Universidade do Minho
Escola de Economia e Gestão

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Macroeconomic Effects of the Real Exchange Rate in Developing Countries: Evidence from Sub-Saharan African Countries

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Doctoral Thesis
PhD in Economics

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and
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"At times our light goes out and is revitalized by a spark from another person. Each of us has a cause to think with deep gratitude of those who have lighted the flame within us."

— Albert Schweitzer (1875-1965)

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Statement of Integrity

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration. I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

Efeitos Macroeconómicos da Taxa de Câmbio Real nos Países em Desenvolvimento: Provas de países da África Subsaariana

Resumo

Nos últimos anos, grande parte da investigação sobre os efeitos macroeconómicos da taxa de câmbio real tem-se centrado geralmente nas economias desenvolvidas, emergentes e em desenvolvimento. Este estudo investiga os efeitos macroeconómicos da taxa de câmbio real (RER) no caso dos países da África Subsaariana (ASS). Este tópico amplo é reduzido a três (3) capítulos principais. O primeiro capítulo investiga o impacto do RER sobre os fluxos comerciais nos países da África Subsariana. A análise empírica baseia-se em dados anuais sobre 23 países da ASS, abrangendo o período 1995-2017. Os resultados da taxa de câmbio real de equilíbrio comportamental (BEER) obtidos através do Sistema de Métodos Generalizados de Momentos (SGMM), juntamente com as séries filtradas de Hodrick-Prescott, são utilizados para construir o indicador de desalinhamento do RER. Também geramos proxies de volatilidade RER com base em modelos do tipo Generalized Autoregressive Conditional Heteroscedasticity (GARCH), particularmente modelos GARCH e Exponential GARCH. A estrutura da variável dummy (BC-LSDV), com o enviesamento corrigido dos mínimos quadrados, é utilizada para estimar o impacto da taxa de câmbio real nos fluxos comerciais. Os resultados indicam que a subvalorização do RER promove as exportações mas afecta negativamente as importações, sublinhando a importância de uma taxa de câmbio competitiva para o comércio. Em contraste, a volatilidade do RER não parece influenciar as exportações, mas tem um impacto positivo significativo sobre as importações.

Utilizando a mesma amostra, o segundo capítulo examina os efeitos da taxa de câmbio real sobre o crescimento económico nos países da África Subsariana. A subavaliação e as medidas de volatilidade geradas pelo RER são incorporadas na regressão do crescimento, juntamente com outros determinantes do crescimento. Estimamos um modelo dinâmico de crescimento do painel utilizando o estimador BC-LSDV. Os resultados mostram que a subavaliação do RER fomenta o crescimento, um resultado que está amplamente de acordo com os reportados em estudos empíricos recentes. Doravante, as políticas que sustentam as taxas de câmbio a níveis competitivos e limitam a volatilidade da taxa de câmbio devem ser prosseguidas pelos países da ASS, como parte da sua estratégia de crescimento.

Finalmente, o terceiro capítulo centra-se na modelização da dinâmica não linear da taxa de câmbio real no Ruanda, utilizando modelos de mudança de regime. A análise é baseada em dados trimestrais, para o período 2000T1-2017T4. Começamos com um modelo linear (Média Móvel Integrada Autoregressiva) como modelo de referência, seguido por modelos não lineares concorrentes. Os resultados indicam que o parâmetro de limiar estimado para os dois regimes é 4,36, com o intervalo de confiança assimptótico (4,34, 4,36) a apontar para a evidência de dois regimes. Além disso, o modelo Markov Switching Autoregressive (MS-AR) mostra que o regime de valorização domina a sua contraparte (depreciação) na maioria dos pontos de dados dentro do período de amostragem especificado. Em termos de capacidade de previsão dos modelos, o modelo Threshold Autoregressive (TAR) supera a contrapartida linear (ARIMA) in-sample, enquanto os modelos TAR e MS-AR, os modelos não lineares utilizados neste estudo, superam o modelo linear (ARIMA) out-of-sample.

Palavras-chave: Painel dinâmico; Crescimento económico; Taxas de câmbio; Mudança de regime; Comércio

Macroeconomic Effects of the Real Exchange Rate in Developing Countries: Evidence from Sub-Saharan African Countries

Abstract

In recent years, much of the research on the macroeconomic effects of the real exchange rate has generally focused on developed, emerging and developing economies. This study investigates macroeconomic effects of the real exchange rate (RER) in the case of Sub-Saharan African Countries (SSA). This broad topic is narrowed down to three (3) main chapters. The first chapter investigates the impact of the RER on trade flows in SSA countries. The empirical analysis builds on annual data on 23 SSA countries, covering the period 1995-2017 .The results of behavioral equilibrium real exchange rate (BEER) obtained through System Generalized Methods of Moments (SGMM), along with Hodrick-Prescott filtered series are used to construct the RER misalignment indicator. We also generate RER volatility proxies based on Generalized Autoregressive Conditional Heteroscedasticity (GARCH) type models, particularly GARCH and Exponential GARCH models. The bias- corrected least squares dummy variable (BC-LSDV) framework is employed to estimate the impact of the real exchange rate on trade flows. The results indicate that the RER undervaluation promotes exports but negatively affects imports, stressing the importance of a competitive exchange rate to trade. In contrast, the RER volatility does not seem to influence exports but has a significant positive impact on imports.

Using the same sample, the second chapter examines the effects of the real exchange rate on economic growth in SSA countries. The generated RER undervaluation and volatility measures are incorporated in the growth regression, along with other growth determinants. We estimate a dynamic panel growth model using the BC-LSDV estimator. The results show that the RER undervaluation fosters growth, a result which is broadly in line with those reported in recent empirical studies. Henceforth, policies that sustain exchange rates at competitive levels and limit exchange rate volatility should be pursued by SSA countries, as part of their growth strategy.

Finally, the third chapter focuses on modeling non-linear dynamics in the real exchange rate in Rwanda using regime switching models. The analysis is based on quarterly data, for the period 2000Q1-2017Q4. We start with a linear model (Autoregressive Integrated Moving Average) as a benchmark model, followed by competing non-linear models. The results indicate that the estimated threshold parameter for the two regimes is 4.36 with the asymptotic confidence interval (4.34, 4.36) pointing to the evidence of two regimes. In addition, the Markov Switching Autoregressive (MS-AR) model shows that the appreciation regime dominates its counterpart (depreciation) in most of the data points within the specified sample period. In terms of forecasting ability of the models, the Threshold Autoregressive (TAR) model outperforms the linear counterpart (ARIMA) in-sample, while both TAR and MS-AR models, the non-linear models used in this study, outperform the linear (ARIMA) model out-of-sample.

Keywords: Dynamic Panel; Economic Growth; Exchange Rates; Regime switching; Trade

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Chapter 1.

General Introduction

1.1 Introduction

The introductory chapter discusses the ongoing issues and gaps in the existing empirical literature on real exchange rate (RER), trade and growth. We first discuss the general context of the thesis so as to position it in the economic literature and to underscore the importance and relevance of RER stability for trade and economic growth. The ensuing subsections focus more on specific research objectives and the broader theoretical and empirical underpinnings that are used throughout the thesis. We also present the contributions of the thesis, a summary of our results, and their policy implications.

1.1.1 Background

The exchange rate is a key price in an economy, which not only influences business decisions but also affects the competitiveness of the domestic traded goods sector, and therefore has a strong influence on a country's macroeconomic management, particularly foreign trade developments and economic growth. It is generally agreed that "getting the exchange rate right" is essential for economic stability and growth in both developed and developing countries (Aziz and Caramazza, 1998).

The discussion of the real exchange rate has not featured in the first generation growth models such as the Solow-Swan (1956) model and Romer's Endogenous growth model (1990) because these models were formulated in a closed economy perspective, which did not provide room for the policy embodiment of exchange rates (Eichengreen, 2007). However, in contemporary economic theory, the RER has attracted a lot of attention, it is now regarded as a key determinant of trade flows and economic growth, both in country specific and cross-country studies. Essentially, two schools of thought assess the role of the real exchange rate in influencing trade and economic growth. These are " the competitive RER school" and " the RER volatility school". These two lines of arguments have far reaching implications on international trade and economic growth. The first line of argument advocates for the adoption of a stable and competitive exchange rate as a strategy to fuel economic growth.

The underlying theory of this is the export-led growth, whereby countries aim at keeping export prices high enough to attract resources into the production of manufactured goods (Eichengreen, 2007). This policy could sustain economic growth provided that the generated income is channeled into saving for investment in the economy. To this end, a competitive exchange rate (a moderately undervalued currency) acts as the " magic wand" for shifting resources from the less productive sectors of the economy into the more productive export sector, which is characterized by technological spillovers and learning by doing (Rodrik, 2008). In a bid to support their stance, proponents of this strategy usually cite the success stories of the "Asian Tigers" (Gala, 2008 and Freund and Pierola, 2008).

Arguably, this has been the most commonly used strategy by economies experiencing unemployment and balance of payments crises (Rodrik, 2008). In Sub-Saharan Africa countries, most governments started to implement several economic policy programs, including allowing exchange rate to float in a bid to boost trade and economic growth, especially after the demise of Bretton-Woods and the advent of structural adjustment programs. From the preceding discussion, it is comprehensible that the real exchange rate is one of the key determinants of economic growth. In fact, empirical evidence indicates that most Eastern Asian countries, namely China, Japan, South Korea, Singapore, Taiwan and Hong Kong have benefited from undervaluing their currencies (Dollar, 1992), while overvalued currencies have had ripple effects on the growth of Latin American and African countries.

On the other hand, volatility school contend that the RER volatility undermines investment, trade, and consequently economic growth. For economies to grow, policies that prevent excessive exchange rate volatility must be devised. According to Eichengreen (2007), the fundamentals of financial fragilities and the balance sheet mismatch are essential in explaining the idea of RER volatility. RER volatility is often associated with floating exchange rate regimes, whereby countries allow their currencies to float in relation to other currencies (Calvo and Reinhart, 2002). In response to the adverse effects of the real exchange rate volatility, most governments, through their central banks, have assumed a vital role of intervening on the foreign exchange market to cushion the negative effects of exchange rate volatility. In addition, the creation of economic blocs, with the objective of establishing monetary union is intended to limit the influence of exchange rate volatility on trade and the economy in general (Chit, 2010 and Choudhry, 2008).

Over the recent years, empirical research has provided compelling evidence indicating that RER are positively associated with investment and growth. Research has also documented that the real exchange rate volatility negatively influences trade, investment and economic growth (Rapetti, 2019). Based on this empirical evidence, some economists and analysts have started to recommend developing countries to target a stable and competitive exchange rate as part of their growth strategy. Indeed, Rodrik (2008) finds that the positive link between the real exchange rate and economic growth is much stronger and significant for developing countries than for developed countries. In the same vein, Di Nino et al.(2011) also find supporting evidence that the relationship is stronger in developing countries and weaker in developed countries. Other studies such as Gala (2007) that exclusively focused on developing countries obtain similar evidence, showing positive association between the real exchange rate competitiveness and economic growth. While the macroeconomic effects of the real exchange rate in developing countries have been extensively studied, little consensus has emerged yet. The point of departure of this thesis is to contribute to the ongoing debate, particularly on the empirical front. The links between the real exchange rate, trade and economic growth remain scanty in the context of Sub-Saharan African (SSA) countries given that literature is awash with evidence mostly on developed economies, thus this thesis fills the gap by assessing the macroeconomic effects of the real exchange rate in selected SSA countries.

Secondly, we use dynamic panel data models, with not only the advantage of exploring both cross-sectional and time series dimensions, but also addressing the issue of endogeneity as opposed to cross-country regressions used by most previous studies, that are less reliable.

The policy questions addressed here include the association between variation in the real exchange rate level and its volatility and trade in SSA, stable and competitive exchange rates and economic growth in SSA and modeling non-linear dynamics of the real exchange rate in Rwanda. Finally, this thesis provides inputs to policy discussion pertaining to exchange rate issues.

1.1.2 Research Objectives

This study seeks to examine the macroeconomic effects of the real exchange rate in developing countries, particularly SSA countries. Given that the scope of this topic is broad, the thesis narrows its focus on three major topics. Specifically, the thesis seeks to:

1. Assess the impact of the real exchange rate on trade flows in SSA countries
2. Examine the impact of the real exchange rate on economic growth in SSA countries
3. Model non-linear dynamics in the real exchange rates in Rwanda

1.2 Structure of the Thesis and Main Results

This doctoral thesis is a collection of five chapters, including three related papers and the main contributions of this thesis to the study of macroeconomic effects of the real exchange rate in developing countries are as follows. Building on the gaps that appear in the empirical literature on the subject matter, chapter two assesses the link between the real exchange rate and trade flows in a panel of 23 Sub-Saharan African countries, covering the period 1995-2017. In this chapter, we first generate both the real exchange rate misalignment and the real exchange rate volatility measures.

For the volatility measure we use monthly exchange rate data and annualize it to match it with the frequency of other variables. [2] Secondly, we incorporate the real exchange rate misalignment indicator, generated via the estimation of the behavioral equilibrium exchange rate (BEER) model together with Hodrik-Prescott (HP) filter, and the real exchange rate volatility measure into the export and import demand functions, along with relevant control variables to estimate the link between the RER and trade flows. We employ dynamic panel data techniques, especially the bias- corrected least squares dummy variable model (BC-LSDV). The results from our analysis indicate that real exchange rate undervaluation supports trade, while real exchange rate volatility negatively influences trade in SSA countries.

Our results become more robust to the exclusion of the extreme values of real exchange rate misalignment and real exchange rate volatility. Key policy implications that arise out of these findings include maintaining a moderately undervalued real exchange rate through monitoring exchange rates relative to trading partners and implementing policies that address problems caused by volatile exchange rates such as putting in place financial instruments to hedge against the exchange rate risk, given that these instruments are not well developed in SSA.

[2] Monthly real exchange rate data for selected SSA countries is used because generating RER volatility measure based on GARCH type models requires high frequency data. We utilize the Bruegel database on exchange rates for 178 countries.

In chapter three of this thesis, we examine the growth effects of the real exchange rate using a sample of 23 SSA countries spanning the period 1995-2017 and follow the same procedures used in chapter two to generate both the real exchange rate level and variability measures. We also generate a complementary real exchange rate misalignment measure based on the Balassa-Samuelson (BS) effect adjusted purchasing power parity. The generated indicators are incorporated in the growth regression, along with other relevant variables that influence economic growth.

The bias-corrected least squares dummy variable model is used to estimate this relationship and the obtained results point to the fact that real exchange rate undervaluation stimulates economic growth, while real exchange rate volatility stifles economic growth. This result is consistent with the recent empirical literature such as those by Rodrik (2008), Di Nino et al.(2011), Vaz and Baer (2014) and Habib et al. (2017). Our results are robust to the BS effect adjusted misalignment measure, the use of an alternative volatility proxy based on EGARCH, and exclusion of extreme values of the real exchange rate misalignment and volatility, but less robust to the choice of exchange rate regime and the use of a different dependent variable. The evidence for the non-linearities in the real exchange rate -growth nexus is not established in this study when we use squared terms of RER undervaluation, but become evident when we use a panel threshold model. These empirical results point to important policy implications such as putting in place policies that sustain the exchange rate at a competitive level and limit RER volatility as part of the broader macroeconomic stability package.

The fourth chapter models non-linear dynamics of the real exchange rate in Rwanda. It addresses the issue of non-linearity in exchange rates given that exchange rate movements characteristically vary around high levels and persist during depreciation, but stay at fairly lower levels during appreciations. Such patterns in data cannot be captured by linear models, which underpins the need to use non-linear models to capture such features. As a matter of fact, existing empirical evidence indicates that exchange rates, like other financial time series, exhibit non-linear behavior (Brooks, Bauwens and Sucarrat, 2006). Tong (1990) introduced the threshold autoregressive (TAR) model, which is the most prominent non-linear model in time series. In this chapter, we use both TAR and Markov Switching (MS) models building on quarterly data, spanning the period 2000Q1-2017Q4. We begin our estimations with a linear model, particularly autoregressive integrated moving average (ARIMA) model as the baseline model to allow for the evaluation of the predictive ability of linear versus non-linear models. This model is compared to TAR and MS-AR models that are applied in this study to capture the non-linear dynamics in the real exchange rate in Rwanda. The results point to strong evidence of non-linear dynamics of real exchange rate in Rwanda. This result is supported by both the in-sample and out-of-sample forecast evaluation, which indicate that non-linear models outperform the baseline model (ARIMA).

Chapter 2.

Real Exchange Rate and Trade Flows in SSA countries

2.1 Introduction

The exchange rate is a key price in an economy, which not only influences business decisions but also affects the competitiveness of the domestic traded goods sector, and therefore has a strong influence on a country's macroeconomic management. Exchange rates have strong impact on cross-border economic transactions, particularly trade and investment. In this respect, there exists a considerable amount of theoretical and empirical evidence that stresses the growing importance of exchange rates in the face of globalization (Frieden, 2008; Di Mauro et al., 2008). Indeed, many countries have pursued a development strategy using the exchange rate as a main policy variable to spur exports growth.

After the demise of the Bretton Woods system, many countries allowed their exchange rates to float, leading to variability in both the nominal and real exchange rates. Since the 1990s, most Sub-Saharan African (SSA) countries have undertaken exchange rate reforms as part of the structural adjustment programs to balance the deteriorating terms of trade with the view to improving foreign trade performance (Ndlela and Ndlela, 2002). The increasing importance attached to the exchange rate in many developing countries has been attributed to following reasons: the need to manage foreign exchange risk exposure associated with the adoption of a floating exchange rate, the globalization process and the resulting increase in the rate and volume of funds flowing among countries, the trade liberalization pursued by most developing countries since the 1980s, resulting in the opening up of their economies, the continued rise in world trade relative to national economies, the emergence of economic integration in some regions, and the rapid pace of change in the technology of money transfer (Ojo and Alege, 2014). Thus, the effects of the real exchange rate on trade have become a major source of concern for policy makers and economists alike . The extent of such concern is more noticeable, especially in developing countries with relatively low levels of financial development.

From the policy standpoint, evidence on the real exchange rate uncertainty adversely affecting trade flows, particularly in developing countries due to lack of well developed financial markets to hedge against the exchange rate risk may push governments to intervene in the foreign exchange markets[3]. This is done

[3] Sekkat and Varoudakis (2000) argue that mismanagement of economic policies in developing countries has led to exchange rate misalignment and volatility, which may have depressing effects on trade and economic performance.

to stabilize the real exchange rate, given that severe fluctuations in currencies can potentially impede export promotion and growth (Arize et al., 2000; Choudhry, 2005; and Bahmani-Oskooee and Hegerty, 2007). Several empirical studies have documented the effect of real exchange rate uncertainty on trade (Clark et al., 2004; Tenyrero, 2007; Ozturk and Kalyoncu, 2009; and Aubion and Ruta, 2011).

In the recent years, the policy and academic debate has shifted away from the effects of exchange rate volatility on trade towards the effects of sustained exchange rate depreciation or perceived exchange rate misalignment (Hinkle and Montiel, 2001; Fang et al., 2006; Freund and Pierola, 2008; Rodrik, 2008; and Aubion and Ruta, 2011). This implies that the focus is more on the level of the real exchange rate than on its variability. While this change in the approach reflects the policy concerns regarding the potential impact of sustained currency misalignment, economic research shows that new global patterns of trade have rendered the effects of exchange rates on trade even more complex.

Therefore, maintaining the real exchange rate close to its equilibrium level is a requisite for sustained growth and mild undervaluation of the real exchange rate, and has been associated with sustained export-led growth and substantial export diversification (Elbadawi and Helleiner, 2004). The rationale behind this argument is that a stable and competitive exchange rate plays a key role in the development of the domestic traded goods sector via reallocation of the domestic demand and increased foreign demand for locally produced goods, allowing infant sectors to emerge and become self-sustaining (Guzman et al., 2018). This is more striking for SSA countries that rely heavily on external trade.

The real exchange rate and trade flows nexus continues to be investigated empirically. While the empirical focus is on verifying the theoretical validity of existing evidence, the assessment of the effect of the real exchange rate on trade remains largely inconclusive. The potential explanations are reflected in the methodological issues such as different country samples, different sample periods, different controls and different degrees of omitted variables and simultaneity bias.

Despite the substantial amount of literature on the link between the real exchange rate and trade flows, very few studies have been conducted in the context of Sub-Saharan Africa to establish whether exchange rate undervaluation helps to boost exports in that sub-region. The major objective of this chapter is therefore to contribute to the debate about the relationship between the exchange rate and trade flows by assessing the effects of real exchange rate undervaluation on trade in Sub-Saharan African (SSA)countries. This analysis employs the bias-corrected least squares dummy variable(BC-LSDV) estimator on a panel of 23 SSA countries spanning the period 1995-2017. The empirical model follows from the theory, controlling for the country-specific effects and endogeneity bias. Our findings provide robust evidence that the real exchange rate undervaluation boosts exports and depresses imports, leading to increased trade surpluses. Our results are consistent with those of Chinn (2006), Rodrik (2008), Haddad and Pancaro (2010) and Elbadawi et al. (2016).

Our contribution to the empirical literature is threefold. While most previous empirical studies on the link between the exchange rate and trade in SSA have been dedicated to exchange rate volatility as the measure of the exchange rate variability, in this chapter, firstly, we employ the exchange rate volatility and the exchange rate misalignment indicator as exchange rate variability measures. In addition, we conduct a number of sensitivity analyses to check the robustness of our results. Secondly, while most empirical work assessing the relationship between the real exchange rate and trade has been examined in the wider context of emerging and developing countries, the current analysis focuses on SSA countries. Thirdly, our data set starts in 1995 in order to explore the impact of structural adjustment programs (SAPs) and the resultant liberalization in most SSA countries.

The rest of the chapter is structured as follows. Section II reviews the theoretical and empirical literature. Section III presents the methodology. Section IV reports and discusses the empirical results. Finally, Section V presents this study's conclusion and policy implications.

2.2 Literature Review

The effect of the real exchange rate on trade flows has been extensively studied in developed, emerging and developing countries. In this section, we review the theoretical and empirical literature analyzing the association between the real exchange rate and trade flows.

2.2.1 Theoretical Literature

Theoretically, there are several approaches that have been employed to account for the effect of exchange rate variability on trade. A number of papers have studied the theoretical link between exchange rate regimes and international trade performance (Cushman,1983; Dixit,1989; and Gagnon, 1993). This relationship follows from the effect of real exchange rate movements on trade and the key role is attributed to the variability rather than the exchange rate changes at a given point in time. Variability is defined as the tendency of the real exchange rate to rise or fall sharply within a short period. This type of exchange rate fluctuation is labeled volatility. The second type of fluctuations relates to less frequent and more persistent swings where the exchange rate deviates from its equilibrium level for many periods (Sekkat, 1998). This is known in literature as misalignment. The two types of exchange rate fluctuations create uncertainty for economic agents operating in international markets, and each type induces a different type of uncertainty and has a different effect on trade (Sekkat, 1998). While in reality both types of variability coexist, the current study is dedicated to assessing the impact of the second type of variability on trade, however, a real exchange rate volatility indicator is part of the control variables included in our model specification. The first aspect of the link between exchange rates and trade flows relates to exchange rate volatility. This is premised on the idea that an increase in exchange rate volatility results in lower international trade because of the risks and transaction costs associated with the movements in the exchange rate, and these reduce the incentives to trade.

The link between the exchange rate movements and trade flows gained prominence in 1973. The first theoretical model was proposed by Ethier (1973), based on a risk-averse firm's decision making in relation to its imports and forward exchange cover in the face of uncertainty in exchange rate movements. He concluded that a high real exchange rate increases risk to a typical risk-averse economic agent and reduces the flow of trade and, consequently, growth. In the same vein, Clark (1973) developed a model of a firm with risk aversion reaching a conclusion similar to Ethier's model.

This postulation applies to most of the developing and emerging countries where well developed financial markets are lacking to hedge against the exchange rate risk. However, the negative response of trade flows to exchange rate uncertainty has been disputed by some studies on the ground that risks associated with volatile exchange rates are dampened by the increasing number of instruments such as forward contracts and currency options that help hedge against these risks (Ethier, 1973). Another critique concerns the presence of sunk costs in exporting firms (Baldwin and Krugman, 1989) and Franke (1991).

The higher the fixed costs of exports are, the less responsive firms will be and, thus, trade flows are less affected by the exchange rate volatility. In line with the drawbacks of the above strand of theoretical literature, Franke (1991) modeled a risk-neutral firm in a monopolistically competitive market, maximizing anticipated proceeds from its exports, where cash flow is defined as a positive function of the real exchange rate. He argues that when a country is hit by real asymmetric shocks, and prices and wages adjust slowly, flexible exchange rates can adjust relative to international prices to compensate for output losses. Frankel and Rose (2002) and De Grauwe and Schnabl (2005a) argue that trade volume would rise given that the associated expected cash flow from exporting will grow faster than entry/exit costs when the real exchange rate increases and that when financial markets are perfect, the expected profit margin might increase with greater exchange rate risk, if export prices are in foreign currency.

The second aspect of the link between the real exchange rates and international trade focuses on real exchange rate misalignment. The effect of real exchange rate misalignment on trade is based on the the idea that the undervalued currency increases competitiveness of exports and import-competing sectors at the expense of consumers and non-tradable sectors (Broz and Frieden, 2006). In this case, the effects of a misaligned currency on prices are similar to those of an export subsidy and import tax. This link is analyzed via three channels.

The first channel that links the real exchange rate fluctuations and trade is through the hysteresis hypothesis which focuses on the response of trade flows to exchange rate changes in line with entry and exit decision in exports markets. According to this theory, the firm will enter the exports market when the expected gross profit accruing from participating in that market is greater than the sunk entry cost. Therefore, the firm will not exit the market up until the point where the expected gross profit from remaining in the market is negative. Studies that support this hypothesis include, Campa (1993) and Roberts and Tybout (1997). The major critique is that while this hypothesis has proven key at the micro level/firm level, it might not be an important driver of the aggregate export supply responses.

The second channel, in line with Rodrik (2009), Freund and Pierola (2008) is premised on the argument that in the presence of institutional weaknesses and market failure that adversely affect the tradable sector more than the non-tradable sector, undervaluation of the real exchange rate could be justifiable as the second best solution to correct this bias. Such policy measure enhances exports by shifting the internal terms of trade in favour of the tradable sector, thereby increasing the profitability of the tradable sector and exports. However, the implications that arise out of this theoretical justification for the role of the real exchange rate in boosting growth and export diversification is that undervaluation is likely to be less effective for export promotion in advanced economies with developed institutions, especially well developed financial institutions because first best policy options are in place. These theoretical predictions are strongly supported by the empirical growth and export performance literature (Rodrik, 2008; Aghion et al., 2009 ; Elbadawi and Kaltani, 2015).

The third channel relates to the concept of heterogeneity of firms, a novel flow of literature describing the optimal behavior of firms based on the specific cost structure, policy strategy and performance (Aubion and Ruta, 2011). With regard to the exchange rates and trade, it describes how heterogeneous reaction of different firms contribute to shaping the aggregate response of countries' exports, and thus trade. From the firm level perspective, the real exchange rate depreciation fosters exports growth through two channels: the intensive margin, which is the increase in foreign sales of existing firms, and the extensive margin, which is the entry of new exporting firms in the exports market. Under the intensive margin, large and more productive exporting firms tend to be less responsive to the real exchange rate movements due to high market power, product diversification and import intensity (Berthou et al., 2015). This is because high performing firms respond to depreciation by increasing their export price rather than their volume and the reverse is true for the low performing export firms. Therefore, for emerging and developing economies, the export sector is dominated by low productivity firms and, thus, the aggregate impact on exports of the undervalued exchange rate is likely to be a lot stronger (Elbadawi et al., 2016). With regard to the extensive margin, the response to the real exchange rate changes is likely to be modest at the aggregate level because firms that enter following a depreciation are smaller relative to existing firms.

While this channel is suitable for firm level analysis, it is thus not appropriate for macro level analysis. In summary, the theoretical findings are contingent on the assumption about the attitudes towards risk, functional forms, types of trade, presence of adjustment costs, market structure and the availability of hedging opportunities. In this respect, the association between the exchange rate movements and trade is analytically indeterminate. Thus , the link between exchange rate and trade flows becomes an empirical issue.

2.2.2 Empirical Literature

The first line of empirical studies employed the bilateral trade gravity model, reaching various conclusions. Authors such as Frankel and Wei (1993), Dell 'ariccia (1999), Tenreyro (2007), Klein and Shambaugh(2006), Ozturk and Kalyoncu (2009), Chit et al.(2010),Qureshi and Tsangarides (2011) and Murkherjee and Pozo (2011) among others have generally obtained a negative link between exchange rate variability and trade. However, Clark et al. (2004) indicate that this negative relationship is not robust to a more general specification of the equation linking trade to its determinants that incorporates the recent theoretical advances in gravity models. Flam and Nordstrom (2003), in their study on the effect of the Euro on trade, introduce a bilateral real exchange rate variable in a gravity equation. Using aggregate trade data for 20 exporting and importing OECD countries for the period 1990-2002, they find a negative elasticity of real exchange rate variations with respect to bilateral exports, which is close to unity. Their analysis is however limited by the small sample size of exporting and importing countries. However, Arize et al.(2000), Vergil (2002) and Sauer and Bohara (2001) argue that the adverse effect of exchange rate volatility may be mitigated by well developed financial system, with hedging instruments that allow firms to properly steer clear of negative shocks, but this is still lacking for developing countries.

Other empirical studies that used the gravity model have established positive results. For instance, Rose (2000) empirically examines the impact of customs unions on trade using a gravity model of bilateral trade flows in a panel of 186 countries, with bilateral observations for the period 1970 to 1990, and finds positive effects of currency unions whereby two countries sharing a currency tend to trade roughly three times as much as they would otherwise. Bahmani-Oskooee and Wang (2007) in their study on United States-China trade over the period 1978-2002, find that the appreciation of the dollar against the Yuan decreased US exports earnings in 18 industries, while it increased imports value in 44 industries. On the other hand, some studies have established inconclusive results, notable among these are Tenreyro (2007), Eicher and Henn (2009), Boug and Fagereng (2010) and Christopher and Caglayan (2010). Despite its empirical success, the gravity model is often criticized on the ground that it lacks a solid theoretical foundation, it is most suitable for bilateral trade flows and regional trade agreements and also neglects the issue of presence of zero bilateral trade flows yet Helpman, Melitz and Rubinstein (2008) and Novy (2012) highlight the presence of zero bilateral trade records. In line with this drawback, the gravity is not an appropriate approach to pursue in this chapter.

The second line of empirical literature on assessing the effects of real exchange rate movements on the aggregate exports and imports is the firm level information examined in the context of "new-new" trade models pioneered by Melitz (2003) to give the gravity equation a strong theoretical basis. This strand of literature is premised on heterogeneity of firms in which differences in behavior of firms influence macroeconomic variables such as the real exchange rate (Aubion and Ruta, 2011). Empirical research using micro-data at the firm level has confirmed that structural characteristics of firms operating in a country or a sector can affect the reaction of aggregate exports to exchange rate changes. For example, Lopez-Garcia, Di Mauro et al. (2015) show that firm productivity is highly heterogeneous across 17 European countries and 60 sectors included in the sample.

Dermian and Di Mauro (2015), in a gravity framework, investigate the response of exports to exchange rate changes and the results indicate lower elasticity in sectors with high levels of productivity dispersion. Berthou et al. (2015) investigate the underlying factors influencing the heterogeneous response of European exporters to exchange rate movements and their estimation results show substantial heterogeneity across the different categories, with large and more productive firms reacting much less than the average firm to exchange rate variations. Berman et al. (2012) examine empirically why high and low performing firms react differently to the exchange rate changes. They find that the high performing firms are more likely to absorb the exchange rate movements in their mark-ups, rather than volume, in reaction to an exchange rate depreciation. Several other studies have documented the fact that higher productivity firms export more than other firms (Eaton, Kartum, and Kramarz, 2011). This is due to the existence of fixed costs of exports that allows only higher performers to export.

While this line of empirical literature has registered considerable amount of success, it is not feasible to espouse it in this study because data on a dis-aggregated level is not readily available, especially for developing countries in SSA. The limitation of this approach explains why the empirical work on this strand of literature is lacking for SSA countries. Thus, our focus is on macro level cross-country panel data analysis. On the macro level, recent empirical work has used cross -country panel data analysis techniques, particularly static and dynamic panel data techniques. Most of these studies have rendered support to the positive association between the real exchange rate and trade. Fang et al. (2006) examine the effect of exchange rate depreciation on exports for eight Asian economies (Malaysia, Philippines, Indonesia, Japan, Singapore, Chinese Taipei, Republic of Korea and Thailand). They find that depreciation stimulates exports for most countries, but its contribution to export growth is weak and heterogeneous across countries. They contend that the reason for this finding is that depreciation raises exports, but the associated exchange rate risk has an offsetting effect. Bernard and Jensen (2004) focus on the US between 1987 and 1992 to analyze the sources of manufacturing export booms. They find that variations in the exchange rates were the major determinant of export growth. Most of the rise in exports was on the intensive rather than the extensive margin. Chinn (2006) investigates the effect of three measures of the real effective exchange rate on real aggregate exports for goods and services using data for the US, the Euro area and several East Asian countries. He employs generalized methods of moments, and the results indicate that the real appreciation of the domestic currency against other major currencies has a strong negative effect on export volumes, with an elasticity close to minus 2. Freund and Pierola (2008) examine the determinants of 92 episodes of export surges, which they defined as increases in manufacturing exports of at least 6 percent that lasted for a period of seven years or longer. They found that large depreciations of the real exchange rate were an important determinant of export surges for developing countries. Specifically, an undervalued exchange rate had a positive effect by facilitating entry in new export products and new markets. These new products and markets accounted for 25 per cent of export growth on average during the surge in developing countries.

Haddad and Pancaro (2010) provide further evidence of the link between the real exchange rate and export expansion. They found a positive association between the two variables, but only for low per capita income countries. Cimoli et al. (2013) investigate the effects of the real exchange rate on diversification and technology intensity of the exports structure in a panel of 111 countries covering the period 1962-2008. They find that higher RERs favor export diversification. Exports diversification in turn is associated with the advancement in the technological intensity of exports and higher economic growth. Senadza and Diaba (2017) examine the effects of exchange rate volatility on trade in a panel of 11 sub-saharan African economies using the pooled mean-group estimator of dynamic heterogeneous panels technique spanning the period of 1993 to 2014. They find no significant effects on imports, but find positive and significant effects on exports in the long-run. Di Nino et al. (2011) conclude that the real exchange rate undervaluation spurs exports, especially in high productive sectors.

Much as recent cross-country studies, especially those applying dynamic panel data techniques provide suitable analytical framework to estimate exchange rate -trade nexus, Corc and Pugh (2010) indicate that the effect depends on whether the countries are advanced or developing as well as different estimation methods, suggesting that conclusions can not easily be generalized. Attempts to reconcile varying conclusions have yielded less comprehensive understanding of the effect of exchange rate movement on trade. To this end, results are robust to the choice of sample period, model specification and proxies for exchange rate variability. In this chapter, we apply dynamic panel techniques, particularly bias-corrected least squares dummy variable (BC-LSDV) approach that addresses both the issues of endogeneity and small sample bias.

2.2.2.1 Current State of Knowledge

Since the break down of the Bretton Woods monetary system, especially, the system of fixed exchange rates, a big chunk of economic literature on the link between the exchange rates and trade has focused on the effect of increased exchange rate volatility on trade. This is entirely the case until 2004, when the International Monetary Fund (IMF) report on the real exchange rate and trade flows was published, and with the incorporation of improvements derived from theoretical refinements and new statistical information (firm-level data), this kind of literature has continued up until now. However, since the mid-2000s, the emphasis has shifted towards the association between the exchange rate misalignment and trade subsequent to increased global imbalances and the outbreak of financial crisis (Aubion and Ruta, 2013).

Both theoretical and empirical work on the effect of the level of exchange rate on trade have yielded inconclusive results. The theoretical literature suggests that exchange rate misalignment has no long-run effects on trade flows when markets are free of failures due to the fact that relative prices do not respond to exchange rate changes. However, long-run effects are established in models that assume market distortions, such as information problems or product market failures. Short-run effects of the exchange rate on trade are also not conclusive given that they are likely to be influenced by specific features of the economy, including the currency in which domestic producers invoice their products and the structure of trade (for instance, the importance of global production networks and firm characteristics). The inconclusiveness of the empirical literature is due to the use of different theoretical frameworks, empirical models and samples which often produce divergent results. In addition, omitted variable bias and measurement errors in constructing some indicators exacerbates the issue. However, most empirical studies tend to support a positive link between the real exchange rate undervaluation and trade.

