beta])$.

Several GMM estimators exist due to different choices of moment conditions and the weighting matrix. Underlying the GMM estimator are independent moment conditions or equations, r, and q unknown parameters to be estimated. To derive GMM estimates, assumptions called moment conditions are made about ε and Z (i.e. $E(\varepsilon) = 0$ and $E(\varepsilon, Z) = 0$) such that for a given sample size, n, it is expected that

[133] A ZxZ weighting matrix, W, is constructed in order to obtain β when the number of instruments exceeds the unknown parameters to be estimated in order to find estimates of β that set all Z sample moment conditions exactly equal to zero. W_z takes different forms.

$f_{\varepsilon} = N^{-1}\sum_{i=1}^{n}\varepsilon_i$ and $f_{\varepsilon,Z} = N^{-1}\sum_{i=1}^{n}\varepsilon_i Z_i$ to be close to zero. Thus, the number of instruments constitute a set of moment conditions (orthogonality conditions) that must be satisfied at the true value of β. Thus, GMM chooses the parameter values for each f_i represented by a vector F as close to zero as possible by minimising the following function

$$\rho = F^{'}WF \tag{45}$$

W is an arbitrary rxr matrix corresponding to the number of moment conditions optimally chosen such that the estimated parameters have the smallest standard errors. In most cases, the weighting matrix is specified as an identity matrix which is argued to be a poor choice because it is not optimal despite generating consistent estimates (Cameron and Trivedi, 2005).

The number of instrumental variables ($Z_1,...,Z_m$) may be fewer, exceed or match endogenous variables ($X_1,...,X_k$). Thus, the parameter coefficients of the model ($\beta_1,...,\beta_k$) are said to be exactly-identified if $m = k$, overidentified if $m > k$ and under-identified if $m < k$. Instrument validity must be tested in the over-identifaction case (explained later).

The GMM results are sensitive to the choice of IVs. As the choice of IVs can be difficult and controversial, the practice in the literature is to use lagged values of each regressor as IVs[134]. The J-statistic is used to test instrument validity (a test of the over-

[134] The choice of instruments is usually ad hoc and subject to availability. Lagged values of the regressors are frequently used since it is difficult to find appropriate instruments. It is rare to find macroeconomic variables that are strictly exogenous (Sims, 1980). The current and lagged values of the regressors are highly correlated as macroeconomic data tend to exhibit a high degree of persistence. It is further assumed that the lagged values of regressors are not correlated with the current error term as the latter is

identifying restrictions)[135]. Further, the Hausman statistic test for endogeneity (or orthogonality assumption) can also be conducted. The heteroskedasticity and autocorrelation consistent (HAC) covariance weighting matrix is employed to ensure inferences are robust to heteroskedasticity and serial correlation[136].

5.4.3 Data Sources and Description

Monthly data from 1995 to 2008 are used to estimate the policy reaction functions. Data are sourced from the BoZ. All the variables are expressed in logarithm except inflation, T-bill rate, exchange rate volatility and foreign exchange intervention.

As data on real output, GDP, are not available at monthly frequency, indicators of economic performance are usually inferred from activities in key sectors that have substantial contribution to GDP (Vdovichenko and Voronina, 2004). In Zambia, the mining sector contributes about 50 percent to GDP (UNDP, 2006). Hence, y_t is proxied by actual copper output (CU – in thousands of metric tonnes). Thus, $ygap$ is obtained by subtracting the logarithm of copper output (LCU) from trend. Trend in copper output is derived using the Hodrick-Prescott Filter in line with most studies i.e. Eleftheriou et al. (2006) and Horváth (2007) [137].

Inflation rate ($\inf_t$) defined as the monthly annualised percentage change in the consumer price index $(CPI, 2000 = 100)$ is used in place of p_t. $\pi\,(INFGAP)$, the

---

realised after the former has materialised. Other IVs used include real world commodity prices like oil price, real money supply and real exchange rate (Clarida and Gertler, 1996).

[135] J-statistic is a generalisation of the Sargan's misspecification test. It is used to test the validity of over-identifyng restrictions when instruments exceed parameters to be estimated (or number of endogenous regressors). The H_0 : all instruments are exogenous (or overidentifying restrictions are valid) and H_1 : H_0 is not true. The J-stat has a chi-square distribution with $m-k$ degrees of freedom where m is number of overidentifying restrictions (or instruments) and k is the number of parameters to be estimated (or number of endogenous regressors).

[136] The optimal weighting matrix ensures that GMM estimates are robust to heteroskedasticity and autocorrelation of unknown form.

[137] Several methods for computing output gap such as residuals from regressing output on a quadratic trend and Band-Pass Filter exist and their weaknesses and strengths are highlighted (see Eleftheriou et al. 2006).

percent deviation of actual inflation from target, is obtained by subtracting actual inflation (INF) from target $(INFPROJ)$.

The nominal 3-month T-bill rate (tbr_t), expressed in annual percentage terms, represents i_t. In line with the monetary policy description in section 5.3, m_t is represented by nominal base money (b_t) and LB is the logarithm of nominal base money such that Δb_t is the logarithmic change in nominal base money. Base money is defined as the sum of currency held outside the banking system and required reserves held by commercial banks at the BoZ, expressed in kwacha.

Alternative measures of erv_t derived using the EGARCH model in chapter 3 but re-estimated over the sample period 1995-2008 are employed: bilateral KUS$ ($EGKUS\$$- $erv_{t,nkus\$}$ and $EGRKUS\$$-$erv_{t,rkus\$}$); trade-weighted exchange rate ($EGNEER$- $erv_{t,neer}$ and $EGREER$-$erv_{t,reer}$); and GARCH-PCA series ($PCAN$-$erv_{t,pcan}$ and $PCAR$- $erv_{t,pcar}$). The GARCH-based conditional volatility measure best approximates observed exchange rate volatility (Kim and Sheen, 2002). The KUS$ bilateral exchange rate is used as the BoZ interventions are almost always conducted in US$ and thus directly affect the KUS$ exchange rate. The trade-weighted exchange rate index and GARCH-PCA capture a broader interaction with other variables in the system. Both nominal and real versions of each measure are examined to determine the relevant exchange rate in the reaction functions.

Most studies tend to use cumulative intervention or net intervention data[138] (Rogers and Siklos, 2003; Simatele, 2004; Özlü and Prokhorov, 2008; and Humala and Rodriguez, 2009) while others use dummy indicators for intervention (purchase or sale) in binary choice dependent variable methods (probit, logit and friction) due to data gaps

[138] Net intervention is defined as the difference between sales and purchases or vice-versa.

as there are periods when intervention does not occur making the series discontinuous[139]. Nonetheless, actual aggregated monthly absolute values of intervention in US$ million are used in this chapter similar to Kamil (2008)[140].

There is evidence to suggest that central banks react asymmetrically to currency movements (see Takagi, 1991; Kim and Sheen, 2002; and Hassan, 2009)[141]. Thus, intervention is split into purchases (fxp_t) and sales (fxs_t) similar to Hassan (2009) in order to determine explicitly their respective reaction to policy variables.

5.4.4 Empirical Results

A preliminary examination of the relationship among variables in the policy rules is undertaken using graphical analysis (figures 5.1a-5.1o) and descriptive statistics (tables 5.1 and 5.2).

Copper output declined from 1995 until 2000 when a rising trend emerged, signifying recovery in mining production after a long period of contraction due to lack of re-investment (see figure 5.1a). Output gap displays erratic movements (figure 5.1b) while plots of nominal monthly base money in level (figure 5.1c) and its growth rate (figure 5.1d) display a rising trend and fluctuations within a narrow range (excluding outliers), respectively.

---

[139] This makes the distribution of intervention to be concentrated around zero ('zero-inflated process' - Kim and Sheen, 2002) such that the relationship between intervention and its determinants is non-linear and the distribution of errors from regressions that include absolute intervention data may not be normal as per OLS assumption especially in small samples. This does not however, preclude the use of a linear model. The OLS method has been used by Rogers and Siklos (2003) among others. Most studies however, focus on the probability of intervention occurring subject to control factors as reason for using cumulative or binary choice dependent variable method such as probit, logit and friction (Lewis, 1995; Kim and Sheen, 2002; and Özlü and Prokhorov, 2008). The friction model simultaneously models purchases and sales interventions in a reaction function by making three distributional assumptions about intervention: buy, sell or none.

[140] Kamil (2008) uses absolute amounts in a GARCH model.

[141] Stability or low volatility in exchange rates is preferred by central banks. Nonetheless, central banks tend to respond more aggressively to exchange rate depreciations than appreciations due to pass-through effects to domestic prices.

The T-bill rate generally trended downwards from about 60 percent to less than 20 percent after 2004 (figure 5.1e). A sharp deceleration occurred between 1996 and mid-1998 as well as from 2002 to early 2004. The extent of T-bill rate fluctuations reduced considerably towards the end of the sample period. The observed fluctuations in interest rates is in line with Clarida and Gertler (1996) who noted that considerable fluctuations in interest rates and exchange rate induced by money demand shocks are likely as the central bank attempts to keep money supply on the desired growth path.

Exchange rate volatility series for the KUS$ (figures 5.1f and 5.1g), trade-weighted (figures 5.1h and 5.1i) and GARCH-PCA series (figures 5.1j and 5.1k) show a general stable movement except for a spike in 2002 due to unusually high demand for foreign exchange related to maize (stable food) importation (BoZ Annual Report, 2002).

Actual inflation tracks the target, but generally persistently exceeded the target over the sample period (figures 5.1l and 5.1m).

The BoZ intervened frequently in some months and not at all in other months with varying operational sizes (figures 5.1n and 5.1o). Overall, the BoZ is a net buyer of US$. Humala and Rodriguez (2009) report that the Central Reserve Bank of Peru was a net buyer of US$ in an attempt to resist currency pressures. In the case of Zambia, the relationship between purchases/sales and large changes in the exchange rate of either sign is not systematic based on the monthly plots of intervention data along with exchange rate changes in figure 5.1n (left scale - fxp_t and right scale – change in exchange rate) and figure 5.1o (left scale - fxs_t and right scale – change in exchange rate). The average intervention size per month for purchases is about US$12 million and US$6 million for sales with particularly large purchases and sales of US$70 million and US$90 million occurring in December 2008 and September 2006, respectively (see table 5.1). The scale of sale interventions is broadly small and frequent (spread throughout the sample period) while purchase interventions are large (with higher standard deviation – table 5.1) but less frequent with hardly any purchase interventions between mid-2003 and early 2006.

Exchange rate volatility and copper output are substantially less volatile than the rest of the variables followed by base money and inflation (table 5.1). Conversely, the 3-month T-bill rate and foreign exchange intervention are the most volatile reflected also in the erratic pattern in graphical plots. Movements in exchange rate volatility are also erratic.

While graphical analysis does not reveal an apparent relationship on casual inspection among the variables, correlation analysis depicts the extent of linear statistical association among them. Correlation coefficients reported in table 5.2 reveal a weak co-movement between policy instruments and policy goals except for the relationship between monetary policy instruments and output. Exchange rate volatility bears the weakest linear association with all policy instruments. Output has a stronger relationship with monetary policy instruments: positive with base money and negative with the T-bill rate. Base money and inflation are negatively related while the interest rate and inflation are positively related in line with the policy rule predictions. The relationship between policy goals and the two foreign exchange intervention measures is asymmetric: fxp_t and fxs_t bear opposite relationships with output, inflation and exchange rate volatility. Similar to the T-bill rate, the correlation between fxp_t and output is negative but positive between fxs_t and output. fxp_t bears a positive relationship with inflation and exchange rate volatility while fxs_t has the opposite relationship.