While the link between real exchange rate variability and trade flows has been extensively studied, this research area has not been adequately analyzed for Sub-Saharan African countries, and much of the empirical work in this area has mainly focused on exchange rate volatility and trade. This study makes an empirical contribution in this regard.

From the methodological viewpoint, some studies have followed the bilateral trade gravity models and standard panel data techniques, particularly fixed effects and generalized methods of moments (SGMM). Despite the fact that the literature does not dictate which estimation technique to employ because no estimation emerged superior to others in estimating the effects of exchange rate changes and trade flows, System GMM appears to be the most appropriate given that it deals with potential endogeneity bias. Besides, gravity models are more suitable for country pairs and model trade flows as a function of the economic sizes and the distance between a pair of countries. However, in a case like ours, where we have few cross-sectional units, GMM estimators produce biased estimates. We therefore, employ bias-corrected dynamic panel estimators, particularly the bias-corrected least squares dummy variable (BC-LSDV) estimator.The synthesis of empirical findings is presented in Table 2.1. It shows a mix of empirical evidences, some in support and others against the hypothesis of a positive relationship between the exchange rate undervaluation and trade flows.

Table 2.1: Synthesis of Empirical Literature

Study	**RER Variability Measure**	**Sample Period**	**Model**	**Main findings**
Chit et al. (2010)	volatility	1982Q1-2006Q4	Gravity model	significant negative relationship
Murkherjee and Pozo (2011)	volatility	1948-2000	Gravity model	mixed results
Elbadawi et al. (2016)	misalignment	2003-2010	GMM	Robust evidence that RER undervaluation boosts exports
Cimoli et al.(2013)	misalignment	1962-2008	SGMM	Higher RER favors export diversification
Freund and Pierola (2008)	misalignment	1980-2008	Fixed effects	undervaluation positively affects exports surge
Bahman-oskooee and Wang (2007)	volatility	1978-2002	Bounds testing	significant positive relationship
Senadza and Diaba (2017)	volatility	1993-2014	Pooled mean group estimator (PMG)	positive and significant effects on exports in the long-run
Christopher and Caglayan (2010)	volatility	1980-1998	Gravity model	inconclusive results
Rodrik (2009)	misalignment	1980-2005	SGMM	positive and significant link between RER undervaluation and trade

Chinn (2006)	misalignment	1970-2000	GMM	RER appreciation has a strong negative impact on export volumes
Berthou et al. (2015)	misalignment	2001-2011	SGMM	high performing firms react much less to RER depreciation
Tenreyro (2007)	volatility	1970-1997	gravity model	inconclusive results
Bernard and Jansen (2004)	misalignment	1987-1992	GMM	positive and significant relationship between RER undervaluation and export growth via the intensive margin link
Berman et al. (2012)	misalignment	1995-2005	Fixed effects	RER undervaluation weakly respond to aggregate exports
Ozturk and Kalyoncu (2009)	volatility	1980-2005	Gravity	negative and significant relationship between RER volatility and trade

Source:Author's Compilation

2.2.3 Exchange Rate Regimes in SSA

This section examines the evolution of the exchange rate arrangements for selected Sub-Saharan African countries. The categorization is based on three classifications, which are pegged, intermediate and floating exchange rate regimes. This classification is based on member countries' actual de facto arrangements as identified by the IMF annual report on exchange arrangements and exchange restrictions (AREAER) (Simwaka, 2010) and IMF (2018). However, other scholars such as Reinhart and Rogoff (2004), Klein and Shambaugh (2010) and Ilzetzki et al. (2019) have updated and developed new classification schemes based on algorithms such as identification of relevant anchor currencies for each country and exchange arrangements by metrics that are fundamental to measuring the degree of flexibility. The exchange rate regimes in SSA countries have evolved over time. Right after the independence , many African countries, including SSA countries' currencies were pegged until after the demise of the Bretton Woods system. This development was further reinforced by the stabilization and liberalization programs that emerged during the 1980s and 1990s.

The majority of SSA countries are classified by the IMF as having flexible exchange rates. However, former colonies of France constitute a core group in the "Communauté Financière Africaine" (CFA) for western African countries and "Coopération financière en Afrique centrale"(CFAC) for central African countries, which is composed of two currency unions with a hard external peg to the Euro. The three neighboring countries of south Africa ,namely, Namibia, Lesotho and Eswatini are part of the rand zone where national currencies are exchanged at par with the South African rand and the rand circulates extensively inside their borders.

Ghosh et al. (2010) indicate that the choice of an exchange rate regime that is appropriate for a country's economic interest depends on a variety of factors such as specific country circumstances (the size and openness of the country to trade and financial flows, structure of its production and exports, stage of its financial development, its inflationary history, and the nature and source of shocks it faces); policy objectives; political conditions in the country; and the credibility of its policy makers and institutions. Therefore, there is no single ideal exchange rate regime that is appropriate for all countries. Table 2.2 shows the evolution of exchange rate arrangements for the selected Sub-Saharan African countries.

Results from Table 2.2 indicate that, prior to 1995, Sub-Saharan African countries were under fixed exchange rate arrangements. However, since 1995, a big number of the SSA countries started to allow their currencies to progressively float. However, in the aftermath of the 2008 financial crisis, some countries with more flexible regimes tended to move toward less flexible arrangements, particularly conventional pegs on de facto basis but not on de jure basis. For Sub-Saharan African countries, this appears to reflect the tendency among many commodity exporters to lean against nominal appreciations in the face of significant foreign exchange inflows when commodity prices are high.

Table 2.2: Evolution of Exchange Rate Regimes for Selected SSA Countries

Country	**1995**	**2000**	**2005**	**2018**
Angola	interim[4]	float	conventional peg[5]	conventional peg
Botswana	conventional peg	conventional peg	conventional peg	crawling peg[6]
Burkina Faso	fix	currency board[7]	conventional peg	conventional peg
Burundi	fix	independent float	managed float	conventional peg
Cape Verde	fix	fix	fix	fix
D.R.C.	fix	independent float	independent float	independent float
Ethiopia	fix	managed float	managed float	crawling peg
Kenya	fix	managed float	managed float	managed float
Ghana	float[8]	independent float	managed float	conventional peg
Guinea Bissau	fix	currency board	currency board	conventional peg
Malawi	managed float	managed float	independent float	conventional peg
Mali	fix	currency board	conventional peg	conventional peg
Madagascar	fix	managed float	managed float	managed float
Mozambique	fix	independent float	managed float	managed float
Namibia	float	conventional peg	conventional peg	conventional peg
Niger	fix	currency board	currency board	conventional peg
Nigeria	interim	managed float	managed float	managed float
Rwanda	fix	independent float	managed float	conventional peg
Senegal	fix	currency board	currency board	conventional peg
South Africa	float	float	independent float	independent float
Tanzania	interim	independent float	independent float	managed float
Togo	fix	currency board	currency board	conventional peg
Uganda	fix	conventional peg	independent float	managed float
Zambia	fix	independent float	managed float	independent float

Source: IMF's AREAER (2018) database

[4]This means an intermediate regime between fixed and flexible exchange rates

[5]The country (formally or de facto) pegs its currency at a fixed rate to another currency or a basket of currencies where the exchange rate fluctuates within a narrow margin.

[6]The currency is adjusted periodically in small amounts at a fixed rate in response to changes in selective quantitative indicators.

[7]A monetary regime based on explicit legislative commitment to exchange domestic currency for a specified foreign currency at a fixed exchange rate, combined with restrictions on the issuing authority to ensure the fulfillment of its obligations.

[8]The monetary authority influences the exchange rate variations through intervention in foreign exchange market without specifying, or pre-committing to, a pre-announced path for the exchange rate.

2.3 Methodology

2.3.1 Generating RER Variability Measures

RER Misalignment

Prior to analyzing the link between the real exchange rate and trade flows, it is necessary to estimate the equilibrium real exchange rate (ERER) to compute the real exchange rate misalignment, which is the deviations of the actual real exchange rate from its equilibrium value. The challenge with any empirical undertaking on this subject is that the equilibrium exchange rate is not observable (Schröder, 2013). Thus, the determination of the equilibrium real exchange rate is a precursor to our empirical analysis. To obtain the equilibrium real exchange rate, different approaches have been used in the empirical literature. These include the fundamental equilibrium exchange rate (FEER) developed by Williamson (1994), the behavioral equilibrium exchange rate (BEER) by Clark and MacDonald (1998) and external sustainability (IMF, 2006). Under the FEER approach, the real exchange rate misalignment is computed as the difference between the current account projected over the medium term at prevailing exchange rates and the estimated current account (CA norm). The BEER approach directly computes an equilibrium exchange rate for each country as a function of medium term to long-term fundamentals of the real exchange rate, while the external sustainability approach estimates the difference between the actual current account balance and the balance that induces stable foreign asset position of a given country at some benchmark level.

In the context of this study, we employ the BEER approach to estimate the equilibrium exchange rate. This choice is motivated by the fact that, while the other two approaches are highly influenced by normative assumptions, the BEER is more pragmatic as it does not require to make the assumptions on the long-run values of economic fundamentals. Secondly, the FEER does not take into account the long-run stock effect via the net foreign position and the stock of capital. To estimate the ERER, the BEER approach entails estimating a long-run relationship between the real exchange rate and a set of economic fundamentals. Edwards (1994), Elbadawi (1994), Hinkle and Montiel (2001) and Elbadawi and Soto (2008) provide suitable theoretical and empirical settings to analyze the equilibrium real exchange rate and their economic fundamentals in developing and emerging countries. The model is specified as:

$$reer_{i,t} = \alpha_0 + \alpha_1 tot_{i,t} + \alpha_2 open_{i,t} + \alpha_3 nfa_{i,t} + \alpha_4 prod_{i,t} + \alpha_5 gov_{i,t} + \mu_i + \epsilon_{i,t} \tag{2.1}$$

where $i = 1, ..., N$ and $t = 1, ..., T$ denote the country and year, respectively, $reer_{i,t}$ is the real effective exchange rate, $tot_{i,t}$ are the terms of trade, $open_{i,t}$ is the degree of trade openness, $prod_{i,t}$ is productivity proxied by real per capita gross domestic product, $nfa_{i,t}$ is net foreign assets relative to GDP, $gov_{i,t}$ is government consumption as percentage of GDP, μ_i are country fixed effects and $\epsilon_{i,t}$ is the error term, which follows standard normal distribution. All the variables are transformed into natural logs.

Empirically, to estimate the equilibrium real exchange rate, we adopt SGMM and the first step involves estimating the long-run equilibrium real exchange rate and its fundamentals[9]. Secondly, deriving sustainable values of economic fundamentals obtained by decomposing the fundamentals of REER into their permanent and cyclical components, implemented through Hodrick-Prescott (HP) filter. The third step is to compute the misalignment indicator given by $Mis_{it} = reer_{it} - ereer_{it}$ where $ereer_{it}$ is the equilibrium real effective exchange rate and where positive (negative) values of Mis_{it} or $Reerhp$ indicate overvaluation (undervaluation).

[9]The estimation results of the equilibrium exchange rate are reported in the appendix Table A3

RER Volatility

To measure volatility some authors have used the standard deviation, where exchange rate volatility is measured according to the degree to which exchange rate fluctuates in relation to its mean over time (Schanbl, 2009) and Z-score, which combines the standard deviation measure and the arithmetic average of the percentage exchange rate changes. This measure is given by $Z_t = \sqrt{\mu_t^2 + \sigma_t^2}$ as suggested by Ghosh, Guide and Wolf (2003), however, using such measures are with challenges such as the inability to reflect the distribution between the unpredictable component of the exchange rate process, hence failing to capture the past information of the exchange rate. The empirical weaknesses of these measures restrict their use, hence we use the generalized autoregressive conditional Heteroscedasticity (GARCH) model, which is empirically supported by extensive literature, notably (Bollerslev, 2009, Boug and Fagereng, 2010, Herinksen, 2011, and Grek, 2014) as the appropriate econometric model to estimate exchange rate volatility characteristics. In the context of this study, we apply the generalized autoregressive conditional heteroscedasticity (GARCH) model and the exponential generalized autoregressive conditional Heteroscedasticity (EGARCH) model to measure the exchange rate volatility[10] The GARCH (p,q) is specified as:

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 \tag{2.2}$$

Where $\epsilon_t \sim N(0, \sigma_t^2)$ is independent and identically distributed (i.i.d), $\omega > 0$ and $\alpha_i \geq 0$ for i an assumption in the model is that ϵ_t follow a standard normal distribution (Tsay, 2005) and $\beta_j \geq 0,$ implying that current volatility is an increasing function of its previous values. While the GARCH model adequately measures conditional heteroscedastic volatility, the exponential generalized autoregressive conditional Heteroscedasticity (EGARCH) developed by Nelson (1991) is designed to capture leverage effects, is also used as an alternative proxy for exchange rate volatility. The term "leverage" derives from the empirical observation that the volatility (conditional variance) of an asset tends to increase when its returns are negative. The EGARCH model specifies the conditional variance as:

$$ln\sigma_t^2 = \omega^\star + \beta ln\sigma_{t-1}^2 + \alpha|\epsilon_{t-1}| + \sigma E\epsilon_{t-1} \tag{2.3}$$

where $\omega^\star = \omega - \alpha|\epsilon_t|$ and the specification of the conditional variance expressed in terms of its logarithmic transformation suggest that there are no restrictions on the parameters to warranty the positivity of the variance (Villar, 2010).

2.3.2 Model Specification

To examine the effect of the real exchange rate on trade in SSA, exports and imports models are estimated. The empirical investigation is based on the idea that increased globalization has reduced non-tariff barriers to trade and thus, improved trade flows. In light of this development, the exchange rate has assumed an important role in influencing the countrys' trade balance through exports and imports. The exports and imports equations are specified as follows:

[10]As a precondition to fitting GARCH type models, we test for arch effects using monthly data, with 12 lags. we use Engle (1982) LM test statistic based on the null hypothesis of no arch effects. Computationally, we use Panelauto", a stata package developed by Christopher (2003), which modifies the official stata commands such as archlm to archlm2, permitting the use on a single time series of a panel dataset. We obtain $chi^2 = 5704.19$ with the associated $P - value = 0.0000$, confirming the presence of arch effects given that the null hypothesis of no arch effects is rejected.

$$Ex_{it} = \alpha_0 + \alpha_1 Ex_{it-1} + \alpha_2 open_{it} + \alpha_3 tot_{it} + \alpha_4 Y_{it^\star} + \alpha_5 Fdi_{it} + \alpha_6 Reerhp_{it} + \alpha_7 Vol_{it} + \mu_{1i} + \epsilon_{1it} \tag{2.4}$$

$$Im_{it} = \beta_0 + \beta_1 Im_{it-1} + \beta_2 open_{it} + \beta_3 tot_{it} + \beta_4 Y_{it} + \beta_5 Fdi_{it} + \beta_6 Reerhp_{it} + \beta_7 Vol_{it} + \mu_{2i} + \epsilon_{2it} \tag{2.5}$$

where Ex and Im are exports and imports, respectively, measured as percentages of gross domestic product of each country i at time t, while Ex_{t-1} and Im_{t-1} denote their respective lagged values to capture the influence of autoregressive components, $open_{it}$ is the degree of trade openness, Tot_{it} is the terms of trade, which is the ratio of export prices to import prices, Y is real domestic product, $Y_{it^\star}$ is world gross domestic product as a proxy of external demand for exports, Fdi is foreign direct investment inflows, $Reerhp$ is the real exchange rate misalignment indicator based on Hodrick-Prescott filtered series ,Vol is the annualized exchange rate volatility proxy based on GARCH and EGARCH, α_i and β_i where (i=0,1,.....7) are coefficients to be estimated, μ_{1i} and μ_{2i} are country fixed effects to control for unobserved heterogeneity in the two equations and ϵ_{it} where $i = (1, 2, .., n)$ are stochastic error terms. We do not include time dummies based on the fact that some variables such as degree of openness and terms of trade capture the macroeconomic shocks that are common to all sampled countries across time. All variables are transformed into natural logarithms. The specifications in equations (4) and (5) are standard in empirical literature similar to Khan et al.(2014), Alege and Osabuohien (2015) and Senadza and Diaba (2017), we make an adjustment by including the real exchange rate misalignment indicator.

With regard to the expected signs, the real domestic income coefficient and foreign income are expected to emerge with positive signs in exports and imports equations respectively. Foreign direct investment is expected to influence both exports and imports positively. Trade openness is expected to positively influence both exports and imports. The terms of trade coefficient are anticipated to be positively associated with exports, but negatively associated with imports. Undervaluation is expected to bear a positive sign for exports and a negative sign for imports. The sign for the coefficients of the real exchange rate volatility proxies are expected to be ambiguous.

2.3.3 Estimation Methods

In this subsection, we discuss the econometric technique used to estimate the link between the real exchange rate and trade flows. We begin model estimation with static panel techniques such as pooled ordinary least squares and fixed effects estimators as baseline models. These models are suitable for large N and small T panel framework. However, they have been challenged due to a number of issues such as the presence of unobserved time and country-specific effects, therefore, using the OLS estimation technique yields biased parameter estimates. This is often mitigated by including into the baseline model time dummies and country-specific effects. However, the methods used to account for country-specific effects, that is, the fixed-effects or difference estimators, tend not to be appropriate owing to the the dynamic nature of the regression (Loayza et al., 2005). Besides, most of the explanatory variables, including the real exchange rate tend to be endogenous to trade and, hence, we need to control for simultaneity or reverse causality. These problems have been mitigated by the use of dynamic panel data estimation methods.

The first dynamic panel estimation method is the first-difference equation well known in the literature as "Difference" GMM estimated by the Generalized Method of Moments (GMM) approach proposed by Holtz-Eakin et al.(1988) and developed by Arellano and Bond (1991). To estimate the parameters of this model we follow Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond (1998) and the estimators are based on differencing regressions and instruments to control for unobserved country-specific effects. In addition, it also uses lagged observations of dependent and explanatory variables as instruments. The difference GMM method represents a major upgrade on the standard fixed-effects and first difference estimators. However, the first-difference GMM method has a problem in dealing with variables that tend to have a low degree of variability over time within a country, especially when the sample size is small. This implies that we eliminate most of the variation in the variable(s) by taking the first difference. In this case, lagged observations of the explanatory variables tend to be weak instruments for the variables in differences, thus, yielding also weak estimators.

To circumvent this problem, the focus has shifted towards the system GMM developed by Arellano and Bover (1995) and Blundell and Bond (1998). This method creates a system of regressions in differences and in levels. The instruments of the regressions in first differences remain the same as in the difference GMM. The instruments used in the regressions in levels are the lagged differences of the explanatory variables. Admittedly, in this estimation technique, the explanatory variables can still be correlated with the country-specific effects; nonetheless, the difference of these variables presents no correlation with these country-specific effects. The validity of the GMM estimators depends on the exogeneity of the instruments used in the model. The exogeneity of the instruments can be tested by the J statistics through Sargan-Hansen test proposed by Sargan(1958). The null hypothesis implies the joint validity of the instruments. In other words, a rejection of the null hypothesis indicates that the instruments are not exogenous and hence the GMM estimator is not consistent. As for the instruments, a large number of instruments is likely to lead to the loss of efficiency. Barajas et al. (2013) postulate that the number of instruments should be less than or equal to the number of cross-sections in the regressions to avoid over-identification of instruments.

The literature is not clear on determining the maximum number of instruments to be used in each case. Roodman (2009) suggests lag limits options based on a relatively arbitrary rule of thumb, that instruments should not be higher than individual units in the panel. In the current analysis, we try to keep the number of instrumental variables to a minimum and use up to 2 lags of the endogenous variables with the "collapse" option in order to limit the large number of instruments. The assumptions on the data generating process of the two dynamic panel techniques discussed above are well documented in Roodman (2009). Due to the small sample bias in GMM estimators (which are appropriate for large N and small T datasets), the associated parameter estimates appear biased and inaccurate, this is particularly the case in macro panels (usually with small N and large T). To correct the bias, we employ the bias-correction methods for dynamic panel data , especially bias corrected least squares dummy variable estimator (BC-LSDV) developed by Kiviet (1995) , which iteratively corrects the bias until unbiased estimates of the true parameters are obtained. Recent research has followed this approach to correct for the bias in fixed effects[11] . Kiviet (1999), Bun and Kiviet (2003), Bruno (2005), and Bun and Carree (2006) extend this estimator to cases with Heteroscedasticity and unbalanced panels. Judson and Owen (1999) strongly support BC-LSDV when N is small as in most macro panels.

[11]The estimation procedure is implemented via xtlsdvc routine in Stata, which builds upon the theoretical approximation formulae found in Bruno (2005) and estimate a bootstrap variance-covariance matrix for the corrected estimator and the consistent estimator is chosen to initialize bias correction.

Indeed, Bun and Kiviet (2003) using monte-carlo simulation show that in small samples, the BC-LSDV estimator outperforms consistent IV-GMM estimators such as Anderson-Hisao (AH), Arrellano and Bond (AB) and Blundell and Bond (BB) estimators given that it has the lowest mean squared error. Accordingly, the bias corrected least squares dummy variable estimator is employed. Our estimation begins with assessing the stationarity properties of the variables included in the model to ensure that our panel data estimations are not spurious. To this end, testing for unit root is a common practice in time series econometrics, however, panel unit root tests have recently become quite popular in panel data econometrics (Levin et al., 2002) and Im et al. (2003). The major distinction between unit root tests in time series and panel data emanate from heterogeneity. For time series, heterogeneity is not an issue given that the unit root hypothesis is tested for a given individual. With regard to panel data, the cross -section dimension is added on to the time dimension, becoming heterogeneous, thus, the panel unit root tests must take into account heterogeneity even if tests based on pooled estimates of autoregressive parameters are consistent compared to a heterogeneous alternative (Moon and Perron, 2004b). In instances where panel data are both stationary and heterogeneous, issues of combining individual unit roots applied to each time series are addressed by Im et al. (2003), Choi (2001) and Maddala and Wu (1992) to allow for different forms of cross-sectional dependence. Therefore, we use three commonly used test statistics: the Levin-Lin-Chu (2002), the Im-Peseran-Shin (2003) and Hadri (2000)[12]. In the Levin-Lin-Chu (2002) and the Im-Pesaran-Shin (2003) the underlying assumption is to test the null hypothesis that all panels contain a unit root. The Hadri (2000) test is based on the null hypothesis that all the panels are trend stationary. Levin et al.(2002) and Im et al.(2003) tests are based on the augmented dickey-fuller test (ADF) proposed by Dickey and Fuller (1979), while Hadri (2000) test is based on a lagrange multiplier based on the simple of average of the individual univariate Kwiatkowski, Phillips , Schmdt and Shin(1992)(KPSS) stationary test that follows a standard normal distribution.

The key advantage of applying these first generation unit root tests is that they provide a good approximation for the empirical distribution of the test statistic in relatively small samples. We proceed by testing for panel cointegration to ascertain whether there exists a stable and long-run relationship between the dependent variable and the explanatory variables. In this chapter, we employ three tests suggested by Pedroni (1999), Kao (1999) and Westerlund (2007) and their test statistics are interpreted under the null hypothesis of no cointegration. Pedroni (1999) and Kao (1999) tests of cointegration work differently, but yield similar conclusions, while Westerlund (2007) uses another approach that imposes fewer restrictions. it tests the same null hypothesis as the first two, but the alternative hypothesis is different (i.e some panels are cointegrated).

2.3.3.1 Data

The series presented in models (2.1), (2.2), (2.3), (2.4) and (2.5) are constructed as follows. The real exchange rate is the relative inflation adjusted exchange rate and trade weighted, computed by multiplying the nominal effective exchange rate by the ratio of consumer price indexes $Reer = \sum_{t=1}^{k}(Neer_{it}) \times \frac{p_{it^\star}}{p_{it}}$. The real exchange rate misalignment indicator is the exchange rate deviation from the equilibrium level based on the Hodrick-Prescott filter $Reerhp_{it} = Reer_{it} - \bar{R}eer_{it}$. Vol is the exchange rate volatility, which is the conditional variance based on GARCH specifications. For this particular indicator, monthly real exchange rate data is used and annualized as $Vol_{it} = \frac{1}{12}(h_{m1} + h_{m2} + ... + h_{m12})$. Real gross domestic product (GDP) is used for the level of domestic economic activity. Real gross domestic product per capita is real gross domestic product divided by population. Exports is measured as exports free on

[12] For a complete survey of the first generation class of panel unit root tests, see Banerjee (1999) and Baltagi and Kao (2000).

board (FOB) value. Imports is imports value including cost, freight and insurance (CIF). Foreign direct investment(FDI) is foreign direct investment inflows in each of the countries included in the sample divided by GDP. Trade openness is measured as the sum of exports and imports divided by real gross domestic product, this is given by $Open_{it} = \frac{x_{it}+m_{it}}{y_{it}}$. Terms of trade (Tot) is the ratio of export prices to import prices. Net foreign assets (nfa) measured as the sum of foreign assets held by the monetary authorities and deposit taking corporations less their liabilities. Government consumption (gov) includes both recurrent and capital spending of individual divided by GDP. All the series are transformed into natural logarithms and measured in US dollars.

We use annual data spanning the period 1995-2017 for 23[13] Sub Saharan African Countries. The sample is also converted into non-overlapping 3-year periods in robustness checks. The sample selection is based on the availability of data, as the appropriate data for the excluded SSA countries is not available.Thus,the included countries are those for which data on the relevant variables are available.

Data is sourced from the World Bank's World Development Indicators (WDI), World Investment Report (WIR), the International Monetary Fund's World Economic Outlook (WEO) and the Bruegel's Reer database (Darvas, 2012a).

[13]The countries included in our sample are: Angola, Botswana, Burkina Faso Burundi, Democratic Republic of Congo, Kenya, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Cape Verde, Ghana, Guinea Bissau, Madagascar, Malawi, Mali, Namibia, Niger, Nigeria Senegal, South Africa and Togo

2.4 Empirical Results

This section reports some descriptive statistics on the variables of interest, it then proceeds with the presentation and discussion of the econometric results on the link between the real exchange rate and trade flows in selected Sub-Saharan Countries.

2.4.1 Descriptive Analysis

The descriptive statistics of variables used in this study are reported in Table 2.3. Descriptive statistics are used to understand the features of the data set to make simpler and meaningful interpretation. The statistics indicate that except for exports, imports and the real exchange rate misalignment indicator, the mean for the rest of the variables is greater than the standard deviation, implying that most of the data is clustered around the mean, thus mean is generally a good indicator of parameters. The minimum and maximum statistics point to potential outliers, particularly for the real exchange rate volatility proxies, given that the spread between the minimum and maximum is high for these indicators, and as such, further investigation on the cause of the extreme values is undertaken.

Table 2.3: Descriptive Statistics

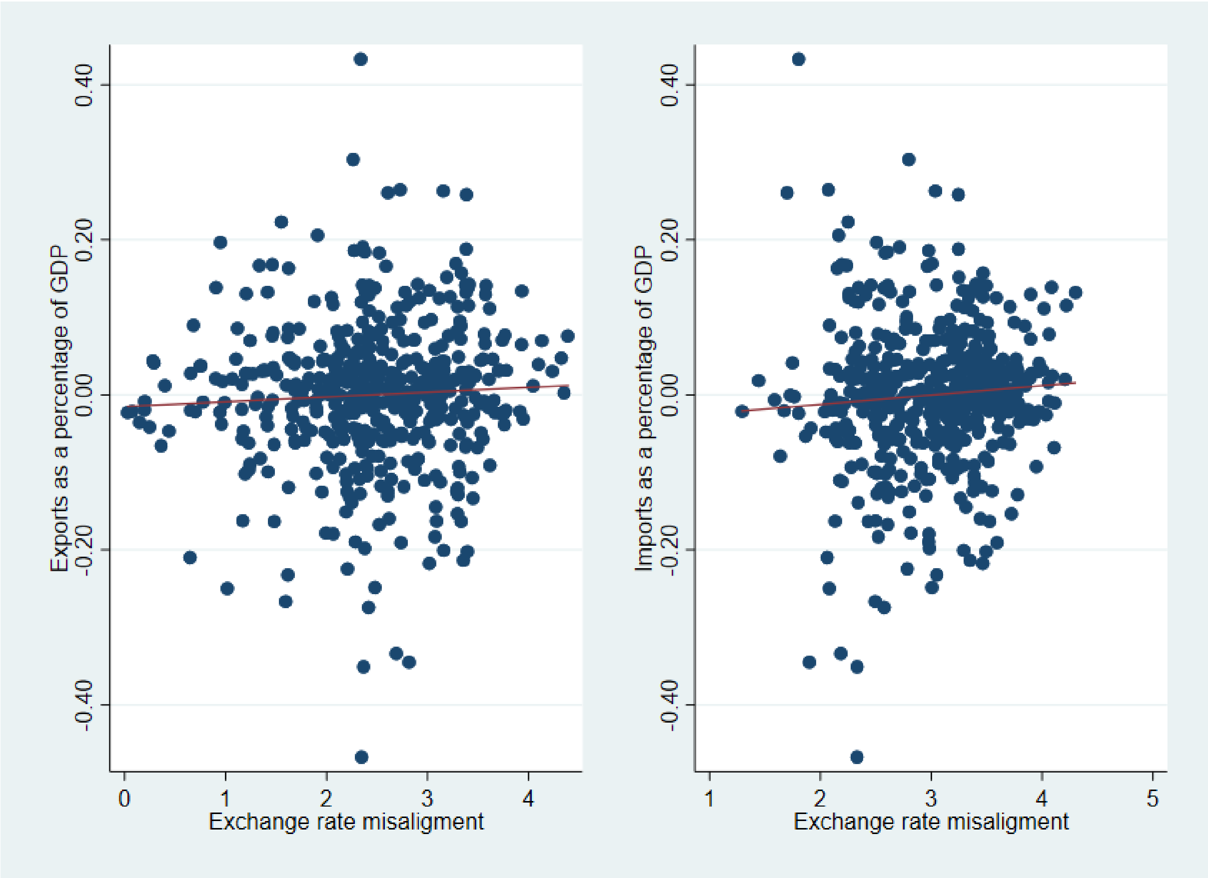
Variables	N	Mean	P50	Sd	Min	Max
lexp	529	0.31	0.37	1.94	-4.83	4.75
lim	529	0.84	0.82	1.49	-2.98	4.85
lopen	529	-1.07	-1.01	0.53	-2.37	0.07
lreer	529	4.61	4.61	0.21	3.49	5.81
lwgdp	529	10.82	10.85	0.36	10.34	11.29
lrgdp	529	2.43	2.34	1.47	-0.62	6.14
ltot	529	4.71	4.66	0.30	3.06	5.53
Vol	529	21.45	21.18	3.01	16.02	68.50
fdi_gdp	529	3.49	2.28	4.69	-6.06	40.17
lreerhp	529	-0.00	0.00	0.11	-0.47	0.86

Source: Author's computation using Stata 15

We also present simple scatter plots on cross-country correlation between the real exchange rate variability indicators and trade, specifically exports and imports. The analysis presented here is purely descriptive given that other variables that influence trade are not controlled for.More convincing empirical evidence is thoroughly discussed in the econometric results section. Concerning the impact of the real exchange rate misalignment on trade, we operate on the premise that the real exchange rate is the relative price of tradable goods and non-tradable goods. Theoretically, an undervalued exchange rate supports domestically produced tradable goods, thus provides incentives to exports and protects domestic firms from imports. In line with this argument, countries with undervalued currencies are expected to have higher exports and lower imports.

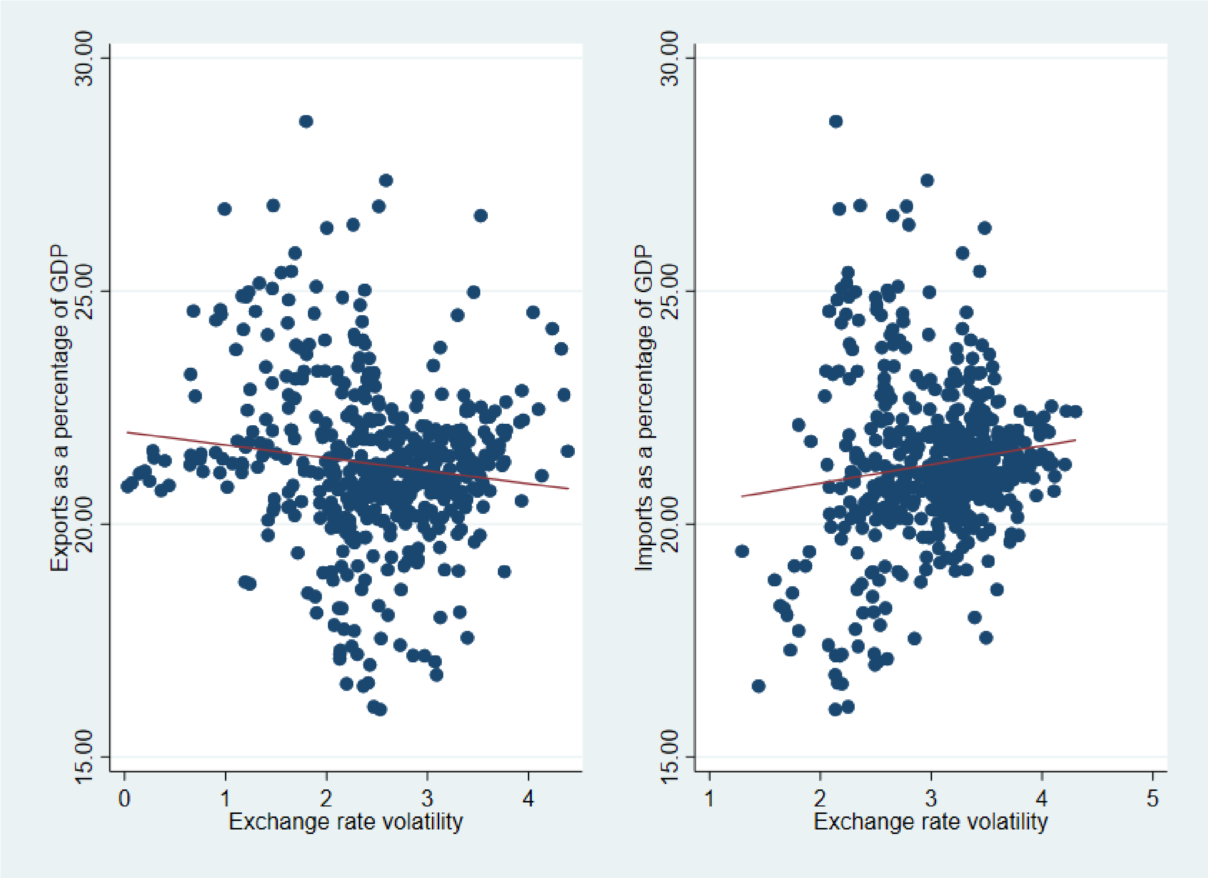
The cross-country evidence presented in Figure 2.1a supports the reasoning that the real exchange rate undervaluation promotes exports. But, Figure 2.1b shows that the real exchange rate undervaluation increases imports, a finding which is counter-intuitive, calling for further empirical investigation.

Figure 2.1: Exchange rate Misalignment and Trade



The real exchange rate volatility as a measure of the tendency of the real exchange rate to rise or fall sharply within a short period of time provides an indication of the stability of a country's currency in relation to the currencies of its major trading partners. In this respect, countries whose currencies are more volatile are expected to engage in less trade, due to the fact that volatility increases trade costs. The cross-country correlation between the real exchange rate volatility and trade, depicted in Figures 2.1a and 2.2b, indicates that real exchange rate volatility negatively impacts exports growth but positively influences imports given that for most SSA countries the demand for intermediate goods, capital goods and energy and lubricants imports is inelastic, implying that regardless of the cost, most SSA countries will still import those goods because they are essential inputs in their local industries. This evidence supports the hypothesized link between the real exchange rate volatility and trade.

Figure 2.2: Exchange rate Volatility and Trade



Prior to estimating the econometric models specified in (2.4) and (2.5), it is crucial to examine whether the data series are stationary and to determine their order of integration. The importance of the stationarity test is rooted in the fact that estimations involving non-stationary variables lead to biased and inconsistent parameter estimates. Table 4 reports panel data unit root test results. The results indicate that all variables are integrated of order one I(1) except for Lreer, Lreerhp and Fdi in Levin-Lin and Chu (2002) (LLC). This implies that the null hypothesis that all panels contain unit roots is rejected at 5 percent level. In the Im, Peseran and Shin (2003) (IPS), save for lreerhp which is stationary at level, all other variables are integrated of order one I(1) under the hypothesis that individual series contain a unit root. Hadri (2000) class of unit root tests was also applied, and the results show that all variables are stationary at first-difference, thus we reject the null hypothesis of stationarity in favour of the alternative. With regard to lag length criteria , we chose Aikake information criteria (AIC) automatic selection and all the tests assume asymptotic normality.

Table 2.4: Panel Unit Root Test Results

Variable	LLC	IPS	Hadri Z-Stat			
	Level	First Diff.	Level	First Diff.	Level	First Diff.
Lreer	-7.4945	-21.3122	-1.5415	-14.5540	17.6333	-1.1112
	(0.0019)	(0.0000)	(0.061)	(0.0000)	(0.0000)	(0.8668)
Lexp	-3.1745	-19.9742	4.3614	-13.6903	18.8789	-1.7456
	(0.337)	(0.0000)	(1.0000)	(0.0000)	(0.0000)	(0.9596)
Lim	-4.2124	-19.1078	3.3407	-12.1317	15.1437	-1.9276
	(0.076)	(0.0000)	(0.9996)	(0.0000)	(0.0000)	(0.9730)
Lreerhp	-12.8810	-20.8718	-5.8469	-15.1484	13.4115	-1.3189
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.9064)
Ltot	-5.8493	-20.1861	0.3066	-13.7685	20.9996	-0.4057
	(0.2971)	(0.0000)	(0.6204)	(0.0000)	(0.0000)	(0.6575
Lopen	-4.9798	-20.2242	2.5053	-13.7240	15.1127	-2.6216
	(0.3077)	(0.0000)	(0.9939)	(0.0000)	(0.0000)	(0.9956)
Lrgdp	-2.3176	17.2138	5.4025	-11.8740	29.2635	1.9955
	(0.0809)	(0.0000)	(1.0000)	(0.0000)	(0.0000)	(0.023)
Lwgdp	-1.7671	-16.1741	6.1719	-8.8567	-7.6515	14.3830
	(0.6340)	(0.00000	(1.0000)	(0.0000)	(1.0000)	(0.0000)
Fdi	-6.7647	-26.7848	-1.4080	-21.6307	10.2467	-4.0307
	(0.0046)	(0.0000)	(0.079)	(0.0000)	(0.0000)	(1.0000)

Notes: P-values appear in brackets. The used tests are proposed by Levin et al.(2002), Im et al.(2003) and Hadri (2000) .Newey-West bandwidth selection with a Bartlett Kernel is used.

Source: Author's computation using Stata 15

All the panel unit root tests conducted show that some variables are stationary at level and others at first-difference, validating the need to test for panel cointegration to check whether a long-run relationship exists between the dependent and explanatory variables. Table 2.5 presents results based on Pedroni (1999),Westerlund (2007) and Kao (1999) panel cointegration tests. The results show that the null hypothesis of no cointegration is rejected for both exports and imports functions under Pedroni and Westerlund cointegration tests, implying that there is a long-run relation between the dependent variable and the regressors. On the other hand, the results for Kao panel cointegration test show that the null hypothesis of no cointegration is rejected only for the imports function.

Table 2.5: Panel Cointegration Results

Model	Pedroni			Westerlund	Kao				
	Modified PP	Panel PP	Panel ADF	Variance ratio	Modified DF	Panel DF	Panel ADF	unadjusted modified DF	unadjusted modified DF
Exports function	4.25***	-4.99***	-4.52***	-0.727	0.92	0.38	0.51	-1.14	-1.21
	(0.000)	(0.000)	(0.000)	(0.2330	(0.177)	0.351	0.303	(0.125)	(0.112)
Imports function	4.09***	-5.85***	-5.94***	-1.37*	-4.54***	-4.53***	-3.13***	-7.95***	-5.76***
	(0.000)	(0.000)	(0.000)	(0.084)	0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: ***,**,and * denote rejection of the null hypothesis of no cointegration at 1,5, and 10 percent respectively. P-values are reported in brackets. Pedroni (1999), Kao (1999)and Westerlund (2007) are based on 3, 5 and 1 test statistics respectively .

Source: Author's computation using Stata 15

2.4.2 Main Results

Table 2. 6 reports ordinary least squares (OLS), fixed effects (FE) and bias-corrected LSDV (BC-LSDV) results on the link between the real exchange rate undervaluation and trade flows. These results are presented in columns 1-3 for the exports function and 4-6 for the imports function. The results are broadly in line with the existing empirical literature. Both the results of export and the import demand equations pass the basic panel econometric diagnostics, the p-values associated with the second order serial correlation test are greater than 5 percent significance level, implying that we fail to reject the null hypothesis that the second order serial correlation is absent, confirming the absence of the second order serial correlation of residuals. In terms of interpretation of parameter estimates, much emphasis is put on the bias corrected least squares dummy variable estimates.

2.4.2.1 Exports Demand Equation Results

The coefficient associated with the lagged dependent variable appears positive and statistically significant in all the specifications, evidencing the existence of an adjustment process and the relevancy of implementing a dynamic panel estimation. The coefficient of the real exchange rate misalignment indicator is positive and statistically significant at conventional levels in specifications 2 and 3, supporting the hypothesis that the real exchange rate undervaluation promotes exports. Indeed, undervalued currencies favour domestically produced tradable goods and incentivize domestic tradable goods sectors to export. This finding is corroborated by Rodrik (2008), Haddad and Pancaro (2010) and Elbadawi et al. (2016). The estimated coefficient of trade openness emerges positive and statistically significant in conformity with ex ante expectations, implying that countries with more liberalized economies engage more in trade. This result is consistent with the reality of Sub-Saharan African countries, given that a large number of developing countries have become part of the globalized economy and this has led to significant increases in international trade. The coefficient of terms of trade is positive and statistically significant, suggesting that improved terms of trade promote exports. This is because for developing countries that rely on a narrow range of primary exports, improvement in terms of trade is essential to their ability to grow, albeit the fact that improved terms of trade increases exports prices more than imports prices leading to the loss of exports competitiveness in the medium term.

The coefficient of foreign income, which is a proxy of external demand for exports is positive and statistically significant under fixed effects and bias-corrected least squares dummy variable estimators, indicating that increased external demand boosts exports.

2.4.2.2 Imports Demand Equation Results

The results of the imports demand equation are presented in columns 4-6 of Table 2.6. The estimated coefficient of lagged imports is positive and statistically significant in all specifications, implying that imports are positively influenced by their past values. The coefficient of the real exchange rate misalignment is negative and statistically significant under fixed effects and biased-corrected least squares dummy variable specifications, implying that the undervalued currencies make imports expensive, thereby reducing the demand for imports. The real exchange rate volatility based on GARCH is positive and statistically significant under the bias-corrected least squares dummy variable estimator, pointing to the fact the real exchange volatility is positively associated with imports. This result is consistent with Agolli (2003), who also finds a positive link between exchange rate volatility and Albania's imports from Germany and Greece. A positive and statistically significant coefficient of the degree of trade openness suggest that openness positively influences imports. This is due to the fact that increased globalization and integration of countries into the global economy has resulted into increased trade along with reduction in tariffs, leading to higher imports of capital and intermediate goods necessary for the growth of most of the SSA countries. The coefficient of terms of trade is negative and statistically significant, which is consistent with the opposite sign obtained for the exports, and indicates that improved terms of trade positively affect the trade balance. The foreign direct investment coefficient emerges positive and statistically significant, which indicates that increased foreign direct investment inflows are associated with high imports required as inputs in the direct investment enterprises in the host economies. Indeed, most SSA countries have in the recent past received substantial amounts of foreign direct investment inflows. Finally, the results confirm the expectation of a positive and statistically significant coefficient for the real domestic income, indicating that a healthy economy leads to higher demand for both domestic and external goods.

Table 2.6: Exports and Imports Functions Estimation Results

Variables	**Exports**			**Imports**		
	OLS	FE	BC-LSDV	OLS	FE	BC-LSDV
	(1)	(2)	(3)	(4)	(5)	(6)
L.lexp	0.978***	0.568***	0.593***			
	(0.007)	(0.051)	(24.019)			
L.lim				0.591***	0.235***	0.242***
				(0.057)	(0.035)	10.297)
Underval	0.010	0.030*	0.030**	-0.136	-0.098*	-0.100**
	(0.021)	(0.016)	(2.081)	(0.088)	(0.056)	(-2.345)
Lopen	0.099***	0.570***	0.560***	0.422***	0.856***	0.848***
	(0.028)	(0.072)	(13.386)	(0.065)	(0.053)	(34.736)
Vol	-0.004	-0.001	-0.001	0.003	0.003	0.003*
	(0.004)	(0.003)	(-0.323)	(0.002)	(0.002)	(1.861)
Ltot	0.073**	0.066	0.058*	0.007	-0.092*	-0.091***
	(0.033)	(0.069)	(1.660)	(0.038)	(0.051)	(-4.790)
Lwgdp	-0.072	0.212**	0.176***			
	(0.043)	(0.081)	(4.336)			
Lrgdp				0.361***	-0.291***	0.693***
				(0.056)	(0.053)	(19.616)
Fdi	0.000*	-0.000	-0.000	0.000	0.000**	0.000**
	(0.000)	(0.000)	(-0.483)	(0.000)	(0.000)	(1.989)
Obs	506	506	483	506	506	483
R-squared	0.989	0.954		0.991	0.963	
AR(1)			0.0000			0.0000
AR(2)			0.973			0.329

*** p<0.01, ** p<0.05, *p<0.1. Dependent variables are logs of exports and imports. For BC-LSDV, biased corrected version of estimates are reported. Bias is initialized by Arellano-Bond (1991) estimator and bootstrapped standard errors using 50 iterations are in parenthesis. Vol is the exchange rate volatility measure based on GARCH. P-values for "AR(1)" and "AR(2)" are reported.

Source:Author's computation using Stata 15

2.4.3 Robustness Checks

We proceed by conducting sensitivity analysis to check the robustness of our main estimation results. Five different sensitivity analyses are conducted. First, we include an alternative measure of the real exchange rate volatility based on exponential generalized autoregressive conditional Heteroscedasticity (EGARCH). Secondly, we check whether trade is robust to the choice of exchange rate regime. Thirdly, we exclude the resource rich countries such as Nigeria , South Africa and Angola. Fourthly, we employ non-overlapping 3-year averages instead of annual data. Finally, excluding the extreme values for the real exchange rate misalignment and volatility indicators.

2.4.3.1 Inclusion of an Alternative proxy for Volatility

Table 2.7 reports the exports and the imports demand equations estimation results obtained by using an alternative real exchange rate volatility proxy based on EGARCH. The estimated coefficients of the lagged exports and imports remain correctly signed and statistically significant. Similar to our main results, the coefficient of the real exchange rate misalignment is positive and statistically significant, confirming that the real exchange rate undervaluation positively influences exports. With regard to imports, the coefficient of the real exchange rate misalignment emerges with the expected sign and is only significant under the bias-corrected LSDV specification.

The coefficient of exchange rate volatility based on EGARCH for the export function appears with the expected sign but is statistically insignificant. For the import function, the coefficient is positive and significant under the specification (6). In both cases, the signs for the respective functions are in line with our main results in Table 2.6. As for the control variables, the coefficients of terms of trade, trade openness and real foreign income for the exports equation emerge correctly signed and statistically significant. For the imports equation, the coefficients of trade openness, terms of trade, real foreign income and foreign direct investment remain broadly in line with our baseline results. Generally, the link between the real exchange rate misalignment and trade does not seem to change with the inclusion of the real exchange rate proxy based on EGARCH.

Table 2.7: Estimation Results with an Alternative Volatility Measure

Variables	Exports			Imports		
	OLS	FE	BC-LSDV	OLS	FE	BC-LSDV
	(1)	(2)	(3)	(4)	(5)	(6)
L.lexp	0.978***	0.568***	0.593***			
	(0.007)	(0.051)	(24.019)			
L.lim				0.591***	0.230***	0.241***
				(0.057)	(0.035)	10.293)
Underval	0.010	0.030*	0.030**	-0.135	-0.097	-0.099**
	(0.021)	(0.016)	(2.075)	(0.088)	(0.057)	(-2.334)
Lopen	0.099***	0.570***	0.560***	0.422***	0.856***	0.848***
	(0.028)	(0.072)	(13.3869	(0.065)	(0.053)	(34.732)
Vol1	-0.004	-0.001	-0.001	0.003	0.003	0.003*
	(0.004)	(0.003)	(-0.342)	(0.002)	(0.002)	(1.861)
Ltot	0.074**	0.066	0.058*	0.007	-0.092*	-0.091***
	(0.033)	(0.069)	(1.662)	(0.038)	(0.051)	(-4.785)
Lwgdp	-0.072	0.212**	0.176***			
	(0.043)	(0.081)	(4.335)			
Lrgdp				0.361***	0.709***	0.694***
				(0.056)	(0.052)	(19.616)
Fdi	0.000*	-0.000	-0.000	0.000	0.000	0.000**
	(0.000)	(0.000)	(-0.483)	(0.000)	(0.000)	(1.989)
Obs	506	506	483	506	506	483
R-squared	0.989	0.954		0.991	0.987	
AR(1)			0.0000			0.0000
AR(2)			0.974			0.325

*** p<0.01, ** p<0.05, *p<0.1. Dependent variables are logs of exports and imports. For BC-LSDV biased corrected version of estimates are reported. Bias is initialized by Arellano-Bond (1991) estimator and bootstrapped standard errors using 50 iterations are in parenthesis. P-values for "AR(1)" and "AR(2)" are reported. Vol1 is the real exchange rate volatility based on EGARCH as an alternative volatility indicator.

Source: Author's computation using Stata 15

2.4.3.2 Choice of the Exchange Rate Regime

Checking for robustness of our results to the choice of the exchange rate regime (ERR) draws from the exchange categorization based on the de facto exchange rate regime classification proposed by Ilzetzki et al.(2019). This categorization builds upon the natural de facto classification scheme developed by Reinhart and Rogoff (2004). The choice of de facto classification is motivated by the drawback of the de jure exchange rate regime classification whereby the central banks claim to follow more flexible exchange rate regime which may some times be different from the official announcements, a phenomenon characterized as "fear of floating" (Calvo and Reinhart, 2002). As a result, policy outcomes attributable to de jure regimes may be misleading. Rogoff et al. (2004) confirm that de jure classification leads to misleading statistical inference and wrong interpretation of the effects of ERR. Extensive work on the new methods of classification include Ghosh et al., 2003), Reinhart and Rogoff (2004), Levy-Yeyati and Sturzeneger (2005), Klein and Shambaugh (2010), and most recently, Ilzetzki et al. (2019).

The de facto exchange rate arrangement by Ilzetzki et al.(2019) is based on the comprehensive reference currencies, exchange rate arrangements and a new measure of foreign exchange restrictions for 194 countries and territories over the period 1946-2016. This arrangement is subdivided into two categories, namely, fine category with 15 classifications and coarse with 6 classifications. In this chapter, the fine category is used given that it is more dis-aggregated. Computationally, the exchange rate regime is coded as a three category ordinal variable based on data. Higher values indicate greater degree of flexibility and vice-versa, thus, categories 1-6 are lumped up to constitute the fixed regime category, 7-10 are lumped together as the intermediate regime and categories 11-14 constitute the flexible exchange rate regime, while category 15 is excluded because of missing data. Preliminary analysis indicates that 43.08 percent of the sampled SSA countries pursue an intermediate regime, 39.53 percent pursue a fixed rate regime, while 17 percent pursue a flexible exchange rate. In our estimation, we introduce the dummy variables for fixed and intermediate categories.

The estimation results for exports and imports equations with fixed and intermediate exchange rate regimes are reported in Table 2.8. The estimated coefficients for the real exchange rate undervaluation and volatility proxy based GARCH are not significant in the export function, but emerge with the correct signs and are statistically significant in the import function. However, we obtain a positive and statistically significant coefficient for the intermediate exchange rate regime under BC-LSDV in the export equation, this is because most developing countries pursue managed floating exchange rate regimes, which reduce exchange rate risk exposure and reduce the real impact of trade shocks thereby increasing exports. This renders support to previous empirical studies by Edwards and Levy-Yeyati (2005) and Broda (2004).

For the control variables on the export side, only the degree of openness and real foreign income appear with the correct signs and is statistically significant, while on the import side, the degree of openness, terms of trade , real domestic income and foreign direct investment are statistically significant, much in line with the baseline results. Broadly speaking, the link between the real exchange rate regimes and trade does not seem to improve the robustness of our main results. In addition, since the exchange rate regime dummies are barely significant in the fixed effects and BC-LSDV estimations, their exclusion from the exports and imports does not lead to omitted-variable bias.

Table 2.8: **Estimation Results with Exchange Rate Regimes**

Variables	**Exports**			**Imports**		
	OLS	FE	BC-LSDV	OLS	FE	BC-LSDV
	(1)	(2)	(3)	(4)	(5)	(6)
L.lexp	0.976***	0.558***	0.583***			
	(0.008)	(0.050)	(27.756)			
L.lim				0.570***	0.223***	0.235***
				(0.054)	(0.036)	(11.312)
Underval	0.009	0.024	0.024	-0.139*	-0.097*	-0.100**
	(0.023)	(0.015)	(1.473)	(0.079)	(0.053)	(-2.393)
Lopen	0.119***	0.599***	0.588***	0.432***	0.866***	0.857***
	(0.034)	(0.094)	(14.237)	(0.065)	(0.052)	(40.630)
Vol	-0.004	-0.000	-0.000	0.003	0.002	0.002*
	(0.006)	(0.003)	(0.104)	(0.002)	(0.002)	(1.475)
Ltot	0.063*	0.051	0.043	-0.018	-0.096*	-0.096***
	(0.035)	(0.067)	(1.169)	(0.040)	(0.050)	(-4.877)
Fixed	0.011	0.018	0.020	0.065	0.003	0.005
	(0.042)	(0.071)	(0.471)	(0.042)	(0.067)	(0.209)
Intermediate	0.051	0.044	0.047*	0.106**	0.012	0.013
	(0.038)	(0.043)	(1.775)	(0.043)	(0.021)	(0.906)
Lwgdp	-0.113*	0.168	0.135**			
	(0.058)	(0.100)	(2.196)			
Lrgdp				0.387***	0.714***	0.697***
				(0.054)	(0.053)	(18.509)
Fdi	0.000*	-0.000	-0.000	0.000	0.000	0.000**
	(0.000)	(0.000)	(-0.483)	(0.000)	(0.000)	(1.874)
Obs	483	483	483	483	483	483
R-squared	0.989	0.955		0.991	0.987	
AR(1)			0.0000			0.0000
AR(2)			0.7585			0.1487

*** p<0.01, ** p<0.05, *p<0.1. Dependent variables are logs of exports and imports. For BC-LSDV biased corrected version of estimates are reported. Bias is initialized by Arellano-Bond (1991) estimator and bootstrapped standard errors using 50 iterations are in parenthesis. P-values for "AR(1)" and "AR(2)" are reported. Fixed and intermediate exchange rate regimes are used.

Source:Author's computation using Stata 15

2.4.3.3 Exclusion of Outlier Countries

As an additional check, we estimate the model while excluding outlier countries to account for the possibility that they bias the results regarding the association between the real exchange rate and trade. Concretely, we exclude from our sample three resource rich SSA countries: Nigeria, South Africa and Angola. The choice of countries is motivated by the fact that South Africa has been known to have registered a different growth pattern compared to other SSA countries. Nigeria is chosen for the big proportion of petroleum products in its export basket (Osabuohien et al., 2014), and Angola is known for a wide range of mineral resources that dominate its exports. Table 2.9 reports the results of exports and imports demand equations with the exclusion of outliers countries. Both the lagged coefficients of exports and imports remain positive and statistically significant. On the export side, regarding the coefficients for our variables of interest, the real exchange rate undervaluation appears with the correct sign and is statistically significant, while the real exchange rate volatility appears insignificant. The coefficients of control variables such as trade openness, terms of trade and real foreign income emerge with the correct signs and are statistically significant. Regarding the import equation, the coefficient of the real exchange rate undervaluation is negative and statistically significant under the bias-corrected least squares dummy variable estimator. The coefficients of the control variables, including the degree of trade openness, the terms of trade and real domestic income appear statistically significant and are correctly signed. Overall, the results with the exclusion of outliers[14] countries indicate that while there is still evidence that exchange rate undervaluation affect trade, exchange rate volatility does not seem to matter.

[14]Excluding each of these outlier countries one at a time does not yield much better results than excluding all the three at once. The results of each outlier country are presented in the appendices as Table A4, Table A5 and Table A6, respectively.

Table 2.9: Exports and Imports Estimation Results Excluding Outliers

Variables	Exports			Imports		
	OLS	FE	BC-LSDV	OLS	FE	BC-LSDV
	(1)	(2)	(3)	(4)	(5)	(6)
L.lexp	0.973***	0.611***	0.639***			
	(0.011)	(0.045)	(21.717)			
L.lim				0.497***	0.195***	0.206***
				(0.061)	(0.039)	(7.930)
Underval	0.008	0.030*	0.029*	-0.136	-0.084	-0.086*
	(0.023)	(0.016)	(1.871)	(0.092)	(0.068)	(-1.757)
Lopen	0.094**	0.508***	0.499***	0.503***	0.913***	0.905***
	(0.034)	(0.069)	(9.912)	(0.060)	(0.056)	(35.195)
Vol	-0.001	0.000	0.000	0.002	0.001	0.001
	(0.002)	(0.002)	(0.038)	(0.003)	(0.002)	(0.907)
Ltot	0.053	0.025	0.017	0.039	-0.054	-0.054***
	(0.035)	(0.064)	(0.435)	(0.045)	(0.044)	(-2.690)
Lwgdp	-0.025	0.215**	0.176**			
	(0.037)	(0.085)	(2.521)			
Lrgdp				0.475***	0.723***	0.710***
				(0.064)	(0.059)	(19.451)
Fdi	0.000	0.000	0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.029)	(0.000)	(0.000)	(-0.992)
Obs	440	440	440	440	440	440
R-squared	0.984	0.953		0.989	0.988	
AR(1)			0.0000			0.0000
AR(2)			0.4754			0.9696

*** p<0.01, ** p<0.05, *p<0.1. Dependent variables are logs of exports and imports. For BC-LSDV biased corrected version of estimates are reported. Bias is initialized by Arellano-Bond (1991) estimator and bootstrapped standard errors using 50 iterations are in parenthesis. P-values for "AR(1)" and "AR(2)" are reported. Outlier countries are excluded in our regression.

Source:Author's computation using Stata

2.4.3.4 Using Non-overlapping 3-year Averages

We also use non-overlapping 3-year averages in our estimation to check whether the results are robust to using longer periods than a single year. The estimated results are reported in Table 2.10. Broadly speaking, the results for non-overlapping 3-year averages are not in line with the estimation results using annual data. For the export demand function, the variables of interest (undervaluation and volatility) are not statistically significant, suggesting that the use of non-overlapping 3-year averages yields weaker results when compared to when using annual data. The coefficient of lagged exports is found to be positive and statistically significant, similar to our main regression and for the control variables, only the coefficient associated with the degree of trade openness appears positive and statistically significant. For the import function, the coefficient of undervaluation is found to be negative and statistically significant, confirming the results obtained with annual data, while the real exchange rate volatility is insignificant, and as for the control variables, the coefficients of trade openness, terms of trade, real domestic income and foreign direct investment remain statistically significant. Overall, the results of non-overlapping 3-year averages are weaker than when using annual data, especially regarding export estimations.

This may happen because using annual data provides more observation, which helps to obtain more statistically significant results. Additionally, 3-year period averages smooth the series of the real exchange rate variables, not capturing intra-year variations in real exchange rate misalignment and volatility, which may have important effects on trade.

Table 2.10: Exports and Imports Estimation Results with 3 year Averages

Variables	**Exports**			**Imports**		
	OLS	FE	BC-LSDV	OLS	FE	BC-LSDV
	(1)	(2)	(3)	(4)	(5)	(6)
L.lexp	0.943***	0.435***	0.475***			
	(0.016)	(0.041)	(10.658)			
L.lim				0.359***	0.091***	0.112***
				(0.059)	(0.027)	(3.684)
Underval	-0.069	0.016	0.012	-0.207	-0.166**	-0.169***
	(0.088)	(0.038)	(0.444)	(0.182)	(0.077)	(-2.825)
Lopen	0.243***	0.869***	0.882***	0.629***	1.002***	0.998***
	(0.075)	(0.108)	(10.169)	(0.064)	(0.050)	(29.841)
Vol	-0.020	-0.009	-0.010	0.002	0.005	0.005
	(0.012)	(0.007)	(-1.555)	(0.006)	(0.004)	(1.445)
Ltot	0.220**	0.101	0.085	0.031	-0.089	-0.089***
	(0.084)	(0.103)	(1.304)	(0.065)	(0.065)	(-2.679)
Lwgdp	-0.222	0.158	0.078			
	(0.134)	(0.153)	(0.529)			
Lrgdp				0.558***	0.817***	0.776***
				(0.070)	(0.056)	(10.968)
Fdi	0.000**	-0.000	-0.000	0.000	0.000*	0.000**
	(0.000)	(0.000)	(-0.230)	(0.000)	(0.000)	(2.096))
Obs	161	161	161	161	161	161
R-squared	0.980	0.957		0.987	0.989	
AR(1)			0.1148			0.8222
AR(2)			0.5860			0.5142

*** p<0.01, ** p<0.05, *p<0.1. Dependent variables are logs of exports and imports. For BC-LSDV biased corrected version of estimates are reported. Bias is initialized by Arellano-Bond(1991) estimator and bootstrapped standard errors using 50 iterations are in parenthesis. P-values for "AR(1)" and "AR(2)" are reported. 8 non-overlapping 3-year averages are created and used.

Source:Author's computation using Stata 15

Excluding the extreme values We exclude observations for extreme values of real exchange rate misalignment and real exchange rate volatility to check whether results are sensitive to exclusion of extreme values. The highest 1 percent is excluded on both tails using winsorization technique, a data transformation procedure that does not remove the values at the tails of distribution, but records them to less extreme values. For instance, 1 percent of the lowest values (lower tail) is recorded to the value of the 1^{st} percentile and 1 percent of the highest values(higher tail) is recorded to the value of 99^{th} percentile. This implies that it replaces values in the tails with selected values closer to the middle of the distribution. This procedure is implemented via" winsor2" stata module developed by Lian Yu-jun (2014). Table 2.11 reports the results of exports and imports demand equations, with winsorized extreme values of real exchange rate misalignment and real exchange rate volatility variables.

The results indicate that the coefficients of lagged exports and imports remain positive and statistically significant across all the specifications. Regarding the variables of interest on the export side, real exchange rate undervaluation is positive and statistically significant under fixed effects and Bias-corrected least squares dummy variable estimator, while real exchange rate volatility appears statistically insignificant. Except foreign direct investment, all other control variables on the export side are correctly signed and statistically significant. On the import side, as expected, the coefficient of real exchange rate undervaluation is negative and statistically significant under FE and BC-LSDV specifications, while real exchange rate volatility becomes marginally significant, with correct signs, but only under BC-LSDV. All control variables including degree of openness, terms of trade, real domestic income and foreign direct investment emerge correctly signed and are statistically significant. Broadly speaking, our results become more robust to excluding the extreme values of real exchange rate misalignment and real exchange rate volatility.

Table 2.11: **Estimation Results Excluding Extreme Values**

Variables	**Exports**			**Imports**		
	OLS	FE	BC-LSDV	OLS	FE	BC-LSDV
	(1)	(2)	(3)	(4)	(5)	(6)
L.lexp	0.978***	0.568***	0.593***			
	(0.007)	(0.0)51	(24.019)			
L.lim				0.591***	0.230***	0.242***
				(0.057)	(0.035)	(10.297)
$Underval_w$	0.010	0.030*	0.030**	-0.136	-0.98*	-0.100**
	(0.021)	(0.016)	(2.081)	(0.088)	(0.056)	(-2.345)
Vol_w	-0.004	-0.001	-0.001	0.003	0.003	0.003*
	(0.004)	(0.003)	(-0.323)	(0.002)	(0.002)	(1.861)
Lopen	0.09***	0.570***	0.560***	0.422***	0.856***	0.848***
	(0.028)	(0.072)	(13.386)	(0.065)	(0.053)	(34.736)
Ltot	0.073**	0.066	0.058*	0.007	-0.092*	-0.091***
	(0.033)	(0.069)	(1.660)	(0.038)	(0.051)	(-4.790)
Lwgdp	-0.072	0.212**	0.176***			
	(0.043)	(0.081)	(4.336)			
Lrgdp				0.361***	0.709***	0.693***
				(0.056)	(0.053)	(19.616)
Fdi	0.000*	-0.000	-0.0000	0.000	0.000	0.000**
	(0.000)	(0.000)	(-0.483)	(0.000)	(0.000)	(1.989)
Obs	506	506	506	506	506	506
R-squared	0.98	0.95		0.99	0.98	
AR(1)			0.0000			0.0000
AR(2)			0.973			0.329

*** p<0.01, ** p<0.05, *p<0.1. Dependent variables are logs of exports and imports. For BC-LSDV, biased corrected version of estimates are reported. Bias is initialized by Arellano-Bond (1991) estimator and bootstrapped standard errors using 50 iterations are in parentheses. P-values for "AR(1)" and "AR (2)" are reported. Variables with subscript w are winsorized real exchange rate misalignment and volatility indicators.

Source:Author's computation using Stata 15

2.5 Conclusions and Policy Recommendations

Following the demise of the Bretton Woods system of fixed exchange rates, the most substantial amount of empirical literature on the relationship between the exchange rates and trade has dealt with the effect of increased exchange rate volatility on trade. However, the focus has in the recent past shifted towards the link between exchange rate misalignment and trade. The objective of this chapter is therefore is to contribute to the debate on the link between the real exchange rate misalignment and trade flows. The empirical investigation is based on a sample of 23 Sub-Saharan African countries during the period 1995-2017. Empirically, the real exchange rate misalignment indicator is generated based on the estimation of the behavior equilibrium exchange rate (BEER) along with Hodrick-Prescott filter, while the real exchange rate volatility proxy is generated by GARCH type models, particularly GARCH and EGARCH. Different estimations are conducted using static and dynamic panel estimators such as ordinary least squares (OLS) and fixed effects (FE), as benchmark regressions, and bias-corrected least squares dummy variable estimator (BC-LSDV).

The major findings indicate that real exchange rate misalignment significantly influences trade flows in SSA countries. As expected, real exchange rate undervaluation is found to promote exports and to decrease imports. Regarding real exchange rate volatility, the results suggest that it does not affect exports, but has a significant positive impact on imports. The positive and significant effect of real exchange rate volatility associated with the import demand function is explained by the fact that, for SSA countries, financial instruments to hedge against exchange rate risk are still limited due to the low level of financial markets development. Control variables such as trade openness, terms of trade, real foreign income, foreign direct investment, and domestic real income have positive and statistically significant coefficients. Our results are robust to the use of an alternative volatility proxy based on EGARCH, but less robust to the choice of the exchange rate regime, the exclusion of Outlier countries as well as to the use non-overlapping 3-year averages. Robustness is greater for the effects of exchange rate misalignment, whose statistical significance tends to become weaker in the last 3 robustness checks , than exchange rate volatility , which generally becomes statistically insignificant.

In light of these results, several policy implications arise. First, maintaining an undervalued real exchange rate through monitoring exchange rates relative to trading partners may be important. However, persistent real exchange rates may provide incentives to the recurrence to non-traditional protectionist policies. Thus, strategies to avoid trade protectionist measures including multilateral cooperation related to the stabilization of exchange rates towards their equilibrium levels should be at the fore. In addition, SSA countries should step up the regional and financial integration efforts. Secondly, our findings show that the real exchange rate volatility has a depressing effect on trade. Therefore, policies to avoid the problems caused by volatile exchange rates, such as putting in place financial instruments to hedge against the exchange rate risk is crucial, especially for SSA countries where these instruments are not well developed.

Finally, implementing sound macroeconomic policies to provide a stable economic environment is important for trade to thrive, for instance, maintaining the real exchange rate undervaluation requires higher savings relative to investment or lower expenditure relative to income. This can be achieved through prudent fiscal policy as part of a wider macroeconomic policy package.

Chapter 3.

Real Exchange Rate and Economic Growth in SSA Countries

3.1 Introduction

Exchange rates are key prices in the economy, their level and variability have far reaching implications for resource allocation and growth (Gadanecz and Mehrotra, 2013). The debate concerning the role of the real exchange rate in macroeconomic policy and long-run growth lies at the heart of economic policy (Lane, 2001) and policy design (Hinkle and Montiel, 1999). Indeed, Gala and Lucinda (2006) argue that a competitive exchange rate is a condition for economic growth. Theoretically, the point of departure is the Washington consensus laid out by Williamson (1990), which recognizes an essential role of the real exchange rate in the growth process. According to this view, a competitive exchange rate is assumed to be consistent with the macroeconomic objectives in the medium term and adequately competitive in a sense that the economy grows at a rate that is congruent with external balance. However, an exceedingly competitive real exchange rate is not appropriate because it would result in higher inflation, but no increase in economic growth (Goldstein, 2002).

Fundamental to this view is the idea that there exists an equilibrium real exchange rate that satisfies both the internal and external balance. To this end, any deviations from the equilibrium exchange rate will hamper economic growth. In contrast, Rodrik (2008) posits that real exchange rate overvaluation harms economic growth, while real exchange rate undervaluation spurs economic growth. This stance is partly informed by the success story of export-led growth along with presumably undervalued currencies in East Asian countries that boosted foreign trade and fueled economic growth, while inward oriented policies implemented in Latin America and Africa are associated with overvalued currencies that inhibited growth (Cottani et al., 1990; Dollar, 1992 and Dooley et al., 2004). Other plausible theoretical explanations on why the real exchange rate undervaluation is healthy for economic growth relate to positive externalities (learning by doing and technology spillovers) that accrue to export linked activities. Another explanation is that undervalued currencies promote higher savings and investment. Several studies including Levy-Yeyati and Sturzenegger (2007), Rodrik (2008), Aizenman and Lee (2010), Di Nino et al.(2011), McLeod and Mileva (2011), Gluzmann et al.(2012) have put forth theoretical arguments supporting this relationship. In recent times, a considerable amount of empirical literature has confirmed this relationship (Rapetti et al., 2012; Béreau et al., 2012, Missio et al., 2015 and Guzman et al., 2018).

While most policy makers are firmly convinced that exchange rate depreciation will stimulate growth, economists generally have reservations that the relative price of two currencies may be a fundamental driver of economic growth over the long-run. For most economists, the exchange rate is an endogenous variable, whose contribution to growth may be difficult to unravel. Literally, the inquiry on whether engineering an exchange rate undervaluation is growth enhancing in the medium-term is still unexpectedly equivocal in the literature (Habib et al., 2017). Although the real exchange rate is an endogenous variable and not a direct policy instrument, we still speak of the real exchange rate policies, cognizant of the fact that these policies so much rely on the management of a set of actual policy instruments that can be vital to implementing optimal exchange rate policies (Guzman et al., 2018). In most developing and emerging economies, remarkable interest has been shifted into the field of foreign exchange management to appreciate the role of a competitive exchange rate in stimulating economic performance (Eichengreen, 2007; Rodrik, 2008; Razmi et al., 2012). Exchange rate movement has thus become central in formulating the appropriate macroeconomic policies (Bauwens et al., 2006). Inasmuch as the link between the real exchange rate and economic growth has been widely investigated in the empirical literature, little consensus has been reached yet. In fact, Loayza et al.(2005), Gala (2008), Rodrik (2008),Gala and Libanio (2010), Razmi et al. (2012) and Vaz and Baer (2014) find a positive and significant relationship between RER competitiveness and economic growth for developing countries. While Ghosh et al.(1997) find no relationship between observed exchange rate variability and economic growth in a panel of 136 countries over the period 1960–89 and Bleaney and Greenaway (2001) find little evidence of a relationship.