Figure 5.1 Plots of monetary policy goals, instrument and intervention data

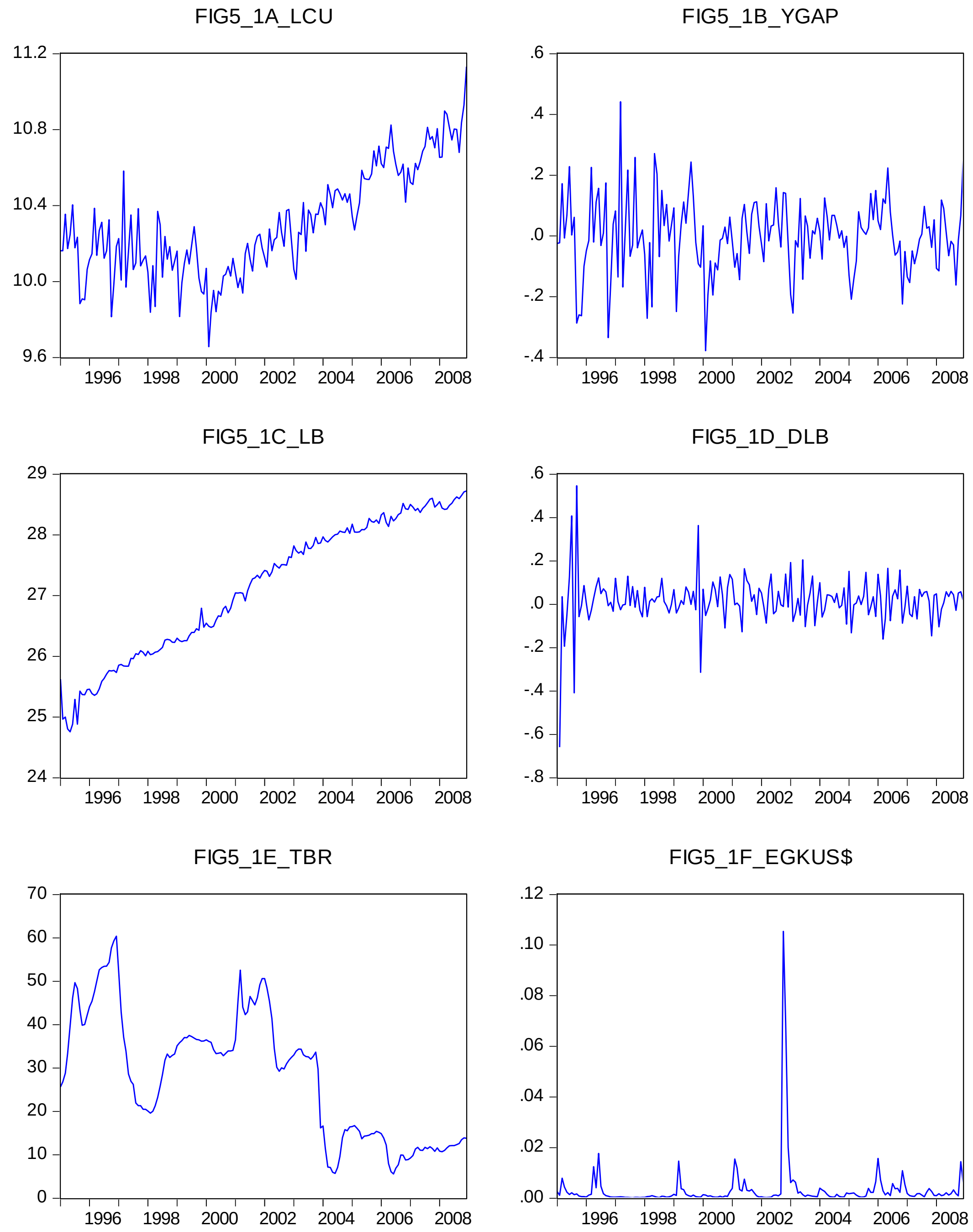


FIG5_1G_EGRKUS$

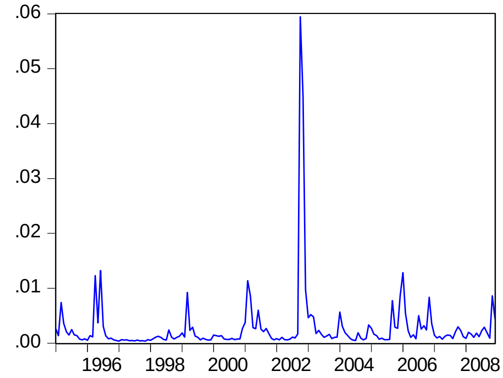


FIG5_1H_EGNEER

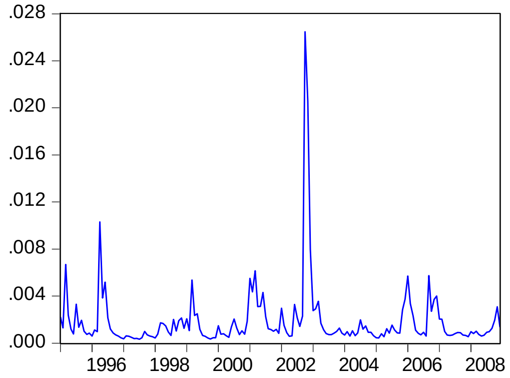


FIG5_1I_EGREER

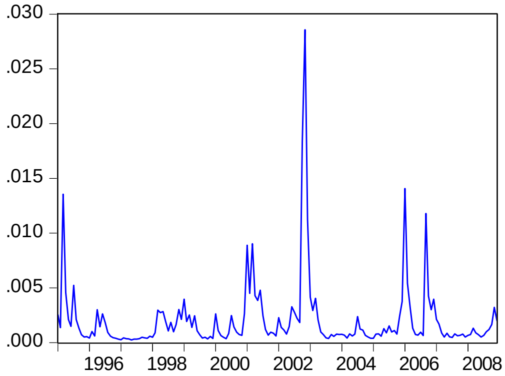


FIG5_1J_PCAN

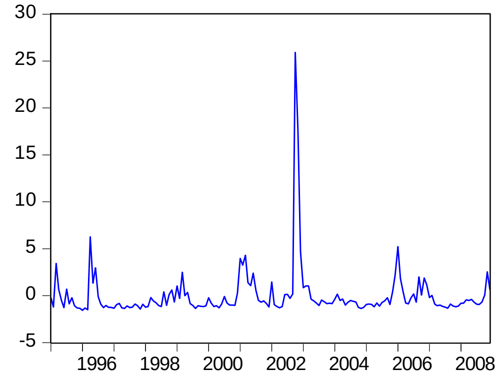


FIG5_1K_PCAR

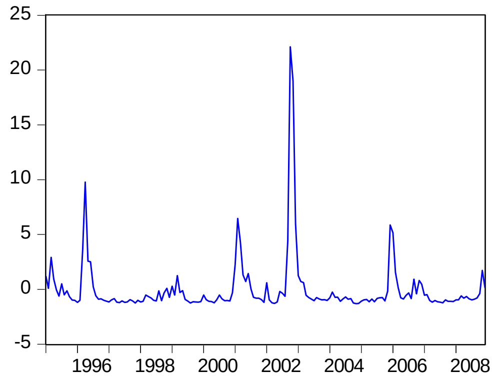


FIG5_1L INF v INFPROJ

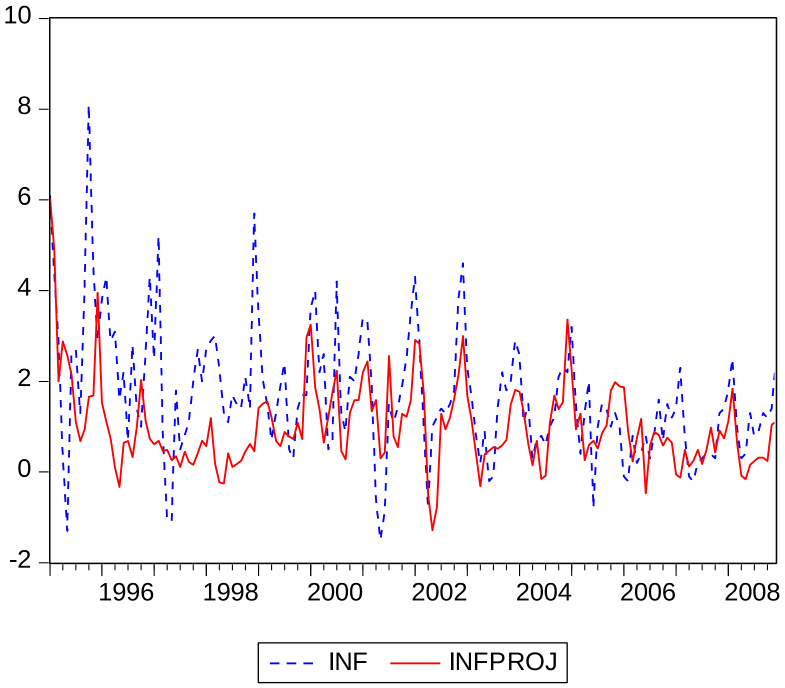


FIG5_1M_INFGAP

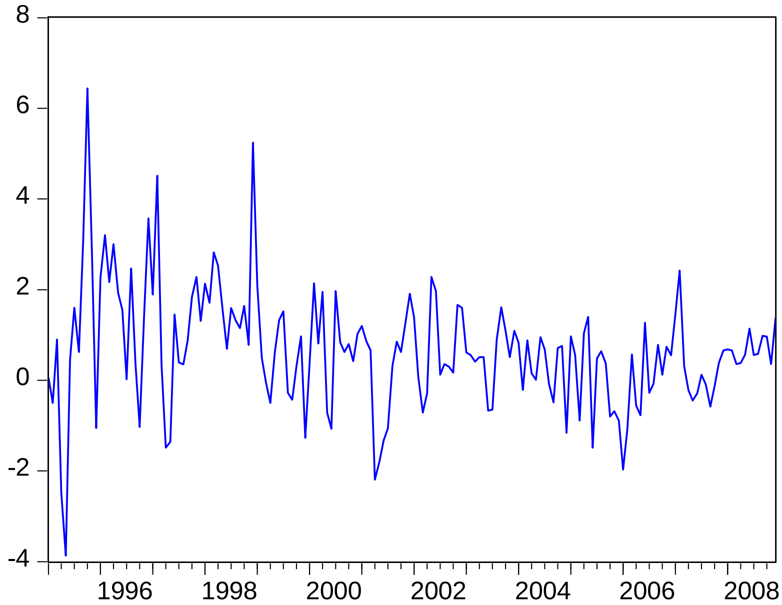


FIG5_1n FXP v DLKUS$

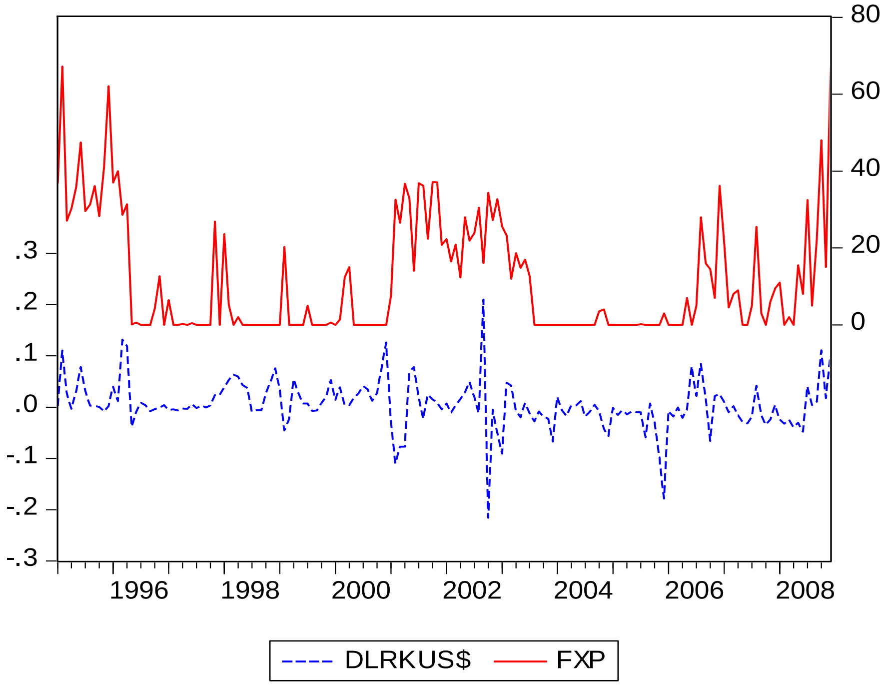


FIG5_1o FXS v DLKUS$

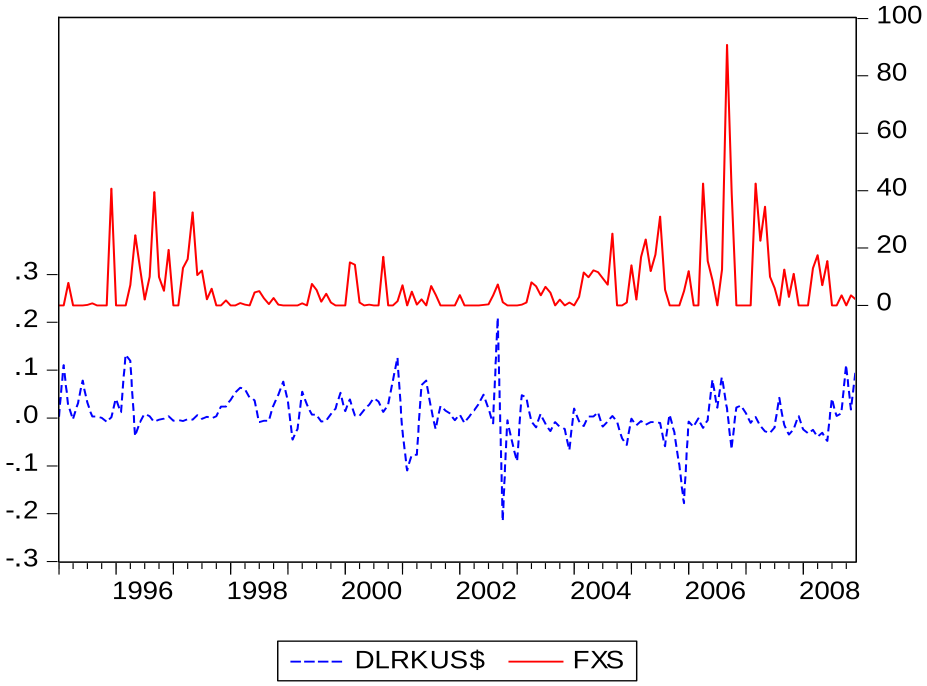


Table 5.1 Descriptive Statistics

	LB	TBR	FXP	FXS	LCU	INF	LKUS$	LREER
Mean	27.13	27.91	11.58	6.41	10.31	1.67	7.93	2.89
Median	27.35	30.58	3.00	1.20	10.26	1.40	8.16	2.90
Maximum	28.72	60.39	70.00	90.80	11.13	8.10	8.63	3.41
Minimum	24.76	5.60	0.00	0.00	9.66	-1.50	6.53	2.12
Std. Dev.	1.12	14.42	15.34	11.36	0.28	1.43	0.56	0.28
Skewness	-0.31	0.19	1.34	3.58	0.36	0.95	-0.86	-0.35
Kurtosis	1.80	1.92	4.40	21.66	2.48	5.32	2.42	2.17
Jarque-Bera	12.87	9.06	64.04	2797.07	5.52	62.83	23.32	8.28
Probability	0.00	0.01	0.00	0.00	0.06	0.00	0.00	0.02
Observations	168	168	168	168	168	168	168	168

Source; Eviews6

Table 5.2 Correlation Matrix

	LB	TBR	FXP	FXS	LCU	INF	EGREER	PCAR	EGKUS$
LB	1.00								
TBR	-0.71	1.00							
FXP	-0.17	0.27	1.00						
FXS	0.15	-0.19	-0.14	1.00					
LCU	0.71	-0.69	-0.05	0.23	1.00				
INF	-0.37	0.32	0.25	-0.21	-0.36	1.00			
GREER	0.07	0.04	0.15	-0.05	0.02	0.12	1.00		
PCAR	-0.02	0.13	0.25	-0.06	0.00	0.14	0.71	1.00	
EGKUS$	0.07	0.04	0.18	-0.07	0.05	0.07	0.64	0.91	1.00

Source: Eviews6

5.4.4.1 SVAR Results

Unit root tests precede the estimation of SVAR models. The unit root tests reported in table 5.3 are conducted using ADF and P-P methods. All the variables are I(1) except inflation, exchange rate volatility, foreign exchange intervention, output gap and inflation gap, which are I(0). Nonetheless, the SVAR model is estimated as its implementation requires at least one variable to be I(1) (Enders, 2004)[142]. Only copper output and base money enter the SVAR model in log level similar to Bjørnland (2008)

---

[142] SVAR results are sensitive to underlying identifying assumptions, variations to sample length and lags in the VAR.

and Bjørnland and Halvorsen (2008)[143]. A lag of two is used in the VAR based on AIC and SBC.

As shown in table 5.4, diagnostic tests indicate absence of serial correlation of order two. The over-identification restrictions under the null hypothesis that the test statistic has a chi-square distribution with two degrees of freedom cannot be rejected at all conventional significance levels.

Table 5.3 Unit Root Tests

	ADF level	First Diff	lags	Deterministic terms	P-P level	First Diff	Deterministic terms
LB	-2.26	-20.75*	0	C&T	-0.36	-27.68*	C
LCU	-2.89	-15.05*	1	C&T	-2.25	-33.32*	C
INF	-7.33*		0	C	-7.89*		C
FXP	-13.34*		1	C	-4.77*		C
FXS	-9.33*		1	C	-9.22*		C
TBR	-3.52	-7.29*	1	C&T	-3.08	-7.25*	C&T
$erv_{nkus\$}$	-7.32*		0	C	-7.19*		C
$erv_{rkus\$}$	-7.73*		1	C	-7.22*		C
erv_{neer}	-6.77*		0	C	-6.85*		C
erv_{reer}	-6.75*		0	C	-6.87*		C
erv_{pcan}	-7.05*		0	C	-7.10*		C
erv_{pcar}	-7.39*		1	C	-5.09*		C

Source: Eviews6
Critical values for unit root tests are Mackinnon (1996) one-sided p-values. All variables are expressed in natural logarithm. *, ** and *** imply 1%, 5% and 10% levels of significance, respectively. C is constant while T stands for trend.

[143] Levels in VARs are used to allow for possible cointegration among variables (Lewis, 1995).

Table 5.4 SVAR Model Results: Estimated *A* Matrix

y_t	$\inf_t$	tbr_t	b_t	erv_t	fxp_t	fxs_t
1						
0.939 (1.42)	1					
0	0	1	4.141 (0.51)			
0.117 (2.30)	-0.012 (-2.09)	-0.006 (-0.53)	1			
-0.001 (-0.48)	-0.0002 (-0.98)	-0.0001 (-1.50)	0.001 (0.50)	1		
-0.987 (-0.17)	-0.490 (-0.72)	-0.391 (-1.12)	-14.934 (-1.66)	-316.261 (-0.99)	1	0
-7.430 (-1.16)	0.919 (1.23)	-0.288 (-0.76)	0.947 (0.10)	243.399 (0.69)	0	1

Test for over-identification restrictions: $\chi^2(2)$ =0.375[0.8289]
Sample period: 1995.03-2008.12. z-statistics are in parenthesis. VAR (2) diagnostics: serial correlation LM test of order 2=46.428[0.578] ; ARCH χ^2 =1109.922[0.0000] ; J-B normality test=5946.476[0.0000] with df=14. Lag length 2 for the VAR was chosen on basis of AIC and SBC.

5.4.4.1.1 Impulse Response Function Results

The impulse response function results of one standard deviation innovations in output, inflation and exchange rate volatility over a three-year horizon are presented in figures 5.2-5.4. The results suggest that although shocks to output, inflation and exchange rate volatility have little effect on all policy instruments especially foreign exchange intervention, they however, exert permanent effects on base money while the impact on interest rate and intervention is temporary. In general, both monetary policy and foreign exchange intervention response to changes in policy goals is low. Monetary policy eases (interest rate falls while base money increases) in response to output shock. While base money expands to support economic activity, it counter-cyclically changes with the shock to inflation in an attempt to offset the effect of a shock to inflation. All monetary and foreign exchange policy instruments respond strongly to own shocks with their effect dying out within a year except for base money whose effect persists for over three years. There is no substantive change to the results among alternative measures of exchange rate volatility, and thus only the trade-weighted measure is reported. Similarly, the inclusion of output gap and inflation gap instead of output and inflation in levels in the VAR did not change the results similar to Bjørnland and Halvorsen (2008).

A detailed analysis of the impulse response function for each policy instrument follows.

Base Money Rule

Base money responds pro-cyclically (loosens) to a positive shock to output (figure 5.2a) and conditional volatility in exchange rate (figure 5.2c) but responds counter-cyclically (tightens) to a positive shock to inflation (figure 5.2b).

On impact, nominal base money falls in response to unexpected increase in output but gradually increases, reversing the initial fall within two months after which it increases and stays higher permanently. Conversely, the response to inflation shock leads to a permanent fall in nominal base money and consequently real base money after about three months[144]. This follows an initial increase in base money on impact[145]. Nominal base money responds with a lag of about two months to a shock to exchange rate volatility after which it gradually rises and moves to a new equilibrium. Impulses to base money generate a strong and permanent effect on itself: any unexpected rise in base money induces a permanent increase in base money with the initial increase exceeding the new equilibrium level (figure 5.2d).

---

[144] The response of monetary policy to shocks to inflation depends on the duration of the shock. Money supply can expand to match the increase in the price level increase one-for-one (full accommodation) to avoid a drastic fall in aggregate demand if the shock to inflation is temporary as expectations from short-lived shocks are not incorporated in underlying inflation. However, if permanent, shocks are incorporated in underlying inflation and the policy response is likely to be partial accommodation (Taylor, 1981).

[145] This is similar to the price-puzzle case (Bjørnland and Halvorsen, 2008). Price puzzle refers to the “rise in the aggregate price level in response to a contractionary innovation to monetary policy” (Hanson, 2004).

Figure 5.2 Base Money Impulse Response Functions

Response to Generalized One S.D. Innovations ± 2 S.E.

Figure 5.2a Response of Base Money to Output Shock

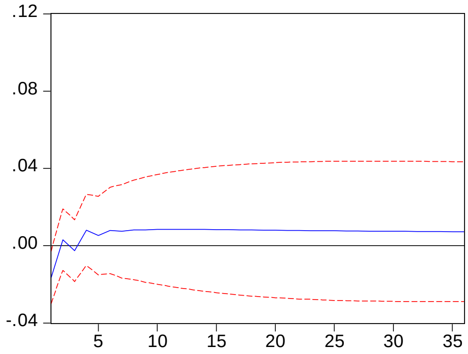


Figure 5.2b Response of Base Money to Inflation Shock

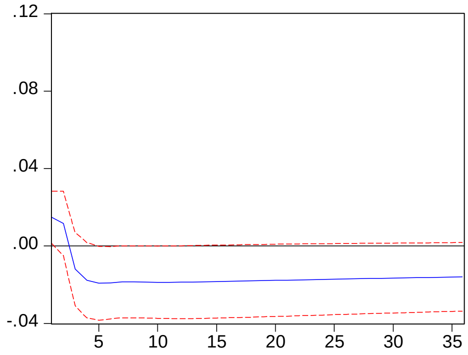


Figure 5.2c Response of Base Money to Exchange rate volatility Shock

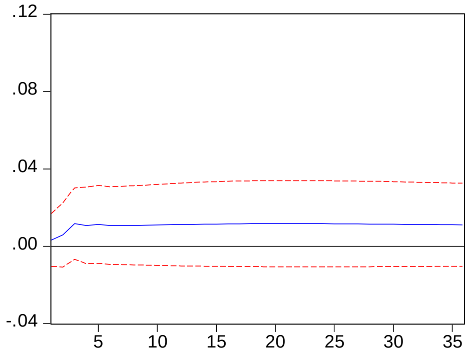
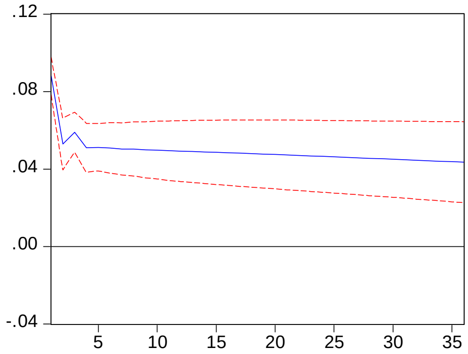


Figure 5.2d Response of Base Money to Base Money Shock



Interest Rate Rule

The interest rate declines (temporarily) though with a delay in response to a shock to output (figure 5.3a). Simialarly, the response to conditional volatility in exchange rate shock in figure 5.3c is marginal and temporary but positive. The response to shocks to inflation in figure 5.3b is cyclical.

There is no immediate reaction by the T-bill rate to output shock. However, the T-bill rate declines from the third month with the initial fall reversed by the tenth month. The delay in T-bill rate response to output shock is in line with the view that monetary policy responds with lag to real economy developments due to delays in collection and publication of macroeconomic data (Gottschalk, 2001). Although negative, there is virtually no T-bill rate response to inflation shock. The positive although relatively small response to exchange rate volatility shock is temporary: a gradual increase in interest rate which peaks around the third month is reversed by the seventh month. Impulses to the T-bill rate cause the T-bill rate to increase on impact but gradually returns to the steady-state by the twenty-fourth month (figure 5.3d).

Figure 5.3 Interest Rate Impulse Response Functions

Response to Generalized One S.D. Innovations ± 2 S.E.

Figure 5.3a Response of Interest Rate to Output shock

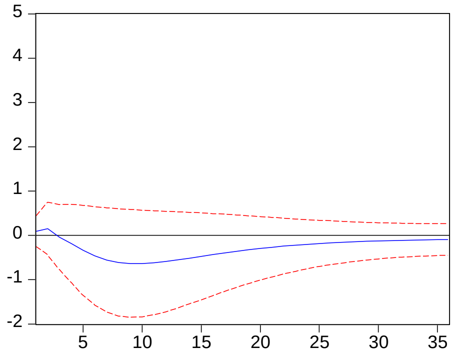


Figure 5.3b Response of Interest Rate to Inflation Shock

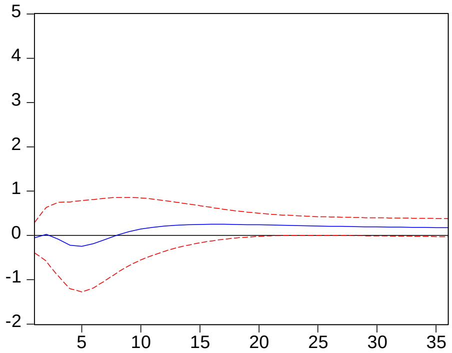


Figure 5.3c Response of Interest Rate to Exchange rate volatility Shock

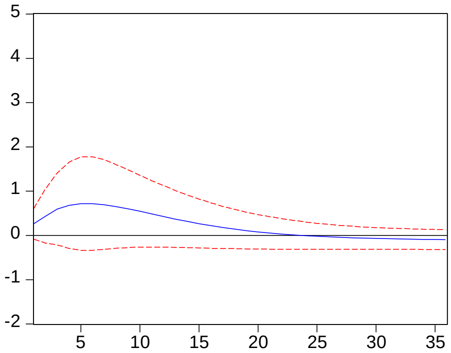
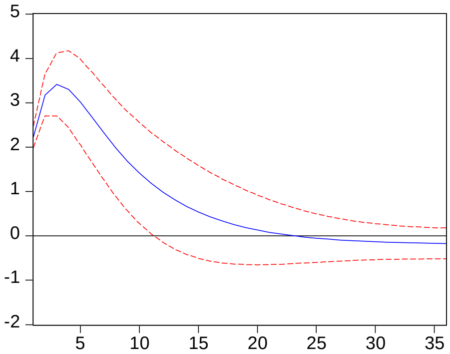


Figure 5.3d Response of Interest Rate to Interest Rate Shock



Foreign Exchange Intervention Rule

Foreign exchange purchase and sales exhibit asymmetric response to shocks to output, inflation and exchange rate volatility in support of the hypothesis of splitting intervention data into purchases and sales. In addition, intervention displays cyclical behaviour and hardly responds to shocks to policy variables especially foreign exchange sales.