Possible explanations for the divergence of results include, differences in measurements of the real exchange misalignment indicator. The concept of the real exchange rate misalignment assumes the concept of equilibrium real exchange rate (ERER), which generates some contention given that different authors use different sets of economic fundamentals to estimate the equilibrium ERER, and finally, the literature also presents different results emanating from the use of different econometric techniques to estimate the model. Motivated by these considerations, the aim of this chapter is to empirically assess the effect of the real exchange rate undervaluation on economic growth in Sub-Saharan African (SSA) countries. We apply the bias-corrected least squares dummy variable (BC-LSDV) estimator in a panel of 23 SSA countries over the period 1995-2017, converted into non-overlapping 3-year averages. Our results provide strong evidence that the RER undervaluation favours economic growth and are in line with those reported in the recent empirical studies such as Rodrik (2008) and Berg and Maio (2010).

The chapter contributes to the empirical literature in four important ways. Firstly, we use the exchange rate misalignment indicator based on purchasing power parity (PPP) and the behavioral equilibrium exchange rate, along with the Hodrick-Prescott filter to generate the real exchange rate misalignment indicator, while most previous empirical work have relied on the RER misalignment indicator based on PPP. Secondly, we use the exchange rate volatility, and the exchange rate misalignment indicators as the exchange rate variability and level indicators, respectively. In addition, we subject our baseline results to a number of robustness checks to obtain better insights into the effects of the real exchange rate on economic growth. Thirdly, whereas vast empirical work assessing the relationship between the real exchange rate and growth has been investigated in the wider context of emerging and developing countries, little has been done to investigate this issue in the case of SSA. A few notable exceptions include Elbadawi et al.(2012), Iyke and Odhiambo (2015) and Habib et al.(2017). This study therefore focuses on SSA countries. Finally, our data set starts in 1995, a period after the advent of structural adjustment programs (SAPs), to explore the impact of SAPs and the resultant economic liberalization in most SSA countries.

The rest of the chapter is organized as follows. Section II reviews the theoretical and empirical literature. Section III presents the methodology. Section IV reports and discusses empirical results. Finally, section V presents the conclusions and policy implications.

3.2 Literature Review

The association between the real exchange rate and economic growth is well documented in the literature, focusing particularly on the deviation of the actual real exchange rate from the equilibrium real exchange rate, which is conceptually referred to as the real exchange rate misalignment. In this section, we review both the theoretical and empirical literature on the link between the real exchange rate and growth.

3.2.1 Theoretical Literature

Several theoretical channels have been put forth to explain the link between the real exchange rate and economic growth. First, the export-led growth channel, which hypothesizes that the real exchange undervaluation promotes growth via export growth given that the real exchange undervaluation enhances productivity in the tradable sector and encourages exports in the tradable sector. According to Eichengreen (2008) the key feature is that countries have incentives to keep the relative prices of tradable goods sufficiently high so as to attract resources into their production. Other advocates of export-led growth such as Giles and Williams (2000) conjecture that increased exports are an engine of growth. Rodrik (2009) posits that the real exchange undervaluation spurs economic growth by incentivizing the productivity of the tradable goods in developing countries, which are generally characterized by market distortions and institutional weaknesses. He argues that the real exchange rate undervaluation serves as the second best policy option to compensate for the negative effects of these distortions by enhancing the sector's productivity. Underlying this theoretical justification is the fact that the real exchange rate undervaluation is likely to be less effective for export promotion and economic growth in advanced economies with well developed institutions, especially financial institutions because first best policy options already exist. These theoretical predictions are strongly supported by the empirical growth and export performance literature (Rodrik, 2008; Aghion et al., 2009 ; Elbadawi and Kaltani, 2015). Relatedly, other scholars such as Aizenman and Lee (2010), Mcleod and Mileva (2011) and Benigno et al.(2015) argue that there are learning by doing effects external to the individual firm in the traded goods sector, and thus, an undervalued real exchange rate is requisite to support the production of tradables.

Another theoretical postulation is the capital accumulation channel, which suggests that an undervalued real exchange rate leads to lower real wages and enhance the profitability of labour intensive sectors and then contributes to more employment and investment, thereby increasing capacity utilization. In a similar fashion, Glüzmann et al. (2012) in line with Dooley et al.(2004), Gala (2008) and Levy-Yeyati and Sturzenegger (2007), demonstrate that undervalued exchange rates foster economic growth via the savings and investment channel, whereby undervalued currencies tend to boost savings and investment through lower labor costs and income re-distribution and the avoidance of the consumption booms associated with the real exchange rate overvaluation, which in turn bolster economic growth.

The third strand of theoretical literature relates to the foreign currency denominated debt channel, which according to Grekou (2018) is premised on the idea that the real exchange rate depreciation substantially raises the foreign denominated debt burden through valuation effects, causing a decline in firms production due to corporate financial distress, absence of trade credits and surge in the cost of imported inputs and goods. These balance sheet effects debilitate the government's fiscal position and the bank's balance sheet and thus, the overall economic growth. On the other hand, an appreciation reduces the value of the foreign denominated debt and improves the potential to borrow. In this regard, overvaluation of the real exchange rate fosters economic growth.

These balance sheet effects are profound for developing countries given that they generally can not borrow in their own currencies, a phenomenon known in literature as " original sin" (Eichengreen and Hausmann, 1999). The foreign denominated debt channel is well documented in the real exchange rate misalignment and growth literature. Notable contributions include Galindo et al (2003), Frankel (2005) and Grekou (2015, 2018).

3.2.2 Empirical Literature

On the empirical front, a growing body of literature has examined the link between exchange rate and economic growth and the evidence from this literature is mixed and conflicting across methodologies and samples. The first strand of empirical literature addressing the issue of the growth effect of the real exchange rate misalignment relates to the Washington consensus highlighted in Krueger (1983), Edwards (1989), Williamson (1990) and Berg and Miao (2010), which is based on the equilibrium real exchange rate that satisfies both the internal and external balance. Indeed, in a sample of developed and emerging economies, Aguire and Calderón (2005) obtain results suggesting that the real exchange misalignment, computed as a residual from the fundamental equilibrium exchange rate (FEER) helps predict economic growth. Johnson et al. (2007) find evidence that avoiding the real exchange rate overvaluation is linked with long growth booms, whilst the real exchange rate undervaluation does not matter for growth. Berg and Miao (2010) argue that the real exchange rate misalignment implies some sort of macroeconomic imbalance that is in itself growth depressing. They, for instance, indicate that fixed exchange rates in the presence of expansionary monetary policy might trigger the exchange rate appreciation and unsustainable current account deficit, eventually calling for domestic contraction or import controls when foreign financing fades. Mbaye (2012) indicate that the real exchange rate misalignment is associated with macroeconomic disequilibrium regardless of the direction of misalignment. Under this argument both the real exchange rate undervaluation and overvaluation are proclaimed to be detrimental to economic growth. Conversely, Rodrik (2008), in a sample of developing countries spanning the period 1950-2004 finds that growth is a lot higher in countries with the undervalued exchange rates and that the effect is linear and similar for the undervaluation and overvaluation, that is, overvaluation hurts growth, but undervaluation supports growth.

The second line of empirical literature investigates the association between real exchange rate misalignment and economic growth. Most empirical work tend to confirm a positive association between exchange rate undervaluation and economic growth. Hausmann et al.(2005), based on the analysis of more than 80 episodes of growth accelerations between 1957 and 1992, suggest that faster economic growth is significantly associated with the real exchange rate depreciation. Gala and Lucinda (2006) developed a dynamic panel data analysis using both the difference and system generalized methods of moments (GMM) techniques, for a set of 58 countries covering the period 1960-1999, with a measure of the real exchange rate misalignment incorporating the Balassa-Samuelson effect and a set of control variables including, physical and human capital, institutional environment, inflation, the output gap, and the terms of trade shocks. The main finding supports the argument that the undervalued exchange rates is associated with higher growth rates. Rodrik (2009) and Aghion et al.(2009) conclude that the real exchange rate does matter for growth in developing countries, which broadly confirms and fortifies the conclusions of Rodrik (2008). Di Nino et al. (2011) examine the relationship between the real exchange rate and economic growth in high productivity sectors in Italy using a panel data set covering the period 1861-2011 and system GMM as an estimation technique. They conclude that there is a positive relationship between undervaluation and economic growth and show that undervaluation supported growth by increasing exports, especially from high-productivity sectors. Examining the macroeconomic effects of large exchange rate appreciations in a sample of 128 developing and advanced economies, covering the period 1960-2008 and employing a dummy panel autoregressive model, Kappler et al. (2013), identify 25 episodes of large nominal and real appreciations and find that the effects on output are limited. The negative effect on the level of output is only 1 percent after six years, and results are statistically insignificant. McMillan and Rodrik (2011) assess the impact of labour flows from low productivity activities to high productivity sectors on economic development using panel data for nine sectors in 38 countries over the period 1990 to 2005. They find that the level of the RER favors structural change in favor of modern tradables and the flow of labor from low-productivity to high-productivity tradable activities. MacDonald and Vieira (2010), study the role of real exchange rate misalignment on long-run growth for a set of 90 countries using data from 1980 to 2004, construct seven different indices of RER misalignment, and apply them alternatively on the right-hand side of the growth regressions. They employ both static and dynamic panel techniques and find a significant and positive correlation between RER competitiveness and economic growth, which is stronger for developing and emerging countries. Razmi et al. (2012) use the rate of investment growth as the dependent variable and find a strong positive association between RER levels and growth. Analyzing the role of the real exchange rate in the growth process in a fixed effects specification , Eichengreen (2008), using a panel of 28 industries for 40 emerging market countries covering the period 1985–2003, finds that higher and more stable RER levels increases tradable employment growth. Vaz and Baer (2014) analyze the impact of the real exchange rate undervaluation on manufacturing sectors in Latin America using a panel data set covering 39 countries and 22 manufacturing sectors for the period 1995-2008. They confirm a positive and significant impact of the real exchange rate undervaluation on the manufacturing sector. Rapetti et al. (2012) builds upon Rodrik's (2008) framework and estimate the effect of exchange rate undervaluation on economic growth for a large sample of both developing and developed countries. They utilize different criteria, compared to Rodrik's (2008) to distinguish between the developed and developing countries. They obtain that exchange rate undervaluation positively impacts growth. A similar result is confirmed in a recent study by Njindan (2017). Other recent panel data studies on the real exchange rate misalignment and growth include, Coudert and Couharde (2008), Nouira and Sekkat (2015), Bahmani-Oskooee and Halicioglu (2017), Communale (2017) and Rodriguez (2017).

On the other hand, some empirical studies such as Dollar (1992), Razin and Collins (1997), Aguire and Calderón (2005), Johnson et al.(2007), Rajan and Subramanian (2009) and Gala (2008) have generally found that the real exchange rate overvaluation hurts economic growth. Easterly (2001) analyzed the effects of the real exchange rate overvaluation on growth of developing countries from 1980 to 1998. He found out that despite the reforms of the 1980s and 1990s, the association between the real exchange rate overvaluation and per capita growth rates is negative. Building upon the real exchange rate overvaluation index by Easterly (2001), Loayza et al.(2002) report similar results when comparing growth in Latin American economies and other countries during the period 1960-1999. They conclude that the overvalued exchange rate has a significant negative impact on growth. The possible explanation of this empirical finding is the increasing likelihood of balance of payments crises due to overvalued exchange rates. Frankel (2004) examines the effect of real exchange rate misalignment on growth in Latin American countries and finds that the overvaluation of their currencies constitutes one of the major explanation of crises and stagnation affecting these countries during the 1990s and 2000s. Bussiére et al.(2015), using propensity score matching techniques, investigate the impact of exchange rate changes on economic growth in a sample of 68 advanced and emerging economies from 1960 to 2011 and conclude that real exchange rate appreciations tend to have negative effects on economic growth. In the context of the SSA countries, Elbadawi et al. (2012), using the GMM estimator in a sample of 77 countries for the period 1970-2004, indicate that the real exchange rate overvaluation is detrimental to economic growth and that the effect is more appalling in countries with less developed financial systems.

Most recently, Habib et al. (2017) in a sample of 150 countries investigates the impact of the movements in exchange rate on economic growth based on the 5 year averages, their results show that a real appreciation significantly reduces annual GDP growth. However, this effect is only confirmed for developing countries and for pegs.

The third strand of literature that has recently gained relevancy is premised on the argument that there is a non-linear relationship between exchange rate misalignment and economic growth. As opposed to the linear view that customarily suggests that undervaluation promotes growth while overvaluation hurts growth, this strand of empirical literature obtains asymmetric effects and suggests that both exchange rate undervaluation and overvaluation are detrimental to economic growth. Notable among these are Williamson (2009) who argues that a small undervaluation can benefit growth. In the particular case of Brazil, for the period 1996-2009, Barbosa et al. (2010) find that both real appreciations and depreciations can have negative effects on growth. Similarly, Haddad and Pancaro (2010) in a panel of 187 countries spanning the period 1950-2004 obtain results which show that a real undervaluation has a positive effect on the economic growth of low income countries in the short-run, but a negative effect in the long-run. Aguirre and Calderón (2005) find that both overvaluation and undervaluation have a negative effect on economic growth, with overvaluation having a strong effect. Schröder (2013) finds both undervaluation and overvaluation to be negatively associated with growth. Béreau et al.(2012) examines the effect of exchange rate misalignment on economic growth using a sample of industrialized and emerging economies, covering the period 1980 to 2007, and they construct the equilibrium exchange rate measure based on the behavioral equilibrium exchange rate (BEER) approach using economic fundamentals such as the terms of trade, the relative productivity and the net foreign assets. Using a panel smooth transition model, they obtain results pointing to the fact that small overvaluation and undervaluation support economic growth while large overvaluations hamper it. Employing an exchange rate equilibrium measure based on Arberola et al.(1999) and a cointegration technique, Couharde and Sallenave (2013) examine the impact of exchange rate misalignment and economic growth using a panel smooth transition model (PSTR), and the obtained results show that real exchange rate undervaluation supports growth up to a threshold, beyond which there is a reversal. They obtain a higher threshold for Asian countries, supporting their use of undervalued currencies as a strategy to boost growth.

3.2.2.1 Current State of Knowledge

In conclusion, the literature indicates theoretical channels through which the real exchange rate affects economic growth and these include the tradable sector channel,the capital accumulation channel and the foreign currency denominated debt channel. However, directions in which the real exchange rate may influence productivity, investment, trade, and thus economic growth remain mixed and conflicting, hence the link between the real exchange rate and economic growth becomes an empirical issue. Despite the fact that the empirical literature has not yet reached consensus, some studies such as Rodrik, (2008), Di Nino et al. (2011), MacDonald and Vieira (2010) and Rodriquez (2017) have found that undervalued currencies support growth while overvalued currencies harm growth. Other studies have reached a conclusion that both undervaluation and overvaluation hurt economic growth (Razin and Collins, 1997; Aguirre and Calderón , 2005 ; and Couharde and Sallenave, 2013) and a third group of studies including Nouira and Sekkat (2012) found no effect. This could be due to measurement error in generating exchange rate misalignment dummies, sample bias and econometric techniques. However, most empirical studies tend to support a positive link between the real exchange rate undervaluation and economic growth. From the methodological viewpoint, some studies have followed static panel data techniques, particularly fixed effects and random effects and other have followed dynamic panel techniques such as generalized methods of moments (GMM) and its extensions. Despite the fact that the literature does not dictate which estimation technique to employ because no estimation emerged superior to others in estimating the effects of exchange rate misalignment on economic growth, system generalized methods of moments (SGMM) appears to be the most appropriate given that it deals with potential endogeneity bias. However, in a case like ours where we have few cross-sectional units, SGMM estimators produce biased estimates. We therefore, employ bias-corrected dynamic panel estimators, particularly the bias-corrected least squares dummy variable (BC-LSDV) estimator.

Table 3.1 summarizes key studies that have investigated the relationship between the real exchange rate and economic growth.

Table 3.1: Synthesis of Empirical Literature

Study	**Sample Period**	**Model**	**Estimation Technique**	**Results**
Rodrik (2008)	1950-2004	Dynamic panel growth model	SGMM[15]	RER undervaluation spurs growth
Gala and Lucinda(2006)	1960-1999	Dynamic panel growth model	SGMM	RER undervaluation is associated with growth
Elbadawi et al.(2012)	1970-2004	Group average model	PMG[16]	RER overvaluation is detrimental to growth
Di Nino et al.(2011)	1861-2011	Dynamic panel growth model	SGMM	positive relationship between RER and growth
McMillan and Rodrik(2011)	1990-2005	Dynamic panel growth model	SGMM	positive link between undervaluation and growth
MacDonald and Vieira(2010)	1980-2006	Dynamic panel growth model	SGMM	significant positive link between RER competitiveness and growth
Eichengreen(2008)	1985-2003	Dynamic panel growth model	SGMM	higher and stable RER increase growth
Béreau et al. (2012)	1980-2007	Panel non-linear model	PSTR [17]	large RER overvaluation hampers growth
Vaz and Baer(2014)	1995-2008	Dynamic panel growth model	SGMM	positive and significant impact of RER on manufacturing sector growth
Haddad and Pancaro(2010)	1950-2004	Dynamic panel growth model	SGMM	RER has positive effect on growth

15 System Generalized Method of Moments
16 Pooled Mean Group Estimator
17 Panel Smooth Transition Regression

Couharde and Sal-lenave(2013)	1980-2006	Panel non-linear model	PSTR	RER undervaluation favors growth up to a threshold level
Hausmann et al.(2005)	1957-1992	Dynamic panel growth model	SGMM	growth is significantly associated with RER undervaluation
Ghosh et al.(1997)	1960-1989	Dynamic panel growth model	SGMM	no relationship between exchange rate variability and growth
Aghion et al.(2009)	1960-2000	Dynamic panel growth model	SGMM	RER undervaluation supports growth
Habib et al.(2017)	1970-2010	Dynamic panel growth model	SGMM	RER undervaluation raises GDP growth
Aguirre and Calderón(2005)	1965-2003	Dynamic panel growth model	GMM	both undervaluation and overvaluation have negative effect on growth
Schröder(2013)	1970-2007	Dynamic panel growth model	SGMM	both RER undervaluation and overvaluation are negatively associated with growth
Bussiére et al.(2015)	1960-2011	Statistical matching model	PSM [18]	RER appreciation tends to have negative effect on growth
Communale(2017)	1994-2012	Dynamic panel growth model	SGMM	RER misalignment are associated with long-run growth

Source:Author's Compilation

[18] Propensity Score Matching

3.3 Methodology

3.3.1 Constructing RER misalignment and volatility

3.3.1.1 RER Misalignment

Prior to analyzing the effect of the real exchange rate on economic growth, it is critical to estimate the deviation of the actual real exchange rate from its equilibrium level. The major challenge associated with any empirical undertaking on this subject is that the equilibrium exchange rate is not observable (Schröder, 2013).

Thus, the point of departure to addressing this issue is to define real exchange rate (RER) and equilibrium real exchange rate (ERER). The real exchange rate is defined as the domestic relative price of traded to non-traded goods, given by $RER = E \times \frac{P_t}{P_n}$ where E is the nominal exchange rate, measured as domestic currency per unit of foreign currency, P_t and P_n are the prices of tradables and non-tradables, respectively. The equilibrium real exchange rate as defined by Nurse (1945) is the value of the RER that results in the simultaneous realization of both internal and external equilibrium, given sustainable values of relevant variables achieving this objective. The deviation from this value is known in the literature as exchange rate misalignment. To obtain measures of exchange rate misalignment, we follow two approaches, namely purchasing power parity adjusted equilibrium real exchange rate and the International Monetary Fund's (IMF) consultative group on exchange rate issues (CGER). We follow Rodrik (2008) to estimate the first RER misalignment indicator, which is basically a measure of the domestic price level that is adjusted for the Balassa-Samuelson (BS) effect. This measure is constructed in 3 steps. The first step involves calculating the RER by dividing the local official exchange rate per unit US dollar by the purchasing power parity conversion factor $lnreer_{it} = ln\left(\frac{XRAT_{it}}{PPP_{it}}\right)$, where i represents the country i, t indexes time period, $XRAT$ and PPP are the exchange rate and purchasing power parity, respectively, expressed in national currency per unit of US dollar.[19]. The second step involves regressing the constructed RER on real per capita GDP to adjust for the BS effect. This is specified as:

$$lnreer_{it} = \alpha + \theta lngdppc_{it} + f_t + \epsilon_{it} \tag{3.1}$$

where f_t is the fixed effect for the time period and ϵ_{it} is the error term. If the estimated coefficient for θ is negative and statistically significant, then the relevance of the Balassa-Samuelson effect is confirmed. The third step measures exchange rate misalignment as the difference between actual RER and the predicted RER obtained in the second step, and this is given by $lunderval_{it} = lnreer_{it} - ln\bar{r}eer_{it}$. When the level of misalignment is greater than unity, it implies that the currency is considered to be more undervalued than is implied by the purchasing power parity, while the level of misalignment that is below unity indicates overvaluation of domestic currency in terms of the US dollar.

The second approach used to obtain the equilibrium real exchange rate relates to IMF's consultative group on exchange rate issues, a package with different models used in the empirical literature. These include the fundamental equilibrium exchange rate (FEER) developed by Williamson (1994), behavioral equilibrium exchange rate (BEER) by Clark and MacDonald (1998) and external sustainability (IMF, 2006).

[19] The US dollar is used as a benchmark given that most international transactions involving SSA countries and their trading partners are denominated in US dollars. Studies that have used the US dollar as a benchmark include Rodrik (2008), Taylor (2000) and Chong et al. (2012)

Under the FEER approach, the real exchange rate misalignment is computed as the difference between the current account projected over the medium term at prevailing exchange rates and the estimated current account (CA norm). The BEER approach directly computes an equilibrium exchange rate for each country as a function of medium to long term fundamentals of the real exchange rate, while the external sustainability approach estimates the difference between the actual current account balance and the balance that induces stable foreign asset position of a given country at some benchmark level. In the context of this study, we employ the BEER approach to estimate the equilibrium exchange rate. This choice is motivated by the fact that, while the other two approaches are highly influenced by normative assumptions, the BEER is more pragmatic as it does not require to make the assumptions on the long-run values of economic fundamentals.

Secondly, the FEER does not take into account long-run stock effects via the net foreign position and the stock of capital. Up until the 1990s, authors such as Faruquee (1995), Clark and MacDonald (1998) and MacDonald (1998), among others, relied on time series analysis to estimate such relationship and derive exchange rate misalignment. Recently, Ricci et al.(2008), Rodrik (2008) and Bénassy-Quéré et al.(2010) have taken a panel perspective. To estimate the ERER, the BEER approach entails estimating a long-run relationship between the real exchange rate and a set of economic fundamentals. Edwards (1994), Elbadawi (1994), Hinkle and Montiel (2001) and Elbadawi and Soto (2008) provide suitable theoretical and empirical settings to analyze the equilibrium real exchange rate and their economic fundamentals in developing and emerging countries. We use similar fundamentals as those of Berg and Miao (2010), MacDonald and Vieira (2010), Schröder (2013) and Communale (2017). The model is thus, specified as:

$$reer_{i,t} = \alpha_0 + \alpha_1 tot_{i,t} + \alpha_2 open_{i,t} + \alpha_3 nfa_{i,t} + \alpha_4 prod_{i,t} + \alpha_5 gov_{i,t} + \mu_i + \lambda_t + \epsilon_{i,t} \quad (3.2)$$

where $i = 1..., N$ and $t = 1, ...T$ denote country and year, respectively, $reer_{i,t}$ is the real effective exchange rate, $tot_{i,t}$ are the terms of trade, $open_{i,t}$ is the degree of trade openness, $prod_{i,t}$ is productivity proxied by real per capita gross domestic product, $nfa_{i,t}$ is net foreign assets relative to GDP, $gov_{i,t}$ is government consumption as percentage of GDP,μ_i are country fixed effects to control for unobserved heterogeneity, λ_t is the time effect to control for the shocks that are common to all the sampled countries and $\epsilon_{i,t}$ is the error term. All the variables are transformed into natural logs.

The procedure to estimate the equilibrium real exchange rate is implemented in five steps. Firstly, we determine the order of integration of variables through panel unit root tests, but before examining stationary properties of data, we check for the cross-sectional dependence and slope homogeneity in the panel data set. Several tests for the detection of cross-sectional dependence are well documented in the literature. The current study applies Breusch and Pagan (1980) Lagrange Multiplier(LM) test, Pesaran (2004) scaled LM, and bias-corrected scaled LM by Baltagi et al.(2012). Secondly, we estimate panel cointegration to confirm the existence of cointegrating relations. Thirdly, we estimate long-run parameters of the equilibrium real exchange rate following dynamic panel cointegration techniques such as fully modified ordinary least squares (FMOLS) akin to Phillips and Hansen (1990), Pedroni (1999, 2000) and dynamic ordinary least squares (DOLS) introduced by Saikkonen (1991) and further developed by Kao and Chiang (2000)and Mark and Sul (2003). [20] In the fourth step, we derive sustainable values of economic fundamentals by decomposing the fundamentals of RER into their permanent and cyclical components, implemented through Hodrik-Prescott (1997) HP filter. Finally, we compute the misalignment indicator

[20]DOLS takes care of endogeneity by adding leads and lags, deals with the problem of cross-sectional dependence and small sample size bias.The lag and lead selection criteria is on the basis of the minimal information criteria (IC) (see Kejriwal and Perron, 2008). FMOLS does the same using a non-parametric approach (see Arize et al.(2015)). For the recent literature on the issue of estimation and inference in panels with cross-sectional dependence (see Mark and Sul (2003), Bai and Kao (2005) and Pesaran (2006).

given by $Mis_{it} = reer_{it} - ereer_{it}$, where $ereer_{it}$ is the equilibrium real effective exchange rate and where positive (negative) values of Mis_{it} or $reerhp$ indicate overvaluation (undervaluation).

In context of this study, we rely on the exchange rate misalignment indicator based on the behavior equilibrium real exchange rate model and only use the PPP based measure as a robustness check because PPP adjusted could be under specified given that it excludes other potential determinants of RER such as government spending, terms of trade, openness and net foreign assets. In addition, sufficient evidence in the literature indicate that PPP only holds in the long-run.[21]

Previous studies that have relied on the PPP based indicator include Dollar (1992), Rogoff (1996), Easterly (2001), Acamoglu et al.(2003) and Loayza et al.(2005). Regarding the expected signs of the economic fundamentals, the impact of changes in terms of trade on the real exchange rate depends on which effect dominates between substitution and income effects (De Gregorio and Wolf, 1994; Nilsson, 2004). If the income effect dominates, an improvement in terms of trade induces high demand for non-tradable goods and a rise in their prices, leading to real appreciation of exchange rate. On the other hand, if the substitution effect dominates, an improvement in terms of trade induces domestic agents to switch their demand towards imported goods, leading to real depreciation of the exchange rate, thus the sign can not be apriori determined. The effect of openness is also not straightforward due to the presence of substitution and income effects working in opposite directions (Edwards, 1989; Elbadawi, 1994). The main feature here relates to the initial tariff conditions, if the tariff is low and tradable and non-tradable goods are substitutes, then a decrease in tariffs induces a real exchange rate depreciation. Conversely, if the tariffs are high, the income effect will result in an increased demand for non-tradables, pushing prices to induce real appreciation of exchange rate. Net foreign assets are expected to have a positive effect on the real exchange rate in a sense that a country running the current account surplus is expected to experience an appreciated real exchange rate. On the other hand, a country running a current account deficit is expected to experience a depreciated real exchange rate to restore the external equilibrium. Indeed, most SSA countries have over the years registered current account deficits and their net international indebtedness has been on the rise. Larger trade surpluses are required to service the debt, thus real exchange rate depreciation is necessary. Productivity is expected to have a positive effect given that productivity improvement relative to trading partners generates real exchange rate appreciation (Alberola et al.,1999). The effect of increased government spending is expected to be negative due to the fact that higher government spending stimulates private consumption, thereby depreciating the real exchange rate. In other words, increased government spending towards the tradable sector leads to an increase in the trade deficit, which requires real depreciation of the exchange rate so that the external balance holds (Bergstrand, 1991; MacDonald, 1998). On the other hand, if the government spending increases towards the non-tradable goods, it yields a positive influence on RER given that it results in excess demand for non-tradables, rising their relative price to restore the internal equilibrium (Ravn et al., 2012).

3.3.1.2 RER Volatility

To measure volatility, different authors have applied different techniques. Some have used the standard deviation, where exchange rate volatility is measured according to the degree to which the exchange rate fluctuates in relation to its mean over time (Schanbl, 2009). Another measure is the Z-score, which combines the standard deviation measure and the arithmetic average of the percentage exchange rate changes.

[21] see Edwards and Savastano (1999), Driver and Westaway (2005) and Nouira and Sekkat (2015) for a thorough discussion on the validity of PPP for developing countries.

This measure is given by $Z_t = \sqrt{\mu_t^2 + \sigma_t^2}$ as suggested by Ghosh, Guide and Wolf (2003). These measures are however with issues such as the inability to reflect the distribution between the unpredictable component of the exchange rate process, hence failing to capture the past information of the exchange rate. To avoid this issue, we use the generalized autoregressive conditional heteroscedasticity (GARCH) model, which is empirically supported by extensive literature, notably by, among other, (Bollerslev, 2009; Boug and Fagereng, 2010; Herinksen, 2011; and Grek, 2014), as the appropriate econometric model to estimate the exchange rate volatility.

Similar to Amado and Teräsvirta (2017), we first formulate the multiplicative decomposition for the error term, which takes the form

$$y_t - \mu_t = \epsilon_t = Z_t \sigma_t^{\frac{1}{2}} g_t^{\frac{1}{2}} \tag{3.3}$$

where z_t is iid(0,1), we take the assumption that μ_t is known such that ϵ_t is observable and y_t is also assumed to be observable. The conditional variance component follows a GARCH specification (Bollerslev, 1986, and Taylor, 1986) In line with this, the current research applies the generalized autoregressive conditional heteroscedasticity (GARCH) model of Bollerslev (1986) and the exponential generalized autoregressive conditional heteroscedasticity (EGARCH) model of Nelson (1991) to measure the exchange rate volatility. The GARCH(p,q) is specified as:

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 \tag{3.4}$$

where $\epsilon_t \sim N(0, \sigma_t^2)$ the errors ϵ_t form a sequence of independent and identically distributed (i.i.d.) random variables with mean zero and variance equal to one. $\omega > 0$, $\alpha_i \geq 0$, and $\beta_i \geq 0$ are the set of parameter restrictions for the positivity of the conditional variance, and the weak stationarity condition is satisfied. In what follows we assume the standard normal distribution for the error terms. While the GARCH model adequately measures the conditional variance, the EGARCH model developed by Nelson (1991) designed to capture leverage effect, is also used as an alternative proxy for exchange rate volatility. The term "leverage" derives from the empirical observation that the volatility (conditional variance) of an asset tends to increase when its returns are negative. The EGARCH model specifies the conditional variance as:

$$ln\sigma_t^2 = \omega^\star + \beta ln\sigma_{t-1}^2 + \alpha|\epsilon_{t-1}| + \sigma E\epsilon_{t-1} \tag{3.5}$$

where $\omega^\star = \omega - \alpha|\epsilon_t|$ and the specification of the conditional variance expressed in terms of its logarithmic transformation suggest that there are no restrictions on the parameters to warranty the positivity of the variance.

3.3.1.3 Results of the Real Exchange Rate Regression

As pretests for the estimation of the real exchange rate model using panel cointegration techniques, we test for the presence cross-section dependence and slope homogeneity. The null hypothesis of no cross-sectional dependence and of homogeneous slope coefficients are rejected, confirming the presence of cross-sectional dependence. Having obtained the evidence of cross-sectional dependence, we proceeded by assessing stationary properties of data, applying the Dickey-Fuller panel unit root test in the presence of cross-section dependence proposed by Pesaran (2007). We also test for panel cointegration to check whether that, there is a long-run relationship between the variables. The results of the unit root test reported in Appendix, Table B4 indicate that except the GDP per capita and openness, the remaining variables become stationary after first difference I(1).

With regard to cointegration, the test results of Pedroni (1999), Kao (1999) and Westerlund (2007) suggest that the null hypothesis of no cointegration is rejected at 5 percent significance level, confirming the presence of long-run relationship.[22] Having confirmed the stationarity of variables and determined the order of integration of variables and the presence of cointegration relations between variables, we then proceed to estimate associated long-run parameters using panel cointegration estimators. Table 2 provides the results for the behavioral equilibrium exchange rate, particularly parameter estimates of FMOLS, DOLS and CCR estimators. The coefficient of GDP per capita is positive and statistically significant, implying that the increase in productivity in the tradable sector leads to the higher demand for non-tradable goods, leading to real appreciation of exchange rate. The estimated coefficient of terms of trade appears with varying signs with respect to different specifications; it is positive and statistically significant under FMOLS, but negative and statistically significant under DOLS and CCR estimates. Overall, the negative sign dominates suggesting that an improvement in terms of trade induces domestic agents to switch their demand towards imported goods, leading to real depreciation of the exchange rate. The estimated coefficient of openness is negative and statistically significant across all the estimators, implying that trade liberalization induces real exchange rate depreciation given that an increase in openness is associated with the decline of tariff rates, leading to a fall in the domestic prices of imported goods, this leads to the higher demand of foreign currency to finance cheaper imports. The coefficient of net foreign assets appears negative and statistically significant which implies that higher net foreign assets lead to the real exchange rate depreciation given that a depreciated exchange rate is required to restore the external balance for countries that experience current account deficits. Indeed, most Sub-Saharan African countries run current account deficits and, thus, need to depreciate their currencies to restore the external balance. The coefficient of government expenditure is negative and statistically significant because higher government expenditure stimulate private consumption, thereby depreciating the real exchange rate.

Table 3.2: Results of BEER Estimation

	Panel FMOLS		Panel DOLS		Panel CCR	
Variable	Beta	T-statistic	Beta	T-statistic	Beta	T-statistic
lrgdppc	0.58***	123.43	0.50***	10.56	0.33***	41.60
ltot	0.05***	9.27	-0.15***	-12.10	-0.12***	-11.54
lopen	-0.35***	-88.12	-0.15***	-11.21	-0.08***	-5.29
nfa_gdp	-0.71***	-19.58	-0.96***	13.11	-0.20***	-8.00
lgov_gdp	0.07***	23.20			-0.14***	-8.00

Notes: *** p<0.01, ** p<0.05, *p<0.1 denote statistical significance level at 1, 5 and 10 percent. FMOLS is fully modified ordinary least squares, DOLS is dynamic ordinary least squares and CCR is canonical cointegration regression.

Source:Author's computation using Stata 15

[22]The results of cross-sectional dependence, slope homogeneity, panel cointegration tests for the real exchange rate regression are reported in Appendices B2, B3, and B5, respectively.

3.3.2 Growth Regressions

3.3.2.1 Model specification

In this subsection, we empirically analyze the link between the real exchange rate and economic growth using dynamic panel data techniques. The generated real exchange rate misalignment, the proxy measures for volatility, along with other determinants of growth are included in the growth regression. Our specification is based on previous empirical studies such as Barro (1991), Mankiw et al.(1992), Levine and Renelt (1992) and Barro and Sala-i-Martin (2004) among others. To estimate this relationship, we follow Schnabl (2009), with minor adjustments where we include RER misalignment indicator. The model is specified as

$$y_{i,t} - y_{i,t-1} = \alpha + (\beta - 1)y_{i,t-1} + \gamma reerhp_{i,t} + \sigma vol_{i,t} + \theta x'_{i,t} + \mu_{i,t} + \lambda_t + \epsilon_{i,t} \tag{3.6}$$

where $y_{i,t} - y_{i,t-1}$ is the log of real GDP per capita growth for each country at time t , $y_{i,t-1}$ is the log of the lagged value of real GDP per capita growth, $reerhp_{i,t}$ is the real exchange rate misalignment indicator based on Hodrick-Prescot filtered series, $vol_{i,t}$ is the exchange rate volatility proxies, $x'_{i,t}$ denotes a vector of control variables, α, β,γ, σ and θ are coefficients to be estimated, $\mu_{i,t}$ are country fixed effects to control for unobserved heterogeneity, λ_t are the time dummies to capture shocks that are common to all the sampled countries across time and ϵ_{it} is the error term.

3.3.2.2 Estimation Methods

In this subsection, we describe the econometric technique used to estimate the link between the real exchange rate and economic growth. We begin model estimation with static panel techniques such as pooled ordinary least squares and fixed effects estimators as baseline models. However, they have been challenged due to a number of issues such as the presence of unobserved time and country-specific effects, therefore, using OLS estimation technique yields biased parameter estimates. This is often mitigated by allowing into the baseline model time dummies and country-specific effects.

However, the methods used to account for country-specific effects, that is, the fixed-effect or difference estimators, tend not to be appropriate owing to the the dynamic nature of the regression (Loayza et al., 2005). Besides, most of the explanatory variables, including the real exchange rate tend to be endogenous to growth in a sense that productivity gains induce real appreciation of exchange rate and hence, we need to control for simultaneity or reverse causality. Cognizant of the fact that the presence of endogeneity could lead to biased results, we use dynamic panel techniques by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998) to account for endogeneity emanating from reverse causality and Nickell (1981) bias due to the autoregressive effect of the income variable y_{t-1}. The first dynamic panel estimation method is first-difference equation well known in literature as “Difference” GMM estimated by the Generalized Method of Moments (GMM) approach proposed by Holtz-Eakin et al.(1988) and developed by Arellano and Bond (1991).

To estimate the parameters of the model we follow Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond (1998). The estimators are based on differencing regressions and instruments to control for unobserved country-specific effects. In addition, it also uses lagged observations of dependent and explanatory variables as instruments. The difference GMM method represents a major upgrade on the ordinary least squares and standard fixed-effects estimators. However, the first-difference GMM method performs poorly in instances where variables tend to have a low degree of variability over time within a country, especially when the sample size is small (Bond et al. 2001). This implies that we eliminate most of the variation in the variable(s) by taking the first difference. In this case, lagged observations of the explanatory variables tend to be weak instruments for the variables in differences, thus, yielding also weak estimators. Indeed, in most of the cross-country growth literature, the lagged dependent variable (in levels) used as instruments for the first-difference become weak in the second stage, and when instruments are weak, large finite sample biases are likely to happen. These issues have been associated with first-difference GMM models (Blundell and Bond, 1998; Bond et al., 2001).

To circumvent the problem of weak instruments and increase efficiency, systems GMM developed by Arellano and Bover (1995) and Blundell and Bond (1998) is used, with an additional set of moments restrictions, combining the first-difference equation using lagged levels as instruments, with an additional equation in levels, using lagged first differences as instruments. The instruments of the regressions in first differences remain the same as in the difference GMM.

As a matter of fact, in this estimation technique, the explanatory variables can still be correlated with the country-specific effects; nonetheless, the difference of these variables presents no correlation with these country-specific effects. Blundell and Bond (1998), Blundell et al. (2000) and Bond et al. (2001) argue that this approach substantially reduces finite sample bias in Monte Carlo experiments. Inasmuch as SGMM is for these reasons generally preferred to difference-GMM, it is also with challenges. Roodman (2009) highlights the effect of instruments proliferation on the Hansen test of joint validity, which tests the exogeneity of the instruments, based on the J statistics of the Sargan-Hansen(1958) test. The null hypothesis implies the joint validity of the instruments. In other words, a rejection of the null hypothesis indicates that the instruments are not exogenous and hence the GMM estimator is not consistent. Instruments proliferation is likely to lead to the loss of efficiency given that it leads to over-fitting of endogenous variables and less precise estimates of the optimal weighting matrix. Barajas et al. (2013) suggest that the number of instruments should be less or equal to the number of cross-sections in the regressions to avoid over-identification of instruments. The literature is not clear on determining the maximum number of instruments to be used in each case. Roodman (2009) proposes lag limits options based on a relatively arbitrary rule of thumb, that instruments should not be higher than individual units in the panel. The assumption on the data generating process of the two dynamic panel techniques discussed above are well documented in Roodman (2009). Although GMM estimators provide a suitable econometric framework to estimate the link between real exchange rate and economic growth, its estimators produce biased and inaccurate parameter estimates due to the small sample bias in GMM estimators, this is particularly the case in macro panels. To correct the bias, we employ bias correction methods for dynamic panel data, specifically the bias-corrected least squares dummy variable estimator (BC-LSDV) developed by Kiviet (1995), which iteratively corrects the bias until unbiased estimates of the true parameters are obtained. Recent research has followed this approach to correct for the bias in fixed effects. Kiviet (1999), Bun and Kiviet (2003), Bruno (2005), and Bun and Carree (2006) extend this estimator to cases with heteroscedasticity and unbalanced panels. Judson and Owen (1999) strongly support BC-LSDV when N is small as in most macro panels.

Indeed, Bun and Kiviet (2003) using Monte-Carlo simulation show that in small samples, the BC-LSDV estimator outperforms consistent IV-GMM estimators such as Anderson-Hisao (AH), Arrellano and Bond (AB) and Blundell and Bond (BB) estimators given that it has the lowest mean square error. Subsequently, employs bias corrected least squares dummy variable estimator is employed. The estimation begins with analyzing the order of integration of variables included in the model to ensure that our panel data estimations do not yield spurious results. To this end, testing for unit root is a common practice in time series econometrics, however, panel unit root tests have recently become quite popular in panel data econometrics (Levin et al.,2002 and Im et al.,2003). The major distinction between unit root tests in time series and panel data revolves around the issue of heterogeneity. For time series, heterogeneity is not an issue given that the unit root hypothesis is tested for a given individual. With regard to panel data, the cross -section dimension is added on to the time dimension, becoming heterogeneous thus, the panel unit root tests must take into account heterogeneity even if tests based on pooled estimates of auto-regressive parameters are consistent compared to a heterogeneous alternative (Moon and Perron, 2004b). Panel unit root tests are generally categorized into two main classes; (1) first generation unit root tests, which assume cross-sectional independence, these include Levin et al.(2002, LLC), Im et al.(2003, IPS), Maddala and Wu (1999), Hadri (2000), and Choi (2001), and (ii) second generation unit root tests that allow for cross-sectional dependence and these include cross-sectionally augmented Dickey-Fuller (CADF) developed by Pesaran (2007) and other tests by Moon and Perron (2004b), Phillips and Sul (2003), Bai and Ng (2004) and Breitung and Das (2005). In this study, we employ both first generation and second generation tests. For the first generation, we use the Levin-Lin-Chu (2002), the Im-Peseran-Shin (2003) and Hadri (2000) and for the second generation panel unit root tests, we apply cross-sectionally augmented Dickey-Fuller (CADF).

To highlight the key assumptions underlying each of these tests, we consider the following auto-regressive (AR) process for the panel data as the point of departure.

$$y_{i,t} = \rho_i y_{i,t-1} + \sigma_i z_{it} + u_{it} \tag{3.7}$$

where ρ_i is the AR coefficient, z_{it} is the individual deterministic effects (fixed effects) and u_{it} is the error term assumed to be independent and identically distributed (i.i.d).

From the preceding equation, Levin et al.(2002) propose a panel unit root test based on the null hypothesis that all panels have a unit root and the alternative hypothesis that all panels are stationary. The LLC test is an extension of the augmented Dickey-Fuller (ADF) in time series. From equation (3.7) above.

We obtain the panel augmented Dickey-Fuller (ADF) test, which is equivalent to LLC test. In the context of the current research, the general specification is presented, combining different forms of the random walk processes, including the random walk with drift, the random walk without drift and the random walk with drift and intercept. The test is specified as

$$\triangle y_{it} = \alpha_0 + \alpha y_{it-1} + \sum_{j=1}^{\rho_i} \beta_{ij} \triangle y_{t-1} + \delta_i z_{it} + u_{it} \tag{3.8}$$

where $\triangle$ is the first difference operator, α_0 is the constant, y_{it} is the dependent variable, u_{it} is a white-noise disturbance with variance σ^2, i = 1,...,N and t = 1,..., T

The Levin et al.(2002) panel unit root test is implemented in a three step procedure: (i) conduct the separate ADF test for each individual variable and generate two orthogonalized residuals. (ii) compute the ratio of long-run to short-run innovation standard deviation for each individual. (iii) compute the pooled t-statistic, with the average number of observations per individual variable and the average lag length. The associated AR coefficient is constrained to be homogeneous across units (i.e $\alpha_i = \alpha$ for all i), thus the null hypothesis assumes a common unit root $(H_0 : \alpha = 0)$ against the alternative hypothesis that each time series is stationary $(H_a : \alpha < 0)$. This test is recommended for moderate sized panel, with $N > 10$ and $T > 25$. This abodes well with our study. Im et al.(2003) panel unit root test modifies the LLC test to allow for heterogeneity on the AR coefficient. Practically, the test involves the estimation of individual ADF regressions and grouping the obtained information to perform a panel unit root test. This test allows for different specifications of the coefficients $(\alpha_i$ for each cross-section), the residual variance and lag length (Asteriou and Hall, 2007). The estimated IPS test statistic is based on the average of the individual unit root (ADF) test statistics. This statistic estimates whether the coefficient α is non-stationary across all individuals ($H_0 : \alpha = 0$ for all i), against the alternative hypothesis that at least a fraction of the series is stationary ($H_a : \alpha < 0$ for at least one i). Both the LLC and the IPS tests require N to be sufficiently small relative to T, while a strongly balanced panel is requisite for LLC (Baltagi, 2008). Hadri (2000) suggests a residual-based Lagrange multiplier (LM) test, which is a generalization of the Kwiatkowski-Phillips-Schmidt-Shin (1992, KPSS). Unit root test that tests for the stationarity of a given series around a deterministic trend, thus the hypothesis of the Hadri's panel unit root test is a reverse of the LLC and IPS tests and states that all the panels are trend stationary against the alternative that some panels are contain unit root. Inasmuch as most macro-panel studies apply first generation tests described above, they are often criticized on the grounds that they assume that the data is independent and identically distributed across individuals (cross-sectional independence) and, thus, do not take into account cross-sectional heterogeneity associated with panel data. This has led to the emergence of panel unit root tests with cross-section dependence, known in the literature as second generation panel unit root tests.

The current research applies the cross-sectionally augmented Dickey Fuller (CADF) test developed by Pesaran (2007), which entails augmenting standard ADF regressions with the cross-section averages of lagged levels and first-differences of the individual series, and this test is applicable for both when $N > T$ and $T > N$, and has good size and power properties, even when N and T are relatively small.

However, $t - bar$ CIPS statistic is estimated for only balanced panels. For unbalanced panels, the modified Z test can be reported. The CADF test is specified as:

$$\triangle y_{it} = \alpha_i + \rho_i y_{it-1} + \delta_i y_{it-1} + \gamma_i \bar{y}_{t-1} + d_i \triangle \bar{y}_{it} + \epsilon_{it} \tag{3.9}$$

where $\triangle y_{it}$ and lagged cross-sectional averages of y_{it}, are according to Pesaran (2007), proxies for the effects of unobserved common factors. The cross-sectionally augmented Im, Pesaran and Shin (CIPS) specified in equation 10 is a simple average of individual cross-sectionally augmented Dickey-Fuller(CADF) which is estimated and then compared to the respective critical value.

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i(N,T) \tag{3.10}$$

where $t_i(N,T)$ is the CADF statistic for i and the average of its t-ratio. We proceed by testing for panel cointegration to ascertain whether there exists a stable and long-run relationship between the dependent variable and the explanatory variables. The prerequisite for conducting this test is the presence of non stationarity in variables. In this study, we employ three tests suggested by Pedroni (1999), Kao (1999) and Westerlund (2007) and their test statistic are interpreted under the null hypothesis of no cointegration. Pedron (1999) came up with a cointegration test for heterogenous panels based on the Engle and Granger (1987) two-step procedure. This test uses the residuals from the long-run regression and generates seven panel cointegration test statistics, categorized under two main dimensions: within dimension (panel statistics test) and between dimension (group statistics test). The within dimension has four test statistics based on pooling and assume homogeneity of AR terms while the between dimension test statistics are less restrictive because they allow for the heterogeneity of AR terms. The assumption has implications on the estimation of the second step and the specification of the alternative hypothesis. The v-statistic is similar to the long-run variance ratio statistic for time series, while the rho-statistic is comparable to the semi-parametric 'rho' statistic by Phillips and Perron (1988). The remaining two test statistics are panel extensions of the Phillips-Perron (PP) test statistic and ADF t-statistics, respectively. These tests allow for heterogeneous slope coefficients, fixed effects and individual specific deterministic trends, but become only valid if the variables are integrated of order one. Kao (1999) proposes residual-based Dickey-Fuller (DF) and ADF tests similar to Pedroni's, but specifies the initial regression with fixed effects', no deterministic trend and homogeneous regression coefficients. Kao's tests converge to a standard normal distribution by sequential limit theory (Baltagi, 2008).

Both Kao and Pedroni tests assume the presence of a single cointegrating vector, even though Pedroni's test permits it to be heterogeneous across units. Westerlund (2007) proposes four cointegration tests based on structural rather than residual dynamics and permits a higher degree of heterogeneity in individual short-run dynamics, intercepts, linear trends and slope parameters. This test is based on the null hypothesis that the error correction term is contingent on the fact that the error correction mechanism (ECM) is zero, implying absence of cointegration.

3.3.2.3 Data

The variables included in models (3.1)-(3.5) are constructed as follows. The real exchange rate is the relative inflation adjusted exchange rate and trade weighted, computed by multiplying the nominal effective exchange rate by the ratio of consumer price indexes $reer = \sum_{t=1}^{k}(neer_{it}) \times \frac{p_{it\star}}{p_{it}}$. The real exchange rate misalignment indicator is the exchange rate deviation from the equilibrium level based on Hodrick-Prescot filter $reerhp_{it} = reer_{it} - \bar{r}eer_{it}$. [23] The exchange rate volatility based on GARCH-type specifications,

[23]The obtained misalignment indicator (lreerhp) is used to create the undervaluation and overvaluation dummies. The dummies take values of 1 and 0 depending on whether lreerhp is greater than 1 or less than 1, for undervaluation the value is 1 if $lreerhp < 0$ and 0 if $lreerhp > 0$, while for overvaluation it takes the value of 1 if $lreerhp > 0$ and 0 if $lreerhp < 0$.

for this particular indicator, monthly real exchange rate data is used and annualized as $Vol_{it} = \frac{1}{12}(h_{m1} + h_{m2} + ... + h_{m12})$, where $h_{mi} = 1, ..., 12)$ is the monthly exchange rate volatility. Real gross domestic product (GDP) is used for the level of domestic economic activity. Real gross domestic product per capita is real gross domestic product divided by population, its growth rate is given by $lrgdppc\_gr = lrgdppc - lrgdppc[t-k]/(lrgdppc[t-k] * (year - year[t-k]))$. Investment is measured as the share of GDP for each of the countries included in our sample. Trade openness is measured as the sum of exports and imports divided by real gross domestic product, this is given by $Open_{it} = \frac{x_{it}+m_{it}}{y_{it}}$. Government expenditure is the total government expenditure, including recurrent and capital spending of each individual countries divided by GDP. For population we consider population growth rates of each of the countries included in our sample. Terms of trade (Tot) is the ratio of export prices to import prices. Net foreign assets (nfa) measured as the sum of foreign assets held by the monetary authorities and deposit taking corporations less their liabilities. Inflation is measured as the average change in consumer price index, computed as $Inf = (\frac{cpi_{it}-cpi_{it-1}}{cpi_{it-1}}) \times 100$. All the series are transformed into natural logarithms. We do not control for education like most growth regressions because data on education is not available for many countries included in our sample. Interpolating it leads to severe loss of observations. We use annual data spanning the period 1995-2017 for 23 countries, divided into non-overlapping 3-year periods, where variables are 3-year averages of annual data to control for cyclical variations [24] Sub Saharan African Countries. The included countries are those for which data on the relevant variables are available. Data is sourced from World Bank's world development indicators (WDI), International Monetary Fund's world economic outlook (WEO) and Bruegel Reer database (Darvas, 2012a).

[24]The countries included in our sample are: Angola, Botswana, Burkina Faso, Burundi, Democratic Republic of Congo, Kenya, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Cape Verde, Ghana, Guinea Bissau, Madagascar, Malawi, Mali, Namibia, Niger, Nigeria, Senegal, South Africa and Togo.

3.4 Empirical Results

This section reports some descriptive statistics on the variables of interest, it then proceeds with the presentation and discussion of econometric results on the relationship between the real exchange rate and economic growth in 23 Sub-Saharan African Countries.

3.4.1 Descriptive Analysis

The descriptive statistics of variables used in this study are reported in Table 3.2. The results indicate that except for openness, inflation and the real exchange rate misalignment indicator, the mean for the rest of the variables is greater than the standard deviation, which shows how closer the sample mean is from the true population mean. This result indicates that most of the data is clustered around the mean, thus mean is generally a good indicator of parameters. The minimum and maximum statistics point to potential outliers, particularly for the real exchange rate volatility proxy given that the spread between the minimum and maximum is high for this indicator.

Table 3.3: Descriptive Statistics

Variables	N	Mean	P50	SD	Min	Max
lreer	529	4.61	4.61	0.21	3.49	5.81
lrgdppc	529	6.61	3.81	1.01	4.68	8.99
ltot	529	4.71	4.66	0.30	3.06	5.53
exchvol	529	21.45	21.18	3.01	16.02	68.50
linv_gdp	529	3.06	3.07	0.45	1.65	4.37
lgov_gdp	529	3.09	3.10	0.41	0.76	3.96
lpop	529	2.52	2.72	1.30	-0.94	5.23
lopen	529	-1.07	-1.01	0.53	-2.37	0.07
lreerhp	529	-0.00	0.00	0.11	-0.47	0.86
linfl	529	1.96	2.02	1.27	-2.92	8.33

Source: Author's computation using Stata 15

Scatter plots showing the cross-country relationships between the real exchange rate misalignment and economic growth and the real exchange rate volatility and economic growth based on annual data and on 3-year period averages are presented in Panels 1 and 2. Panel 1. More compelling empirical evidence is presented and discussed in the econometric results section. Concerning the impact of the real exchange rate misalignment on economic growth, it is postulated that the real exchange rate undervaluation promotes growth. Theoretically, an undervalued exchange rate enhances productivity in tradable goods sector, and thus provides incentives to exports promotion and economic growth. In line with this argument, countries with undervalued currencies are associated with higher economic growth given that undervaluation has an expansionary effect on the aggregate demand and output through the reduction of their relative prices. The cross-country correlations presented in Figure 3.1a supports the reasoning that the real exchange rate undervaluation promotes economic growth. On the other hand, Figure 3.1b shows that the real exchange rate volatility hampers economic growth. Indeed, countries whose currencies are more volatile are expected to engage in less trade and thus have a depressing effect on economic growth due to the fact that volatility increases trade costs and reduces profits in the tradable sector. The cross-country correlation suggests the existence of a negative relationship between exchange rate volatility and real per capita GDP growth, supporting the view that a stable and competitive real exchange rate is a necessary condition for low income economies to achieve sustained economic growth.

Figure 3.1: Exchange rate Misalignment, Volatility and Growth

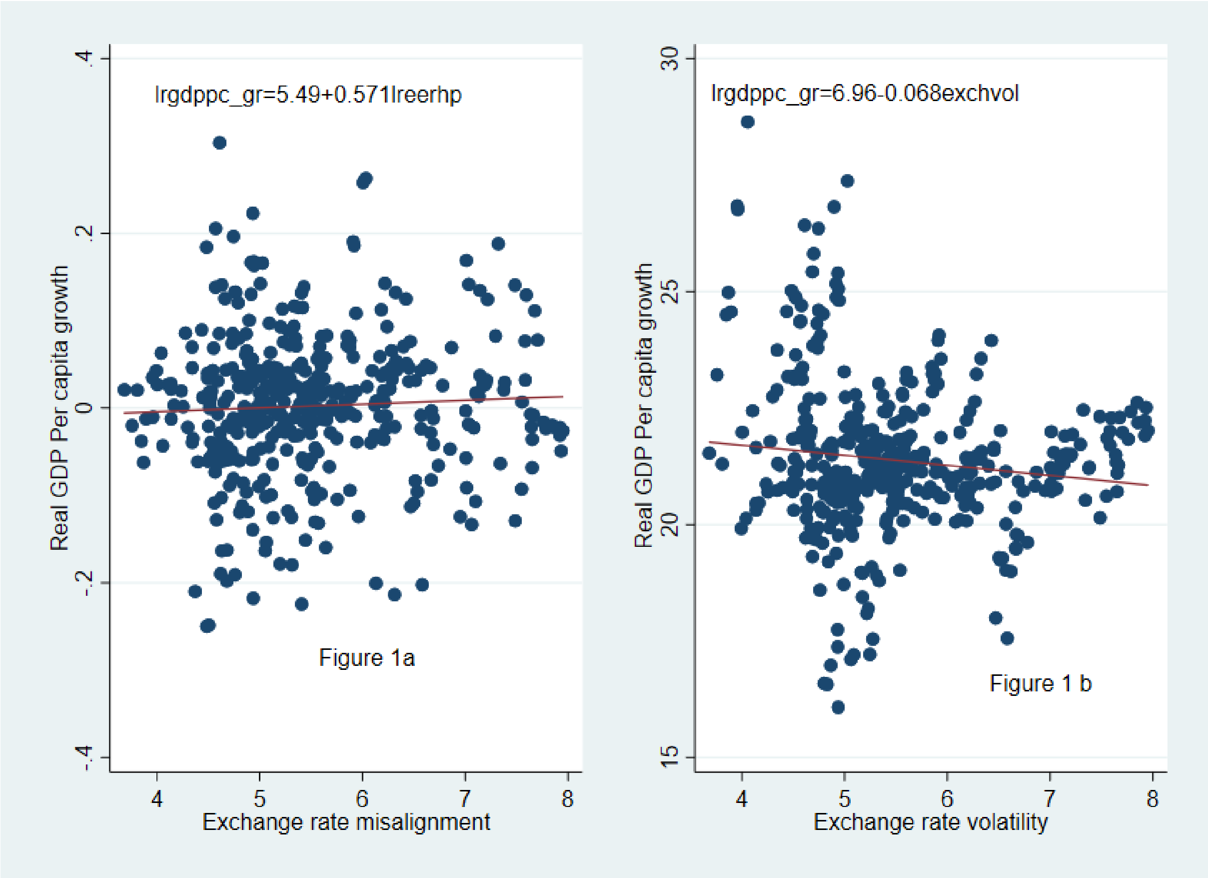


Figure 3.2 presents the scatter plots using 3-year period data and the plots depict similar trends, and the coefficients of fitted regression lines appear with correct signs. However, similar to the regressions with annual data, the estimated coefficient on the relationship between real exchange rate volatility and real GDP per capita is negative and statistically significant and are statistically significant, while the estimated coefficient on the link between real exchange rate misalignment and real GDP per capita growth is positive,but statistically insignificant. The negative coefficient of the real exchange rate volatility on economic growth implies that real exchange rate volatility hampers growth.

Figure 3.2: Exchange rate Misalignment, Volatility and Growth

The empirical analysis begins with assessing the stationary properties of data series and determining their order of integration. This study employs four panel unit root tests, namely the LLC, the IPS, the Hadri and the CADF tests. We tests take into account the appropriateness of these tests to the nature of the panel data set used, particularly, homogeneity and cross-sectional dependence assumptions. The test results are reported in Table 3.4. The results indicate mixed evidence on the order of integration of variables, suggesting that some variables are stationary in levels, while others become stationary after first-differencing the series. For the LLC and the IPS panel unit root tests, 5 out of 9 variables are integrated of order zero except for lrgdppc, lpop, ltot, and lopen lopen for which the presence of unit root cannot be rejected at the 5 percent level. However, the Hadri class of panel unit root tests has a different null hypothesis, which states that all panels are (trend) stationary. Under this test, all variables are stationary at first differences, providing evidence that some panels have a unit root. The CADF* panel unit root test allows for the presence of cross-sectional dependence and provides strong evidence of stationarity of variables given that most variables are stationary in levels.

Table 3.4: Panel Unit Root Tests Results

Variable	Test Statistic	Level	First Diff	Order of Integ
lrgdppc	LLC	-1.13	-19.29***	I(1)
	IPS	3.14	-12.27***	I(1)
	Hadri	20.48	1.032***	I(1)
	CIPS*	-2.94***	-4.99***	I(0)
lpop	LLC	4.35	-5.59***	I(1)
	IPS	3.14	-6.23***	I(1)
	Hadri	34.18	11.16**	I(1)
	CIPS*	-2.88***	-2.80**	I(0)
lreerhp	LLC	-5.75***	-15.8***	I(0)
	IPS	-5.84***	-15.14***	I(0)
	Hadri	20.48	-0.358***	I(1)
	CIPS*	-2.47	-4.44***	I(1)
ltot	LLC	-0.53	-13.97***	I(1)
	IPS	0.30	-13.76***	I(1)
	Hadri	20.99	1.41**	I(1)
	CIPS*	-2.47	-4.29***	I(1)
lopen	LLC	-0.502	-14.95***	I(1)
	IPS	2.50	-13.72***	I(1)
	Hadri	20.99	-2.011***	I(1)
	CIPS*	-3.18***	-4.94***	I(0)
lgov_gdp	LLC	-2.85***	-16.88***	I(0)
	IPS	3.14**	-16.11***	I(0)
	Hadri	20.99	0.18***	I(1)
	CIPS*	-2.38	-4.71***	I(1)
Exchvol	LLC	-2.97***	-13.3***	I(0)
	IPS	-1.69**	13.10***	I(0)
	Hadri	12.89	-0.87***	I(1)
	CIPS*	-2.26	-4.54***	I(1)
linv_gdp	LLC	-4.36***	-19.43***	I(0)
	IPS	-3.95***	-12.24***	I(0)
	Hadri	15.52***	1.83***	I(0)
	CIPS*	-2.74**	-5.02***	I(0)
infl	LLC	-9.99***	-12.61***	I(0)
	IPS	-13.27***	-22.10***	I(0)
	Hadri	15.38	-4.27***	I(1)
	CIPS*	-4.15***	-5.41***	I(0)

Notes: The asterisks denote the level of statistical significance
at 10 percent (*), 5 percent (**), and 1 percent (***), respectively.

Source: Author's computation using Stata 15

All the panel unit root tests conducted reveal that some variables are stationary at level and others at first difference, confirming the need to test for panel cointegration to check whether a long-run relationship exists between the dependent and explanatory variables. Table 3.5 reports the results based on Pedroni (1999), Westerlund (2007) and Kao(1999) panel cointegration tests. The results show that the null hypothesis of no cointegration is strongly rejected under the three panel cointegration tests, suggesting that there is a long-run relation between dependent variable and regressors.

Table 3.5: Panel Cointegration Tests Results

Cointegration test	Test statistic	P-value
Kao test		
H_0: No cointegration Versus H_1: all panels are cointegrated		
Modified Dickey-Fuller	-2.56**	0.051
Dickey-Fuller	-3.81***	0.0001
Augmented Dickey-Fuller	-4.56***	0.0000
unadjusted modified Dickey-Fuller	-2.81***	0.0025
unadjusted Dickey-Fuller	-3.92***	0.0000
Pedroni test		
H_0: No cointegration Versus H_1 : all panels are cointegrated		
Modified Phillips-Perron	5.96***	0.0000
Phillips-Perron	-1.91***	0.028
Augmented Dickey-Fuller	-1.32*	0.092
Westerlund test		
H_0: No cointegration versus $H1$: some panels are cointegrated		
Variance ratio	4.63 ***	0.0000
Notes: *** p<0.01, ** p<0.05, *p<0.1 represent the statistical significant level at 1,5 and 10 percent, respectively. H_0 and H_1 are the null and alternative hypotheses, respectively.		

Source:Author's computation using Stata 15

3.4.2 Main Results

Table 3.6 reports ordinary least squares (OLS), fixed effects (FE), system generalized methods of moments (SGMM) and bias-corrected least dummy variable (BC-LSDV) estimator results on the link between the real exchange rate undervaluation and economic growth. The results are broadly consistent with the economic theory and the existing empirical literature. Despite the fact that the OLS and fixed effects are not informative due to their draw backs discussed earlier, we use them as benchmark regressions. The SGMM is also less appropriate given that our data set suffers from small sample bias, leading to biased and inaccurate results. We therefore do not report SGMM results in the subsequent estimations. Thus, our main focus is on the bias-corrected least squares dummy variable estimates. Across all the estimators, the estimated coefficient associated with the lagged value of the dependent is positive and statistically significant, demonstrating the existence of the adjustment process and the relevance of implementing a dynamic panel estimation.Arellano-Bond for AR(1) and and Arellano-Bond for AR(2) tests for the first order and second order serial correlation. The p-values associated with AR(2) are greater than 5 percent significance level, confirming the absence of the second order serial correlation.[25]

The coefficient of the real exchange rate misalignment indicator is positive and statistically significant, implying that real exchange rate undervaluation makes domestically produced goods cheaper, leading to export expansion and thus economic growth. This supports the view that a competitive real exchange rate stimulates economic growth. This result is consistent with the recent empirical literature such as those by Rodrik (2008), Di Nino et al.(2011), Vaz and Baer (2014) and Habib et al. (2017) who all document that real exchange rate undervaluation is positively and significantly related to economic growth. The coefficient of government consumption is negative and statistically significant, suggesting that increased government spending decelerates economic growth. The negative effect of government spending could be due to the fact that when governments increase their expenditure, private consumption increases, but in the future it will increase taxes and crowd out private investment through higher interest rates, thus a negative relationship between government expenditure and economic growth in the long-run. This particularly applies in the case of the SSA countries given that government spending has been mainly directed to recurrent expenditure, especially wage increments and social protection purposes, both of which are non-productive expenditures that do not support economic growth.

This is exacerbated by the fact that a sizeable amount of this non-productive expenditure is financed through excessive loans, which the governments will have to repay in the long-run. The coefficient of trade openness is positive and statistically significant in line with ex ante expectations. This implies that the more the economies are liberalized, the more it fosters economic growth, and this result corroborates those obtained by Calderon (2004) and Dufrénot (2009). The coefficient of terms of trade is positive and statistically significant, suggesting that improved terms of trade lead to the increase in investment and thus economic growth. This result is in line with Bleaney and Greenaway (2001) and Blattman et al.(2003). However, There is no consensus in the literature given that while some studies document that an increase in terms of trade lead to the expansion in investment and thus trade and growth, Other studies such as Eicher et al. (2008) indicate that an improvement in terms of trade result in economic slow down in the long-run. The coefficient of investment as a percentage of real GDP is positive and statistically significant, implying that capital accumulation is essential for economic growth, especially so for developing economies.

[25] The estimates are consistent when AR(2) test statistic is not rejected, implying the absence of serial correlation. For AR(1) the presence of first order serial correlation is expected due to lagged dependent variable.

Table 3.6: Growth Regression Results

Variable	OLS (1)	FE (2)	SGMM (3)	BC-LSDV (4)
lrgdppc_gr	0.958***	0.283**	0.934***	0.383***
	(0.020)	(0.101)	(9.831)	(6.284)
underval	0.265	0.435*	-1.730	0.383**
	(0.158)	(0.212)	(-1.343)	(2.360)
exchvol	-0.030**	-0.000	-0.058	-0.004
	(0.013)	(0.019)	(-1.256)	(-0.499)
lgov_gdp	0.023	-0.386***	-0.522	-0.355***
	(0.053)	(0.101)	(-1.395)	(-3.890)
lopen	0.069	0.339***	-0.474	0.330***
	(0.048)	(0.098)	(-1.319)	(3.013)
ltot	0.225**	0.302***	0.790**	0.290***
	(0.097)	(0.103)	(2.427)	(4.479)
linv_gdp	0.062	0.140**	0.431	0.135**
	(0.045)	(0.066)	(1.625)	(2.369)
pop_gr	-0.014	0.025	-0.222	0.005
	(0.014)	(0.368)	(-1.186)	(0.012)
infl	0.000	-0.001	0.002	-0.001
	(0.001)	(0.001)	(1.466)	(-1.430)
Obs	160	160	160	160
R-squared	0.972	0.920		
AR(1)			0.016	0.087
AR(2)			0.029	0.113

Notes: *** p<0.01, ** p<0.05, *p<0.1 denote the level of statistical significance level at 1, 5, and 10 percent respectively. Standard errors are in parenthesis

Source:Author's computation using Stata 15

3.4.3 Robustness Checks

We investigate whether growth regressions are robust to different sensitivity analysis because the relationship between real exchange rate undervaluation and growth may emerge significant in certain specific cases and less plausible in others. We conduct six different sensitivity analyses. Firstly, we use alternative indicator of the real exchange rate misalignment based on purchasing power parity. Secondly, we use real GDP growth as the dependent variable. Thirdly, we include in our estimation an alternative exchange rate volatility measure based on the exponential generalized autoregressive conditional heteroscedasticity (EGARCH). Fourthly, we check whether economic growth is robust to the choice of exchange rate regime. Fifthly, we assess whether the link between real exchange rate and growth is non-linear. Finally, we exclude the extreme values of the real exchange rate misalignment and real exchange rate volatility in data.

3.4.3.1 Misalignment Indicator Based on PPP

Table 3.7 reports the estimated results of growth regression obtained by using the Balassa-Samuelson effect adjusted measure of real exchange rate undervaluation. The estimated coefficient of lagged per capita GDP growth remain in line with the baseline results. It is positive and statistically significant. The coefficient of the RER undervaluation measure based on the purchasing power parity (PPP) is positive and statistically significant, suggesting that the effect of the real exchange rate undervaluation on economic growth remain unchanged regardless of the definition of misalignment used, it therefore becomes difficult to unravel which measure of misalignment is more important for growth, confirming that misalignment measures based on behavioral equilibrium exchange rate (BEER) and PPP are not competing indicators , but complementary. However, the magnitude of the PPP based measure is higher. This conforms to the results obtained by Woodford (2009) who argues that Balassa-Samuelson (BS) effect adjusted measure of RER undervaluation tend to overstate the impact of the RER undervaluation on income per capita growth. He attributes this upward bias to the fact that other variables that may influence both real exchange rate and economic growth are omitted when regressing the RER on real GDP per capita. The coefficient of exchange rate volatility turns out be correctly signed and marginally significant, while it is statistically insignificant in the baseline regression.Turning to control variables, the coefficients of government spending, trade openness, terms of trade and investment have the correct signs and are statistically significant.

Table 3.7: Growth Results with Underval_PPP

Variable	OLS (1)	FE (2)	BC-LSDV (3)
l.rgdppc_gr	0.956***	0.232**	0.301***
	(0.020)	(0.103)	(10.720)
underval_PPP	0.363*	0.664***	0.623***
	(0.177)	(0.220)	(4.525)
exchvol	-0.043***	-0.016	-0.018*
	(0.015)	(0.014)	(-1.865)
lgov_gdp	0.039	-0.342***	-0.328***
	(0.058)	(0.106)	(-3.677)
lopen	0.063	0.301**	0.297***
	(0.047)	(0.108)	(2.750)
ltot	0.242**	0.334**	0.326***
	(0.096)	(0.122)	(5.079)
pop_gr	-0.018	-0.177	-0.175
	(0.014)	(0.348)	(-0.440)
linv_gdp	0.062	0.143**	0.139**
	(0.045)	(0.056)	(2.493)
infl	0.001	0.000	0.000
	(0.001)	(0.001)	(0.148)
Obs	160	160	160
R-squared	0.972	0.927	
AR(1)			0.080
AR(2)			0.118

Notes: *** p<0.01, ** p<0.05, *p<0.1 denote the statistical significance levels at 1, 5, and 10 percent respectively. Standard errors are in parentheses.

Source:Author's computation using Stata 15

3.4.3.2 Growth Regression Using a Different Dependent Variable

Table 3.8 reports the growth regression results obtained by using a different dependent variable. We use real GDP growth as opposed to Real GDP per capita growth used in the baseline regression. The obtained results indicate that the lagged real GDP growth coefficient is positive and statistically significant, supporting the theory of cumulative causation in economic growth developed by Myrdal (1957) and Kaldor (1970) who contend that initial conditions determine economic growth in a self-sustained and incremental way.

Turning to our variables of interest, the change in the dependent variable renders the coefficient of the real exchange rate misalignment statistically insignificant, while exchange rate volatility emerge with correct signs and statistically significant. It is negative and significant, implying that the real exchange rate volatility depresses economic growth.The change in the dependent variable points to the absence of the link between real exchange rate undervaluation and economic growth. Regarding the control variables, the coefficients of trade openness and terms of trade appear with correct signs and are statistically significant. The coefficient of government spending is however rendered statistically insignificant. These results support the use of real GDP per capita as the dependent variable given that it yields much more plausible results compared to when real GDP growth is used as the dependent variable.