The central bank undertakes foreign intervention sales in small amounts lasting about a year in response to output shock while purchases are conducted in slightly higher amounts for a longer period (see figures 5.4a and 5.4e). In the case of the inflation shock, the central bank responds by immediately buying foreign exchange and continues doing so, although in reduced amounts, until about the tenth month (figure 5.4b). Conversely, foreign exchange sales decline but gradually increase, peaking around the around the fifth month (figure 5.4f). In response to an unexpected increase in the conditional volatility of exchange rate, the central bank purchases foreign exchange more than it sells (see figures 5.4c and 5.4g). In effect the central bank hardly sells foreign exchange, but buys more foreign exchange although it does so for a limited period and in reduced amounts. Impulses to intervention cause intervention to initially increase on impact but gradually return to the steady-state although it takes longer for purchases than it does for sales (see figures 5.4d and 5.4h).

Overall, the central bank acts more aggressively with purchases than sales of foreign exchange in response to shocks to policy variables.

Figure 5.4 Foreign Exchange Intervention Impulse Response Functions

Response to Generalized One S.D. Innovations ± 2 S.E.

Figure 5.4a Response of FXP to Output Shock

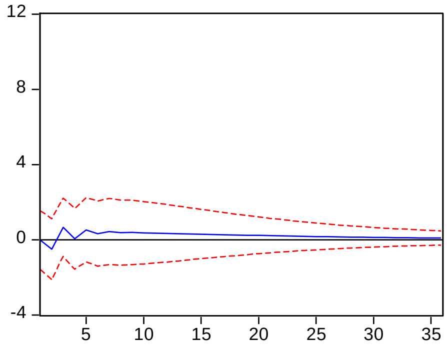


Figure 5.4b Response of FXP to Inflation Shock

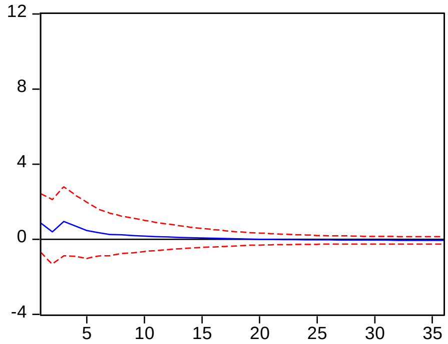


Figure 5.4c Response of FXP to Exchange rate volatility Shock

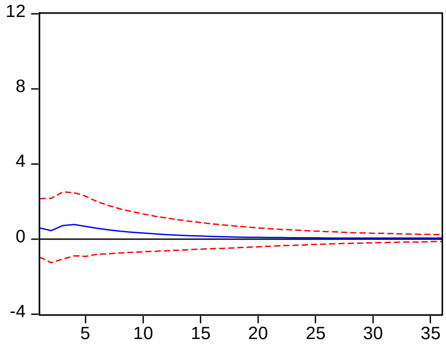
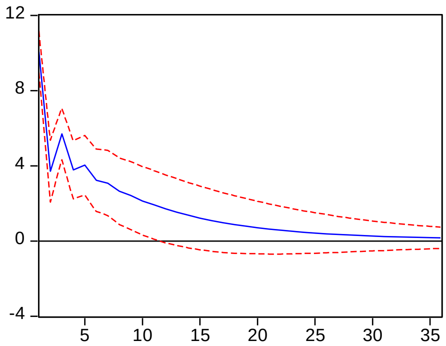


Figure 5.4d Response of FXP to FXP Shock



Response to Generalized One S.D. Innovations ± 2 S.E.

Figure 5.4e Response of FXS to Output Shock

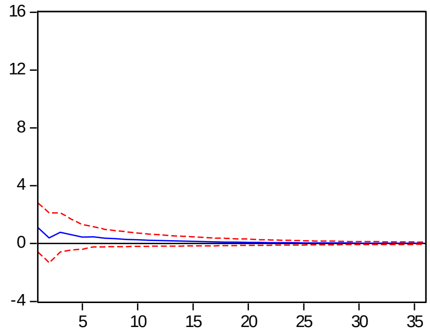


Figure 5.4f Response of FXS to Inflation Shock

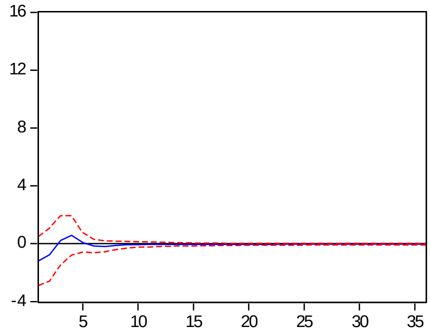


Figure 5.4g Response of FXS to Exchange rate volatility Shock

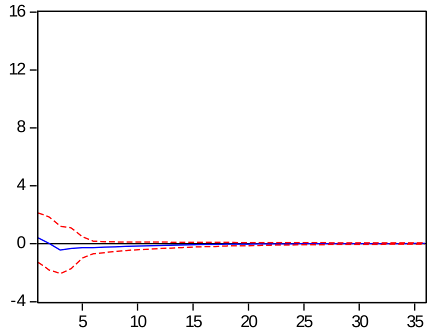
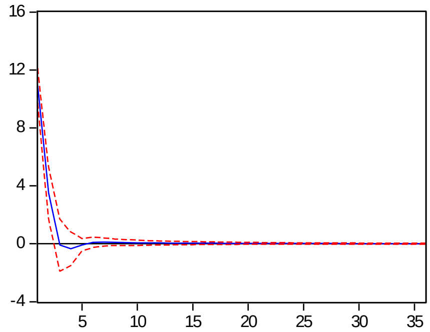


Figure 5.4h Response of FXS to FXS Shock



5.4.4.1.2 Variance Decomposition

The proportion of the error of forecast for 1, 6, 12, 24, 36 and 60 months forecast horizon attributed to shocks to output, inflation and exchange rate volatility is reported in table 5.4. This determines the fraction of the variation in base money, interest rate and intervention due to output, inflation and exchange rate volatility shocks.

Movements in base money, T-bill rate and foreign exchange interventions are largely driven by own shocks at both short and long forecast horizons in line with most previous studies. Nonetheless, at long forecast horizon (5 years), inflation shocks dominate output and exchange rate volatility in terms of their contribution to explaining movements in base money. With respect to the T-bill rate, variance of innovations to output dominates inflation and exchange rate volatility at long horizon. Generally, the influence of exchange rate volatility is relatively higher on base money movements than on interest rate and foreign exchange interventions. This result is consistent with the evidence in the SVAR literature regarding the importance of exchange rate in monetary policy rules (see Clarida and Gertler, 1996 for the Bundesbank; Lubik and Schorfheide, 2007 for Canada and the UK; and Bjørnland and Halvorsen, 2008 for Australia, Canada, New Zealand, Norway, Sweden and the UK). This justifies the explicit inclusion of exchange rate volatility in the base money rule i.e. the exchange rate serves as an essential channel through which monetary policy effects are transmitted to the rest of the economy. The policy instrument response results reported above are consistent with the GMM results discussed in the next sub-section.

Table 5.4 Variance Decomposition

Variance decomposition of b_t					
Forecast Horizon (months)	S.E	Shock to y_t	Shock to $\inf_t$	Shock to erv_t	Shock to b_t
1	0.09	3.60	2.43	0.00	91.38
6	0.16	1.68	5.32	2.56	82.53
12	0.22	1.70	6.43	3.45	77.04
24	0.30	1.73	6.98	3.78	72.00
36	0.36	1.72	7.07	3.86	69.88
60	0.44	1.72	7.10	3.89	68.11
Variance decomposition of tbr_t					
Forecast Horizon (months)	S.E	Shock to y_t	Shock to $\inf_t$	Shock to erv_t	Shock to tbr_t
1	2.21	0.10	0.07	0.00	97.37
6	7.63	0.92	0.34	1.21	90.81
12	9.17	3.20	0.29	0.87	83.16
24	9.64	4.37	0.64	0.84	77.47
36	9.83	4.38	0.96	0.96	74.88
60	10.17	4.21	1.39	1.17	71.31
Variance decomposition of fxp_t					
Forecast Horizon (months)	S.E	Shock to y_t	Shock to $\inf_t$	Shock to erv_t	Shock to fxp_t
1	10.02	0.01	0.62	0.57	96.35
6	14.00	0.56	1.39	0.70	90.31
12	15.26	0.93	1.24	0.63	89.21
24	15.69	1.26	1.18	0.61	88.63
36	15.75	1.34	1.18	0.60	88.30
60	15.80	1.36	1.21	0.62	87.79
Variance decomposition of fxs_t					
Forecast Horizon (months)	S.E	Shock to y_t	Shock to $\inf_t$	Shock to erv_t	Shock to fxs_t
1	10.92	1.05	1.04	0.28	97.36
6	11.72	2.07	1.74	0.45	93.60
12	11.78	2.38	1.75	0.47	92.67
24	11.79	2.45	1.75	0.47	92.45
36	11.79	2.46	1.76	0.47	92.38
60	11.80	2.46	1.76	0.47	92.24

Source: Eviews6
S.E=standard error

5.4.4.2 GMM Results

Lagged values of regressors are used as IVs in line with the practice in the literature. However, given the small sample size, a small set of instruments (i.e. a constant and six lags of each regressor) is used similar to Maria-Dolores (2005) in order to avoid generating biased and inconsistent GMM estimates. Most studies tend to use lags 1-6, 9 and 12 (see Clarida et al. 1998; and Eleftheriou et al. 2006).

Variables entering the reaction functions are assumed to be stationary (Florens et al. 2001). The unit root test results in table 5.3 above confirm stationarity of all variables used in the estimated model. Similar to Eleftheriou et al. (2006), additional lags of the policy instrument and an intervention dummy, D, are included in some model equations to improve fit and capture outliers/unexpected events, respectively.

The results in tables 5.5-5.23 indicate that the estimated models are adequate as the residuals are free of serial correlation of fifth order. The J-statistic result confirms the validity of the chosen instruments as the null hypothesis cannot be rejected at all conventional significance levels. Further, the over-identifying restriction is empirically supported by the J-statistic as the instrument list or set exceeds the estimated parameters.

By and large, monetary policy is inflation stabilising in line with the policy stance of the BoZ, albeit small coefficient estimates. The BoZ pays attention to output as well. The GMM results are consistent with impulse response results reported earlier. Evidence of low response of monetary policy (base money) to output, inflation and exchange rate is also reported by Vdovichenko and Voronina (2004). The base money rule performs better than the interest rate rule in terms of statistical significance of the policy variables. The T-bill rate does not respond to movements in exchange rate volatility at all. Monetary policy tends to rely more on past rather than current and future information in adjusting instruments especially base money. The decision to intervene in the foreign exchange market tends to be driven largely by exchange rate volatility considerations. In addition, foreign exchange purchases and sales exhibit asymmetric response to policy variables. The coefficient estimates on nominal and real measures of exchange rate volatility are similar in magnitude across all alternative measures. In addition, coefficient estimates on the GARCH-PCA measure are comparable to the trade-weighted measure in terms of sign, size and statistical significance (see coefficients in {} brackets below p-values)[146].

A detailed analysis for each policy rule result follows.

Base Money Rule

The coefficients on lagged base money term ($\alpha_{1,t-1}$ and $\alpha_{1,t-2}$) are negative and highly statistically significant predominantly at 1 percent level similar to Tagaki (1991) for the Bank of Japan and Vdovichenko and Voronina (2004) for the Bank of Russia (see tables 5.5-5.9). This suggests that the BoZ routinely corrects base money deviations from target in order to keep it on the desired path in line with the monetary policy framework[147]. Similarly, the coefficient on lead base money ($\alpha_{1,t+1}$) in tables 5.5 and 5.9 is negative and highly statistically significant, suggesting that monetary policy action leads anticipated inflation and output gaps as well as movements in exchange rate volatility in time.

---

[146] The estimated coefficients on conditional exchange rate volatility are made comparable across alternative measures by multiplying each coefficient by the corresponding standard deviation of the exchange rate volatility measure (i.e. $EGKUSD$ = 0.010, $EGRKUSD$ = 0.006, $EGNEER$ = 0.003, $EGREER$ = 0.003, $PCAN$ = 2.778 and $PCAR$ = 2.779). For instance in table 5.6 seventh row and second column corresponding to $\delta_{nkus\$}$, the value of 0.008 (re-scaled coefficient) is obtained by multiplying the coefficient 0.772 by the standard error 0.010. The re-scaled coefficients are reported in {} brackets below p-values.

[147] Deviations constitute errors which are observed with a lag due to data unavailability, measurement errors and frequent data revisions.

Under the base money rule, monetary policy focuses on both inflation and output stabilisation similar to Clarida et al. (1998). The coefficient estimate on inflation gap (ϕ) is negative, implying monetary contraction when inflation exceeds the target. In the baseline specification (table 5.5), the fall in nominal (real) base money when inflation gap increases by 1 percent ranges from 0.2 to 1.1 percent (1.2 to 2.5 percent). In the augmented specifications, it ranges from 0.3 to 2.1 percent (1.3 to 3.1 percent) under the contemporaneous setting (see table 5.6), 0.6 to 1.4 percent (1.6 to 2.4 percent) in the forward-looking specification with lead base money (table 5.9) and averages about 0.6 percent (1.6 percent) in the backward-looking specification (table 5.7)[148]. The fall in real base money by more than proportionate for a 1 percent increase in inflation gap demonstrates the ability of the central bank to stabilise inflation as real money balances matter for inflation control.

The coefficient estimate on output gap (γ) is consistently positive and statistically significant mostly at 1 percent level under both baseline and augmented specifications suggesting that the BoZ accommodates output fluctuations around trend.

The statistical significance of the inflation gap is more sensitive to alternative measures of exchange rate volatility than output gap. Output gap is statistically significant across all alternative measures of exchange rate volatility except erv_{neer} and erv_{pcan} under forward-looking (lead inflation gap, table 5.8). Conversely, the ϕ coefficient is hardly statistically significant under the forward-looking with lead inflation gap (table 5.8), lagged and forward-looking policy instrument settings (table 5.9).

Movements in exchange rate volatility (δ) impose a strong positive influence (lean-with-the-wind) on base money changes similar to Vdovichenko and Voronina

[148] The reported coefficient estimates in the tables are transformed into percent by multiplying by 100 given the semi-log functional form specification.

(2004)[149]. Both the trade-weighted and GARCH-PCA in particular, real measures of exchange rate volatility perform better than the bilateral exchange rate volatility measure as the latter is statistically insignificant in the majority of equations. This underscores the importance of examining many measures of exchange rate volatility in order to obtain results that are robust to conditional volatility derived from different definitions of exchange rate.

Finally, the coefficient on the inflation gap under both baseline and augmented specifications is consistently statistically significant (at least at 5 percent level) under the backward-looking than contemporaneous and forward-looking policy settings. Additionally, output gap and exchange rate volatility enter significantly in the backward-looking policy setting. This suggests that past information is relevant for base money changes. Moreover, the sign on inflation gap in the forward-looking specification with lead inflation has a positive sign, thus contradicting the inflation stabilisation objective.

[149] Rotich et al. (2008) obtained a negative coefficient on exchange rate level and argued that the central bank of Kenya pursues a leaning-against-the-wind policy.

Table 5.5 GMM Results: Baseline Scenarios under Different Policy Settings

	(a)	(b)	(c)	(d)
	Δb_t	Δb_t	Δb_t	Δb_t
α_0	0.028* (2.74) [0.0068]	0.036* (7.43) [0.0000]	0.007 (0.70) [0.4847]	0.048* (4.45) [0.0000]
$\alpha_{1,t-1}$	-0.180** (-1.90) [0.0591]	-0.418* (-6.09) [0.0000]	-0.313* (-3.20) [0.0017]	-0.213* (-2.63) [0.0094]
$\alpha_{1,t-2}$				
$\alpha_{1,t+1}$				-0.537 (-3.54) [0.0005]
γ	0.572* (3.15) [0.0020]	0.219* (5.91) [0.0000]	0.566* (4.26) [0.0000]	0.491* (3.33) [0.0011]
ϕ	-0.002 (-0.16) [0.8726]	-0.005** (-1.93) [0.0551]		-0.011 (-1.21) [0.2299]
$\phi_{\pi_{t+1}}$			0.035* (3.04) [0.0027]	
S.E. of regression	0.117	0.084	0.117	0.101
Q-test: Q(5)	4.1477 [0.528]	5.3263 [0.377]	5.5006 [0.358]	10.166 [0.071]
J-stat	9.8 [0.75]	14.3 [0.42]	9.4 [0.80]	8.0 [0.89]
Real Δb_t (%)	-1.2	-2.5	1.5	-2.1

Sources: Eviews6

Instrument list: constant, six lags of $ygap$, π, erv_t and b_t. Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

(a), (b), (c) and (d) are empirical mirrors of equations 27, 28, 29 and 30

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.6 GMM Results: Contemporaneous y , π and erv (augmented scenario)

	Δb_t	Δb_t	Δb_t	Δb_t	Δb_t	Δb_t
α_0	0.031* (4.00) [0.0001]	0.029* (4.14) [0.0001]	0.035* (4.89) [0.0000]	0.031* (3.83) [0.0002]	0.045* (5.89) [0.0000]	0.042* (5.68) [0.0000]
$\alpha_{1,t-1}$	-0.327* (-3.36) [0.0010]	-0.271* (-3.01) [0.0031]	-0.064 (-0.98) [0.3270]	-0.167** (-1.96) [0.0515]	-0.110 (-1.60) [0.1123]	-0.114+ (-1.68) [0.0957]
$\alpha_{1,t-2}$	-0.207* (-3.17) [0.0018]	-0.196* (-3.33) [0.0011]		-0.187* (-2.82) [0.0054]		
γ	0.458* (4.37) [0.0000]	0.347* (3.82) [0.0002]	0.174* (1.95) [0.0525]	0.352* (2.84) [0.0051]	0.193* (2.24) [0.0263]	0.247* (2.73) [0.0071]
ϕ	-0.003 (-0.44) [0.6582]	-0.005 (-0.78) [0.4337]	-0.019* (-3.03) [0.0028]	-0.012+ (-1.72) [0.0883]	-0.021* (-3.28) [0.0013]	-0.017* (-2.77) [0.0063]
$\delta_{nkus\$}$	0.772* (2.72) [0.0072] {0.008}					
$\delta_{rkus\$}$		1.704* (3.95) [0.0001] {0.010}				
δ_{neer}			3.924* (2.74) [0.0068] {0.011}			
δ_{reer}				3.581* (2.43) [0.0164] {0.012}		
δ_{pcan}					0.003* (1.85) [0.0658] {0.008}	
δ_{pcar}						0.002* (1.76) [0.0799] {0.006}
D			-0.200* (-3.75) [0.0003]		-0.208* (-3.91) [0.0001]	-0.178* (-3.14) [0.0020]
S.E. of regression	0.108	0.102	0.115	0.106	0.116	0.113
Q-test: Q(5)	1.0481 [0.959]	2.7822 [0.734]	6.0645 [0.300]	5.2722 [0.384]	3.9112 [0.562]	4.1494 [0.528]
J-stat	8.1 [0.84]	9.7 [0.77]	15.8 [0.28]	11.3 [0.66]	14.7 [0.40]	14.2 [0.43]
Real Δb_t (%)	-1.3	-1.5	-2.9	-2.2	-3.1	-2.7

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π , erv_t and b_t . Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.7 GMM Results: Backward-Looking (Lagged y , π and erv)