Table 3.8: Growth Results with Different Dependent variable

Variable	OLS (1)	FE (2)	BC-LSDV (3)
l.rgdp_gr	0.978*** (0.010)	0.732*** (0.070)	0.780*** (21.929)
underval	-0.009 (0.043)	0.012 (0.048)	0.009 (0.217)
exchvol	-0.003 (0.003)	-0.005** (0.002)	-0.005** (-2.312)
lgov_gdp	0.031 (0.027)	0.006 (0.030)	0.041 (0.011)
lopen	0.023 (0.027)	0.099** (0.041)	0.101*** (2.922)
ltot	0.076*** (0.023)	0.066** (0.024)	0.060*** (3.007)
pop_gr	0.032*** (0.009)	0.152 (0.141)	0.157 (1.253)
linv_gdp	0.059*** (0.014)	0.031 (0.019)	0.027 (1.560)
infl	-0.000 (0.000)	-0.000 (0.000)	-0.000 (-0.665)
Obs	161	161	161
R-squared	0.999	0.986	
AR(1)			0.2287
AR(2)			0.999

Notes: *** p<0.01, ** p<0.05, *p<0.1 denote the statistical significance levels at 1, 5, and 10 percent respectively. Standard errors are in parentheses.

Source:Author's computation using Stata 15

Table 3.9 reports the growth regression results obtained by using an alternative real exchange rate volatility proxy based on EGARCH, denoted as exchvol1. The estimated coefficients of the real GDP per capita growth remain correctly signed and statistically significant. Similar to our main results, the coefficient of the real exchange rate misalignment is positive and statistically significant, confirming that the real exchange rate undervaluation positively influences growth. The coefficient of the alternative exchange rate volatility measure is statistically insignificant, indicating that the effect of exchange rate volatility on economic growth remain less robust regardless of the measure of exchange rate volatility used. With regard to control variables, the estimated coefficients of government spending, trade openness, investment and terms of trade emerge with correct signs and are statistically significant. These results remain broadly in line with our baseline results. Generally, the inclusion of an alternative measure of the real exchange rate volatility proxy based on EGARCH does not change the link between the real exchange rate and economic growth.

Table 3.9: **Growth Results Using EGARCH**

Variable	OLS (1)	FE (2)	BC-LSDV (3)
l.rgdppc_gr	0.958***	0.282**	0.361***
	(0.020)	(0.101)	(4.574)
underval	0.266	0.434*	0.430***
	(0.159)	(0.213)	(3.228)
exchvol1	-0.030**	-0.000	-0.003
	(0.013)	(0.019)	(-0.342)
lgov_gdp	0.023	-0.386***	-0.362***
	(0.053)	(0.101)	(-4.790)
lopen	0.070	0.338***	0.332***
	(0.048)	(0.098)	(3.298)
ltot	0.225**	0.302***	0.293***
	(0.097)	(0.103)	(4.139)
pop_gr	-0.014	0.023	0.103
	(0.014)	(0.368)	(0.021)
linv_gdp	0.063	0.140**	0.136**
	(0.045)	(0.066)	(2.235)
infl	0.000	-0.001	-0.001
	(0.001)	(0.001)	(-1.129)
Obs	160	160	160
R-squared	0.972	0.920	
AR(1)			0.030
AR(2)			0.115

Notes: *** p<0.01, ** p<0.05, *p<0.1 denote the statistical significance levels at 1, 5, and 10 percent respectively. Standard errors are in parentheses.

Source:Author's computation using Stata 15

3.4.3.3 Choice of Exchange Rate Regime

Conducting sensitivity analysis to check whether the baseline results are robust to the choice of the exchange rate regime draws from the exchange categorization based on de facto exchange rate regime classification proposed by Ilzetzki et al.(2019). This categorization builds upon the natural de facto classification scheme developed by Reinhart and Rogoff (2004). The choice of de facto classification is motivated by the drawback of the de jure exchange rate regime classification whereby the central banks claim to follow more flexible exchange rate regime which may some times be different from the official announcements, a phenomenon characterized as "fear of floating" (Calvo and Reinhart, 2002) as a result, policy outcomes attributable to de jure regimes may be misleading. Rogoff et al.(2004) confirm that de jure classification leads to misleading statistical inference and wrong interpretation of the effects of ERR. Extensive work on the new methods of classification include Ghosh et al., 2003), Reinhart and Rogoff (2004),Levy-Yeyati and Sturzeneger (2005), Klein and Shambaugh (2010) and most recently Ilzetzki et al.(2019).

The de facto exchange rate arrangement proposed by Ilzetzki et al.(2019) depends on the comprehensive reference currencies, exchange rate arrangements and a new measure of foreign exchange restrictions for 194 countries and territories over the period 1946-2016. This arrangement is subdivided into two categories namely, fine category with 15 classifications and coarse with 6 classifications. In the context of this study, we use the fine category given that it is more dis-aggregated. Computationally, the exchange rate regime is coded as a three category ordinal variable based on data, higher values indicate greater degree of flexibility and vice-versa thus, categories 1-6 are lumped up to constitute fixed regime category, 7-10 are lumped together as intermediate regime and categories 11-14 constitute flexible exchange rate regime while category 15 is excluded because of missing data. Preliminary analysis indicate that 43.08 percent of the sampled SSA countries pursue intermediate regime, 39.53 percent pursue fixed rate regime while 17 percent pursue flexible exchange rate. In our estimation, we introduce fixed and intermediate categories in our estimations.

The estimation results for the growth regression with fixed and intermediate exchange rate regimes are reported in Table 3.10. Consistent with the baseline regression, the coefficient of lagged dependent variable is positive and statistically significant. For the variables of interest, The estimated coefficients for the real exchange rate undervaluation is positive and statistically significant, while the coefficient for the real exchange rate volatility is not significant. The coefficient of fixed exchange rate regimes is positive, but marginally significant, indicating that exchange rate regimes do not seem to significantly explain economic growth in the case of the selected SSA countries. As for the control variables, the coefficients of government spending, degree of trade openness, terms of trade and investment appear with correct signs and are statistically significant. Broadly speaking, the link between the real exchange rate regimes and economic growth does not seem to improve the robustness of our main results.

Table 3.10: Growth and Exchange Rate Regime

Variable	OLS (1)	FE (2)	BC-LSDV (3)
l.rgdppc_gr	0.977***	0.304***	0.383***
	(0.018)	(0.104)	(4.914)
underval	0.191	0.365*	0.354**
	(0.156)	(0.200)	(2.543)
exchvol	-0.034**	0.001	-0.002
	(0.012)	(0.018)	(-0.249)
lgov_gdp	0.049	-0.362***	-0.334***
	(0.038)	(0.108)	(-4.256)
lopen	0.073	0.326***	0.319***
	(0.048)	(0.083)	(3.083)
ltot	0.199**	0.256**	0.246***
	(0.073)	(0.103)	(3.306)
pop_gr	-1.722*	-0.973	-0.997
	(0.905)	(0.832)	(-0.995)
linv_gdp	0.035	0.121*	0.118**
	(0.036)	(0.062)	(1.990)
infl	0.001	-0.000	-0.000
	(0.001)	(0.001)	(-0.392)
fixed	0.143**	0.172*	0.171*
	(0.053)	(0.090)	(1.695)
intermediate	0.182***	0.081	0.091
	(0.053)	(0.062)	(1.418)
Obs	160	160	160
R-squared	0.974	0.924	

Notes: *** p<0.01, ** p<0.05, *p<0.1 denote the statistical significance levels at 1, 5, and 10 percent respectively. Robust standard errors are in parentheses.

Source:Author's computation using Stata 15

3.4.3.4 Extreme values

As additional robustness check, We trim the observations for extreme values of real exchange rate misalignment and real exchange rate volatility to check whether results are sensitive to trimming of extreme values. The highest 1 percent is excluded on both tails using winsorization technique, a data transformation procedure that does not remove the values at the tails of distribution, but records them to less extreme values. For instance, 1 percent of the lowest values (lower tail) is recorded to the value of the 1^{st} percentile and 1 percent of the highest values(higher tail) is recorded to the value of 99^{th} percentile. This implies that it replaces values in the tails with selected values closer to the middle of the distribution. This procedure is implemented via" winsor2" stata module developed by Lian Yu-jun (2014). Table 3.11 reports the results of growth regression, with winsorized extreme values of real exchange rate misalignment and real exchange rate volatility variables. The estimated results indicate that the coefficients of lagged dependent variable remain positive and statistically significant across all the specifications. Regarding the variables of interest, real exchange rate undervaluation is positive and statistically significant across all the estimators. The real exchange rate volatility coefficient is negative and statistically significant, implying that the real exchange rate volatility negatively influences economic growth. Turning to control variables, government spending, trade openness and terms of trade are correctly signed and statistically significant. Overall, our results become more robust to trimming of the extreme values of real exchange rate misalignment and real exchange rate volatility because it improves the significance of our variables of interest.

Table 3.11: Growth Results Excluding Extreme values

Variable	OLS (1)	FE (2)	BC-LSDV (3)
l.rgdppc_gr	0.979***	0.700***	0.697***
	(0.007)	(0.058)	(35.924)
underval	0.281***	0.385***	0.306***
	(0.084)	(0.097)	(4.984)
exchvol	-0.013**	-0.007	-0.007**
	(0.005)	(0.008)	(-2.393)
lgov_gdp	0.026	-0.146***	-0.176***
	(0.020)	(0.043)	(-6.031)
lopen	0.047**	0.200***	0.299***
	(0.019)	(0.037)	(13.671)
ltot	0.099***	0.120***	0.083***
	(0.034)	(0.035)	(3.498)
pop_gr	-0.001	-0.049	0.027
	(0.005)	(0.033)	(0.558)
linv_gdp	-0.003	0.027	0.001
	(0.018)	(0.046)	(0.029)
infl	0.000	-0.000	-0.000
	(0.000)	(0.000)	(-1.228)
Obs	483	483	483
R-squared	0.988	0.950	
AR(1)			0.0000
AR(2)			0.8470

Notes: *** p<0.01, ** p<0.05, *p<0.1 denote the statistical significance levels at 1, 5, and 10 percent respectively. Standard errors are in parentheses.

Source:Author's computation using Stata 15

3.4.3.5 Non-Linear Specification Results

We investigate the robustness of results to non-linear terms to check whether the real exchange rate undervaluation affects economic growth in a non-linear manner. To examine this, we include squared term of RER [26] undervaluation in our growth regression and observe its behavior both in terms of the sign and statistical significance. The effect of RER undervaluation becomes non-linear if the sign of the

[26] The motivation behind including squared term of RER undervaluation is to ascertain the asymmetric effects of the real exchange rate on growth.

linear term is positive whereas that of the non-linear term is negative and statistically significant. The estimated results are reported in Table 3.12. The coefficient of the linear term remains largely positive and statistically significant. The coefficient of the squared term is positive and statistically significant, pointing to no evidence of asymmetric effects and thus non-linearity, a result that corroborates results obtained by Rodrik (2008). However, when we run a non-linear regression based panel threshold autoregressive (PTAR) model, we obtain a significantly positive non-linear relationship between RER and economic growth. The Panel TAR results are reported in Table B6 in the Appendix. These contrasting results support the view that there is no consensus in the empirical literature on the asymmetric link between RER and economic growth given that while Rodrik (2008) finds only symmetric relationship between RER undervaluation and growth, other recent studies such as Aguirre and Calderon (2005), Béreau (2012) and Couharde and Sallenave (2013) find the existence of non-linearities in the exchange rate-growth nexus. Regarding other variables in our regression, the coefficient of lagged per capita GDP remains broadly consistent with the baseline regression. It is positive and statistically significant. As for control variables, government spending, trade openness, terms of trade, investment and inflation emerge correctly signed and are statistically significant. The negative association between inflation and growth is consistent with the results found by Aisen and Veiga (2006).

Table 3.12: Non-linear Growth Results

Variable	OLS (1)	FE (2)	BC-LSDV (3)
l.rgdppc_gr	0.958***	0.246**	0.324***
	(0.020)	(0.106)	(4.068)
underval	0.269	0.416**	0.422***
	(0.160)	(0.187)	(3.416)
sq_underval	-0.151	1.376**	1.243**
	(1.051)	(0.549)	(2.089)
exchvol	-0.030**	0.004	-0.000
	(0.013)	(0.016)	(-0.004)
lgov_gdp	0.019	-0.341***	-0.324***
	(0.055)	(0.090)	(-4.270)
lopen	0.069	0.318***	0.312***
	(0.049)	(0.099)	(3.205)
ltot	0.225**	0.283**	0.276***
	(0.098)	(0.106)	(4.144)
pop_gr	-0.015	-0.113	-0.119
	(0.015)	(0.354)	(-0.366)
linv_gdp	0.062	0.127*	0.124**
	(0.045)	(0.062)	(2.157)
infl	0.000	-0.002**	-0.002**
	(0.001)	(0.001)	(-2.152)
Obs	160	160	160
R-squared	0.972	0.923	
AR(1)			0.007
AR(2)			0.190

Notes: *** p<0.01, ** p<0.05, *p<0.1 denote the statistical significance levels at 1, 5, and 10 percent respectively. Standard errors are in parentheses.

Source:Author's computation using Stata 15

3.4.4 Conclusion and Policy Recommendations

The main purpose of this study is to empirically investigate the relationship between real exchange rate and economic growth in a panel of 23 SSA countries over the period 1995 -2017, transformed into non-overlapping 3-year averages. The rationale for contributing to the ongoing debate on the link between real exchange rate misalignment and growth is informed by the recent literature. While the traditional view on the subject matter advocates for the real exchange that is close to the equilibrium level, recent theoretical and empirical literature focuses on the growth enhancing benefits of the real exchange rate undervaluation. This study estimates RER misalignment indicators based on the behavioral equilibrium exchange rate framework and the Balassa-Samuelson (BS) effect adjusted misalignment indicator. The former is estimated using panel group mean estimators such as DOLS, FMOLS and CCR, along with Hodrick-Prescott (HP) filter to decompose trend from the cyclical component, while the latter is estimated by regressing the RER that is implied by the purchasing power parity on the real GDP per capita growth. In addition, the real exchange rate volatility proxy is generated by GARCH type models. The generated RER misalignment and volatility measures are then incorporated in the growth regression, alongside a number of control variables. We apply dynamic panel estimators, especially bias-corrected least squares dummy variable (BC-LSDV) estimator as our main model and pooled ordinary least squares (OLS) and fixed effects (FE) estimators as benchmark regressions. The main results indicate that the real exchange rate undervaluation significantly supports economic growth in SSA countries. We find strong evidence from both measures of RER misalignment. In some instances, the exchange rate volatility emerged negative and statistically significant, suggesting that exchange rate volatility is disruptive to growth. Control variables such as trade openness and terms of trade emerge positively significant, while government spending has a significantly negative relationship with economic growth. Our results are robust to the BS effect adjusted misalignment measure, use of alternative volatility proxy based on EGARCH and exclusion of extreme values of the real exchange rate misalignment and volatility but less robust to the choice of exchange rate regime and use of a different dependent variable. Finally, we fail to confirm the evidence for the non-linearities in the real exchange rate -growth nexus. Our overall conclusion point to the fact that RER matters for growth in SSA countries.

The obtained empirical results point to important policy implications. Results suggest that there is need to revisit exchange rate as a policy instrument given that it favors growth. However, when currencies are highly undervalued, the impact on growth becomes minimal. For instance large foreign denominated liabilities such as external debts may impede growth when currencies are extremely undervalued, nonetheless policies that sustain exchange rate at a competitive level and limit RER volatility should be pursued as part of the broader macroeconomic stability package.

Chapter 4.

Modeling Non-linear Dynamics of Real Exchange Rate in Rwanda

4.1 Introduction

A substantial amount of empirical econometric modelling in macroeconomics have tended to assume that economic links are linear and as such a number of linear time series models have been employed to analyse the dynamic behavior of economic and financial variables. These have included autoregressive (AR), moving average (MA) models as well as autoregressive and moving average (ARMA) models. While these models have been successful in various applications, they have proven deficient in fitting many non-linear dynamic patterns such as fat tails, asymmetry, volatility clustering, long memory and the possibility of regime changes (Chen and Lin, 2000a, b). For instance, exchange rate movements characteristically vary around a high level and persist during depreciation, but stay at fairly lower levels during appreciations, and such patterns in data cannot be captured by linear models. In addition, existing empirical evidence confirm that exchange rates, like other financial time series, exhibit non-linear behavior (Brooks, 2006 ; and Bauwens and Sucarrat, 2006). Given such a finding, many researchers have quite logically deduced that the inaccurate performance of linear models could be attributed to the inability of such models to capture the non-linear dynamics in exchange rate data, thus non-linear models are appropriate representations of data generation processes. Consequently, vast research have tried to exploit the non-linearities in exchange rate data by employing conventional time series non-linear models such as regime switching models, especially threshold models, to produce accurate forecasts (Brooks, 1997; Chappell et al., 1998).

In the recent past, considerable amount of literature on the development of non-linear time series models has emerged (Tsay, 1989; Tong, 1990 and Granger and Teräsvirta, 1993). The threshold autoregressive model (TAR) is the most prominent in the non-linear time series literature. This class of regime switching models also emerges as a special case of more complicated statistical frameworks such as mixture models and other regime switching models like Markov switching models (MSM), introduced by Hamilton (1989) and smooth transition autoregressive models (STAR). Since the work of Engel and Hamilton(1990), several researchers have found that non-linear models tend to outperform linear models in investigating the dynamics of exchange rates (Engle and Hamilton, 1990; Van Dijk and Franses, 2003). This is premised on the idea that non-linear time series modelling assumes that different states and regimes, exist and that the dynamic behaviour of economic variables is contingent on the regime occurring at a point in time.

The first class of such models is the Markov-switching models, based on the reasoning that the state is unobserved but is influenced by an underlying stochastic process, implying that despite the fact that probabilities on the occurrence of the different regimes can be assigned, it would be difficult to establish which particular regime has occurred at a given point in time. A unique feature of the Markov switching model is that the switching mechanism is controlled by an unobservable state variable that follows a first order markov process. The second class of models suggests modelling the regime explicitly as a continuous function of an observable variable like in threshold autoregressive (TAR) models proposed by Tong (1978) and discussed in detail in Tong and Lim (1980) and Tong (1983) . As a result, both the past and the present regimes are identified with the use of statistical techniques, thereby giving TAR models an advantage over the Markov-switching models (Ahmad and Pentecost, 2009).

A key characteristic of the threshold models is their capacity to capture persistent patterns while series remain stationary. For example, it is contended that macroeconomic variables like unemployment, exchange rates and interest rates should be stationary. However, conventional unit root tests fail to reject the null hypothesis of non-stationarity. This has resulted in the argument that threshold class of non-linear models are superior in explaining the dynamics in such series (Chang and Lee, 2011). This is evoked by the fact that the tests and distribution developed by Caner and Hansen (2001) are appropriate to such an approach given that they allow for the joint consideration of non-linearity and non-stationarity. In line with this, Bec, Ben-Salem and Carrasco (2004) cite the real exchange rates as a key example, which have been documented to have unit root, suggesting non-existence of international arbitrage and therefore, violation of the purchasing power parity (PPP) hypothesis.

However, when threshold models are utilized, the effects of transaction costs are captured and the series appear globally stationary. Movements towards equilibrium could not take place due to the fact that economic agents incur adjustment costs, therefore, deviations from the equilibrium remain persistent until such deviations exceed a critical threshold, thereby resulting in a higher benefit to adjust relative to the cost (Sarno et al., 2004).

The main purpose of this study is therefore to assess non-linear dynamics in the real effective exchange rate of Rwanda using regime switching models such as TAR and Markov switching models, and investigate whether these models provide better forecasting accuracy compared to traditionally used linear modes such as ARIMA. We model non-linear dynamics of the real effective exchange rate using quarterly data for the period 2000Q1-2017Q4. Our specification begins with the autoregressive integrated moving average (ARIMA) model as a benchmark to allow for the evaluation and comparison of forecasting performance in linear models versus non-linear models while TAR and MS-AR models are applied to capture non-linear dynamics in real exchange rate. Our results point to a strong evidence of non-linear dynamics in Rwanda's real exchange rate. This finding is corroborated by the results of out-of-sample forecast evaluation which unveils that the non-linear models specified in this study outperform the linear counterpart in terms of predictive accuracy. These conclusions extend the existing stock of literature, a key contribution of this chapter is that this has not been unexplored for the case of Rwanda.

The rest of the chapter is structured as follows: Section 2 includes the analytical framework of the benchmark model and the selected regime switching models; section 3 presents the application of selected regime switching models to the case of Rwanda, including subsections on empirical methodology, data sources and definition of variables, and the estimation strategy; and, section 4 reports empirical results and analysis, as well as the conclusion.

4.2 Analytical Framework of Regime Switching Models

4.2.1 Autoregressive Integrated Moving Average (ARIMA) Model

In their seminal work, Box and Jenkins (1970) identify a procedure for time series forecasting, namely the autoregressive integrated moving average (ARIMA) approach which includes model identification, parameter estimation and model checking. Tseng (2001), Mondal (2014) and Babu and Reddy (2015) have applied ARIMA approach to the exchange rates. They conclude that the ARIMA model surpasses the artificial neural network (ANN) and the fuzzy neuron (FN) in predicting the Indian rupee against the major currencies. However, Zhang (2003) and Pai and Hong (2005) find limitations of the ARIMA model. Zhang (2003) contends that the approximation of linearity does not give satisfactory conclusions of the real-world problems, in other words, ARIMA cannot adequately characterize the non-linear patterns of data. Considering this drawback, this study, derives non-linear models and compares their forecasting ability with the standard ARIMA model. We begin the analysis with a linear time series model, particularly the ARIMA model as a benchmark to allow for the comparison of predictive ability of linear versus non-linear time series models specified in this study. The ARIMA model is a time series model used to understand the data by predicting future data points in a series.

The AR component implies that the variable of interest is regressed on its own lagged values, while the MA part indicates that the regression error is a linear combination of error terms whose values occur contemporaneously (Chu , 2008). The representation of the ARIMA (p,d,q) model is as follows:

$$A(L)(1-L)^d y_t = \alpha + B(L)\epsilon_t \tag{4.1}$$

where p defines the autoregressive polynomial in the lag operator L :

$$A(L) = 1 - \rho_1 L - \rho_2 L^2 .... - \rho_p L^p \tag{4.2}$$

and the moving average polynomial (q) in the independent and identically distributed disturbance process ϵ_t is given as

$$B(L) = 1 + \theta_1 L + \theta_2 L^2 + ... + \theta_q L^q \tag{4.3}$$

The third parameter d expresses the integer order of differencing to be applied to the series before estimation to make it stationary. For the model to be estimated, the d -difference time series must be stationary such that the AR polynomial in the lag operator may be inverted and that is,

$$y_t^\star = A(L)^{-1}(\alpha + B(L)\epsilon_t) \tag{4.4}$$

where the stability condition requires that the eigenvalues of the $A(L)$ polynomial lie outside the unit circle.

4.2.2 Threshold Autoregressive Model (TAR)

The estimation of regime switching models such as TAR is influenced by whether the regime -determining (threshold) variable is observable or not. The model assumes that the regime is determined by variable q_t relative to a threshold value. Building on the study by Hansen (2000), least squares estimation of the regression parameters is considered. The model construction begins with developing the asymptotic distribution theory for the regression estimates and constructing asymptotic confidence intervals through inverting the likelihood ratio statistic. The key idea behind the threshold autoregressive model is to allow for a conditional expectation function without over-parameterisation and choose a valid threshold at which to split the sample. The threshold autoregressive model takes the form:

$$y_t = \theta_1' x_t + \epsilon_{1t}, q_{t-1} \leq \gamma \tag{4.5}$$

$$y_t = \theta_2' x_t + \epsilon_{2t}, q_{t-1} > \gamma \tag{4.6}$$

where y_t and q_{t-1} are real valued, x_t is a vector of regressors including lagged values of y_t, q_{t-1} is the threshold variable and the threshold parameter γ is based on to split the sample into two regimes or states, θ_1' andθ_2' are autoregressive parameter vectors when $q_{t-1} \leq \gamma$, and $q_{t-1} > \gamma$, respectively while ϵ_t is the error term assumed to be a martingale difference sequence with respect to the past history of y_t and is allowed to be conditionally heteroskedastic.

We base on the above specifications to derive the asymptotic approximation to the distribution of the least squares estimate $\hat{\gamma}$ of the threshold parameter γ. The model allows the regression parameters to vary depending on the value of q_{t-1}. The likelihood ratio is quite crucial when δ_n decreases with the sample size and this asymptotic distribution is an upper bound on the asymptotic distribution for the case that δ_n does not decrease with sample size. This allows us to construct asymptotically valid confidence intervals for the threshold estimates based on inverting the likelihood ratio statistic.

In a single equation form, we define a dummy variable $d_t(\gamma) = q_{t-1} \leq \gamma$ where $\{\cdot\}$ is the indicator function and set $x_t(\gamma) = x_t d_t(\gamma)$ such that models (4.5) and (4.6) can be written as:

$$y_t = \theta' x_t + \delta_n' x_t(\gamma) \tag{4.7}$$

where $\theta_1 = \theta_2$ and equation (8) allows all the parameters to switch between the regimes.

To represent the model in matrix form, define the $n \times 1$ vectors y and ϵ by stacking the variables y_i and ϵ_i , and the $n \times m$ matrices X and X_γ by stacking the vectors x_t and x_γ such that equation (4.7) can be written as

$$y_t = X\theta_t + X\gamma d_n + \epsilon \tag{4.8}$$

Where the regression parameters are$(\theta, \delta_n, \gamma)$ and the estimator is least squares.This implies that the sum of squared errors function can be expressed as:

$$s_n = (\theta\delta_n\gamma) = (Y - X\theta - X\delta)'(Y - X\theta - X_\gamma\delta) \tag{4.9}$$

thus by definition the least squares estimators[27] $\hat{\theta}\ \hat{\delta}\ \hat{\gamma}$ jointly minimize equation (4.9).

[27] The LS estimator is also the MLE when ϵ_{it} is iid (see Hansen, 2000)

For the minimization to occur, γ is assumed to be restricted to a bounded set $[\underline{\gamma}, \bar{\gamma}] = \Gamma$. The key applications of TAR models has been to the forecasting performance of economic and financial time series like output growth, unemployment, stock returns, interest rates and exchange rates and the major objective has been to compare the forecasting ability of TAR and other non-linear models with the traditional linear models such as ARIMA. In the context of this study, we focus our discussion on the application of the model to exchange rates. Chappell, Padmore, Mistry and Ellis (1998) apply SETAR on the franc/ deutschmark exchange rate and find improved fit and superior forecasting performance relative to a linear random walk. Balke and Wohar (1998) use a TAR model for the deviations from the covered interest rate parity and obtain evidence for asymmetric transaction costs. Taylor (2001) uses a TAR model to demonstrate that linear autoregressions can give very misleading estimates of persistence and mean-reversion. Several empirical investigations of PPP across exchange rates have been conducted, for example, Sarno, Taylor and Chowdhury (2004) and Bec, Salem and Carrasco (2004) show that a set of European exchange rates reject the null hypothesis of a linear unit root process in favour of the alternative that the series are stationary in three regime SETAR models.

In recent applications, Narayan (2006) applies an unrestricted TAR model on monthly stock price indices and finds evidence for a TAR model with a unit root, Griffin, Nardari and Stulz (2007) use a vector threshold autoregressive (VTAR) model to investigate the dynamic relation between stock market turnover, volatility and returns across 46 countries. Chen et al. (2012) applies a TAR model to the Hong kong's daily return series of the Hang seng index with a sample running from January 3, 1995 to January 13, 2005. They find that Hong Kong market is classified into 3 regime, namely, a high return stable regime, a low return volatile regime, and a neutral regime. Sun et al.(2019) employ threshold autoregressive interval-valued (TARI) models to investigate asymmetric pass-through of oil prices to gasoline with interval time series modeling. Their results indicate that both the level and volatility of oil prices have a positive impact on the price of gasoline, which contributes to the asymmetries in the transmission of oil price shocks.

A related line of research has employed the flexible target zone model on exchange rate introduced by Krugman(1991). He argues that a credible target zone model predicts that the exchange rates will exhibit a non-linear form of mean reversion and conditional volatility that depends on the position of the exchange rate relative to the target zone boundaries. However, empirical evidence have rejected this model on the grounds that non-linearities do not sufficiently explain all the leptokurtosis and ARCH effects on the data. Empirical studies such as Diebold and Nason (1990), Meese and Rose (1991), Flood et al.(1991), Svensson (1991a, 1991b), Frankel and Phillips (1992), Mizrach (1992), Lindberg and Söderlind (1994), Klaster and Knot (2002) and Duarte et al. (2008) have obtained results that support this line of argument. New lines of empirical research extended the model to incorporate the assumptions of imperfect credibility of bands and the existence of intra-marginal interventions. The major contributions include Lindberg and Söderlind(1992), Tranzano et al.(2003) and Baghli(2004). More recently, Lundbergh and Teräsvirta (2006) apply the flexible target zone model on exchange rate for the Swedish and Nowergian currency indices to characterize the dynamic behaviour of the exchange rate implied by the original target zone model of Krugman (1991). Their findings suggest that the exchange rate exhibits target zones.

4.2.3 The Markov Switching Autoregressive Model (MS-AR)

The Markov switching model was introduced by Hamilton (1989). It entails multiple structures that characterize the time series behaviour under different regimes. By allowing transitioning between states, the model is able to capture more complex patterns. The salient feature of this model is that the switching process is controlled by an unobserved state variable that follows a first order Markov chain.

In particular, the Markovian property regulates that the current value of the state variable depends on its immediate past value. The Markov switching model is widely applied to macroeconomic and financial time series by following the process that governs the time at which given macroeconomic series transitions between different states (i.e depreciation and appreciation in exchange rate movements) and the duration of each period. Building this model begins with the specification of the state intercept terms, that is,

$$y_t = \mu_1 + \epsilon_t \tag{4.10}$$

$$y_t = \mu_2 + \epsilon_t \tag{4.11}$$

where μ_1 and μ_2 are the intercept terms in state 1 and state 2, respectively, ϵ_t is a white noise error with variance σ^2. The two states model shifts in the intercept and if the timing of switches is known, the above model can be expressed as:

$$y_t = s_t\mu_1 + 1 - s_t\mu_2 + \epsilon_t \tag{4.12}$$

where s_t equals 1 if the process is in state 1 and 0 otherwise.

However, s_t is unobservable, so markov switching model allows the parameters to vary over the unobserved states $y_t = \mu s_t + \epsilon_t$ from which we obtain the general form of the autoregressive markov switching model:

$$y_t = \mu s_t + x_t\alpha + z_t\beta s_t + \varphi_i s_t(y_{t-1} - x_{t-1}\alpha - z_{t-1}\beta s_{t-1}) + \epsilon s_t \tag{4.13}$$

where y_t is the dependent variable at time t ,μs_t is the state dependent intercept , x_t is the vector of exogenous variables with state invariant coefficients α , z_t is a vector of exogenous variables with state dependent coefficients βs, $\varphi_i s_t$ are the AR terms in state s_t, and ϵ_t is an independent and identically distributed error term (i.i.d).

The transition between the states is expected to follow an ergodic and irreducible a first order Markov process. This implies that the probability of the current state is influenced by the previous state as shown below:

$$P_{ij} = Pr(s_t = j|s_{t-1} = i) \tag{4.14}$$

where $\sum_{j=1}^{k} p_{ij} = 1.$

and p_{ij} is the probability of being in state j in the current period given that the process was in state i in the previous period. The transitional probabilities can be expressed in a matrix representation:

$$P = \begin{pmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{pmatrix} \tag{4.15}$$

where $p_{11} + p_{12} = 1$ and $p_{21} + p_{22} = 1.$

From the transition probabilities matrix, we can extract the expected duration of the state which is given by:

$$E(D_i) = \frac{1}{1 - p_{ij}} \tag{4.16}$$

The closer p_{ij} is to one, the longer it takes to transition to the next state. The fact that $\sum_{j=1}^{k} p_{ij} = 1$ leads to numerical complications and requires us to address these complications by estimating functions of p_{ij} and through normalizing p_{ik}. In particular, we estimate q_{ij} in

$$p_{ij} = \frac{exp(-q_{ij})}{(1 + exp(-q_{i1}) + exp(-q_{i2}) + ... + exp(-qik_1)} \tag{4.17}$$

for $j \in 1, 2, ..., k$, We normalize p_{ik} by imposing

$$p_{ij} = \frac{1}{(1 + exp(-q_{i1}) + exp(-q_{i2}) + ... + exp(-qik_1)} \tag{4.18}$$

Computationally, the estimation procedure for the two-regime markov switching model follows the maximum likelihood method via an expectation maximization algorithm[28] akin to Franses and Dijk (2003).

Under the assumption that $\alpha s_t, t$ is normally distributed, the density of y_t conditional on state s_t has a distribution with mean $\phi s_t, 0 + \sum_{i=1}^{k} \phi s_t, y_{t-1}$ and variance σ^2 . The conditional density y_t is given by $f(y_t|s_t = i, y_{t-1}; \theta)$ for $i = 1..k$. The marginal density of y_t is obtained by weighting the conditional densities by their respective probabilities. This is given by:

$$f(y_t|\theta) = \sum_{i=1}^{k} f(y_t|s_t = i, y_{t-1}; \theta) pr(s_t = i; \theta) \tag{4.19}$$

Assume η_t is a $k \times 1$, the vector of conditional densities is expressed as:

$$\eta_t = \begin{pmatrix} f(y_t|s_t \\ f(y_t|s_t \\ f(y_t|s_t \end{pmatrix} = \begin{pmatrix} 1 & ; y_{t-1} & ; \theta) \\ 2 & ; y_{t-1} & ; \theta) \\ k & ; y_{t-1} & ; \theta) \end{pmatrix} \tag{4.20}$$

Constructing the likelihood function requires estimating the probability that s_t takes on a specific value using the data through time t and the model parameters θ. Let $pr(s_t = i/y_t; \theta)$ denote the conditional probability of observing $s_t = i$ based on data until time t , thus,

[28]To maximize the log likelihood function, a numerical optimization algorithm is used in deriving parameter estimates. The commonly used algorithms are Berndt, Hall, Hall and Hausman (BHHH) and Marquardt in Gould, Pitblado and Poi (2010). This study utilizes BHHH which is the default algorithm.

$$pr(s_t = i|y_t; \theta) = f(y_t|st = i, y_{t-1}, \theta)f(y_t|y_{t-1}; \theta) \tag{4.21}$$

where $f(y_t|y_{t-1}; \theta)$ is the likelihood of y_t and $pr(s_t = i|y_t; \theta)$ is the forecasted probability of $s_t = 1$ given observations until time $t = 1$. Thus,

$$pr(s_t = i|y_t; \theta) = \sum_{j=1}^{k} pr(s_t = i|s_{t-1} = j, y_{t-1}, \theta)pr(s_{t-1} = j|y_{t-1}; \theta) \tag{4.22}$$

Markov switching models have been applied to a wide range of economic and financial time series. The earliest applications of markov switching models in the foreign exchange market include, Engel and Hamilton (1990), Engel (1994), Hamilton (1996), Garcia and Perron (1996) and Kim and Nelson (1998). Engel and Hamilton (1990) strongly rejected a random walk for the exchange rate in favor of a time-varying trend alternating between a fixed positive and negative value. Engle (1994) extends this work and investigates whether the Markov Switching model is a useful tool for describing the behavior of 18 exchange rates, and he concludes that the Markov switching model fits well in-sample for many exchange rates, but the Markov model does not generate superior forecasts to a random walk or the forward rate. Engle and Hakkio (1996) investigate the behavior of European Monetary System exchange rates using a Markov switching model and find that the changes in exchange rates match the periodic extreme volatility. Marsh (2000) goes one step further and studies the daily exchange rates of three countries against the US dollar and concludes that the data are well estimated by Markov switching model. However, the out-of-sample forecasts are very poor due to parameter instability. Bollen et al. (2000) examine the ability of the regime switching model to capture the dynamics of foreign exchange rates and their test shows that a regime-switching model with independent shifts in mean and variance exhibits a closer fit and more accurate variance forecasts than a range of other models. Similarly, Karikos (2000), Corporale and Spagnolo (2004) and Bergman and Hansson (2005) model regime shifts in exchange rates and found that regime switching models provide better in-sample and out-of -sample than random walk specifications. Cheung and Erlandsson(2005) test three dollar-based exchange rates using quarterly and monthly data, respectively, and observe that monthly data provide unequivocal evidence of the presence of Markov switching dynamics. Their finding suggest that data frequency, in addition to sample size, is essential for determining the number of regimes. More recently, Ismail and Isa (2007) apply a Markov switching model to capture regime shifts behavior in Malaysia ringgit exchange rates against four other countries between 1990 and 2005. They conclude that the Markov Switching model is found to successfully capture the timing of regime shifts in the four series.

Other notable contributions include Chen and Lin (2000a, b), Hsu and Kuan (2001), Sim et al., (2008) and Liu et al., (2011). In recent years, the Markov switching framework and its more advanced extensions have been applied widely in the international finance literature, from contexts related to contagion (Casarin et al. 2018); linkages to commodities (Balcilar et al., 2018; Basher et al., 2016; Beckmann and Czudaj, 2013) and the volatility effects of equity versus bond flows (Caporale et al., 2017 and Carrasco et al., 2014). From the foregoing analyses, Hamilton's Markov switching model proves to be a good specification to study exchange rate behavior given the fact that the real world economies change from one state to another due to different crises and policies changes.

4.3 Empirical Application to Rwanda's case

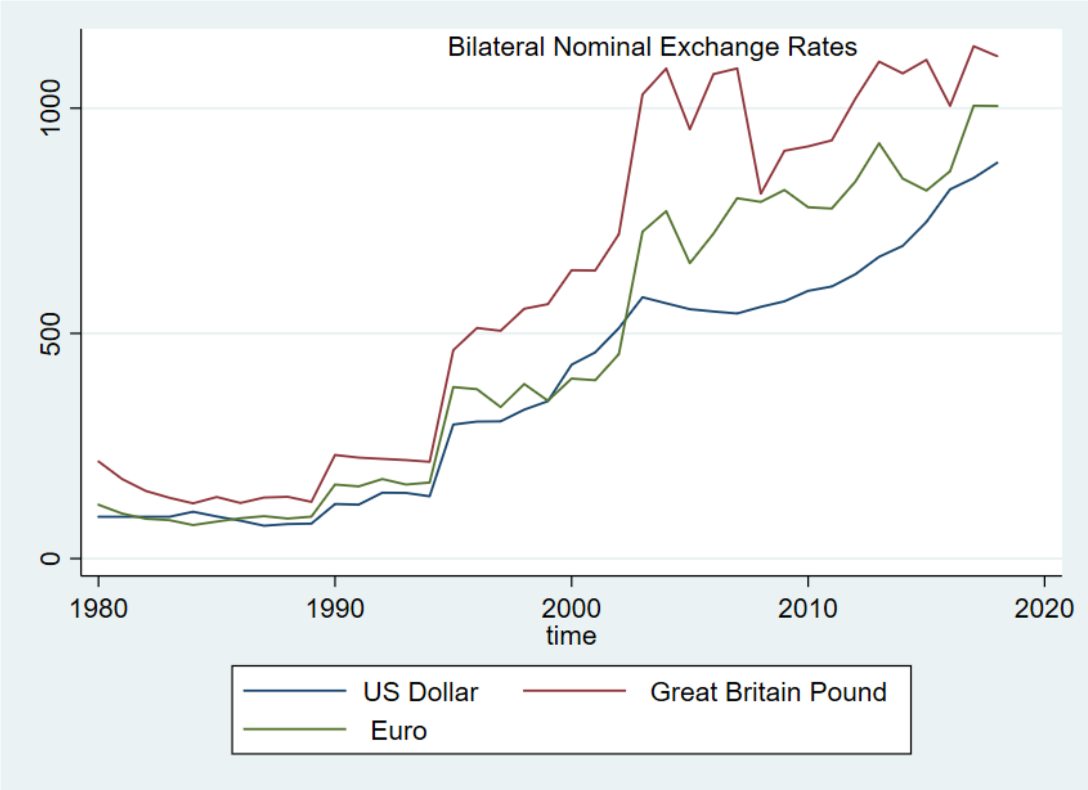
4.3.1 Overview of Exchange Rate Developments in Rwanda

Rwanda's exchange rate policy is analysed in under two different periods; the first period reflects a system of fixed exchange rate and the second period, a more flexible exchange rate system. During the fixed exchange rate system, foreign currencies of the banking system were held by the central bank, it was the sole institution authorized to conduct exchange transactions. The exchange rate was at the start pegged to the Belgian franc, then to the American dollar, and finally to the special drawing rights (SDR). Its value did not reflect economic conditions given that it lacked of flexibility (Nuwagira, 2015).

During this period, the exchange rate seemed to be overstated; triggering the rising of effective prices for Rwandan exports and loss of competitiveness on the international market. However, exchange rate reforms have since 1990 been undertaken to correct the overvaluation of the Rwandan franc (FRW) in a bid to improve external competitiveness. The statutory order No SP1 of 3rd March 1995 organizing the foreign exchange market introduced a flexible system of exchange of Rwandan francs. To avoid the risks associated to the flexible exchange system, the central bank has since chosen a more flexible exchange rate policy of RWF with a nominal anchor, which links the level of the exchange rate to the fundamentals of the economy. The reform of the exchange rate system began with the advent of the structural adjustment programs (SAP). Since 1990, Residents were authorized to hold accounts in foreign currencies in commercial banks, while in 1995, the flexible exchange rate system was introduced and new exchange control regulations were put in place. The main features of these new regulations are: full liberalization of both the current and capital account operations, determination of the exchange rate by the market forces, introduction of foreign exchange bureaus, authorization of foreign direct investment in Rwanda and the transfer of returns on investment abroad.

Other supplementary initiatives were taken. For example, the right granted to exporters to own and use their foreign currency proceeds from exports, and the authorization given to residents to withdraw money from their foreign currency accounts without providing any justification. For some operations, however, prior approval from the National Bank of Rwanda (NBR) was maintained; this concerned invisible operations (medical care, tourist trips, etc.) for which the purchase of foreign currency was subject to ceilings and capital transfers abroad that were not related to current operations. The objective of this flexible system is approaching as much as possible the equilibrium exchange rate level; to stabilize prices and support growth. Under this arrangement, the NBR intervenes on the foreign exchange market to cushion the volatility of exchange rate using its reference rate as the average of the interbank exchange rate and the NBR intervention rate.

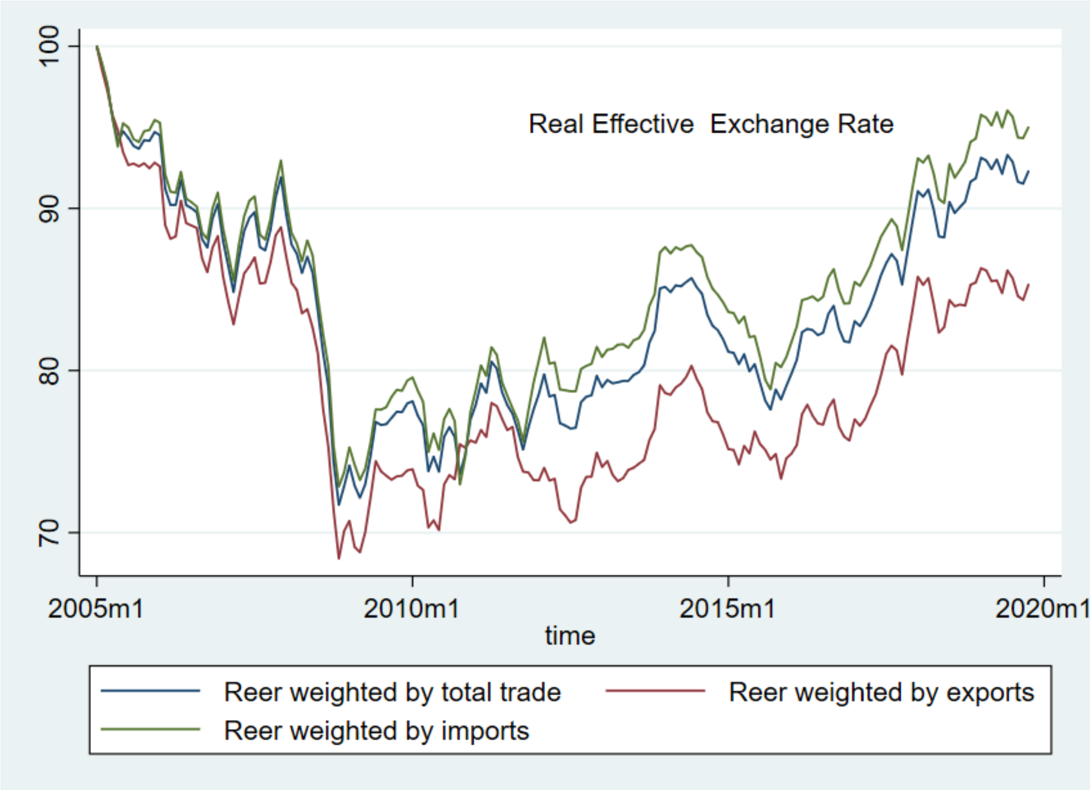
Figure 4.1: Bilateral Nominal Exchange Rate of RWF (1980-2018)



Source: Author's Computation

Figure 4.1 shows that Rwanda's bilateral nominal exchange rates generally appreciated during the period 1980-1990s due to rigidity in exchange rate, and it started depreciating from 1995 with the advent of financial liberalization that led to exchange rate flexibility which reflects changes in economic fundamentals. Up to now minor fluctuations prevail but the trend shows that the exchange rate has remained relatively stable. However, being driven by market forces, the exchange rate has been under relative pressure since 2015 emanating from a swift increase in foreign exchange demand on the account of increased demand for imports, especially imports of capital and intermediate goods, including construction materials, following government effort geared towards industrialization coupled with the construction boom that the country is experiencing.

Figure 4.2: Evolution of Real Effective Exchange Rate in Rwanda



Source: Author's Computation

Figure 4.2 depicts the trends of the three time series of real effective exchange rates (REER) obtained by using different weights from imports $(REER_m)$, exports $(REER_x)$ and total trade $(REER_t)$. It shows that since 2005, the real effective exchange rate has been appreciating with a sharp real appreciation observed in 2008 mainly due to the appreciation of the nominal value of the RWF against the currencies of major trading partners[29] as a result of the surge in aid flows during this period which helped to beef up the international reserves buffer. However, we observe moderate REER depreciation since 2015 up to present. But the RWF remains quite stable as moderate bilateral depreciation against USD, GBP and EURO during this period is insulated by the increase in relative prices, given that domestic inflation has increased in relation to foreign inflation coupled with the slowing pace of nominal exchange rate depreciation.

4.3.2 Data

To model non-linear dynamics of the exchange rate in Rwanda, we employ the threshold autoregressive model implemented by least squares estimation and consider a two regime threshold autoregression. The estimated empirical equation is specified in equations (6) and (7). The threshold variable q_{t-1} is in this case the lagged value of the real effective exchange rate,γ is a threshold parameter, and x_t is a vector of control variables which include lagged value of the exchange rate, real gross domestic product, consumer price index and exports. We also employ the autoregressive Markov switching model (MS-AR) specified in equations (4.14) through to (4.22) to estimate parameters transitioning in a finite set of unobserved states with unknown transition points.

[29] In computing Rwanda's real effective exchange rate, we consider a basket of 10 currencies for the major trading partners determined on the basis of trade shares. The major trading partners include Uganda, Kenya, Tanzania, Burundi, USA, Euro Area, UK, Sweden and Switzerland.

The empirical analysis builds on a quarterly data series spanning the period 2000Q1 to 2017Q4. For the out-of-sample, the forecasting horizon covers the period 2018Q1-2020Q4, indicating that we add 12 data points a head.

4.3.2.1 Data Description and Sources

The series are defined as follows. The real exchange rate is the relative inflation adjusted exchange rate and trade weighted, and is constructed by multiplying the nominal effective exchange rate by the ratio of consumer price indexes $Reer = \sum_{t=1}^{k}(Neer_{it}) \times \frac{p_{it^\star}}{p_{it}}$, where $Neer_{it}$ is the nominal effective exchange rate for Rwanda with respect to the trading partner i , $p_{it^\star}$ is the price index in trading partner i representing the price of tradables and p_{it} is the CPI of the home country as a proxy for price of non-tradables. In the context of this study, we consider the real effective exchange rate computed by the arithmetic mean method. The real gross domestic product growth rate (GDP) is used for the level of domestic economic growth, the consumer price index is used as the period average consumer price index and exports is exports free on board (FOB) value. All the data series are sourced from the National Bank of Rwanda and our data series are transformed into natural logarithms.

4.3.3 Forecast Performance Evaluation

Producing better forecasts is at the heart of economic and financial time series modeling, the predictive ability of models is in the context of this study is evaluated using different forecast performance evaluation measures. In this subsection, we evaluate and compare the forecasting performance of linear models such as ARIMA with competing non-linear models, particularly the threshold autoregressive model (TAR) and the Markov switching autoregressive model (MS-AR). We consider in-sample and out-of-sample forecasting performance evaluation of the specified models. However, research findings indicate that the performance of forecasting methods varies according to the accuracy measure being used (Makridakis and Hibon, 2000), thus the models' forecast performance evaluation measures are classified into three categories such as graphical analysis, relative predictive accuracy measures and equal predictive accuracy measures. The criteria required for accuracy measures have been explicitly addressed by Armstrong and Collopy (1992) and further discussed by Fildes (1992) and Clements and Hendry (1993).

4.3.3.1 Graphical Analysis

By using graphical analyses, we compare the ARIMA model with the TAR and MS-AR models based on their ability to describe the predictive distributions of the economic time series, in terms of their ability to handle regime switching. Thus, graphs comparing how the predicted values of the models track the actual data for the observed data points (in-sample) and the graphs for the models based on h-step ahead out-of-sample forecasts are constructed and the inference is informed by their predictive distributions.

4.3.3.2 Absolute and Relative Predictive Accuracy Measures

In this subsection, we discuss statistics that are commonly used in the literature to evaluate and compare the forecasting performance of competing models. The evaluation of the accuracy of forecasting models is premised on two key aspects: measuring the predictive accuracy of models and comparing various forecasting models. In context of this study, a number of absolute and relative predictive accuracy measures are considered and most of the measures are assumed to follow the Gaussian distribution. There is no universally preferred measure of estimation accuracy and forecasting experts often disagree on which measure should be used. Most commonly known measures of accuracy include mean absolute error (ME), mean absolute percentage error (MAPE), mean square error(MSE) and root mean square error (RMSE).

The first measure is mean absolute error (MAE) which is the average deviation between the actual value and the predicted value. The MAE is defined as:

$$MAE = \sum_{i=1}^{n} \left| \frac{y_i - \hat{y}_i}{n} \right| \tag{4.23}$$

The MAE is more sensitive to small deviations from 0 and much less sensitive to large deviations than the usual squared loss. Therefore, the MAE can be viewed as a "robust" measure of predictive accuracy. The Mean absolute percentage error (MAPE) measures how accurate the forecast models are, it is given by the average absolute percent error for each time period less actual values divided by actual values. it is given by:

$$MAPE = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{y_i - \hat{y}_i}{\hat{y}_i} \right| \tag{4.24}$$

The lower the MAPE, the more accurate is the forecast model (Tsay, 2005). This is supported by Lewis's judgment scale , where an average absolute percentage error lower than 10 percent implies highly accurate forecasts (Lewis, 1982).

The mean square error (MSE) measures the amount of dispersion of error, that is the average squared difference between the forecasted values and the actual value. The MSE is defined as:

$$MSE = \frac{1}{n} \sum_{i=1}^{n} \left| y_i - \hat{y}_i \right|^2 \tag{4.25}$$

Again,the smaller the mean square error, the better the forecast. However, MSE is often criticized as being inappropriate given that it is more vulnerable to outliers since it gives extra weight to large errors (Armstrong and Collopy 1992). In addition, the squared errors are on a different scale from the original data. Thus, the RMSE, which is the squre root of MSE, is often preferred to MSE as it is on the same scale as the data. However,the RMSE is also sensitive to forecasting outliers (Armstrong, 2001).The Root mean square error (RMSE) is the standard deviation of the residuals and measures how close the actual data is to the predicted values. The smaller the standard errors, the better the forecast model. It is specified as:

$$RMSE = \sum_{i=1}^{n} \sqrt{\left(\frac{y_i - \hat{y}_i}{n} \right)^2} \tag{4.26}$$

4.3.3.3 Tests of Equal Predictive Accuracy

The tests of equal predictive accuracy evaluate and compare competing forecast models on the basis of the null hypothesis that a set of two models have equal predictive ability against the alternative that one of the competing models is more accurate. In the present analysis, we consider three key tests, which are Diebold-Mariano (DM) test developed by Diebold and Mariano (1995), the Giacomini–Rossi fluctuation test and model confidence sets.

The Diebold-Mariano (DM) tests for the equal forecast accuracy of competing models based on its associated mean square error. Suppose y_t represents the actual data, $\hat{y_{it}^h}$ is the competing h-step forecasting series and $e_{it}^h = y_{it}^h - \hat{y_{it}^h}(i = 1, 2, 3, ..., m)$ where m is the number of forecasting models. The accuracy of each forecast is measured by the loss function given by $L\left(y_{it}^h, \hat{y_{it}^h}\right) = L(e_{it}^h)$. The Diebold and Mariano test is based on the loss differential $d_t = L(e_{1t}) - L(e_{2t}$ and $\bar{d} = \frac{1}{n}\sum_{t=1}^{n} d_t = \left[\frac{L(e_{1t}) - L(e_{2t})}{n}\right]$,this implies that

$$DM = \frac{\bar{d}}{\sqrt{\frac{2\pi sd}{n}}} \longrightarrow N(0, 1) \tag{4.27}$$

From the above expression the null hypothesis of equal predictive accuracy is given by $H0 : E(d_t) = 0$ and the alternative hypothesis is stated as $H_1 : E(d_t) \neq 0$

Another important equal predictive accuracy test, particularly for the out-of –sample forecasts evaluation was developed by Giacomini and Rossi (2010). The Giacomini-Rossi fluctuation test evaluates which model forecasts better in an unstable environment, it provides visual illustration of when the predictive ability appears or breaks down in data. Let $L(\cdot)$ denote the loss function and $L^j(\cdot)$ denote the loss associated with model j where $j = (1, 2, ..m)$. The out-of-sample loss differences are thus given by $\{\triangle L_t, h\}_{t=1}^{p}$, where $\triangle L_t, h \equiv L_{t,h} - {l_{t,h}}^{(2)}$ which is influenced by the realizations of the variable $y_t + h$. The quadratic loss associated with MSFE measures,$L_{t,h}^{(1)} = v_t^2 + h$ and $\triangle L_{t,h}$ is the difference between the squared error of the two competing models, thus the Giacomini-Rossi test defines the local relative loss for the two competing models as the sequence of out-of-sample loss differences computed over rolling windows of the size m. this yields:

$$m^{-1} \sum_{j=t-m+1}^{t} \triangle L_{j,h,t} = m, m + 1, ..., p \tag{4.28}$$

The hypotheses are stated as follows: $H_0^{GR} : E[\triangle L_{t,h}] = 0$ and $H_1^{GR} : E[\triangle L_{t,h}] \neq 0$

Model Confidence Set

The model confidence set (MCS) entails constructing a set of models such that it will contain the best model with a given level of confidence $M_{1-\alpha}$. This model forecast evaluation technique was introduced by Hansen et al. (2011). It requires the specification of a collection of competing models and criteria for evaluating these models empirically. The MCS is constructed via sequential testing procedure where an equivalence test determines whether all models in the current set are equally good. The equivalence test amounts to a test for equal predictive ability (EPA), similar to Diebold and Mariano (1995). The null hypothesis of equal predictive ability (EPA) is rejected at a specified confidence level and the EPA test statistic is evaluated based on a loss function, particularly the mean square error associated with the forecasting models.

To derive the construction of the loss function and the equal predictive ability, we start with inital set of models $\mathcal{M}^0$ and let $\mathcal{M}$ be the dimension for the specified models for a given level of confidence $1-\alpha$.

The superior model is obtained when the final set consists of a single model $\mathcal{M}^\star = 1$ (Bernardi et al.,2014). Let $d_{ij,t}$ denote the loss function between two models i and j, that is $d_{ij} \equiv \bar{L_{i,t}} - \bar{L_{j,t}}, j = 1,..,m, t = 1,..N$, where $\bar{d}_{ij} = \frac{1}{n}\sum_{t=1}^{n} d_{ij}, t$ and $\bar{d}_t = \frac{1}{m}\sum_{j\epsilon\mathcal{M}} \bar{d}_{ij}$, as the loss function of the model i relative to any other model j at time t , let $c_{ij} = E(d_{ij})$ and $c_i = E(d_i)$ be finite and not time dependent. The equal predictive ability hypothesis for a set of $\mathcal{M}$ candidate models can be formulated as follows:

$H_0, \mathcal{M} : C_{ij} = 0, \forall i, j = 1, 2, ...m$

$H_1, \mathcal{M} : c_{ij} \neq 0$ for some $i, j = 1, ..., m$

or $H_0, \mathcal{M} : c_i = 0$, $\forall i = 1, 2, ..m$

$H_1, \mathcal{M} = c_i \neq 0$ for some $i = 1, ..., m$

According to Hansen et al. (2011), in order to test the two hypothesis above, the following two statistics are constructed:

$$t_i = \frac{\bar{d}_i}{\sqrt{\hat{var}(\bar{d}_i)}} \tag{4.29}$$

$$t_{ij} = \frac{\bar{d}_{ij}}{\sqrt{\hat{var}(\bar{d}_{ij})}} \tag{4.30}$$

Where $\bar{d}_i = (\bar{L}i - \bar{L})$ is the sample loss of the i^{th} model compared to the averaged loss across models in $\mathcal{M}$, $\bar{L}_i \equiv \frac{1}{n}\sum_{t=1} L_{i,t}$ and $\bar{L} \equiv \frac{1}{m}\sum_{i\epsilon\mathcal{M}} \bar{L}_t$ measures the relative sample loss between i^{th} and j^{th} models. $\hat{var}(\bar{d}_i)$ and $\hat{var}((\bar{d}_{ij})$ are bootstrapped estimates of $var(\bar{d}_i)$ and $var(\bar{d}_{ij})$ respectively.

Bernardi and Catania (2014) implement a block bootstrap procedure with 5,000 bootstrap samples by default, where the block length is given by the maximum number of significant parameters obtained by fitting an autoregressive process on all the d_{ij} terms. Details on boostrap implementation procedure are well elaborated in Clark and McCracken (2001),Hansen et al. (2003), Hansen and Lunde (2005), Hansen et al. (2011). The two equal predictive ability null hypotheses presented above map naturally into the two test statistics:

$T_{R,\mathcal{M}} = \max_{ij\in\mathcal{M}} |t_{ij}|$ and $T_{\max,\mathcal{M}} = \max_{i\in\mathcal{M}} t_i$ where t_{ij} and t_i are defined in equations 44 and 45 and these statistics are used to test the stated hypotheses.

The model confidence set procedure sequentially eliminates the worst model at each step until the hypothesis of equal predictive ability is accepted for all the models belonging to the set of superior models. If MCS P-value is less than the predetermined significance level α , we reject the null hypothesis that no inferior model is present, thus the worst model is eliminated. The decision on which model to remove is based on the elimination rules that are implied by the test statistic. When the test statistic fails to reject the null hypothesis at a predetermined significance level, the procedure stops and delivers the remaining models as estimated model confidence sets and the best models are returned with the associated MCS p-values. The elimination rules are therefore specified below:

$$eR,\mathcal{M} = \underset{i\in\mathcal{M}}{\text{argmax}} \left\{ \sup_{j\in\mathcal{M}} \frac{\bar{d}_i}{\sqrt{v\hat{a}r(\bar{d}_i)}} \right. \tag{4.31}$$

$$e\max,\mathcal{M} = \underset{i\in\mathcal{M}}{\text{argmax}} \frac{\bar{d}_i}{v\hat{a}r(\bar{d}_i)} \tag{4.32}$$

The model confidence set procedure is implemented and can be summarized in the following steps:

1. Initially set $\mathcal{M} = \mathcal{M}^0$
2. Test the equal predictive ability hypothesis $H_0, \mathcal{M}$ at significance level α
3. If the null hypothesis of equal predictive ability is not rejected, then the process ends and the set of superior models is $\mathcal{M}_{1-\alpha} = \mathcal{M}$, otherwise, $e\mathcal{M}$ eliminates the worst model from the set $\mathcal{M}$ and the process is repeated until we fail to reject the null hypothesis.

4.4 Empirical Results

4.4.1 Descriptive Statistics

The descriptive statistics results of the variables used in this study are presented in Table 4.1 . Looking at the mean and the standard deviation, we see that there was no case where the standard deviation was greater than the mean, suggesting that the mean is a good estimator of the parameters. Kurtosis is less than 3 for lrgdp, lcpi and lexp, indicating a flatter distribution than the Gaussian distribution (lighter tails than normal distribution) but Kurtosis for lreer is greater than 3 which implies that it has heavier tails than the normal distribution(excess kurtosis). In line with this result, the Jarque –Bera's chi (2) 43.03 with the p-value equal to (0.0005) implying that residual series are not normally distributed and portmanteau Q statistic: 77.7 with p-value equal to (0.0000), which implies that the null hypothesis of no autocorrelation is rejected.

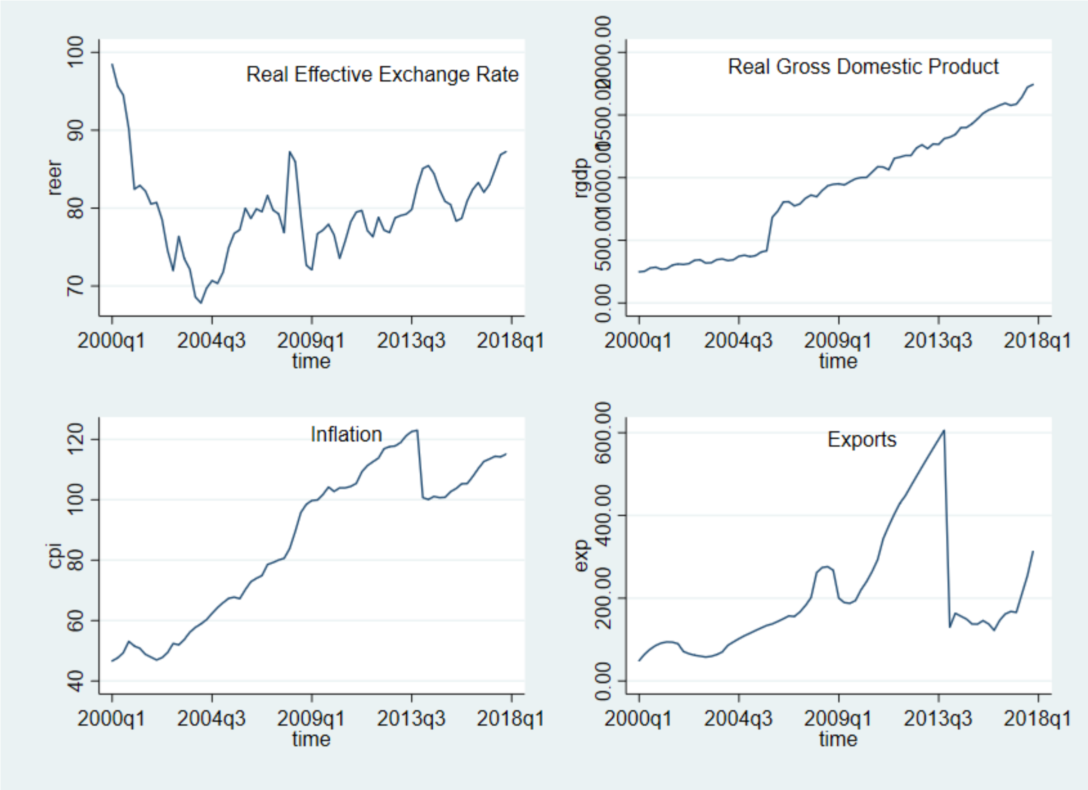
Table 4.1: Descriptive Statistics

Variables	N	Mean	SD	Variance	Skewness	Kurtosis
Lreer	72	4.37	0.07	0.005	0.43	3.89
Lrgdp	72	6.62	0.64	0.41	-0.44	1.63
Lcpi	72	4.41	0.32	0.10	-0.49	1.72
Lexp	72	5.10	0.65	0.42	0.24	2.31

Source:Author's computation

Figure 4.3 presents trends in the variables included in this study. The graphs indicate that the series depict non-linear patterns, pointing to regime shifting at some point in the series. This visual inspection of the data confirms the need to test for non-linearity of the exchange rate as the variable of focus before proceeding with the estimation of specified empirical models.

Figure 4.3: Trends for Main Variables



Source: Author's Computation

4.4.2 Unit Root Test

We checked for stochastic properties of data given that financial time series such as exchange rates are characterized by time invariant distribution, implying that they follow a stationary process. We implemented the augmented dickey- fuller (ADF) class of unit root tests by Dickey and Fuller (1979). The unit root test results reported in Table 4.2 indicate that lreer is stationary at level given that the absolute value of augmented dickey-fuller statistic(ADF) is greater than the critical value at the conventional significance level (5 percent), suggesting that the null hypothesis of the presence of unit root is rejected. The rest of the variables are integrated of order one given that their ADF statistics in absolute terms are lower than the critical values at significance levels implying that they become stationary after differencing. The stationarity of the real exchange rate as a threshold variable is particularly essential because if it is non-stationary,the process has a certain probability that is absorbed into a single regime and in this respect, there are no asymptotics for other regimes (Bec et al., 2004). Indeed, Caner and Hansen (2001) develop both unit root and linearity tests based on models where the threshold variable is stationary.

Table 4.2: Unit Root Test Results

Variables	ADF statistic	Critical values			Decision
		1%	5%	10%	
Lreer	-3.10	-3.55	-2.91	-2.59	I(0)
Lrgdp	-4.67	-3.55	-2.91	-2.59	I(1)
Lcpi	-4.43	-3.55	-2.91	-2.59	I(1)
Lexp	-4,15	3.55	-2.91	-2.59	I(1)

Notes: I(0) and I(1)denote stationarity at level and first difference, respectively.

Source: Author's Computation

4.4.3 Results of ARIMA (1, 0, 1)

Table 4.3 presents the results of ARIMA (1, 0, 1) model which is estimated as a baseline model in our analysis. The selection of this ARIMA specification is based on the information criteria for the competing ARIMA specifications, including the ARIMA(1,1,1), the ARIMA(2,0,1), the ARIMA(2,0,2) and the ARIMA(2,2,2). The used specification has the lowest Akaike information criteria (AIC) compared to the competing models. AR and MA terms were also determined by plotting the autocorrelation function (ACF) and the partial autocorrelation function (PACF), where the plots suggest ACF (1) and PACF (1), meaning that the order of AR and MA terms is 1, thus, ARIMA (1,0,1). The AR, MA and sigma components are positive and statistically significant confirming that the model is well specified.

Table 4.3: ARIMA Estimation Results

Dependent variable: $Lreer_t$				
Variables	**Coeff**	**Std.err**	**95% CI**	
μ	4.40***	0.324	4.33	4.46
AR(1)	0.883***	0.518	0.78	0.98
MA(1)	0.261***	0.965	0.71	0.45
Sigma	0.32***	0.001	0.28	0.03

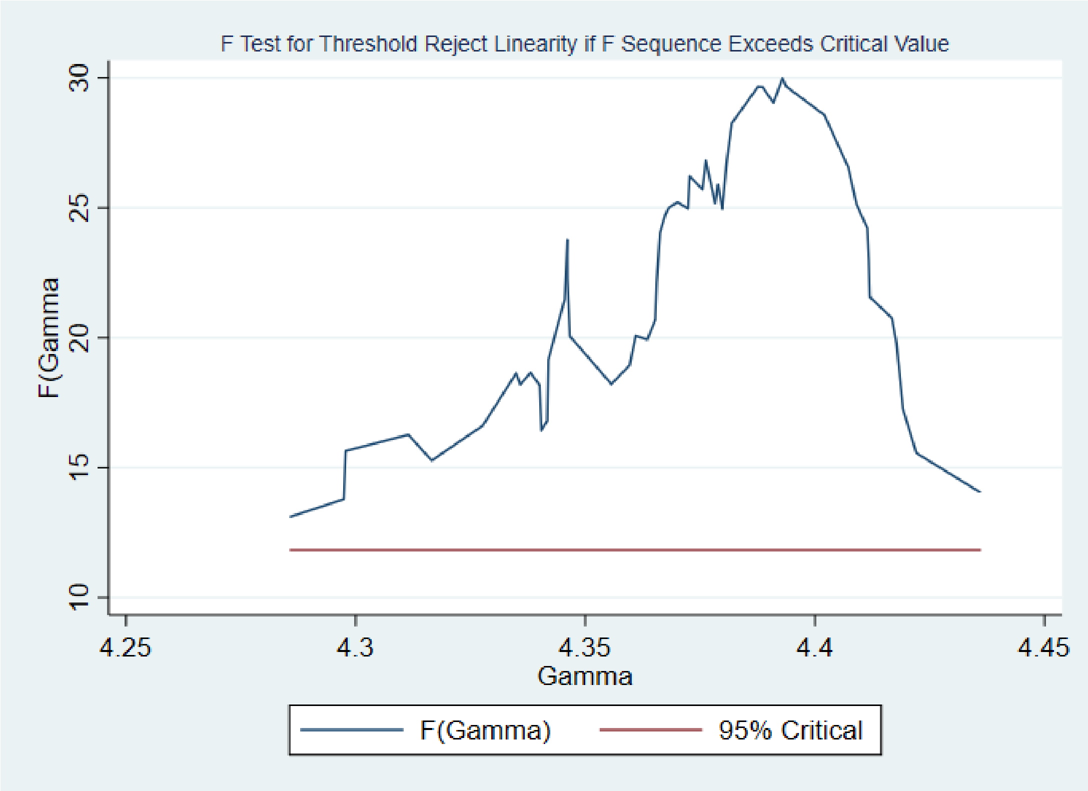
Notes: *** p<0.01, ** p<0.05 and *p<0.1 denote the statistical level of significance. The test of the variance against zero is one sided, and the two-sided confidence interval is truncated at zero.

Source: Author's Computation

4.4.4 Threshold Estimation Results

Based on the standard F statistic test, we test the null hypothesis of linearity against the alternative of existence of a threshold model. The results of the F test for the threshold in the real effective exchange rate as per the above figure indicates that the null hypothesis of linearity is rejected, thereby suggesting the presence of the threshold given that the sequence (F Gamma) is above the critical value at 95 percent confidence interval. This indicates that Rwanda's real exchange rate exhibits non-linear dynamics. This finding corroborates results by Hansen (2001).

Figure 4.4: Linearity Test



Source: Author's Computation

Table 4.4 indicate a two regime specification in the exchange rate with the threshold estimate at 4.36. This finding is similar to Chen and Tsay (1991), Hansen (2000), Ling and Tong(2005) and Ling, Tong and Li (2007). Despite the fact that our major focus is the application of the regime switching models to the real exchange rate, we also included other macroeconomic variables that influence the exchange rate. The results indicate that these variables emerge with correct signs and are statistically significant. The coefficient of the lagged real exchange rate is positive and statistically significant, indicating persistence in exchange rates. The estimated coefficient of real gross domestic income (RGDP) is positive and statistically significant, suggesting that productivity gains induce real exchange rate appreciation. The obtained parameter estimate for inflation is negative and significant, pointing to the fact that higher inflation erodes the value of the currency and as such leads to the depreciation of the real exchange rate. Finally, the coefficient of exports is positive and statistically significant and this implies that higher export revenues induce real exchange rate appreciation via boosting the reserve assets of the central bank.