	Δb_t	Δb_t	Δb_t	Δb_t	Δb_t	Δb_t
α_0	0.032* (6.70) [0.0000]	0.032* (6.48) [0.0000]	0.029* (5.62) [0.0000]	0.031* (5.92) [0.0000]	0.036* (7.41) [0.0000]	0.035* (7.36) [0.0000]
$\alpha_{1,t-1}$	-0.432* (-6.32) [0.0000]	-0.434* (-6.33) [0.0000]	-0.423* (-6.27) [0.0000]	-0.419* (-6.18) [0.0000]	-0.428* (-6.30) [0.0000]	-0.430* (-6.32) [0.0000]
γ	0.190* (5.28) [0.0000]	0.190* (5.29) [0.0000]	0.175* (4.99) [0.0000]	0.180* (4.97) [0.0000]	0.181* (5.11) [0.0000]	0.175* (4.97) [0.0000]
ϕ	-0.006** (-2.05) [0.0423]	-0.006** (-2.05) [0.0417]	-0.007* (-2.38) [0.0186]	-0.007* (-2.55) [0.0118]	-0.006** (-2.23) [0.0272]	-0.007** (-2.34) [0.0205]
$\delta_{nkus\$}$	0.724* (4.61) [0.0000] {0.007}					
$\delta_{rkus\$}$		1.185* (3.81) [0.0002] {0.007}				
δ_{neer}			3.643* (3.38) [0.0000] {0.010}			
δ_{reer}				3.232** (2.78) [0.0061] {0.011}		
δ_{pcan}					0.003* (3.55) [0.0005] {0.008}	
δ_{pcar}						0.003* (3.48) [0.0007] {0.008}
S.E. of regression	0.083	0.083	0.083	0.084	0.083	0.083
Q-test: Q(5)	6.5209 [0.259]	6.3734 [0.272]	6.4951 [0.261]	5.3842 [0.371]	6.3687 [0.272]	6.3026 [0.278]
J-stat	14.0 [0.45]	13.8 [0.45]	14.0 [0.45]	14.8 [0.39]	13.8 [0.45]	13.5 [0.48]
Real Δb_t (%)	-1.6	-1.6	-1.7	-1.7	-1.6	-1.7

Source: Eviews6. Instrument list: constant, six lags of $ygap$, π , erv_t and b_t . Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations. *,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.8 GMM Results: Contemporaneous y, erv and π_{t+1}

	Δb_t	Δb_t	Δb_t	Δb_t	Δb_t	Δb_t
α_0	0.027* (4.05) [0.0001]	0.019* (2.75) [0.0066]	0.025* (4.20) [0.0000]	0.016** (2.27) [0.0243]	0.035* (6.05) [0.0000]	0.017** (2.35) [0.0200]
$\alpha_{1,t-1}$	-0.440* (-4.82) [0.0000]	-0.355* (-4.31) [0.0000]	-0.230* (-2.95) [0.0037]	-0.200* (-2.90) [0.0042]	-0.250* (-3.20) [0.0017]	-0.277* (-3.81) [0.0002]
$\alpha_{1,t-2}$	-0.260* (-3.78) [0.0002]	-0.169* (-2.92) [0.0040]	-0.204* (-4.19) [0.0000]	-0.131* (-2.73) [0.0071]	-0.193* (-4.04) [0.0001]	-0.185* (-3.11) [0.0022]
γ	0.456* (4.11) [0.0001]	0.377* (4.31) [0.0000]	0.002 (0.03) [0.9780]	0.258* (2.79) [0.0060]	0.063 (0.70) [0.4829]	0.306* (3.85) [0.0002]
$\phi_{\pi_{t+1}}$	0.001 (0.23) [0.8153]	0.008 (1.27) [0.2045]	-0.010+ (-1.73) [0.0861]	0.005 (0.70) [0.4842]	-0.009+ (-1.62) [0.1071]	0.010 (1.39) [0.1657]
$\delta_{nkus\$}$	0.858* (3.00) [0.0032] {0.009}					
$\delta_{rkus\$}$		2.019** (3.01) [0.0031] {0.012}				
δ_{neer}			5.722** (4.70) [0.0000] {0.016}			
δ_{reer}				3.252** (2.17) [0.0313] {0.011}		
δ_{pcan}					0.006** (5.37) [0.0000] {0.017}	
δ_{pcar}						0.004** (2.79) [0.0059] {0.011}
S.E. of regression	0.106	0.100	0.091	0.096	0.091	0.098
Q-test: Q(1-5)	1.8095 [0.875]	2.3564 [0.798]	9.8757 [0.079]	9.5385 [0.089]	7.3431 [0.196]	5.8793 [0.318]
J-stat	11.2 [0.65]	10.9 [0.70]	17.6 [0.20]	13.6 [0.47]	17.6 [0.22]	11.2 [0.66]
Real Δb_t (%)	-0.9	-0.2	-2.0	-0.5	-1.9	0.0

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π, erv_t and b_t. Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.9 GMM Results: Lagged and Forward-Looking Policy Instrument with Contemporaneous y , erv and π

	Δb_t	Δb_t	Δb_t	Δb_t	Δb_t	Δb_t
α_0	0.038* (3.68) [0.0003]	0.043* (5.82) [0.0000]	0.035* (4.39) [0.0000]	0.042* (4.76) [0.0000]	0.042* (5.34) [0.0000]	0.043* (6.58) [0.0000]
$\alpha_{1,t-1}$	-0.333* (-3.41) [0.0008]	-0.141** (-2.09) [0.0383]	-0.231* (-2.74) [0.0070]	-0.064 (-0.95) [0.3436]	-0.274* (-3.38) [0.0009]	-0.080 (-1.14) [0.2557]
$\alpha_{1,t-2}$	-0.267* (-3.55) [0.0005]		-0.237* (-3.18) [0.0018]		-0.225* (-3.18) [0.0018]	
$\alpha_{1,t+1}$	-0.358* (-2.68) [0.0081]	-0.526* (-4.86) [0.0000]	-0.447* (-3.93) [0.0001]	-0.540* (3.92) [0.0001]	-0.446* (-3.94) [0.0001]	-0.440* (-3.41) [0.0008]
γ	0.567* (4.44) [0.0000]	0.299* (3.50) [0.0006]	0.346* (3.29) [0.0012]	0.352* (3.20) [0.0017]	0.349* (3.45) [0.0007]	0.234* (2.86) [0.0048]
ϕ	-0.006 (-0.61) [0.5416]	-0.010 (-1.60) [0.1108]	-0.012+ (-1.62) [0.1066]	-0.014** (-1.99) [0.0483]	-0.009 (-1.22) [0.2239]	-0.011+ (-1.94) [0.0546]
$\delta_{nkus\$}$	0.632* (2.14) [0.0339] {0.006}					
$\delta_{rkus\$}$		1.359* (2.80) [0.0058] {0.008}				
δ_{neer}			3.808** (2.64) [0.0091] {0.011}			
δ_{reer}				2.926** (1.70) [0.0915] {0.010}		
δ_{pcan}					0.004** (3.20) [0.0017] {0.011}	
δ_{pcar}						0.003* (2.47) [0.0147] {0.008}
S.E. of regression	0.109	0.091	0.096	0.097	0.094	0.090
Q-test: Q(5)	6.5454 [0.257]	9.1584 [0.103]	4.2992 [0.507]	5.6465 [0.342]	6.8608 [0.231]	4.7901 [0.442]
J-stat	6.4 [0.93]	13.8 [0.47]	12.8 [0.53]	11.2 [0.54]	12.3 [0.57]	16.5 [0.28]
Real Δb_t (%)	-1.6	-2.0	-2.2	-2.4	-1.9	-2.1

Source: Eviews6. Instrument list: constant, six lags of $ygap$, π , erv_t and b_t . Number of observations: 161. t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.
*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Interest Rate Rule

According to the results in tables 5.10-5.14, coefficients on lagged ($\alpha_{1,t-1}$ and $\alpha_{1,t-2}$) and lead T-bill rate ($\alpha_{1,t+1}$) are positive (close to 1) and highly statistically significant at 1 percent level, suggesting instrument smoothing by the BoZ in line with the evidence in the literature (see Adam et al. 2005; and Eleftheriou et al. 2006). The significance of the lead T-bill rate coefficient implies that the BoZ anticipates inflationary pressures to increase in the next period and thus adjusts the interest rate accordingly.

While the coefficient on inflation gap (ϕ) is statistically significantly and positive in virtually all the specifications (except the forward-looking case with a lead T-bill rate which has a negative sign in tables 5.10 and 5.14) in line with the Taylor rule prediction, the magnitude of the estimated coefficient is small, less than unity, averaging about 0.3 percent[150]. This implies that the nominal T-bill rate does not raise sufficiently enough to induce a rise in the real interest rate so as to contain inflationary pressures when inflation gap increases by 1 percent. Instead the BoZ accommodates changes in inflation as real interest rates are negative and thus do not dampen inflationary pressures arising from increases in aggregate demand: monetary policy does not tighten enough when inflation exceeds the target.

The sign and statistical significance of the output gap coefficient (γ) vary across alternative measures of exchange rate volatility under contemporaneous (table 5.11) and backward-looking (table 5.12) specifications. The coefficient is statistically insignificant in the forward-looking specification with a lead T-bill rate (table 5.14).

The estimated coefficients on output and inflation gaps are only consistently correctly signed and statistically significant under the forward-looking specification

[150] Theory predicts a coefficient in excess of unity for monetary policy to be inflation stabilising otherwise it is deemed to be accommodative.

with lead inflation gap (table 5.13). Further, the coefficient on output gap is very large in magnitude, in excess of 4 percent on average, compared with other policy settings, suggesting cyclical movements in output (Hall and Nixon, 1997). Thus, monetary policy under the interest rate rule would have been both inflation and output accommodating with some weight placed on future inflation gap (unlike base money) had the BoZ conducted monetary policy according to the estimated modified Taylor rule.

There is no discernible relationship between the T-bill rate and movements in exchange rate volatility in all specifications. The coefficient on the latter (δ) is statistically insignificant irrespective of the measure employed. This suggests that exchange rate volatility plays no role in interest rate adjustments.

Table 5.10 GMM Results: Baseline Scenarios under Different Policy Settings

	(a)	(b)	(c)	(d)
	tbr_t	tbr_t	tbr_t	tbr_t
α_0	-0.025 (-0.11) [0.9107]	0.231 (1.11) [0.2681]	0.343 (1.48) [0.1415]	-0.075 (-0.50) [0.6157]
$\alpha_{1,t-1}$	1.414* (24.87) [0.0000]	1.475* (27.03) [0.0000]	1.499* (25.52) [0.0000]	0.356* (10.74) [0.0000]
$\alpha_{1,t-2}$	-0.415* (-7.03) [0.0000]	-0.485* (-8.95) [0.0000]	-0.521* (-8.46) [0.0000]	
$\alpha_{1,t+1}$				0.650* (18.33) [0.0000]
γ	1.035 (0.62) [0.5394]	1.182** (2.51) [0.0130]	5.415** (2.08) [0.0396]	-1.567 (-1.28) [0.2029]
ϕ	0.388** (2.52) [0.0129]	0.219* (3.15) [0.0019]		-0.326* (-3.33) [0.0011]
$\phi_{\pi_{t+1}}$			0.558* (2.93) [0.0039]	
S.E. of regression	2.369	2.271	2.396	1.528
Q-test: Q(5)	2.9743 [0.704]	1.7204 [0.886]	1.8760 [0.866]	2.0801 [0.838]
J-stat	11.3 [0.28]	8.1 [0.85]	6.3 [0.96]	9.2 [0.82]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π , erv_t and tbr_t . Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

(a), (b), (c) and (d) are empirical mirrors of equations 32, 33, 34 and 35

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.11 GMM Results: Contemporaneous y , π and erv

	tbr_t	tbr_t	tbr_t	tbr_t	tbr_t	tbr_t
α_0	-0.007 (-0.04) [0.9681]	-0.010 (-0.05) [0.9565]	-0.002 (-0.01) [0.9929]	0.026 (0.14) [0.8925]	-0.111 (-0.59) [0.5563]	-0.132 (-0.68) [0.4989]
$\alpha_{1,t-1}$	1.541* (30.56) [0.0000]	1.532* (29.73) [0.0000]	1.533* (30.84) [0.0000]	1.439* (28.49) [0.0000]	1.535* (30.30) [0.0000]	1.497* (28.72) [0.0000]
$\alpha_{1,t-2}$	-0.541* (-10.56) [0.0000]	-0.532* (-10.17) [0.0000]	-0.529* (-10.47) [0.0000]	-0.432* (-8.35) [0.0000]	-0.526* (-10.25) [0.0000]	-0.494* (-9.31) [0.0000]
γ	0.361 (0.304) [0.7618]	1.093 (0.79) [0.4289]	-1.977+ (-1.92) [0.0567]	-0.031 (-0.02) [0.9811]	-1.728+ (-1.70) [0.0910]	1.818 (1.21) [0.2274]
ϕ	0.346** (2.48) [0.0141]	0.359** (2.58) [0.0106]	0.097 (0.93) [0.3518]	0.226+ (1.94) [0.0546]	0.130 (1.24) [0.2151]	0.419* (3.13) [0.0021]
$\delta_{nkus\$}$	-1.841 (-0.33) [0.7419] {-0.019}					
$\delta_{rkus\$}$		-3.848 (-0.35) [0.7260] {-0.023}				
δ_{neer}			6.062 (0.205) [0.8375] {0.017}			
δ_{reer}				-14.017 (-0.44) [0.6586] {-0.046}		
δ_{pcan}					0.013 (0.45) [0.6564] {0.036}	
δ_{pcar}						-0.008 (-0.31) [0.7594] {-0.022}
S.E. of regression	2.373	2.371	2.357	2.397	2.378	2.394
Q-test: Q(5)	2.4541 [0.783]	2.2920 [0.807]	2.6396 [0.755]	2.556 [0.768]	2.2835 [0.809]	2.1160 [0.833]
J-stat	13.0 [0.48]	13.0 [0.52]	16.2 [0.29]	14.1 [0.43]	16.0 [0.30]	13.0 [0.52]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π , erv_t and tbr_t . Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.12 GMM Results: Lagged y , π and erv

	tbr_t	tbr_t	tbr_t	tbr_t	tbr_t	tbr_t
α_0	0.075 (0.48) [0.6296]	0.072 (0.47) [0.6362]	0.051 (0.30) [0.7651]	0.105 (0.60) [0.5496]	0.062 (0.35) [0.7294]	-0.002 (-0.01) [0.9901]
$\alpha_{1,t-1}$	1.649* (32.51) [0.0000]	1.643* (31.22) [0.0000]	1.563* (31.94) [0.0000]	1.496* (30.90) [0.0000]	1.545* (30.21) [0.0000]	1.639* (31.50) [0.0000]
$\alpha_{1,t-2}$	-0.649* (-12.61) [0.0000]	-0.643* (-12.13) [0.0000]	-0.566* (-11.47) [0.0000]	-0.495* (-10.13) [0.0000]	-0.544* (-10.66) [0.0000]	-0.636* (-12.21) [0.0000]
γ	-0.107 (-0.23) [0.8165]	0.012 (0.03) [0.9789]	0.678 (1.47) [0.1440]	0.776+ (1.72) [0.0870]	0.627 (1.35) [0.1780]	0.352 (0.74) [0.4628]
ϕ	0.165** (2.47) [0.0145]	0.157** (2.39) [0.0181]	0.204* (3.08) [0.0024]	0.214* (3.34) [0.0011]	0.215* (3.26) [0.0013]	0.202* (3.00) [0.0031]
$\delta_{nkus\$}$	3.596 (0.92) [0.3588] {0.036}					
$\delta_{rkus\$}$		6.047 (0.84) [0.4050] {0.036}				
δ_{neer}			51.720 (1.22) [0.2238] {0.147}			
δ_{reer}				22.135 (0.63) [0.5309] {0.073}		
δ_{pcan}					0.044 (1.12) [0.2636] {0.122}	
δ_{pcar}						0.033 (1.07) [0.2883] {0.092}
S.E. of regression	2.355	2.353	2.321	2.334	2.331	2.363
Q-test: Q(5)	5.7708 [0.329]	5.5248 [0.355]	3.2513 [0.661]	1.6905 [0.890]	2.3874 [0.793]	4.8583 [0.433]
J-stat	13.0 [0.49]	13.3 [0.49]	11.3 [0.58]	12.3 [0.58]	12.3 [0.57]	12.2 [0.59]

Source: Eviews6. Instrument list: constant, six lags of $ygap$, π , erv_t and tbr_t. Number of observations: 161.
t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.
*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.13 GMM Results: Contemporaneous y , erv and π_{t+1}

	tbr_t	tbr_t	tbr_t	tbr_t	tbr_t	tbr_t
α_0	0.401** (2.28) [0.0273]	0.389** (2.07) [0.0400]	0.389** (2.13) [0.0347]	0.209 (0.98) [0.3288]	0.345+ (1.78) [0.0775]	0.276 (1.37) [0.1718]
$\alpha_{1,t-1}$	1.591* (30.13) [0.0000]	1.576* (29.39) [0.0000]	1.533* (30.89) [0.0000]	1.478* (28.56) [0.0000]	1.521* (29.96) [0.0000]	1.542* (30.30) [0.0000]
$\alpha_{1,t-2}$	-0.612* (-11.49) [0.0000]	-0.596* (-10.99) [0.0000]	-0.551* (-11.08) [0.0000]	-0.494* (-9.30) [0.0000]	-0.533* (-10.49) [0.0000]	-0.553* (-10.82) [0.0000]
γ	4.841** (2.32) [0.0219]	5.071** (2.22) [0.0279]	4.361** (2.34) [0.0206]	4.700** (2.30) [0.0227]	3.721** (1.97) [0.0507]	3.703+ (1.95) [0.0528]
$\phi_{\pi_{t+1}}$	0.378** (2.45) [0.0154]	0.395** (2.40) [0.0178]	0.326** (2.21) [0.0284]	0.585* (3.36) [0.0010]	0.283** (2.07) [0.0405]	0.337** (2.35) [0.0202]
$\delta_{nkus\$}$	4.982 (0.38) [0.7031] {0.050}					
$\delta_{rkus\$}$		5.780 (0.27) [0.7840] {0.035}				
δ_{neer}			19.194 (0.40) [0.6907] {0.055}			
δ_{reer}				6.323 (0.12) [0.9030] {0.021}		
δ_{pcan}					0.035 (0.62) [0.5380] {0.097}	
δ_{pcar}						0.059 (1.10) [0.2737] {0.164}
S.E. of regression	2.360	2.364	2.335	2.418	2.324	2.336
Q-test: Q(5)	3.2531 [0.661]	2.7581 [0.937]	2.2080 [0.820]	2.1617 [0.826]	2.0934 [0.836]	2.3794 [0.795]
J-stat	9.7 [0.75]	9.7 [0.76]	9.7 [0.74]	8.0 [0.89]	11.1 [0.68]	11.3 [0.63]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π , erv_t and tbr_t . Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.14 GMM Results: Lagged and Forward-Looking Policy Instrument with Contemporaneous y, erv and π

	tbr_t	tbr_t	tbr_t	tbr_t	tbr_t	tbr_t
α_0	-0.016 (-0.15) [0.8780]	-0.009 (-0.09) [0.9276]	-0.011 (-0.12) [0.9026]	-0.013 (-0.11) [0.9149]	0.071 (0.80) [0.4263]	0.100 (1.15) [0.2516]
$\alpha_{1,t-1}$	0.398* (14.68) [0.0000]	0.409* (15.71) [0.0000]	0.409* (16.23) [0.0000]	0.322* (10.49) [0.0000]	0.419* (16.91) [0.0000]	0.437* (18.97) [0.0000]
$\alpha_{1,t+1}$	0.602* (21.48) [0.0000]	0.592* (22.01) [0.0000]	0.590* (22.89) [0.0000]	0.678* (21.13) [0.0000]	0.579* (22.67) [0.0000]	0.562* (24.19) [0.0000]
γ	0.798 (1.19) [0.2375]	0.670 (0.96) [0.3392]	0.061 (0.10) [0.9221]	-0.053 (-0.06) [0.9487]	0.305 (0.45) [0.6555]	0.230 (0.31) [0.7540]
ϕ	-0.148** (-1.98) [0.0492]	-0.165** (-2.21) [0.0287]	-0.201* (-2.63) [0.0093]	-0.290* (-3.14) [0.0021]	-0.149** (-2.03) [0.0438]	-0.187** (-2.48) [0.0142]
$\delta_{nkus\$}$	5.220 (1.01) [0.3149] {0.053}					
$\delta_{rkus\$}$		8.709 (0.96) [0.3368] {0.053}				
δ_{neer}			50.25 (1.83) [0.0699] {0.143}			
δ_{reer}				14.513 (0.75) [0.4557] {0.048}		
δ_{pcan}					0.037 (1.61) [0.1101] {0.103}	
δ_{pcar}						0.017 (0.75) [0.4523] {0.047}
S.E. of regression	1.440	1.423	1.430	1.614	1.407	1.392
Q-test: Q(5)	5.2265 [0.389]	6.2203 [0.285]	5.2804 [0.383]	1.6936 [0.890]	7.0375 [0.218]	8.3682 [0.137]
J-stat	13.5 [0.48]	12.9 [0.53]	12.4 [0.56]	12.0 [0.60]	12.9 [0.53]	11.3 [0.61]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π, erv_t and tbr_t. Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Intervention Rule

As shown in tables 5.15-5.23, evidence of intervention persistence (clustering) is found as the coefficient on the lagged intervention value ($\alpha_{1,t-1}$ and $\alpha_{1,t-2}$) is positive and highly statistically significant at 1 percent level consistent with Kim and Sheen (2002), Kamil (2008) and Hassan (2009). Unlike in base money and the interest rate rules, the coefficient on lead intervention ($\alpha_{1,t+1}$) is not statistically significant in all the policy settings except in the baseline specification (table 5.15 - at 10 percent level) and in three and one out of eight cases in the augmented specifications in tables 5.19 and 5.23, respectively. Additionally, serial correlation in residuals is uniquely present in the fxp_t equations (see table 5.16 at 10 percent significance level and table 5.19 at 5 percent significance level), highlighting the potential problem associated with discontinuous intervention data.

Estimates of the intervention reaction function confirm evidence from previous studies such as Kim and Sheen (2002), Rogers and Siklos (2003) and Kamil (2008) that movements in exchange rate volatility induce the central bank to intervene in the foreign exchange market. More importantly, the conjecture of asymmetric response of purchases and sales to policy variables is empirically supported by the data similar to Kim and Sheen (2002) and Hassan (2009). Exchange rate volatility (δ) is positively related to foreign exchange purchases (tables 5.16-5.19) but negatively related to foreign exchange sales (tables 5.20-5.23) similar to the impulse response results. A rise in conditional volatility triggers more purchases than sales. Similarly, more purchases are conducted in response to an increase in inflation gap but reduce for a given increase in output gap. Conversely, sales tend to rise as output gap increases but decline with the increase in the inflation gap.

Foreign exchange purchases respond to deviations of inflation from target (marginally significant at 10 percent significance level) while deviation of output from trend matters for foreign exchange sales in the base line scenario (marginally significant at 5 percent level) in table 5.15. However, the statistical significance of both output and inflation gaps improves in the augmented specifications (tables 5.16-5.23), suggesting that exchange rate volatility significantly influences intervention decisions of the BoZ.

Similar to the base money rule, conditional volatility in the bilateral exchange rate is notably statistically insignificant in the majority of specifications compared with the trade-weighted and GARCH-PCA measures, suggesting that they do not play a statistically significant role in the intervention rule.

Table 5.15 GMM Results: Baseline Scenarios under Different Policy Settings

	(a)	(b)	(c)	(d)		(a)	(b)	(c)	(d)
	fxp_t	fxp_t	fxp_t	fxp_t		fxs_t	fxs_t	fxs_t	fxs_t
α_0	-0.024 (-0.04) [0.9659]	0.515 (1.08) [0.2824]	1.095+ (1.66) [0.0987]	2.438* (2.67) [0.0085]		3.231* (3.54) [0.0000]	3.343* (5.83) [0.0000]	3.454* (3.57) [0.0005]	2.313** (1.84) [0.0673]
$\alpha_{1,t-1}$	0.449* (6.98) [0.0000]	0.494* (8.01) [0.0000]	0.428* (8.01) [0.0000]	0.163+ (1.81) [0.0726]		0.299* (7.52) [0.0000]	0.327* (11.04) [0.0000]	0.333* (8.62) [0.0000]	0.340* (8.62) [0.0000]
$\alpha_{1,t-2}$	0.348* (6.06) [0.0000]	0.298* (5.16) [0.0000]	0.381* (7.84) [0.0000]	0.183** (2.29) [0.0232]					
$\alpha_{1,t+1}$				0.462* (2.91) [0.0042]					0.205+ (1.74) [0.0831]
γ	9.310 (0.71) [0.4776]	-1.082 (-0.24) [0.8128]	-10.543 (-0.96) [0.3366]	-26.115** (-2.04) [0.0427]		22.171+ (1.94) [0.0544]	-1.692 (0.61) [0.5456]	29.111** (2.30) [0.0230]	35.038* (2.61) [0.0099]
ϕ	1.380+ (1.62) [0.1062]	0.742** (1.99) [0.0485]		0.509 (0.48) [0.6341]		-0.313 (-0.37) [0.7086]	-0.628+ (-1.93) [0.0551]		-0.405 (-0.501) [0.6169]
$\phi_{\pi_{t+1}}$			0.218 (0.31) [0.7578]					-0.295 (-0.32) [0.7465]	
D				-33.712+ (-1.62) [0.1073]					
S.E. of regression	10.185	9.954	9.130	12.094		11.339	11.165	11.531	11.195
Q-test: Q(5)	6.5514 [0.256]	7.7088 [0.173]	4.6334 [0.462]	11.301 [0.046]		5.1648 [0.396]	3.9523 [0.556]	4.1898 [0.522]	5.4118 [0.368]
J-stat	15.7 [0.33]	15.9 [0.32]	12.9 [0.61]	9.7 [0.75]		10.7 [0.70]	9.7 [0.44]	9.7 [0.59]	8.1 [0.98]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π , erv_t and fxp_t / fxs_t . Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

(a), (b), (c) and (d) are empirical mirrors of equations 37, 38, 39 and 40

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.16 GMM Results: Contemporaneous y , π and erv

	fxp_t	fxp_t	fxp_t	fxp_t	fxp_t	fxp_t
α_0	-1.237** (-2.27) [0.0243]	-2.066** (-2.46) [0.0148]	-0.897 (-1.48) [0.1422]	-0.846 (-1.46) [0.1457]	1.794* (2.61) [0.0099]	0.633 (0.96) [0.3370]
$\alpha_{1,t-1}$	0.357* (5.43) [0.0000]	0.336* (5.04) [0.0000]	0.411* (7.23) [0.0000]	0.524* (8.65) [0.0000]	0.342* (6.04) [0.0000]	0.412* (7.22) [0.0000]
$\alpha_{1,t-2}$	0.182* (2.98) [0.0033]	0.274* (4.16) [0.0001]	0.288* (4.99) [0.0000]	0.209* (3.63) [0.0004]	0.350* (5.82) [0.0000]	0.286* (4.85) [0.0000]
γ	-12.327+ (-1.63) [0.1059]	-23.594** (2.30) [0.0226]	-26.600* (-3.11) [0.0022]	-22.278* (-2.89) [0.0044]	-29.237* (-3.13) [0.0021]	-29.577* (-3.12) [0.0022]
ϕ	2.547* (2.95) [0.0036]	2.177** (2.44) [0.0159]	1.309+ (1.73) [0.0851]	1.550** (2.27) [0.0245]	0.870 (1.14) [0.2545]	1.686** (2.05) [0.0423]
$\delta_{nkus\$}$	722.212* (4.82) [0.0000] {7.268}					
$\delta_{rkus\$}$		1455.263* (3.77) [0.0002] {8.774}				
δ_{neer}			1120.445* (3.53) [0.0005] {3.184}			
δ_{reer}				777.838* (2.68) [0.0081] {2.555}		
δ_{pcan}					1.862* (4.06) [0.0001] {5.173}	
δ_{pcar}						0.735* (4.04) [0.0001] {2.042}
S.E. of regression	12.250	12.833	10.568	10.612	10.891	10.658
Q-test: Q(5)	6.4475 [0.265]	4.0810 [0.538]	4.3658 [0.498]	10.070 [0.073]	1.4817 [0.915]	5.7440 [0.332]
J-stat	15.4 [0.34]	14.6 [0.39]	15.7 [0.32]	16.3 [0.29]	14.9 [0.38]	16.2 [0.30]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π , erv_t and fxp_t / fxs_t . Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.17 GMM Results: Lagged y, π and erv

	fxp_t	fxp_t	fxp_t	fxp_t	fxp_t	fxp_t
α_0	0.284 (0.65) [0.5139]	0.007 (0.01) [0.9846]	0.170 (0.36) [0.7165]	-0.153 (-0.34) [0.7367]	1.101** (2.21) [0.0285]	1.055** (2.09) [0.0379]
$\alpha_{1,t-1}$	0.430* (8.00) [0.0000]	0.429* (8.20) [0.0000]	0.466* (8.69) [0.0000]	0.517* (9.86) [0.0000]	0.473* (8.64) [0.0000]	0.513* (9.24) [0.0000]
$\alpha_{1,t-2}$	0.351* (6.83) [0.0000]	0.295* (5.44) [0.0000]	0.330* (6.21) [0.0000]	0.246* (4.68) [0.0000]	0.328* (6.06) [0.0000]	0.278* (5.00) [0.0000]
γ	-3.778 (-0.86) [0.3923]	-1.748 (-0.41) [0.6860]	-4.983 (-1.14) [0.2577]	-3.217 (-0.77) [0.4419]	-6.352 (-1.46) [0.1459]	-4.756 (-1.13) [0.2622]
ϕ	0.288 (0.85) [0.3945]	0.229 (0.74) [0.4629]	0.293 (0.90) [0.3681]	0.636 (2.01) [0.0463]	0.292 (0.89) [0.3743]	0.371 (1.17) [0.2450]
$\delta_{nkus\$}$	244.019** (2.28) [0.0242] {2.456}					
$\delta_{rkus\$}$		277.367* (4.16) [0.0001] {1.672}				
δ_{neer}			513.787* (2.79) [0.0059] {1.460}			
δ_{reer}				520.046* (2.73) [0.0070] {1.708}		
δ_{pcan}					0.568* (2.95) [0.0036] {1.578}	
δ_{pcar}						0.661* (2.78) [0.0061] {1.837}
D						
S.E. of regression	9.916	10.083	9.904	9.975	9.847	10.002
Q-test: Q(5)	4.7038 [0.453]	6.9955 [0.221]	5.6105 [0.346]	8.9062 [0.113]	6.0784 [0.299]	7.5791 [0.181]
J-stat	15.7 [0.32]	16.0 [0.30]	16.2 [0.28]	15.4 [0.34]	15.7 [0.33]	15.9 [0.31]

Source: Eviews6. Instrument list: constant, six lags of $ygap$, π, erv_t and fxp_t / fxs_t. Number of observations: 161. t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.18 GMM Results: Contemporaneous y, erv and π_{t+1}

	fxp_t	fxp_t	fxp_t	fxp_t	fxp_t	fxp_t
α_0	-1.084+ (-1.70) [0.0613]	-0.678 (-1.22) [0.2262]	-0.502 (-0.77) [0.4399]	-0.071 (-0.11) [0.9115]	0.299 (0.42) [0.6739]	1.205+ (1.74) [0.0841]
$\alpha_{1,t-1}$	0.783* (15.45) [0.0000]	0.516* (8.77) [0.0000]	0.436* (8.08) [0.0000]	0.412* (8.01) [0.0000]	0.453* (8.10) [0.0000]	0.385* (7.85) [0.0000]
$\alpha_{1,t-2}$		0.232* (4.26) [0.0000]	0.285* (5.45) [0.0000]	0.328* (6.76) [0.0000]	0.280* (5.25) [0.0000]	0.333* (6.76) [0.0000]
γ	-9.771 (-1.02) [0.3085]	11.291 (1.34) [0.1831]	-19.088+ (-1.89) [0.0608]	-19.938** (-2.49) [0.0140]	-16.392 (-1.55) [0.1234]	-24.137** (-2.61) [0.0100]
$\phi_{\pi_{t+1}}$	2.894* (3.64) [0.0004]	2.390* (3.67) [0.0010]	2.110* (3.32) [0.0011]	1.322** (2.23) [0.0272]	2.520* (4.12) [0.0001]	1.215+ (1.77) [0.0794]
$\delta_{nkus\$}$	402.774** (2.14) [0.0341] {4.053}					
$\delta_{rkus\$}$		92.650 (1.35) [0.1785] {0.559}				
δ_{neer}			587.776** (2.38) [0.0184] {1.670}			
δ_{reer}				541.129* (2.65) [0.0088] {1.778}		
δ_{pcan}					0.584** (2.22) [0.0278] {1.622}	
δ_{pcar}						0.601* (3.40) [0.0009] {1.670}
S.E. of regression	10.764	9.878	9.543	9.314	9.66	9.344
Q-test: Q(5)	9.6970 [0.084]	6.5722 [0.254]	3.8910 [0.565]	3.4747 [0.627]	4.1097 [0.534]	3.4481 [0.631]
J-stat	16.1 [0.59]	16.1 [0.60]	16.0 [0.63]	14.5 [0.62]	16.1 [0.58]	14.5 [0.59]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π, erv_t and fxp_t / fxs_t. Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.19 GMM Results: Lagged and Forward-Looking Policy Instrument with Contemporaneous y, erv and π

	fxp_t	fxp_t	fxp_t	fxp_t	fxp_t	fxp_t
α_0	-1.359** (-2.40) [0.0175]	0.557** (0.66) [0.5085]	-0.483 (-0.92) [0.3595]	-0.651 (-1.12) [0.2646]	1.272+ (1.79) [0.0756]	1.458** (2.23) [0.0275]
$\alpha_{1,t-1}$	0.290* (3.54) [0.0000]	0.642* (8.58) [0.0000]	0.301* (4.14) [0.0001]	0.298* (4.09) [0.0001]	0.353* (3.99) [0.0001]	0.312* (3.98) [0.0001]
$\alpha_{1,t-2}$	0.145** (2.55) [0.0118]	0.212* (2.67) [0.0080]	0.187* (3.18) [0.0018]	0.212* (3.36) [0.0010]	0.355* (6.05) [0.0000]	0.350* (6.15) [0.0000]
$\alpha_{1,t+1}$	0.202+ (1.70) [0.0916]	0.013 (0.07) [0.9463]	0.216** (2.06) [0.0409]	0.200+ (1.75) [0.0821]	0.022 (0.16) [0.8726]	0.088 (0.70) [0.4851]
$\alpha_{1,t+2}$		-0.023 (-0.17) [0.8673]				
γ	-18.628** (-2.14) [0.0336]	-16.189+ (-1.72) [0.0882]	-24.387* (-3.47) [0.0007]	-25.192* (-2.81) [0.0055]	-22.890* (-2.82) [0.0054]	-22.707* (-3.07) [0.0026]
ϕ	2.220** (2.12) [0.0354]	0.532 (0.52) [0.6007]	1.662** (2.16) [0.0321]	1.538** (2.07) [0.0399]	0.846 (1.28) [0.2033]	0.139 (0.22) [0.8243]
$erv_{nkus\$}$	767.636* (4.16) [0.0001] {7.725}					
$erv_{rkus\$}$		4.572 (0.04) [0.972] {0.028}				
δ_{neer}			572.787* (2.72) [0.0074] {1.628}			
δ_{reer}				670.844* (3.04) [0.0028] {2.204}		
δ_{pcan}					0.532+ (1.63) [0.1062] {1.478}	
δ_{pcar}						0.492** (2.44) [0.0157] {1.367}
S.E. of regression	11.488	9.506	9.364	9.402	9.283	9.021
Q-test: Q(5)	1.5045 [0.913]	7.4896 [0.187]	12.344 [0.030]	11.546 [0.042]	5.1000 [0.404]	5.5248 [0.355]
J-stat	14.5 [0.35]	14.5 [0.32]	16.1 [0.30]	16.1 [0.30]	15.2 [0.35]	14.3 [0.36]

Source: Eviews6. Instrument list: constant, six lags of $ygap$, π, erv_t and fxp_t / fxs_t. Number of observations: 161.
t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.
*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.20 GMM Results: Contemporaneous y , π and erv

	fxs_t	fxs_t	fxs_t	fxs_t	fxs_t	fxs_t
α_0	2.585* (3.62) [0.004]	3.341* (5.52) [0.0000]	3.311* (4.66) [0.0000]	2.574* (3.86) [0.0000]	2.511* (4.38) [0.0000]	2.762* (4.96) [0.0000]
$\alpha_{1,t-1}$	0.307* (9.16) [0.0000]	0.333* (12.15) [0.0000]	0.328* (11.23) [0.0000]	0.311* (9.12) [0.0000]	0.331* (12.13) [0.0000]	0.317* (11.32) [0.0000]
γ	24.595* (3.20) [0.0017]	-3.353 (-0.41) [0.6794]	12.492** (2.21) [0.0288]	20.849* (2.83) [0.0053]	11.516+ (1.95) [0.0532]	8.909 (1.18) [0.2396]
ϕ	0.023 (0.04) [0.9670]	-0.792+ (-1.85) [0.0659]	-0.530 (-1.09) [0.2777]	-0.030 (-0.04) [0.9644]	-0.141 (-0.35) [0.7268]	-0.297 (-0.79) [0.4323]
$\delta_{nkus\$}$	-51.188 (-1.49) [0.1394] {-0.515}					
$\delta_{rkus\$}$		-29.589 (-0.62) [0.5330] {-0.178}				
δ_{neer}			-150.137 (-1.21) [0.2274] {-0.427}			
δ_{reer}				-162.038+ (-1.78) [0.0763] {-0.532}		
δ_{pcan}					-0.119 (-0.90) [0.3719] {-0.331}	
δ_{pcar}						0.046 (0.22) [0.8295] {0.128}
D						
S.E. of regression	11.538	11.081	11.175	11.538	11.237	11.200
Q-test: Q(5)	4.7704 [0.445]	4.0509 [0.542]	4.6957 [0.454]	4.6703 [0.457]	4.3672 [0.498]	4.3795 [0.496]
J-stat	13.8 [0.47]	14.9 [0.38]	13.9 [0.44]	13.0 [0.52]	14.6 [0.38]	14.3 [0.42]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π , erv_t and fxp_t / fxs_t . Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.21 GMM Results: Lagged y , π and erv

	fxs_t	fxs_t	fxs_t	fxs_t	fxs_t	fxs_t
α_0	2.715* (5.47) [0.0000]	2.962* (6.07) [0.0000]	3.073* (5.88) [0.0000]	2.650* (5.35) [0.0000]	2.767* (5.94) [0.0000]	3.231* (6.12) [0.0000]
$\alpha_{1,t-1}$	0.313* (10.61) [0.0000]	0.350* (13.37) [0.0000]	0.323* (10.57) [0.0000]	0.277* (7.42) [0.0000]	0.321* (10.96) [0.0000]	0.336* (11.81) [0.0000]
γ	7.336* (3.73) [0.0003]	2.198 (1.02) [0.3090]	5.338** (2.10) [0.0370]	5.921** (2.44) [0.0157]	5.204** (2.31) [0.0220]	0.438 (0.18) [0.8542]
ϕ	-0.059** (-2.36) [0.0193]	-0.543** (-2.41) [0.0172]	-0.604** (-2.60) [0.0103]	-0.694* (-2.86) [0.0048]	-0.422** (-2.08) [0.0389]	-0.714* (-3.22) [0.0016]
$\delta_{nkus\$}$	-34.934* (-3.48) [0.0006] {-0.352}					
$\delta_{rkus\$}$		-45.933** (-2.10) [0.0376] {-0.277}				
δ_{neer}			-75.230 (-0.90) [0.3719] {-0.214}			
δ_{reer}				-130.900** (-2.29) [0.0232] {-0.430}		
δ_{pcan}					-0.113** (-1.97) [0.0503] {-0.314}	
δ_{pcar}						-0.083 (-0.95) [0.3448] {-0.231}
S.E. of regression	11.422	11.244	11.311	11.512	11.299	11.208
Q-test: Q(5)	3.5142 [0.621]	3.9640 [0.555]	3.7348 [0.588]	4.1345 [0.530]	3.6553 [0.600]	4.1175 [0.533]
J-stat	13.9 [0.45]	13.1 [0.51]	12.3 [0.59]	14.4 [0.41]	13.1 [0.51]	11.2 [0.67]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π , erv_t and fxp_t / fxs_t . Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.22 GMM Results: Contemporaneous y, erv and π_{t+1}

	fxs_t	fxs_t	fxs_t	fxs_t	fxs_t	fxs_t
α_0	3.792* (4.55) [0.0000]	3.754* (4.50) [0.0000]	4.382* (5.15) [0.0000]	3.322* (4.33) [0.0000]	3.600* (4.67) [0.0000]	3.253* (4.74) [0.0000]
$\alpha_{1,t-1}$	0.360* (11.21) [0.0000]	0.367* (11.78) [0.0000]	0.359* (11.33) [0.0000]	0.370* (13.19) [0.0000]	0.368* (11.44) [0.0000]	0.373* (13.16) [0.0000]
γ	27.548* (3.50) [0.0006]	24.651* (2.90) [0.0043]	22.304* (2.65) [0.0088]	24.713** (2.60) [0.0103]	26.307* (2.82) [0.0054]	20.098** (2.09) [0.0387]
$\phi_{\pi_{t+1}}$	-0.858 (-1.43) [0.1543]	-0.817 (-1.42) [0.1590]	-0.740 (-1.18) [0.2409]	-0.116 (-0.15) [0.8780]	-0.676 (-1.11) [0.2684]	-0.462 (-0.73) [0.4650]
$\delta_{nkus\$}$	-74.698** (-2.50) [0.0133] {-0.752}					
$\delta_{rkus\$}$		-98.324 (-1.56) [0.1212] {-0.593}				
δ_{neer}			-350.203** (-2.50) [0.0134] {-0.995}			
δ_{reer}				-268.450* (-2.65) [0.0089] {-0.882}		
δ_{pcan}					-0.337** (-2.57) [0.011] {-0.936}	
δ_{pcar}						-0.197 (-1.24) [0.2163] {-0.548}
S.E. of regression	11.506	11.415	11.369	11.554	11.454	11.302
Q-test: Q(5)	3.7558 [0.585]	3.8739 [0.568]	4.2222 [0.518]	3.9719 [0.553]	3.9195 [0.561]	4.2755 [0.510]
J-stat	11.3 [0.59]	12.9 [0.63]	11.3 [0.60]	11.3 [0.62]	11.3 [0.61]	12.9 [0.63]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π, erv_t and fxp_t / fxs_t. Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

Table 5.23 GMM Results: Lagged and Forward-Looking Policy Instrument with Contemporaneous y, erv and π

	fxs_t	fxs_t	fxs_t	fxs_t	fxs_t	fxs_t
α_0	3.024** (2.61) [0.0100]	2.742** (2.20) [0.0294]	4.829* (3.87) [0.0002]	3.378* (3.04) [0.0028]	3.531* (3.08) [0.0024]	2.404** (2.48) [0.0141]
$\alpha_{1,t-1}$	0.369* (11.57) [0.0000]	0.372* (11.79) [0.0000]	0.356* (10.11) [0.0000]	0.379* (14.20) [0.0000]	0.369* (10.99) [0.0000]	0.365* (12.64) [0.0000]
$\alpha_{1,t+1}$	0.113 (1.02) [0.3082]	0.151 (1.31) [0.1922]	-0.021 (-0.19) [0.8465]	0.021 (0.22) [0.8282]	0.022 (0.20) [0.8451]	0.157+ (1.63) [0.1045]
γ	34.096* (4.01) [0.0001]	35.387* (3.77) [0.0002]	25.672* (3.03) [0.0029]	24.313* (3.08) [0.0025]	29.824* (3.13) [0.0021]	24.861* (2.64) [0.0092]
ϕ	-0.744 (-1.25) [0.2126]	-0.678 (-1.10) [0.2752]	-0.902 (-1.31) [0.1932]	-0.344 (-0.53) [0.5970]	-0.704 (-1.07) [0.2859]	-0.340 (-0.61) [0.5413]
$\delta_{nkus\$}$	-74.745** (-2.43) [0.0162] {-0.752}					
$\delta_{rkus\$}$		-102.821 (-1.44) [0.1506] {-0.620}				
δ_{neer}			-430.299** (-2.55) [0.0118] {-1.223}			
δ_{reer}				-283.459** (-2.13) [0.0351] {-0.931}		
δ_{pcan}					-0.356** (-2.34) [0.0205] {-0.989}	
δ_{pcar}						-0.080 (-0.41) [0.6813] {-0.222}
S.E. of regression	11.355	11.323	11.529	11.475	11.465	10.952
Q-test: Q(5)	4.0842 [0.537]	4.9537 [0.422]	4.9984 [0.416]	4.1010 [0.535]	3.9883 [0.551]	6.2405 [0.284]
J-stat	9.7 [0.93]	11.3 [0.91]	11.3 [0.91]	11.3 [0.91]	11.3 [0.90]	11.3 [0.88]

Source: Eviews6

Instrument list: constant, six lags of $ygap$, π, erv_t and fxp_t / fxs_t. Number of observations: 161.

t-statistics are reported in parenthesis while p-values are in square brackets. Q-test is the test for presence of serial correlation. The optimal lag length (k) of 4 for the Q-test statistic is chosen according to Tsay (2002): k=ln(T), where T is the number of observations.

*,**,+ refer to statistical significance at 1% (2.58), 5% (1.96) and 10% (1.65), respectively: critical values in parenthesis.

5.5 Conclusion

Monetary policy and foreign exchange intervention reaction functions for Zambia were estimated over the period 1995-2008 using monthly data. Modified McCallum and Taylor rules were estimated as monetary policy rules while a version of Edison's (1993) foreign exchange intervention reaction function was employed to determine the extent to which the BoZ takes into account, in its policy decisions, output and inflation deviations from trend and target, respectively, as well as changes in exchange rate volatility.

The thrust of the chapter was to determine the importance of exchange rate volatility in particular the GARCH-PCA alternative measure which has not been employed in empirical work thus far in the two policy reaction functions. In addition, the extent of coordination between monetary and foreign exchange rate polices was considered by controlling for the same factors in the two reaction functions. Furthermore, different policy specifications under which the policy instrument is adjusted (past, current or future information on output gap, inflation gap and movements in exchange rate volatility) were examined. Finally, two estimation techniques; namely SVAR and GMM, were employed to ensure validity of results as the two treat the interaction of policy instruments and goals differently.

The SVAR model and GMM approach provide consistent results. The results reveal that monetary policy is inflation stabilising in line with the announced policy stance. In addition, monetary policy accommodates output fluctuations around trend while exchange rate volatility is an essential factor in monetary policy and foreign exchange intervention decision process. Monetary policy tends to rely more on past information in adjusting operating policy instruments. Further, the performance of the GARCH-PCA measure is comparable to trade weighted measure in terms of sign, size and statistical significance of the estimated coefficients. The coefficient size and statistical significance for both real and nominal versions of each exchange rate volatility measure is similar. Both monetary policy and foreign exchange intervention rules respond to the same factors: output and inflation gaps as well as movements in exchange rate volatility, suggesting complementarity between the two policies. With respect to foreign exchange intervention decisions, evidence of central bank reacting asymmetrically to changes in policy goals is found. The results in chapter 3 suggesting asymmetric response of kwacha bilateral exchange rates to price shocks are re-enforced by the SVAR and GMM results that reveal asymmetric intervention behavior by the central bank.

Some policy lessons can be drawn from these results. There is scope for the BoZ to enhance its inflation control objective. Notwithstanding the shortcomings of the monetary targeting framework highlighted by Svensson (1999), base money can effectively improve the achievement of the inflation objective. More tightening of base money is required when inflationary pressures are projected. While the results indicate that the BoZ attempts to keep base money on the desired path, it is imperative to comprehensively review how the desired path is derived in relation to inflation *inter alia* underlying assumptions and factors inhibiting the central bank from consistently keeping base money on the desired path. Data on base money target/projection were not available to determine the extent of deviations of actual base money from target. Finally, it is appropriate to use volatility in a basket of currencies for policy instrument adjustment as the bilateral exchange rate measure tends to play a statistically insignificant role in the majority of the policy reaction function equations estimated.

Chapter 6 CONCLUSION

6.1 Introduction

The interrelationships between exchange rate volatility and selected macroeconomic variables were analysed over the period 1964-2008. The effect of exchange rate volatility analysis was restricted to trade, monetary policy and foreign exchange intervention given the broad nature of the subject. This analysis was preceded by the modelling of kwacha exchange rates and a brief review of the main macroeconomic policies undertaken in Zambia since independence in 1964.

6.2 Summary of Findings

Firstly, three alternative GARCH models (GARCH (1, 1), TGARCH (1, 1) and EGARCH (1, 1)) were employed in modelling exchange rate volatility in Zambia over the period 1964.01-2006.12. Eight kwacha bilateral exchange rates of Zambia's main trading partner currencies in addition to the trade-weighted exchange rates both real and nominal were examined. The influence of exchange rate regime, monetary and real factors on conditional volatility was also investigated.

The results revealed that virtually all exchange rates are described by the EGARCH (1, 1) process. This underscores the importance of examining alternative GARCH model specifications as opposed to imposing a uniform GARCH model specification without testing the appropriateness of alternative models when a large sample of currencies is involved. Further, kwacha exchange rates are characterised by different conditional volatility dynamics. Some exchange rates exhibit higher conditional volatility persistence than others. Volatility in kwacha exchange rates responds asymmetrically to shocks with the majority of exchange rates revealing negative conditional volatility response to price shocks. This result is particularly important for central bank foreign exchange operations. It suggests that the central bank is likely to respond asymmetrically to exchange rate shocks by intervening directly in the foreign exchange market depending on the nature of price shocks affecting the exchange rate of policy concern. The zim$ exhibits special features in conditional volatility that are not common to conditional volatility in exchange rates involving other currencies. This highlights the feature of an outlier currency that must be considered in policy decisions.

The positive influence of exchange rate regime, money supply and openness on conditional volatility predominates. This signifies the important role of monetary and trade policies in exchange rate management.

Principal components analysis was used to generate a new GARCH series (GARCH-PCA) capturing the common underlying pattern in the estimated conditional volatility from the three GARCH models. GARCH-PCA, *an index of exchange rate volatility*, reflecting influences from Zambia, mimics the pattern in the original exchange rate series. Thus GARCH-PCA was subsequently used in trade and monetary and foreign exchange intervention rules analysis as an alternative measure of exchange rate uncertainty. The results demonstrate its appropriateness as an alternative measure of exchange rate volatility.

Secondly, the exchange rate volatility-trade link was analysed by estimating import and export demand equations for Zambia over the period 1980.01-2007.12 with emphasis on exchange rate volatility as one of the key determinants. To ensure robustness of results, two cointegration tests; namely the Johansen (1988) method and the ARDL proposed by Pesaran et al. (2001) as well as the error-correction model were used to examine the underlying long-run equilibrium between trade flows and their determinants. Alternative measures of exchange rate volatility for real and nominal bilateral and trade-weighted exchange rates generated from GARCH models were used in the empirical model in line with McKenzie (1999). Additionally, a GARCH-PCA measure which has not been used in the literature was employed as an alternative measure of exchange rate risk. In line with theory and recent trends in the literature, individual export commodities were analysed in addition to aggregate exports and imports. Total import and export demand equations were estimated to serve as a benchmark against which specific individual commodity effects could be evaluated despite the aggregation bias associated with them.

A stable long-run equilibrium relationship between trade flows and income, relative price and exchange rate volatility was found. Volatility in kwacha exchange rates tends to reduce the value of both total imports and exports. While individual export commodities exhibit varied sensitivity to exchange rate volatility across alternative measures employed, by and large, the value of individual export commodities increases, suggesting that exporters of these commodities are not necessarily deterred by exchange rate fluctuations. Hence, the positive influence of exchange rate volatility on some exports should, all else being equal, improve the trade balance. In addition, the varied response of individual exports underscores the importance of disaggregating trade data which has been lacking in Zambia thus far.

Furthermore, exchange rate volatility tends to matter most in the long-run while in the short-run, some trade flows especially aggregate imports and exports are insensitive to exchange rate volatility. The GARCH-PCA measure performs reasonably well compared with other measures of exchange rate volatility employed and thus provides a useful alternative measure in trade analysis. The sign of the coefficient is broadly consistent with other measures and the extent of statistical significance is comparable. It also exhibits a more stable cointegrating relationship than other measures.

Thus, the results suggest that exchange rate volatility forms an essential part of exchange rate and trade policy formulation and implementation as volatility in exchange rates has the potential to influence the allocation of resources between tradeable and non-tradeable sectors in Zambia.

Finally, monetary policy and foreign exchange intervention reaction functions were examined over the period 1995-2008 using monthly data. Modified McCallum (1988) and Taylor (1993) rules were estimated as monetary policy rules while a version of Edison's (1993) foreign exchange intervention reaction function was employed. Both reaction functions were examined under three policy settings (past, current and future) to determine the type of information used to adjust policy instruments. In both reaction function specifications, identical control factors; namely output gap, inflation gap and exchange rate volatility were used in order to determine the extent of coordination between monetary and foreign exchange rate policies. The importance of exchange rate volatility in these policy decisions was the main focus of the study. In view of this, an alternative measure of exchange rate volatility, GARCH-PCA, was employed in addition to the trade-weighted and bilateral kwacha/US dollar exchange rate volatility derived from GARCH models. The GARCH-PCA has not been employed in empirical work in policy reaction functions thus far.

SVAR and GMM were used to ensure validity of results as the two methods treat the interaction of policy instruments and goals differently. Not only does the analysis consider interaction among the macroeconomic variables traditionally studied in the monetary reaction functions, but it extends the SVAR specification to incorporate foreign exchange intervention data split into purchases and sales to allow for the possibility of central bank asymmetric response to changes in policy goal variables.

Monetary policy in Zambia is found to be inflation stabilising in line with the announced policy stance, albeit not sufficient. In addition, monetary policy accommodates output fluctuations around trend while exchange rate volatility is an essential factor in both monetary policy and foreign exchange intervention decision-making process. Monetary policy tends to be backward-looking and is best characterised by base money rather than the presumed interest rate rule. The central bank considers output deviations from trend, inflation gap and movements in exchange rate volatility in making both monetary policy and foreign exchange intervention decisions. This suggests complementarity between the two policies. The central bank interventions (purchases and sales) react asymmetrically to changes in policy goals. Further, similar to trade analysis results, the performance of GARCH-PCA measure is comparable to the trade-weighted measure in terms of sign, size and statistical significance, and thus proves to be a valuable alternative measure of exchange rate volatility.

6.3 Contributions of the Thesis

The thesis makes an empirical contribution to the literature on exchange rate volatility and the effects it imposes on the economy. As the scope of the subject is broad, the thesis has focused on three areas: modelling of volatility in kwacha bilateral exchange rates and assessment of the estimated conditional volatility on trade and its relevance in monetary policy and foreign exchange intervention rules. Besides studying Zambia where empirical work on this subject is very limited and having used high frequency data (at monthly interval) over a relatively longer sample period (1964-2008) compared with previous studies on Zambia, the thesis makes the following specific contributions highlighted in chapters 3, 4 and 5:

(a) In modelling exchange rate volatility, a relatively large sample of foreign currencies (eight) involving Zambia's main trading partners is analysed. Most previous studies focus on a single bilateral exchange rate or very limited number (two or three) of bilateral exchange rates or the trade-weighted exchange rate index. This approach allows for the identification of the dynamic volatility structure embedded in each exchange rate[151]. As the results show, the eight bilateral exchange rates exhibit different conditional variance dynamics. It is also established that the kwacha exchange rates responds asymmetrically to shocks with the majority of exchange rates revealing negative conditional volatility response to price shocks. This result suggests that the central bank is likely to intervene asymmetrically in the foreign exchange market depending on the nature of price shocks affecting exchange rate(s) of policy concern. Further, an outlier currency, zim$, is identified whose conditional volatility is unrelated to conditional volatility present in other Zambia's trade partner currencies. This underscores the relevance of outlier currencies in policy decisions. Finally, PCA was conducted on the estimated conditional variance from the three GARCH models in order to identify the underlying common variance structure in the kwacha bilateral exchange rates. This kind of analysis has not been conducted in previous empirical work in the literature to the knowledge of the author. The constructed GARCH-PCA series, *an index of exchange rate volatility*, attributed to influences from Zambia, mimics the original conditional variance series for

[151] Volatility dynamics in bilateral exchange rates are not directly observable in a trade-weighted exchange rate index as the full characteristic features of each exchange rate are concealed in the index.

individual bilateral exchange rates and proves to be a constructive alternative measure of exchange rate volatility or risk in subsequent empirical estimations in trade and policy rule (monetary policy and foreign exchange intervention) analysis.

(b) With respect to trade flow analysis, in line with Mckenzie (1999), disaggregated export trade data involving 12 commodities are used in the export demand equation, the first study ever to conduct this analysis on Zambia. The results obtained from the two cointegrating methods (uncommon in the literature) with different methodological procedures and data treatment unambiguously confirm the negative effect of exchange rate volatility on aggregate trade data. This is against the background of seemingly contradictory results obtained from previous studies on Zambia. In line with theoretical arguments, the 12 export commodities exhibit different sensitivity to changes in exchange rate volatility although positive responses dominate and this thus justifies the use of sectoral or firm level data which unmask different responses to exchange rate risk not evident in aggregated trade series. As pointed out in (a) above, the application of GARCH-PCA series in trade analysis proves to be a useful measure and highly comparable to existing measures. Moreover, it yields a more stable relationship in cointegration analysis compared with the other measures employed.

(c) The conventional specification of the SVAR model in monetary policy reaction function analysis is to include output gap, inflation gap, and in the extended version, the level of exchange rate as policy goals. The thesis modifies the specification to incorporate a measure of exchange rate volatility that includes

GARCH-PCA instead of the level of the exchange rate as volatility matters for monetary policy and intervention purpose as explained earlier. In addition, foreign exchange intervention is included in the specification to determine the interaction between the two policies: whether parameter decisions are similar in monetary and foreign exchange policies. Further, foreign exchange intervention is split into purchases and sales to allow for the possibility of central bank asymmetric response to changes in policy variables. Similarly, the GMM specification includes the same policy variables in both monetary and foreign intervention reaction functions as those in the SVAR specification. The two estimation techniques yield non-conflicting results, reveal complementarity between the two policies and confirm the importance of exchange rate volatility in monetary policy and foreign exchange intervention reaction functions.

6.4 Suggestions for Further Research

To strenghthen the results, the following areas in chapters 3, 4 and 5 are suggested for further research.

6.4.1 Chapter 3

Firtsly, to fully characterise volatility in exchange rates, future studies could consider detecting the presence of structural breaks (relating to policy reforms and other relevant change such as changes to the foreign exchange trading system) in the volatility series and if found, incorporate them in the model specification, as ignoring them could lead to unstable GARCH processes in exchange rates.

Secondly, build a model that takes into account the asymmetric effect of changes in fundamental variables specified in both the conditional mean and variance equations.

Finally, given the prominent role of (raw) export commodities in the economies of most developing countries, the influence of commodity prices (i.e. copper price in Zambia) on exchange rate volatility should be explored.

6.4.2 Chapter 4

Further, more firm level export data and yet to be explored individual import commodities should be examined subject to data availability in order to reach a balanced conclusion regarding the relevance of exchange rate volatility in trade. The results should be compared with the level of the exchange rate effect which most agents engaged in trade tend to base their decisions on as it is observed directly on a day-to-day basis.

6.4.3 Chapter 5

As noted earlier that the parameters for central bank intervention in the foreign exchange market are not explicitly stated, it is imperative to consider the level of the exchange rate as an alternative or possible trigger for intervention in both monetary and intervention rules examined. This is against the background that most central banks tend to react to the deviation of the level of the exchange rate from a particular target as highlighted in the literature.

References

Adam, C. (1995) ‘Financial Liberalisation and Currency Demand in Zambia’, *Journal of African Economies,* 8(3): 268-306.

Adam, C., D. Cobham and E. Girardin (2005) ‘Monetary Frameworks and Institutional Constraints: UK Monetary Policy Reaction Functions, 1985-2003’, *Oxford Bulletin of Economics and Statistics*, 67(4): 497-516.

Aghion, P., P. Bacchetta, R. Ranciere and K. Rogoff (2009) ‘Exchange Rate Volatility and Productivity Growth: The Role of Financial Development’, Journal of Monetary Economics, 56: 494-513.

Akhtar, M. A. and R. Spence-Hilton (1984) ‘Effects of Exchange Rate Uncertainty on German and U.S. Trade’, *Quarterly Review* (Federal Reserve Bank of New York, Spring): 7-16.

Almekinders, G. and S. Eijffinger (1994) ‘Daily Bundesbank and Federal Reserve Intervention – Are They A Reaction to Changes in the Level and Volatility of the DM/$ Rate?’ *Empirical Economics*, 19: 111–130.

Almekinders, G. and S. Eijffinger (1996) ‘A Friction Model of Daily Bundesbank and Federal Reserve Intervention’, *Journal of Banking and Finance*, 20: 1365–1380.

Andersson, P. and B. Sjöö (2000) ‘Controlling Inflation During Structural Adjustment: The Case of Zambia’, *Harvard University Development Discussion Paper No.754.*

Ardalani, Z. and M. Bahmani-Oskooee (2006) ‘Exchange Rate Sensitivity of U.S. Trade Flows: Evidence from Industry Data’, *Southern Economic Journal*, 72(3): 542-559.

Aristotelous, K. (2001) ‘Exchange-Rate Volatility, Exchange-Rate Regime and Trade Volume: Evidence from the UK-US Export Function (1889-1999)’, *Economic Letters*, 72: 87-94.

Arize, A., T. Osang and J. D. Slottje (2000) ‘Exchange-Rate Volatility and Foreign Trade: Evidence from Thirteen LDCs’, *Journal of Business and Economic Statistics*, 18(1): 10-17.

Arize, A., T. Osang and J. D. Slottje (2008) ‘Exchange-Rate Volatility in Latin America and its Impact on Foreign Trade’, *International Review of Economics and Finance*, 17: 33-44.

Aron, J. and J. Muellbauer (2000) ‘Estimating Monetary Policy Rules for South Africa’, *Central Bank of Chile Working Papers No.89*, December.

Asseery, A. and D. Peel (1991) ‘The Effects of Exchange Rate Volatility on Exports’, *Economic Letters*, 37: 173-177.

Asso, P., G. A. Khan and R. Leeson (2007) 'The Taylor Rule and the Transformation of Monetary Policy', *The Federal Reserve Bank of Kansas City Economic Research Department, research Working Papers, RWP 07-11*.

Asteriou, D. and S. G. Hall (2007) *Applied Econometrics: A Modern Approach*, New York: Palgrave Macmillan.

Astley, M. and A. Garrat (1996) 'Interpreting Sterling Exchange Rate Movements' *Banl of England Quarterly Bulletin*, 36: 394-404.

Baak, S. J., M. A. Al-Mahmood and S. Vixathep (2007) 'Exchange Rate Volatility and Exports from East Asian Countries to Japan and the USA', *Applied Economics,* 39: 947-959.

Bah, I. and H. A. Amusa (2003) 'Real Exchange Rate Volatility and Foreign Trade: Evidence from South Africa's Exports to the United States', *The African Finance Journal*, 5, Part 2.

Bahmani-Oskooee, M. and G. G. Goswami (2004) 'Exchange Rate Sensitivity of Japan's Bilateral Trade Flows', *Japan and the World Economy*, 16: 1-15.

Bahmani-Oskooee, M. and S. W. Hegerty (2008) 'Exchange-rate Risk and U.S.-Japan Trade: Evidence from Industry Level Data', *Journal of The Japanese and International Economies*, 22: 518-534.

Bahmani-Oskooee, M. and S. W. Hegerty (2009) 'The Effects of Exchange-rate Volatility on Commodity Trade between the United States and Mexico', *Southern Economic Journal*, 75(4): 1019-1044.

Bailey, M., G. Tavlas and M. Ulan (1986) 'Exchange-rate Variability and Trade Performance: Evidence from the Big Seven Industrial Countries', *Weltwirtsch. Arch.* 122: 466-477.

Bailey, M., G. Tavlas and M. Ulan (1987) 'The Impact of Exchange-Rate Volatility on Export Growth: Some Theoretical Considerations and Empirical Results', *Journal of Political Modeling*, 9: 225-243.

Ball, L. (1999) 'Policy Rules for Open Economies', in Taylor, J.B (ed), *Monetary Policy Rules*, University of Chicago Press, Chicago, NBER Studies in Business Cycles, 31: 127-156.

Bangaké, C. (2008) 'Exchange Rate Volatility and Optimum Currency Area: Evidence from Africa', *Economics Bulletin*, 6(12): 1-10.

Bank of Zambia Act of 1996 available at http://www.boz.zm, accessed 10 July 2009.

Bank of Zambia Annual Reports: 1970-2006.

Bank of Zambia (2006) ‘Report of the Survey on the Impact of the Appreciation of the Kwacha on the Performance of Non-Traditional Exports and Tourism’, (*unpublished*).

Baron, D. P. (1976) ‘Fluctuating Exchange Rates and the Pricing of Exports’, *Economic Enquiry,* 14: 425-438.

Bartolini, L. and G. M. Bodnar (1996) ‘Are Exchange Rates Excessively Volatile? And What Does “Excessively Volatile” Mean, anyway?’ *Federal Reserve Bank of New York Research Paper No.9601, January.*

Baum, C. F. and C. Mustafa (2008) ‘On the Sensitivity of the Volume and Volatility of Bilateral Trade Flows to Exchange Rate Uncertainty’, *Boston College Working Paper Series No.641.*

Bauwens, L., D. Rime and G. Sucarrat (2006) ‘Exchange Rate Volatility and the Mixture of Distribution Hypothesis’, *Empirical Economics,* 30: 889-911.

Baxter, M. and A. Stockman (1989) ‘Business Cycles and the Exchange Rate Regime. Some International Evidence’, *Journal of Monetary Economics,* 23: 377-400.

Bayoumi, T. and B. Eichengreen (1998) ‘Exchange Rate Volatility and Intervention: Implications of the Theory of Optimum Currency Areas’, *Journal of International Economics,* 45: 191-209.

Bergin, P. (2004) ‘Measuring the Costs of Exchange Rate Volatility’, *FRBSF Economic Letter*, 22, August.

Bernanke, B. (1986) ‘Alternative Explanations of the Money-Income Correlations’, *Carnegie-Rochester Conference Series on Public Policy,* 25: 49-99

Bini-Smaghi, L. (1991) ‘Exchange Rate Variability and Trade: Why is it so Difficult to find any Relationship?’ *Applied Economics,* 23: 927-936.

Björksten, N., A. Grimes and K, Özer (2004) ‘What Does the Tyalor Rule say about a New Zealand-Australia Currency Union?’ *The Economic Record,* 80 (Special Issue): 34-42.

Bjørnland, H. C. (2008) Monetary Policy and Exchange Rate Interactions in a Small Open Economy’, *The Scandinavian Journal of Economics*, 110 (1): 197-221.

Bjørnland, H. C. and J. I. Halvorsen (2008) ‘How Does Monetary Policy Respond to Exchange Rate Movements? New International Evidence’, *Norges Bank Working Paper 2008/15.*

Blanchard, O. J. and D. Quah (1989) ‘The Dynamic Effects of Aggregate Demand and Supply Disturbances’, *American Economic Review,* 79: 655-673.

Bleaney, M. (2006) ‘Fundamentals and Exchange Rate Volatility’, *University of Nottingham, Economics Department Discussion Paper No. 06/03.*

Bollen, B. (2008) 'Long-Term Asymmetry in the USD-DEM Spot Exchange Rate Volatility Process', *Applied Financial Economics Letters,* 4: 403-407.

Bollerslev, T. (1986) 'Generalized Autoregressive Conditional Heteroskedasticity', *Journal of Econometrics,* 31: 307-327.

Brischetto, A. and G. Voss (1999) 'A Structural Vector Autoregression Model of Monetary Policy in Australia', *Reserve Bank of Australia Research Discussion Paper No.1999-11.*

Brooks, C. (2001) 'A Double-Threshold GARCH Model for the French/Deutschmark Exchange Rate', *Journal of Forecasting,* 20: 135-143.

Brooks, C. (2006) *Introductory Econometrics for Finance,* Cambridge: Cambridge University Press.

Burke, P. S. and J. Hunter (2005) *Modelling Non-Stationary Economic Time Series. A Multivariate Approach,* New York: Palgrave Macmillan.

Bustaman, A. and K. Jayanthakumaran (2006) 'The Impact of Exchange Rate Volatility on Indonesia's Exports to the USA: An Application of ARDL Bounds Testing Procedure', *Department of Economics, Padjadjaran University Working Paper No.200610.*

Byrne, J. P., J. Darby and R. MacDonald (2008) 'US Trade and Exchange Rate Volatility: A Real Sector Bilateral Analysis', *Journal of Macroeconomics,* 30: 238-259.

Cady, J. and J. Gonzalez-Garcia (2006) 'The IMF's Reserve Template and Nominal Exchange Rate Volatility', *International Monetary Fund Working Paper No.274.*

Calderón, C. (2004) 'Trade Openness and Real Exchange Rate Volatility: Panel Data Evidence', *Central Bank of Chile Working Paper No. 294*.

Cameron. A. C. and P. K. Trivedi (2005), *Microeconometrics: Methods and Applications,* Cambridge: Cambridge University Press.

Canales-Kriljenko, J. and K. Habermeier (2004) 'Structural Factors Affecting Exchange Rate Volatility: A Cross-Section Study', *International Monetary Fund Working Paper No.147.*

Cashin, P., L. Céspedes, R. Sahay (2002) 'Keynes, Cocoa, and Copper: In search of Commodity Currencies', *IMF Working Paper WP/02/223*.

Cecchetti, S. G. (2000) 'Making Monetary Policy: Objectives and Rules', *Oxford Review of Economic Policy,* 16(4): 43-59.

Central Statistics Office, Zambia Monthly Digest of Statistics: 1970-2006.

Chit, M. M. (2008) 'Exchange Rate Volatility and Exports: Evidence from the ASEAN-China Free Trade Are', *Journal of Chinese Economic and Business Studies,* 6(3): 261-277.

Choudhry, T. (2005) 'Exchange Rate Volatility and the United States Exports: Evidence from Canada and Japan', *Journal of Japanese International Economies,* 19: 51-71.

Choudhry, T. (2008) 'Exchange Rate Volatility and United Kingdom Trade: Evidence from Canada, Japan and New Zealand', *Empirical Economics,* 35: 607-619.

Clarida, R. and M. Gertler (1996) 'How the Bundesbank Conducts Monetary Policy', *Economic Research Reports C.V. STARR Center for applied Economics, RR No.96-14, April.*

Clarida, R., J. Gali and M. Gertler (1998) 'Monetary Policy Rules in Practice: Some International Evidence', *European Economic Review,* 42: 1033-1067.

Clark, P. B. (1973) 'Uncertainty, Exchange Risk and the Level of International Trade', *Western Economic Journal,* 11: 302-313.

Clark, P. N., Tamirisa, Shang-Wei, A. Sadikov and L. Zeng (2004), 'Exchange Rate Volatility and Trade Flows: Some New Evidence', *IMF, May.*

Copeland, L. (2005) *Exchange Rates and International Finance,* London: Pearson Education Limited.

Côté, A. (1994) 'Exchange Rate Volatility and Trade – A Survey', *Bank of Canada, Working Paper 94-5, May.*

Craighead, W. D. (2009) 'Real Rigidities and Real Exchange Rate Volatility', *Journal of International Money and Finance,* 28: 135-147.

Crosby, M. (2000) 'Exchange Rate Volatility and Macroeconomic Performance in Hong Kong', *Department of Economics, University of Melbourne and Hong Kong Institute for Monetary Research.*

Cushman, D. (1983) 'The Effects of Real Exchange Rate Risk on International Trade', *Journal of International Economics,* 15: 45-63.

De Grauwe, P., M. Janssens and H. Leliaert (1985) 'Real-Exchange Rate Variability from 1920 to 1926 and 1973 to 1982', *Princenton Studies in International Finance, No.56.*

De Grauwe, P. and M. Rosiers (1987) 'Real Exchange Rate Variability and Monetary Disturbances', *Weltwirtschaftliches Archiv,* 123: 430-448.

De Grauwe, P. (1988) 'Exchange Rate Variability and the Slowdown in Growth of International trade', *IMF Staff Paper* : 63-84.

De Grauwe, P., D. Roberto and G. Marianna (2005) ‘Fundamental and Non-Fundamental Equilibria in the Foreign Exchange Market. A Behavioral Finance Framework’, *CESifo Working Paper No.1431.*

de Vita, G. and A. Abbott (2004) ‘The Impact of Exchange Rate Volatility on UK Exports to EU Countries’, *Scottish Journal of Political Economy,* 51(1): 62-81.

Dellas, H. and B. Zilberfarb, B (1993) ‘Real Exchange Rate Volatility and International Trade: A Re-examination of the Theory’, *Southern Economic Journal,* 59: 641-647.

Demers, M. (1991) ‘Investment Under Uncertainty, Irreversibility and the Arrival of Information over Time’, *Review of Economic Studies,* 58: 333-350.

Devereux, M. B. and P. R. Lane (2003) ‘Understanding Bilateral Exchange Rate Volatility’, *Journal of International Economics,* 60: 109-132.

Dickinson, D. and J. Liu (2007) ‘The Real Effects of Monetary Policy in China: An Empirical Analysis’, *China Economic Review,* 18: 87-111.

Ding, Z., R. F. Engel and C. W. J. Granger (1993) ‘ Long Memory Properties of Stock Market Returns and a New Model’, *Journal of Empirical Fianance,* 1: 83-106.

Dominguez, K. (1998) ‘Central Bank Intervention and Exchange Rate Volatility’, *Journal of International Money and Finance,* 18: 161-190.

Dornbusch, R. (1976) ‘Expectations and Exchange Rate Dynamics’, *The Journal of Political Economy,* 84(6): 1161-1176.

Doyle, E. (2001) ‘Exchange Rate Volatility and Irish-UK Trade, 1979-1992’, *Applied Economics,* 33: 249-265.

Dungey, M. H. (1999) ‘Decomposing Exchange Rate Volatility around the Pacific Rim’, *Journal of Asian Economics,* 10: 525-535.

Dwyer Jr. G. P. (1993) ‘Rules and Discretion in Monetary Policy’, Federal Reserve Bank of St. Louis Review, May: 3-13.

Easterley, W. (2006) ‘An Identity Crisis? Examining IMF Financial Programming’, *World Development*, 34(6): 964-980.

Edison, H. J. (1993) ‘The Effectiveness of Central Bank Intervention: A Survey of the Literature after 1982’, *Special Papers in International Economics No.18, International Finance Section, Department of Economics, Princeton University, New Jersey, July.*

Edwards, S. (1987) ‘Real Exchange Rate Variability: An Empirical Analysis of the Developing Countries Case’, *International Economic Journal, Spring,* 1: 91-106.

Eichengreen, B. (2007) 'The Role of Exchange Rate in Inflation Targeting: A Case Study of Korea, in Batini, N. "*Monetary Policy in Emerging Markets and Other Developing Countries*", New York: Nova Science Publishers, Inc.

Eleftheriou, M., D. Gerdesmeier and B. Roffia (2006) 'Monetary Policy Rules in the Pre-EMU Era, Is there a Common Rule?' *European Central Bank Working Paper Series No.659, July*.

Enders, W. (2004) *Applied Econometric Time Series,* New York: Wiley.

Engle, R. F. (1982) 'Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of the United Kingdom Inflation', *Econometrica,* 50: 987-1007.

Engle, R. F. and C. W. Granger (1987) 'Co-integration and Error Correction: Representation, Estimation and Testing', *Econometrica,* 55: 251-276.

Engle, R. F., T. Ito and W. Lin (1990) 'Meteor Showers or Heat Waves? Heteroskedastic Intra-Daily Volatility in the Foreign Exchange Market', *Econometrica,* 58(3): 525-542.

Esquivel, G. and L. B. Felipe (2002) 'The Impact of G-3 Exchange Rate Volatility on Developing Countries', *G-24 Discussion Paper No.16*.

Ethier, W. (1973) 'International Trade and the Forward Exchange Market', *American Economic Review,* 63: 494-503.

Fang, W. and S. M. Miller (2009) 'Modeling the Volatility of Real GDP Growth: The Case of Japan Revisited', *Japan and the World Economy,* 21: 312-324.

Fang, W., YiHao and S. M. Miller (2006) 'Export Promotion through Exchange Rate Changes: Exchange Rate Depreciation or Stabilisation?' *Southern Economic Journal,* 72(3): 611-626.

Farrell, V. S., D. A. DeRosa and T. A. McCown (1983) 'Effects of Exchange Rate Variability on International Trade and Other Economic variables: A Review of the Literature', *Board of Governors of the Federal Reserve, Wahington, D.C.,* December.

Fidrmuc, J. and R. Horváth (2008) 'Volatility of Exchange Rates in Selected New EU Members: Evidence from Daily Data', *Economic Systems,* 32: 103-118.

Flood, P. R. and A. Rose (1995) 'Fixing Exchange Rates: A Virtual Quest for Fundamentals', *Journal of Monetary Economics,* 36: 3-37.

Florens, C., E. Jondeau and H. Le Bihan (2001) 'Assessing GMM Estimates of the Federal Reserve Reaction Function', *Univerite Paris XII Val De Marne, Doc. No. 01-04.*

Franke, G. (1991) 'Exchange Rate Volatility and International Trade', *Journal of International Money and Finance,* 10: 292-305.

Gagnon, P. (1993) ‘Exchange Rate Variability and the Level of International Trade’, *Journal of International Economics,* 25: 269-287.

Giovannini, A. (1988) ‘Exchange Rates and Traded Goods Prices’, *Journal of International Economics,* 24: 45-68.

Gloten, L. R., R. Jagannathan and D. E. Runkle (1993) ‘On the Relation Between the Expected Value and the Volatility of Nominal Excess Return on Stocks’, *The Journal of Finance*, 48(5): 1779-1801.

Goldstein, M. and M. Khan (1985) ‘Income and Price Effects in Foreign Trade’, in Jones, R and Kenen, P. (Eds), *Handbook of International Economics*, North Holland, Amsterdam.

Gonzalo, J. (1994) ‘Five Alternative Methods of Estimating Long-run Equilibrium Relationships’, *Journal of Econometrics,* 60: 203-233.

Gottschalk, J. (2001) ‘An Introduction into the SVAR Methodology: Identification, Interpretation and Limitations of SVAR Models’, *Kiel Institute of World Economics, Kiel Working Paper No.1072.*

Gotur, P. (1985) ‘Effects of Exchange Rate Volatility on Trade: Some Further Evidence’, *IMF Staff Paper,* 32: 475-512.

Grydaki, M. and S. Fountas (2009) ‘Exchange Rate Volatility and Output Volatility: A Theoretical Approach’, *Review of International Economics,* 17(3): 552-569.

Hall, S. and J. Nixon (1997) ‘Controlling Inflation: Modelling Monetary Policy in the 1990s’, in Allen, C. and S. Hall, ‘*Macroeconomic Modelling in A Changing World: Towards a Common Approach*’, West Sussex: John Wiley & Sons Ltd: 201-216.

Hanson, M. S. (2004) ‘The ‘‘Price Puzzle’’ Reconsidered’, *Journal of Monetary Economics,* 51: 1385–1413.

Harrathi, N. and M. Darmoul (2007) ‘Monetary Information Arrivals and Intraday Exchange Rate Volatility: A Comparison of the GARCH and the EGARCH models’, *CES Working Papers No.35.*

Hasan, S. and M. Wallace (1996) ‘Real Exchange Rate Volatility and Exchange Rate Regimes: Evidence from Long-Term Data’, *Economics Letters,* 52: 67-73.

Hassan, M. (2009) ‘A Comprehensive Study on Japanese Foreign Exchange Intervention in the JPY/USD Exchange Market’, *Graduate Centre City University of New York Working Paper.*

Hau, H. (2002) ‘Real Exchange Rate Volatility and Economic Openness: Theory and Evidence’, *Journal of Money, Credit and Banking,* 34(3): 611-630.

Hausmann, R., U. Panizza and R. Rigobon (2006) 'The Long-Run Volatility Puzzle of the Real Exchange Rate', *Journal of International Money and Finance*, 25: 93-124.

Hooper, P. and S. Kohlhagen (1978) 'The Effect of Exchange Rate Uncertainty on the Price and Volume of International Trade', *Journal of International Economics*, 8: 483-511.

Horváth, R. (2007) 'Modelling Central Bank Intervention Activity Under Inflation Targeting', *Economics Bulletin*, 6(29): 1-8.

Hu, Y. M., C. X. Jiang and C. Tsoukalas (1997) 'The European Exchange Rates Before and After the Establishment of the European Monetary System', *Journal of International Financial Markets, Institutions and Money*, 7: 235-253.

Hua, M. and Y. Gau (2006) 'Determinants of Periodic Volatility of Intraday Exchange Rates in the Taipei FX market', *Pacific-Basin Finance Journal*, 14: 193-208.

Humala, A. and G. Rodriguez (2009) 'Foreign Exchange Intervention and Exchange Rate Volatility in Peru', *Central reserve Bank of Peru Working Paper No.2009-008.*

Hviding, K., M. Nowak and L. A. Ricci (2004) 'Can Higher Reserves Help Reduce Exchange Rate Volatility?' *International Monetary Fund Working Paper No.189.*

IMF (1984) 'Exchange Rate Volatility and World Trade', *International Monetary Fund Occasional Paper No.28*.

IMF (1997) 'A Premier on the IMF's Information Notice System' *WP/97/71- A Summary*: available at http://www.imf.org: accessed 22 November 2006.

IMF Country Reports for Zimbabwe: 2000-2006, Washington, D. C.

Ito, T. and T. Yabu (2007) 'What Prompts Japan to Intervene in the Forex Market? A New Approach to a Reaction Function', *Journal of International Money and Finance*, 26: 193-212.

Jeong, J. (2000) 'What Drives Exchange Rates? The Case of the yen/dollar Rate', *Multinational Business Review*, Fall: 31-36.

Johansen, S. (1988) 'Statistical Analysis of Cointegration Vectors', *Journal of Economic Dynamic Control*, 12: 231-254.

Johansen, S. (1991) 'Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models', *Econometrica*, 59: 1551-1580.

Johansen, S. and K. Juselius (1990) 'Maximum Likelihood Estimation and Inference on Cointegration with Application to the Demand for Money', *Oxford Bulletin of Economics Statistics*, 52: 169-210.

Johnson, R. A. and D. W. Wichern (2007) *Applied Multivariate Statistical Analysis*, New Jersey: Prentice-Hall, Inc.

Judd, P. J. and B. Motley (1991) 'Nominal Feedback Rules for Monetary Policy', *Economic Review Federal Reserve Bank of San Francisco, Summer No.3*: 3-17.

Kahya, E., G. Koutmos and D. Nuven (1994) 'Modeling Volatility of Foreign Exchange Price Changes', *Managerial Finance*, 20: (5/6).

Kamil, H. (2008) 'Is Central Bank Intervention Effective under Inflation Targeting Regimes? The Case of Colombia', *IMF Working Paper WP/08/88.*

Karras, G. (2006) 'Trade Openness, Economic Size, and Macroeconomic Volatility: Theory and Empirical Evidence', *Journal of Economic Integration*, 21: 254-272.

Katseli, L. T. (1984) 'Real Exchange Rates in the 1970s', in J.F.O. Bilson and R.C. Marston (eds), *Exchange Rate Theory and Practice*, Chicago: The University of Chicago Press.

Kim, S.-J. and J. Sheen (2002) 'The Determinants of Foreign Exchange Intervention by Central Banks: Evidence from Australia', *Journal of International Money and Finance*, 21: 619-649.

Klaassen, F. (1999) 'Have Exchange Rates Become More Closely Tied? Evidence from a New Multivariate GARCH Model', *CentER for Economic Research, Tilburg University, Discussion Paper 9910.*

Klaassen, F. (2004), 'Why is it so Difficult to find an Effect of Exchange Rate Risk on Trade?' *Journal of International Money and Finance*, 23: 817-839.

Koay, K. N. and K. T. Kwek (2006), 'Exchange Rate Volatility and Volatility Asymmetries: An Application to Finding a Natural Dollar Currency', *Applied Economics*, 38: 307-323.

Kočenda, E. and J. Valachy (2006) 'Exchange Rate Volatility and Regime Change: A Visegrad Comparison', *Journal of Comparative Economics*, 34: 727-753.

Koivu, T., A. Mehrotra and R. Nuutilainen (2008) 'McCallum Rule and Chinese Monetary Policy', *Bank of Finland, BOFIT Discussion Papers 15/2008.*

Kool, C. J. M. and K. G. Koedijk (1997) 'Real Exchange Rates Between the Wars', *Journal of International Money and Fianance*, 16(2): 211-232.

Koray, F. and D. W. Lastrapes (1989) 'Real Exchange Rate Volatility and US Bilateral Trade: A VAR Approach', *The Review of Economics and Statistics*, 71(4), November.

Korteweg, P. (1980) ‘Exchange Rate Policy, Monetary Policy and Real Exchange-Rate Variability’, *Essays in International Finance*, No.140, Pricenton.

Koutmos, G. and P. Theodossiou (1994) ‘Time-Series Properties and Predictability of Greek Exchange Rates’, *Managerial and Decision Economics,* 15: 159-167.

Lee, J. (1997) ‘Sterilising Capital Inflows’, Economic Issues 7, International Monetary Fund, Washington, D. C.

Leeper, E. M. and T. Zha (2001) ‘Assessing Simple Policy Rules: A View from a Complete Macroeconomic Model’, *Federal Reserve Bank of St. Louis, July/August: 83-110.*

Lewis, K. K. (1995) ‘Are Foreign Exchange Intervention and Monetary Policy Related, and Does it Really Matter?’ *The Journal of Business*, 68(2): 185-214.

Lubik, T. A. and F. Schorfheide (2007) ‘Do Central Banks Respond to Exchange Rate Movements? A Structural Investigation’, *Journal of Monetary Economics*, 54: 1069-1087.

Lütkepohl, H. (2005) ‘Structural Vector Autoregressive Analysis for Cointegrated Variables’, *European University Institute, Department of Economics, EUI Working Paper ECO No.2005/2.*

MacDonald, R. (1999) ‘Exchange Rate Behaviour: Are Fundamentals Important?’ *The Economic Journal*, 109(459): 673-691.

Malmsten, H. and T. Terasvirta (2004) ‘Stylised Facts of Financial Time Series and Three Popular Models of Volatility’, *SSE/EFI Working Paper Series in Economics and Finance No.563, Department of Economic Statistics, Stockholm School of Economics*.

Maria-Dolores, R. (2005) ‘Monetary Policy Rules in Accession Countries to EU: Is the Taylor Rule a Pattern?’ *Economics Bulletin*, 5(5): 1-16.

Mazlum, N., A. özer and S. Mazlum (1999) ‘Interpretation of Water Quality Data by Principal Components Analysis’, *Tr. Journal of Engineering and Environmental Science,* 23: 19-26.

McCallum, T. B. (1988) ‘Robustness Properties of a Rule for Monetary’, *Carnegie-Rochester Conference Series on Public Policy,* 29: 173-204, North-Holland.

McKenzie, M. D. (1997) ‘ARCH Modelling of Australian bilateral Exchange Rate Data’, *Applied Financial Economics*, 7: 147-164.

Mckenzie, M. D. (1998) ‘The Impact of Exchange Rate Volatility on Australian Trade Flows’, *Journal of International Financial Markets, Institutions and Money,* 8: 21-38.

McKenzie, M. D. (1999) ‘The Impact of Exchange Rate Volatility on International Trade Flows’, *Journal of Economic Surveys*, 13(1): 71-106.

Mckenzie, M. and R. Brooks (1997) ‘The Impact of Exchange Rate Volatility on German-US Trade Flows’, *Journal of International Financial Markets, Institutions and Money*, 7(1): 73-87.

MacKinnon, J. G. (1990) ‘Critical Values for Cointegration Tests’, *UCSD Discussion Papers*, 90(4).

Melvin, M. and D. Bernstein (1984) ‘Trade Concentration, Openness, and Deviations from Purchasing Power Parity’, *Journal of International Money and Finance*, 3: 369-376.

Merriam-Webster Online Dictionary, http://www.merriam-webster.com/, accessed on 10 January 2010.

Mkenda, B. K. (2001) ‘Long-Run and Short-Run Determinants of the Real Exchange Rate in Zambia’, *Working Papers in Economics No.40, Department of Economics, Goteborg University.*

Mohanty, M. S. and P. Turner (2005) ‘Foreign Exchange Market Intervention in Emerging Markets: Motives, Techniques and Implications’, Bank for International Settlements’, *BIS Papers No.24*, May.

Morana, C. (2009) ‘On the Macroeconomic Causes of Exchange Rate Volatility’, *International Journal of Forecasting*, 25: 328-350.

Mudenda, D. (2005) ‘An Analysis of Zambia’s Trade Situation: Implications for Debt and Poverty Reduction’, *Jesuit Centre for Theological Reflections, Lusaka, Zambia*, available at http://www.jctr.org.zm.

Mungule, K. O. (2004) ‘The Determinants of the Real Exchange Rate in Zambia’, *AERC Research Paper No.146.*

Munro, A. (2004) ‘What Drives the New Zealand Dollar?’ *Reserve Bank of New Zealand Bulletin*, 67(2).

Munyama, T. V. and K. R. Todani (2005) ‘Exchange Rate Volatility and Exports in South Africa’, *Annual Forum 2005, Trade and Uneven Development: Opportunities and Challenges*.

Musonda, A. (2008) ‘Exchange Rate Volatility and Non-traditional Export Performance: Zambia, 1965-1999’, *AERC Research Paper 185.*

Mussa, M. (1986) ‘Nominal Exchange Rate Regimes and the Behaviour of Real Exchange Rates: Evidence and Implications’, *Carnegie-Rochester Conference Series on Public Policy, 26.*

Mutoti, N. (2006) ‘Monetary Policy Transmission in Zambia’, *Bank of Zambia Working Paper, WP/06/2006* available at: http://www.boz.zm, accessed January 2008.

Mwenda, A. (1996) ‘Foreign Exchange Liberalisation in Zambia: Nature, Performance and Prospects’, *Bank of Zambia International Conference on Economic Liberalisation: Experiences and the Way Forward, Lusaka, 21-23 August*.

Narayan, P. K., S. Narayan and A. Prasad (2009) ‘Modelling Fiji-US Exchange Rate Volatility’, *Applied Economics Letters,* 16: 831-834.

Neely, C. (2000) ‘The Practice of Central Bank Intervention: Looking Under the Hood’, *Central Banking Quarterly Journal*, XI(2), November.

Nellis, G. J. (1982) ‘A Principal Components Analysis of International Financial Integration under Fixed and Floating Rate Regimes’, *Applied Economics*, 14: 339-354.

Nelson, D. B. (1991) ‘Conditional Heteroskedasticity in Asset Returns: A New Approach’, Econometrica, 59(2): 347-370.

Nelson, E. (2008) ‘Friedman and Taylor on Monetary Policy Rules: A Comparison’, *Federal Reserve Bank of St. Louis Review*, March/April: 95-116.

Ngalawa, H. P. E. (2009) ‘Dynamic Effects of Monetary Policy Shocks in Malawi’, *14th Annual African Econometric Society Conference Papers*, Abuja, 8-10 July, 2009: available at http://www.africametrics.org, accessed on 2 August 2009.

Obstfeld, M. and K. Rogoff (1998) ‘Risk and Exchange Rates’, *NBER Working Paper No. 6694*.

Obstfeld, M. and K. Rogoff (2000) ‘New Directions in Open Macroeconomics’, *Journal of International Economics*, 50: 117-153.

Olowe, R. A. (2009) ‘Modelling Naira/Dollar Exchange Rate Volatility: Application of Garch and Asymmetric Models’, *International Review of Business Research Papers*, 5(3): 377-398.

Onafowora, O. A. and O. Owoye (2008) ‘Exchange Rate Volatility and Export Growth in Nigeraia’, *Applied Economics,* 40: 1547-1556.

Orphanides, A. (2007) ‘Taylor Rules’, *Board of Governors of the Federal Reserve System*, Division of Monetary Affairs, Washington, D.C.

Özlü, P. and A. Prokhorov (2008) ‘Modeling Central Bank Intervention as a Threshold Regression: Evidence from Turkey’, *Journal of Economic and Social Research*, 10(2): 1-23.

Ozturk, I. (2006) ‘Exchange Rate Volatility and Trade: A Literature Survey’, *International Journal of Applied Econometrics and Quantitative Studies*, 3(1): 85-102.

Pagan, A. R. and A. Ullah (1988) 'The Econometric Analysis of Models with Risk Terms', *Journal of Applied Econometrics*, 3: 87-105.

Pagan, A. R. and G. W. Schwert (1990) 'Alternative Models for Conditional Stock Volatility', *Journal of Econometrics*, 45: 267-290.

Pattichis, C., C. Cheong, T. Mehari and L. V. Williams (2004) 'Exchange Rate Uncertainty, UK Trade and the Euro', *Apllied Financial Economics*, 14: 885-893.

Pesaran, M. H., Y. Shin and J. R. Smith (2001) 'Bounds Testing Approaches to the Analysis of Level Relationships', *Journal of Applied Econometrics*, 16: 289-326.

Pesaran, M. H. and Y. Shin (2002) 'Long-Run Structural Modelling', *Econometric Reviews*, 21: 49-87.

Poole, W. (1999) 'Monetary Policy Rules?' *Federal Reserve Bank of St. Louis Review*, March/April: 3-12.

Pozo, S. (1992) 'Are Flexible Exchange Rates Really More Volatile? Evidence from the Early 1900s', *Applied Economics*, 24: 1213-1218.

Rahmatsyah, T., G. Rajaguru and R. Y. Siregar (2002) 'Exchange-Rate Volatility, Trade and "fixing for life" in Thailand', *Japan and the World Economy*, 14: 445-470.

Rasche, H. R. and M. M. Williams (2007) 'The Effectiveness of Monetary Policy', *Federal Reserve Bank of St. Louis Review*, September/October: 447-480.

Robertson, D. and J. Symons (1992) 'Output, Inflation and the ERM' *Oxford Economic Papers*, 44(3): 373-386.

Rogers, J. M. and P. L. Siklos (2003) 'Foreign Exchange Market Intervention in Two Small Open Economies: The Canadian and Australian Experience', *Journal of International Money and Finance*, 22: 393-416.

Rotich, H., M. Kathanje and I. Maana (2008) 'A Monetary Policy Reaction Function for Kenya', *13th Annual African Econometric Society Conference Papers*, Pretoria, 9-11 July, 2008: available at http://www.africametrics.org, accessed on 5 August 2009.

Sack, B. and V. Wieland (1999) 'Interest-Rate Smoothing and Optimal Monetary Policy: A Review of Recent Empirical Evidence', *Board of Governors of the Federal Reserve System*, August.

Sapir, A. and K. Sekkat (1995) 'The Impact of Exchange Rate Fluctuations on European Community Trade' available at: http://ideas.repec.org/p/bon/bonsfb/282.html : accessed on 5 May 2009.

.

Savvides, A. (1990) ‘Real Exchange Rate Variability and the Choice of Exchange Rate Regime by Developing Countries’, *Journal of International Money and Finance*, 9: 440-454.

Schnabl, G. (2009) ‘Exchange Rate Volatility and Growth in Emerging Europe and East Asia’, *Open Economic Review*, 20: 565-587.

Sengupta, J. T. (2002) ‘Modelling Exchange Rate Volatility’, *University of California, Santa Barbara, Department of Economics, Departmental Working Paper 12-96*.

Sercu, P. and C. Vanhulle (1997) ‘Exchange Rate Volatility and International Trade: A case for Agnosticism’. *Mimeo, University of British Columbia*.

Sfia, M. D. (2006) ‘Tunisia: Sources of Real Exchange Rate Fluctuations’, *Munich Personal RePEc Archive, Paper No.3129*.

Shapiro, M. D. and M. W. Watson (1988) ‘Sources of Business Cycle Fluctuations’, in *Macroeconomics Annual*, edited by Stanley Fischer, Cambridge, MA: MIT Press: 111-148.

Simatele, M. (2004) ‘Financial Sector Reforms and Monetary Policy in Zambia’, *Department of Economics, Goteborg University, PhD Thesis.*

Sims, A. C. (1980) ‘Macroeconomics and Reality’ *Econometrica*, 48: 1-48.

Sims, A. C. (1986) ‘Are Forecasting Models Usable for Policy Analysis?’ *Federal Reserve Bank of Minneapolis Quarterly Review*, Winter, 3-16.

Singh, T. (2002) ‘On the GARCH Estimates of Exchange Rate Volatility in India’, *Applied Economics Letters*, 9: 391-395.

Smith, M. (2004) ‘Impact of the Exchange Rate on Export Volumes’, *Reserve Bank of New Zealand: Bulletin*, 67(1), March.

Stančík, J. (2007) ‘Determinants of Exchange Rate Volatility: The Case of the New EU Members’, *Czech Journal of Economics and Finance*, 57(9-10): 414432.

Stockman, A. C. (1983) ‘Real Exchange Rates Under Alternative Nominal Exchange-Rate Systems’, *Journal of International Money and Finance*, 2: 147-166.

Suliman, O. (2005) ‘Interest Rate Volatility, Exchange Rates, and External Contagion’, *Applied Financial Economics*, 15: 883-894.

Svensson, L. E. O. (1999) ’Inflation Targeting as a Monetary Policy Rule’, *Journal of Monetary Economics*, 43: 607-654.

Takagi, S. (1991) ‘Foreign Exchange Market Intervention and Domestic Monetary Control in Japan, 1973-89’, *Japan and the World Economy*, 3: 147-180, North-Holland.

Taylor, J. B. (1981) 'Stabilisation, Accommodation, and Monetary Rules', *The American Economic Review*, 71(2): 145-149.

Taylor, S. J. (1986) 'Forecasting the Volatility of Currency Exchange Rates', *International Journal of Forecasting*, 3: 159-170.

Taylor, J. B. (1993) 'Discretion Versus Policy Rules in Practice', *Carnegie-Rochester Conference Series on Public Policy*, 39: 195-214.

Taylor, J. (2001) 'The Role of the Exchange Rate in Monetary Policy Rules', *American Economic Review*, 91: 263-267.

Tenreyro, S. (2007) 'On the Trade Impact of Nominal Exchange Rate Volatility', *Journal of Development Economics*, 82(2): 485-508.

Thursby, J. and M. Thursby (1987) 'Bilateral Trade Flows, the Linder Hypothesis and Exchange Risk', *Review of Economic Statistics*, 69: 488-495.

Tsay, R. S. (2002) *Analysis of Financial Time Series*, New York: John Wiley & Sons.

Tussie, D. and C. Aggio (2006) 'Economic and Social Impacts of Trade Liberalisation', available at: http://www.dianatussie.com.ar/docs/aggio_tussie.pdf: accessed on 13 August 2008.

UK Treasury (2003) 'EMU and Trade', available at http://ww.hm-treasury.gov.uk/documents/the-euro/assessments/studies/euro: accessed on 15 July 2008.

Ulugbek, O. and S. Nishanbay (2008) 'The Effects of the Real Exchange Rate Volatility and Misalignments on Foreign Trade Flows in Uzbekistan', *MPRA Paper No.9749*.

UNDP (2006) 'Economic Policies for Growth, Employment and Poverty Reduction. Case Study of Zambia', Lusaka, available at: http://www.undp.org.zm: accessed on 10 June 2008.

Vdovichenko, A. G. and V. G. Voronina (2004) 'Monetary Policy Rules and their Application to Russia', *Economics Education and Research Consortium Working Paper Series No.04/09.*

Vonnák, B. (2005) 'Estimating the Effect of Hungarian Monetary Policy Within A Structural VAR Framework', *MNB Working papers 2005/1.*

Willett, T. D. (1982) 'The Causes and Effects of Exchange Rate Volatility', in *The International Monetary System*, pp24-64, edited by Dreyer, J., G. Haberler and T. D. Willett, Washington D.C., American Enterprise Institute.

Wooldridge, J. M. (2001) ‘Applications of Generalised Method of Moments Estimation’, *Journal of Economic Perspectives*, 15(4), Fall: 87-100.