Table 4.4: Threshold Regression Results

Dependent variable: Lreer_t				
Variables	**Coeff**	**Std.err**	**[95% CI]**	
$lreer_{t-1}$	0.940***	11.62	0.781	1.098
$lrgdp_t$	0.846***	2.76	0.024	0.144
$lcpi_t$	-0.171**	-2.30	-0.317	-0.0025
$lexp_t$	0.026**	1.93	-0.0004	0.0537
Region1 - μ	0.345	0.366	-0.372	1.063
Region2 - μ	0.316	0.370	-0.410	1.043
Region3 - μ	0.305	0.375	-0.429	1.041
Threshold order1	4.34			
Threshold order 2	4.36			

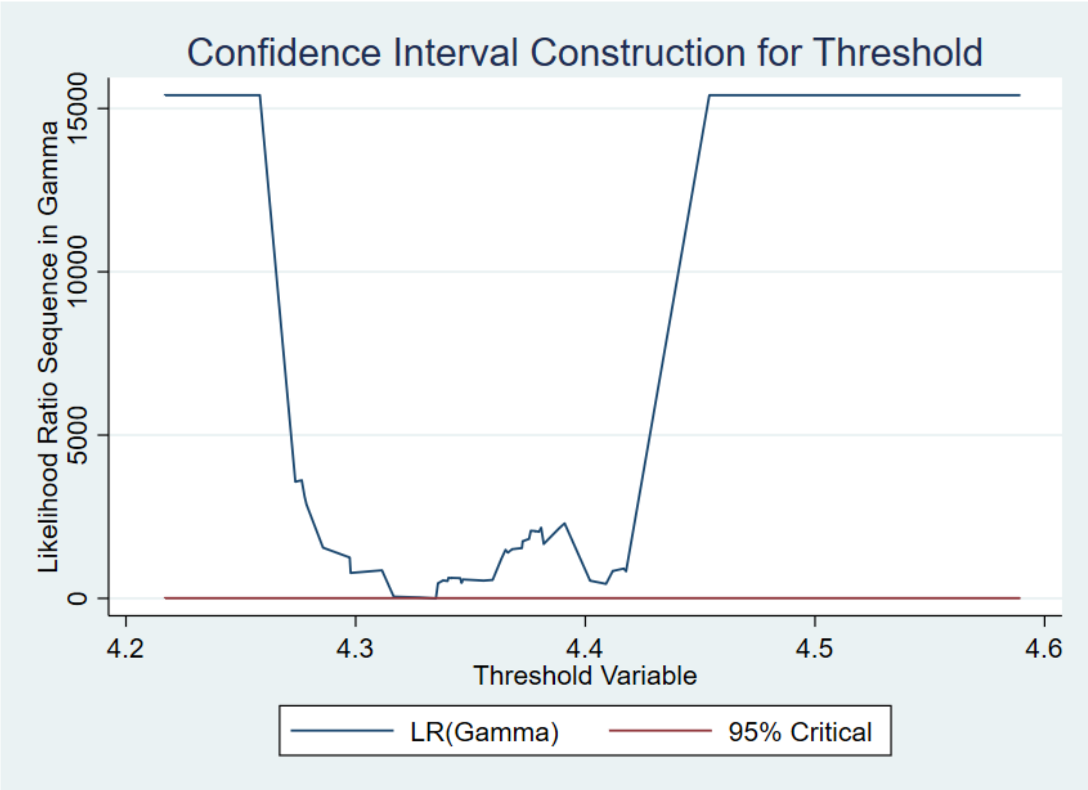
Notes: *** p<0.01, **p<0.05 and * p<0.1 denote statistical significance level.

Source: Author's Computation

Figure 4.5 supports the above finding, it depicts the normalized likelihood ratio as the function of the threshold in real exchange rate. The estimate of γ is the value that minimizes this graph at $\hat{\gamma} = 4.36$ with 95 percent asymptotic confidence interval (4.34, 4.36). The value of gamma where the likelihood ratio lies below the red line yields the confidence region. The estimate 4.36 points to a reasonable evidence for a two regime specification and that the threshold exists within the interval ipso facto, TAR splits the regression function into two regimes depending on whether real effective exchange rate has been above or below 4.36, and this threshold is interpreted as the level beyond which exchange rate fluctuation destabilizes Rwanda's real effective exchange rate. From these point estimates we can look back into the historical sample and examine how the TAR model splits the model into two regimes and regime one is the unusual regime consisting of 39 percent of the observations and regime two is the usual regime as it includes 61 percent of the observations. This result is consistent with Ahmad and Pentecost (2009) who obtained 4.12 point estimate for South Africa with 21 percent of the observations falling under the unusual regime and 79 percent being in the usual regime, and a 0.9 point estimate for a two regime threshold for Kenya with

22 percent of the observations falling under the unusual regime and 78 percent of the observations falling under the usual regime and the estimated two-regime threshold for Nigeria with a threshold of 0.97. The first regime is the unusual or extreme regime, including 40 percent of the observations included, while the second and the usual regime has 60 of the observations.

Figure 4.5: Confidence Interval Construction Results



Source: Author's Computation

4.4.5 Estimation Results of the Markov Switching Model

4.4.5.1 Testing for Non-Linearity

Prior to estimating the markov switching model, we determine whether non-linear is suitable given that there is presence of non-linearities in the economic series, particularly financial economics. The hypothesis of linearity against non-linearity is determined on statistical grounds. While there are several tests for detecting non-linear dynamics in time series data, we focus on the Brock, Dechert and Scheinkman (BDS) test, a non-parametric technique that was developed by Brock, Dechert and Scheinkman (1987). The BDS test is based on the null hypothesis of independent and identically distributed data and has an asymptotic $N(0,1)$ distribution. The main notion behind the BDS is the correlation integral, which is a measure of the frequency with which temporal patterns are in data and the measure is specified as:

$$BDS_m, M(r) = \sqrt{M}\frac{c_{m(r)} - c_1^r(r)}{\sigma_m, M(r)} \tag{4.33}$$

where M is the surrounded points of the space with m embedding dimension, which evaluates the sequence of length $2, \ldots m$ with the default option set at 3, r is the radius of the sphere centered on the

X_i , c is the constant and σ_m is the standard deviation of $\sqrt{M} c_{m(r)} - c_1^r(r)$. The null hypothesis of the BDS test [30] is that the series are linearly dependent against the alternative that they are not linearly dependent. Table 4.5 reports the BDS test results. The results indicate that the linearity assumption is rejected given that the p-value is less that 0.05 level significance. This finding points to the existence of non-linearity in Rwanda's real exchange rate, supporting the estimation of non-linear models such as the markov switching model.

Table 4.5: BDS Test for Non-Linearity

Dimension	BDSstat	Std.err	P-value
2	13.94***	0.0063	0.0000
3	17.41***	0.0048	0.0000

Notes: The distributed normal (z-value) is considered as the P-value.The reported statistics correspond to $0.5sd$.

Source: Author's Computation using Stata

Similar to Hamilton and Engel (1990), the results of the Markov switching models show the process that governs the time at which real effective exchange rate movements transition between depreciation and appreciation and the duration of each episode. The estimation procedure is via the expectation maximization (EM) algorithm developed by Dempster, Laird and Ruben (1977). With this algorithm each iteration increases the value of likelihood function, and thus the final estimates are maximum likelihood estimates. The model parameters and the results are presented in Table 4.6.

Table 4.6: Markov Switching Autoregression Results

Dependent variable: $\mathbf{lreer_t}$

Variables	Coeff	Std.Err	[95% CI]	
State 1				
-AR(2)	0.650***	8.59	0.501	0.798
- μ	4.328***	298.3	4.299	4.356
State 2				
-AR(2)	0.443**	1.92	-0.0090	0.896
- μ	4.422***	321.1	4.395	4.449
Sigma	0.035	0.0031	0.029	0.041
P11	0.961	0.029	0.842	0.991
P21	0.073	0.057	0.145	0.295

Notes: *** p<0.01, **p<0.05 and *p<0.1 denote statistical significance level.

Source: Author's Computation

[30] The BDS test is implemented using a statistical software package developed by Christopher, Hurn, and Lindsay (2021)

Table 4.6 reports the estimated results, including the mean of the two states, sigma (standard deviation), the autoregressive terms and the transition probabilities of the two states. The mean of state dependent intercepts for both states emerge positive and statistically significant at conventional level as shown in table 6 above. The parameter estimates for the state dependent intercepts is 4.33 and 4.42 for state 1 and state 2, respectively. These state dependent intercepts describe the appreciation and depreciation regimes respectively. State 1 is modest with a mean of 4.33 while state 2 is a high rate state with the mean of 4.42. The obtained results are quite close to TAR estimates, with a point estimate of 4.36 and 95 percent confidence interval (4.34, 4.36). The results of the two-state markov switching autoregression are in line with De Grauwe and Vansteenkiste (2007) who find evidence of markov switching between two-regimes in industrial countries. The transitional probabilities matrix is given by:

$$P = \begin{pmatrix} 0.961 & 0.039 \\ 0.073 & 0.927 \end{pmatrix} \tag{4.34}$$

The results for the associated transition probabilities matrix above indicate that the estimated probability that the same state prevails (state 1) is high at 96 percent, implying that the process is persistent and thus there are few switches within the same state. On the other hand, the probability of transitioning from state 1 (appreciation regime) to state 2 (depreciation regime) is lower, at 4 percent. Similarly, for state 2, the estimated transition probability of switching within that same state is 93 percent and a lower probability of 7 percent to switch to state 1. The estimated transition probability of staying in state 1 is high, implying that the process is persistent. Overall, the results from the transition probability estimates indicate that none of the states/regimes is permanent given that all the estimated transition probabilities are less than one.

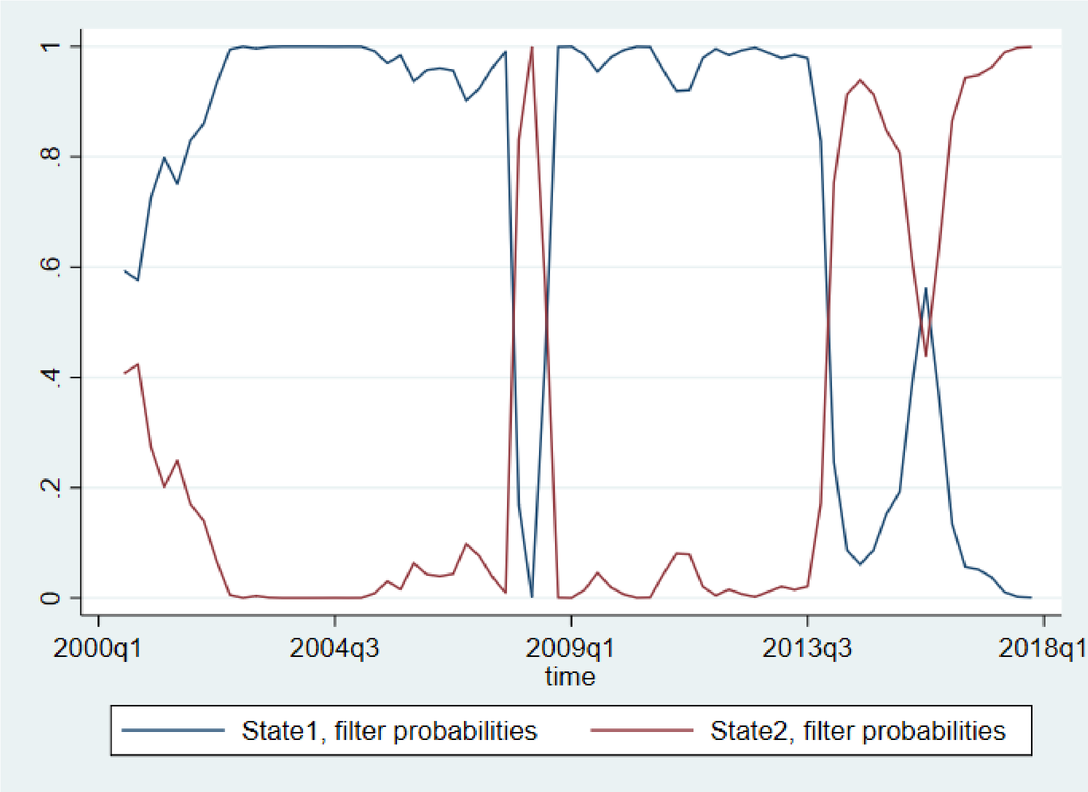
Table 4.7: Expected Duration Results

Expected duration	**Estimate**	**Std.Err**	**[95% CI]**	
State 1	25.40	18.86	6.36	112.03
State 2	13.69	10.85	3.37	68.81

Source:Author's Computations

The estimated results for the expected duration reported in Table 4.7 show that episodes of appreciation last for an average of 25.4 quarters, while episodes of depreciation last for an average duration of 13.69 quarters. This implies that Rwanda's real effective exchange will be in the appreciation state for 25.4 quarters and in the depreciation state on average 13.69 quarters, suggesting that the appreciation regime is a lot longer compared to its counterpart (depreciation).

Figure 4.6: Filtered and Smoothed Probabilities for State1 and State2



Source: Author's Computation

The results of filtered and smoothed predicted probabilities show that the appreciation regime dominates the depreciation regime in most of the data points. This finding confirms that state 1 prevails longer than state 2. From the results, we identify 2 episodes of appreciation and 2 episodes of depreciation and trace antecedents characterizing each of the identified episodes within the data points. The episode 2000Q1-2005Q1 was characterized by the appreciation of Rwandan currency due to the upsurge in donor aid flows and increasing private financial flows such as foreign direct investments which beefed up international reserves thereby appreciating the currency. The episode 2008Q1-2009Q4 depicts the depreciation of the currency resulting from the global financial crisis which weighed down on export receipts as well as private financial flows from the affected advanced economies. The period 2010Q1-2015Q1 was characterized by the appreciation of Rwandan currency following the recovery of the global economy which led to the increase in donor aid flows, exports earnings as well as foreign capital flows. Finally, the episode 2015Q2-up to the present depicts depreciation due to low exports earnings on the account of the decline in international commodity prices coupled with high demand for imports especially construction materials following construction boom.

4.4.5.2 Multivariate Markov Switching Model

While the univariate autoregressive markov switching model emerges successful in characterizing exchange rate movements as regime specific dynamics, we also estimate a markov switching model with selected variables such as lrgdp, lcpi and lexports in a bid to shed light on the link between exchange rate movements and other macroeconomic variables. The estimated results are presented in Table 4.8.

Table 4.8: Multivariate Markov switching Results

Dependent variable: $lreer_t$				
Variables	**Coeff**	**Std.Err**	**[95% CI]**	
$lrgdp_t$	0.239***	0.019	0.201	0.277
$lcpi_t$	-0.463***	0.051	-0.564	-0.361
$lexp_t$	0.070***	0.011	0.049	0.092
States 1				
-AR(2)	-0.561***	0.168	-0.892	-0.230
-μ	4.424***	0.075	4.277	4.572
States 2				
-AR(2)	0.539***	12.76	0.456	0.622
-μ	4.485***	59.89	4.338	4.632
Sigma	0.024	0.001	0.017	0.024
P11	0.836	0.059	0.685	0.922
P21	0.242	0.083	0.116	0.438

Notes: *** p<0.01, **p<0.05 and *p<0.1
denote statistical significance level.

Source: Author's Computation

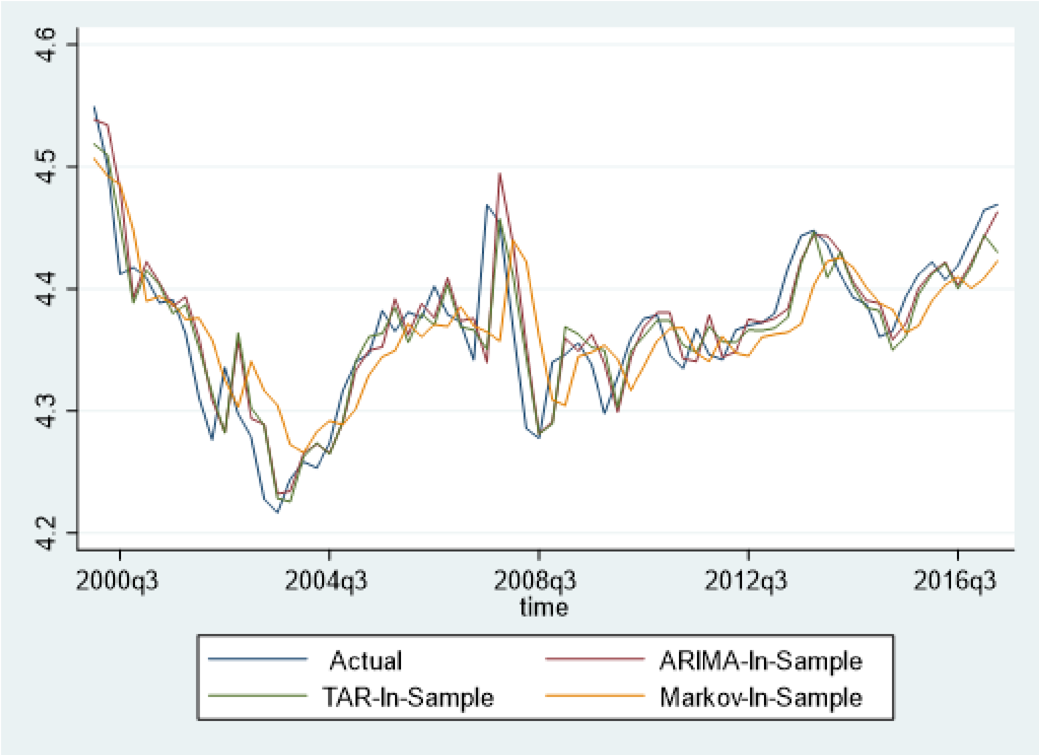
The results reported in Table 4.8 indicate that the selected variables are correctly signed and statistically significant, implying that Rwanda's exchange rate is influenced by macroeconomic variables. The means of state dependent intercepts for the two states are statistically significant and consistent with their univariate counterparts. The coefficients for state dependent intercepts is 4.42 and 4.49 for state1 and state 2, respectively, suggesting that state 1 is modest with a mean of 4.42 and state 2 is high rate state with the mean of 4.49, and the autoregressive terms for state 2 which is 54 percent indicate that exchange rate shocks will die out moderately quickly. The associated transition probabilities are consistent with the univariate model, with the probability of switching from state 1 to state 2 being 16 percent, while the probability of staying within state 1 is 84 percent. Similarly for state 2, the probability of switching from state 2 to state 1 is 24 percent and the probability that the same state (state 2) prevails is 76 percent, implying that in the process is persistent in both states.

4.4.6 Results of Model Forecast Evaluation

4.4.6.1 In-sample Forecast Evaluation

To supplement log-likelihood ratios and the information criteria associated with the fitted models, we conduct the in-sample forecasting performance evaluation based on absolute, relative and equal predictive ability measures to compare the forecasting abilities of these models. In context of this study, several accuracy measures are used such as mean absolute percentage error, mean absolute error, mean square error, root mean square error, Diebold and Mariano, Giacomini-Rossi and model confidence set.

Figure 4.7: In-Sample Forecasts



Source: Author's Computation

From Figure 4.7, the visual inspection of the in-sample prediction shows that all models (ARIMA, TAR and MS) seem to track the actual data well, but from the graphical analysis, we can clearly observe that TAR and ARIMA forecasts track the actual data better than the markov switching model. In addition to visual inspection, we conducted other forecast performance evaluation measures, especially the absolute and relative predictive measures, as well as equal predictive ability measures to evaluate the robustness of this finding.

Table 4.9: In-Sample Results of Relative Predictive Measures

In-Sample Results of Relative Predictive Measures			
Statistic	**ARIMA**	**TAR**	**MS-AR**
MSE	-0.0014	-0.00018	-0.0014
RMSE	0.0383	0.0297	0.0439
MAE	0.0254	0.0228	0.0342
MAPE	0.0058	0.0052	0.007

Source:Author's Computations

The absolute and relative predictive measures presented in Table 4.9 show that most of the measures indicate that non-linear models, especially threshold autoregressive model (TAR) forecasts better than the linear model, in this case, the autoregressive integrated moving average model (ARIMA). However, ARIMA model has smaller root mean square error compared to the Markov switching model (MS), suggesting that ARIMA forests better than MS in-sample. Overall, the threshold autoregressive (TAR) model outperforms the competing models given that it has smaller mean square error (MSE) and root mean square error (RMSE) compared to its counterparts.

Table 4.10: In-Sample Results of Diebold and Mariano Test

In-Sample Results of Diebold and Mariano Test

Model	MSE
DM-ARIMA	0.0010
DM-TAR	0.0008
DM-ARIMA	0.0010
DM-MSAR	0.0019
DM-TAR	0.0008
DM-MSAR	0.0019

Source:Author's Computations

Diebold and Mariano test is a pairwise test, it evaluates and compares a pair of two competing forecasting models based on the null hypothesis that they have equal forecast accuracy against the alternative that one of the forecasting models is better. In the context of this study, we compare our benchmark model (ARIMA), which is a linear model, with each of the two non-linear models and lastly we pit the non-linear models against one another. The results are presented in Table 4.10 above and they indicate that the null hypothesis of equal predictive ability is rejected in favour of the alternative that one model is better than the other. The outcome is that TAR model performs better than the ARIMA model given that their Diebold and Mariano test statistics based on mean square errors are smaller, but ARIMA model outperforms MS-AR model in-sample. Generally, the threshold autoregressive model performs better than the competing models.

Table 4.11: In-Sample Results of Model Confidence Set

In-Sample Results of Model Confidence Set Test

Model	P-value	MCS P-value
ARIMA	0.2864	0.2864
TAR	1.0000	1.0000
MSAR	0.0194	0.0194

Source:Author's Computations

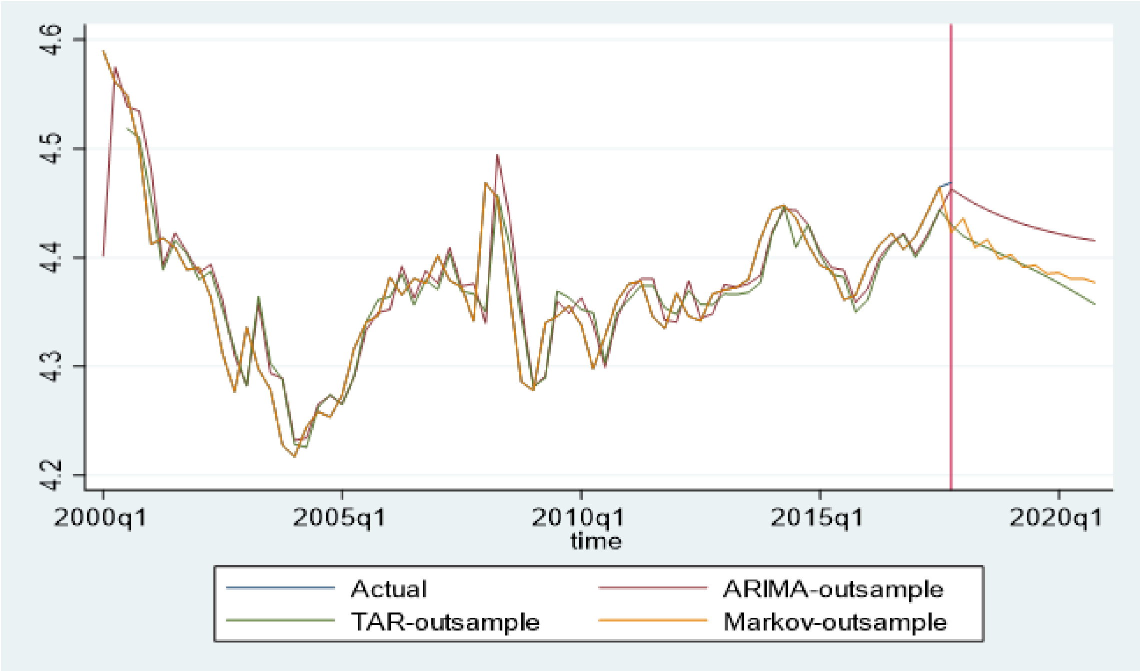
The model confidence set procedure was applied to a set of models that we use to forecast Rwanda's real exchange rate. The model with the lowest expected loss is considered the best model. In our study, the in-sample forecasting ability of the ARIMA , TAR and MS-AR models are compared and evaluated and the interpretation is based on the null hypothesis that no inferior model is present. If the null hypothesis is rejected, the model is removed and the null is tested again until we fail to reject the null hypothesis of equal predictive ability at a predetermined significance level and the remaining models are returned with their associated MCS P-values. In this regard, the results from Table 4.11 above, indicate that all the competing models are in line with the MCS, implying that they are good models because they are not significantly inferior given that their p-values equals to the MCS associated p-values . However, the p-values associated with MS-AR are lower than the predetermined significance level(10 percent), thus in terms of ranking, the MCS procedure shows that ARIMA and TAR models are the best models with the p-value of 0.286 and 1.000 respectively, equivalent to the apriori significance level which, lies within the 90 percent confidence interval that we considered in this procedure. This finding is in line with results obtained for the Diebold and Mariano as well as other in-sample forecast evaluation tests used in this study.

4.4.6.2 Out-of-Sample Forecast Evaluation

While in-sample forecast performance evaluation indicate that TAR performs better than the linear (ARIMA) model, the ARIMA model outperforms the MS-AR model, suggesting that there is no clear cut conclusion on whether non-linear models outperform their linear counterparts.

Besides, literature shows that a satisfactory in-sample fit is not a guarantee of out-of-sample forecast performance even for linear models (Clements and Hendry, 1998; Clements and Smith, 2000; Clements and Hendry, 2002; and Franses and Van Dijk, 2003). In this respect, it becomes relevant to check the out-of-sample forecasting performance of each model and compare their predictive ability. The models' forecasting procedure is h-step ahead forecasting. The red vertical line in the out-of-sample forecast graph indicates where the actual data points end (2017Q4) and the trend beyond that line depicts the out of sample period. The out-of-sample forecasting process produces twelve one-step-ahead forecasts in the validation data period from 2018Q1 to 2020Q4.

Figure 4.8: Out-of-Sample Forecasts



Source: Author's Computation

Figure 4.8 presents the out-of-sample graphical forecast, the results clearly indicate that TAR and MS-AR predict better than the ARIMA model, implying that non-linear models outperform their linear counterpart out-of-sample. This finding is fortified by the relative predictive measures presented in Table 4.12.

Table 4.12: Out-of-Sample Results of Relative Predictive Measures

Out-of-Sample Results Relative Predictive Measures			
Statistic	**ARIMA**	**TAR**	**MS-AR**
MSE	-0.0014	-0.00018	-0.00018
RMSE	0.0254	0.0284	0.0054
MAE	0.0383	0.0219	0.0063
MAPE	0.0058	0.0050	0.00014

Source:Author's Computations

The results presented in Table 4.12 show that practically all test statistics for the non-linear models are small compared to the linear counterpart, implying that non-linear models outperform the competing linear model and this is in line with the results of the graphical forecasts. Our results are in line with Karikos (2000), Corporale and Spagnolo (2004) and Bergman and Hansson (2005) who model regime shifts in exchange rates and found that regime switching models provide better in-sample and out-of -sample forecasts than random walk specifications. Specifically for markov switching models, studies by Frömmel et al. (2005) and De Grauwe and Vansteenkiste (2007) support our finding by providing evidence that a two-regime Markov switching model outperforms linear versions of their models in out-of-sample fit.

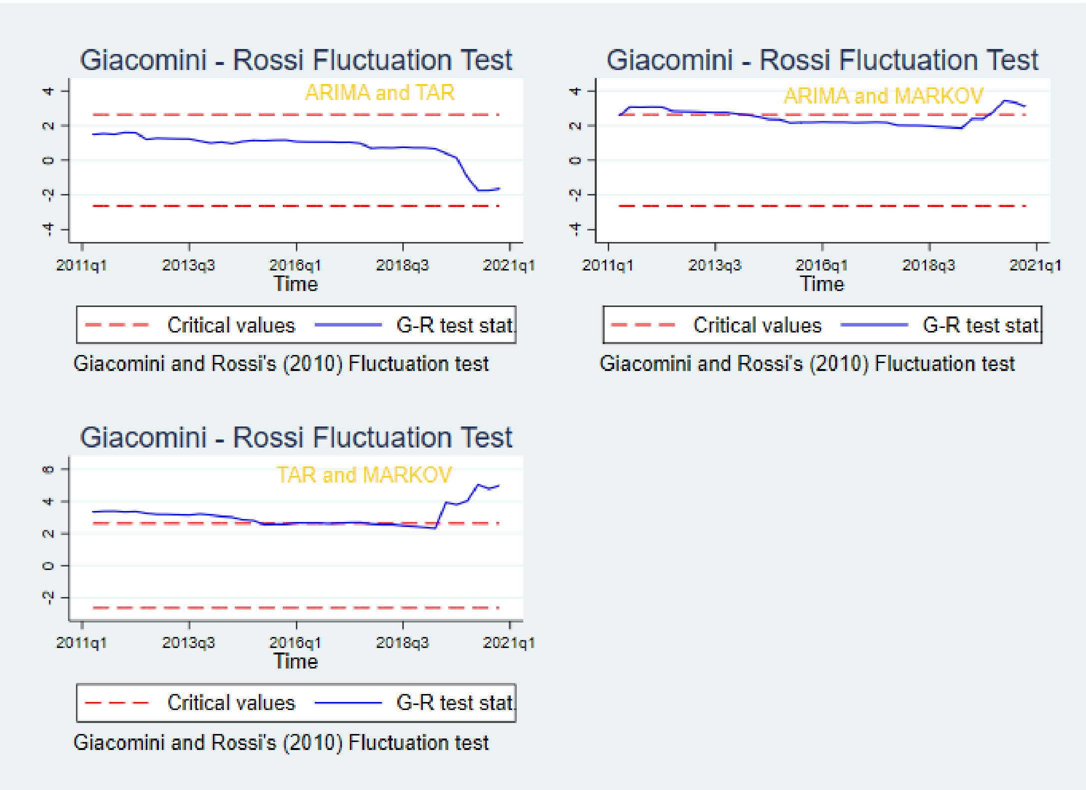
Table 4.13: Out-of-Sample Results of Diebold and Mariano Test

Out-of-Sample Results of Diebold and Mariano Test	
Model	**MSE**
DM-ARIMA	0.0010
DM-TAR	0.0008
DM-ARIMA	0.0014
DM-MSAR	0.00002
DM-TAR	0.0008
DM-MSAR	0.00003

Source:Author's Computations

The results from the above table indicate that the pairwise Diebold and Mariano (1995) test also supports non-linear models against the linear alternative because mean square error associated with the test statistic is smaller in the case of non-linear models compared to the linear model. In terms of individual model ranking, the Markov switching model emerges as the best forecasting model.

Figure 4.9: Giacomini-Rossi Fluctuation Test



Source: Author's Computation

Figure 4.9 presents the results of the Giacomini-Rossi test. The first graph compares ARIMA and TAR models, the second compares ARIMA and MS models and the third compares TAR and MS. These graphs are interpreted with respect to the test statistic and critical values associated with each of these plots. The value of the test statistic in the first graph is 1.73 and the critical value is 2.63 at 5 percent significance level, thus, we fail to reject the null hypothesis that the models' forecasting performance is the same against the alternative that the second model(TAR) forecasts better than the first model. The value of the test statistic in the second graph in the figure is 3.44, larger than the critical value at the 5 percent significance level, equal to 2.63, this implies that the null hypothesis is rejected in favour of the alternative that the first model forecasts better. The value of the test statistic is 5.05 and the critical value is 2.63 at 5 percent significance level in the third graph, therefore, null hypothesis is rejected, implying that the first model (TAR) forecasts better than the second model (MS). Overall, the Giacomini-Rossi test indicates higher predictive ability of non-linear models compared to their linear counterpart, as reflected in graphs two and three in Figure4.9.

Table 4.14: Out-of-Sample Results of Model Confidence Set

Out- of-Sample Results of Model Confidence Set Test		
Model	**P-value**	**MCS P-value**
ARIMA	0.0048	0.0048
TAR	0.0038	0.0038
MSAR	1.0000	1.0000

Source:Author's Computations

The MCS results for out-of-sample forecast evaluation indicate that all the employed models remain in the MCS because they are not significantly inferior as shown in Table 4.14, implying that they are good models. The Markov switching model turns out to be the superior model because it lies within 90 percent confidence interval given that its associated MCS p-Value is equal to the apriori significance level and thus, passes both the equivalence test and elimination rules. This finding supports the results by other out-of -sample model forecast evaluation procedures, except for the Giacomini- Rossi test which depicts the TAR model to be the superior model. Generally, non-linear models appear to be superior to the competing linear model.

4.4.7 Conclusion

The major objective of this study is to investigate non-linear dynamics in Rwanda's exchange rate, using quarterly data spanning the period 2000Q1-2017Q4. We employ both sequential least squares and maximum likelihood procedure to estimate both TAR and MS-DR models to capture non-linear patterns in the real exchange rate. We also conduct both in-sample and out-of-sample forecasting and evaluate the predictive ability of the non-linear modes (TAR and MS-AR) in comparison with our baseline model (ARIMA), which is a linear model. The key findings point to the fact that the null hypothesis of linearity is rejected and we deduce that Rwanda's real exchange rate exhibits non-linear dynamics. The estimated threshold parameter for the two regime specification is 4.36 with the asymptotic confidence interval (4.34, 4.36) insinuating that the point estimate 4.36 is the level beyond which Rwanda's exchange rate becomes disruptive. In addition, the results of the autoregressive Markov switching model support the above findings, as the coefficients of the mean dependent intercepts (4.33 for state 1 and 4.42 for state 2) are broadly in line with the TAR point estimates. The MS-AR further shows that the appreciation regime dominates the depreciation regime in most of the data points.

In terms of model evaluation, the out-of-sample forecasting performance evaluation measures indicate that non-linear models have better predictive accuracy than the linear counterpart indicating statistical preference for non-linear models. TAR model proves to be the superior model for in-sample forecasting while MS-AR emerges the best model for out-of-sample forecasting.

Chapter 5.

General Conclusion

5.1 Introduction

This chapter presents the general conclusion of the thesis by summarizing the main results, contribution of the thesis, policy implications that arise out of the major findings, as well as suggestions for further research. This thesis is comprised of three related papers on the macroeconomic effects of the real exchange rate in SSA countries, an area that is not fully explored in the context of SSA. Yet the real exchange rate remains a key international price that has far reaching effects for international trade and economic growth.

At the inception, we set out to achieve three objectives that were met. These included assessing the impact of the real exchange rate on trade flows in SSA countries, examining the impact of the real exchange rate on economic growth in SSA countries, and modeling non-linear dynamics in Rwanda's exchange rate. The macroeconomic effects of the exchange rate is narrowed to trade flows , economic growth and modeling the non-linear patterns of Rwanda's exchange rate given the broad nature of the topic.

5.1.1 Contribution of the Thesis and Policy Implications

Chapter 2 assesses the trade effects of real exchange rate variations, especially focusing on the effect of the real exchange rate volatility and the real exchange rate misalignment indicators on trade flows. Thus, our research begins with the construction of these indicators, and the generated indicators are incorporated in the real exchange rate -trade nexus specification. This chapter makes an empirical contribution to the real exchange rate and trade literature by estimating the link between real exchange rate and trade flows in SSA countries. The results indicate that real exchange rate undervaluation has a positive and statistically significant effect on trade flows, indicating that real exchange rate undervaluation promotes exports, but negatively affects imports. Indeed, for developing countries real exchange rate undervaluations are considered as conducive for trade growth. For instance, (Rodrik, 2008 and Haddad and Pancaro, 2010) indicate that undervalued currencies favour domestically produced goods and incentivize the domestic tradable sector to export. Our results also show that real exchange rate volatility does not seem to influence exports, but has a positive significant effect on imports, pointing to the fact that real exchange rate misalignment depresses trade flows in SSA countries. Some empirical implications arise out of our contribution in this chapter. First, maintaining an undervalued real exchange rate through monitoring exchange rates relative to trading partners may be important. However, persistent real exchange rate misalignment may provide incentives to the recurrence to non-traditional protectionist policies. Thus, strategies to avoid trade protectionist measures including multilateral cooperation related to the stabilization of exchange rates towards their equilibrium levels should be at the fore. Second, our findings show that the real exchange rate volatility has a depressing effect on trade. Therefore, policies to avoid the problems caused by volatile exchange rates, such as putting in place financial instruments to hedge against the exchange rate risk is crucial, especially for SSA countries where these instruments are not well developed. Finally, implementing sound macroeconomic policies to provide a stable economic environment is important for trade to thrive, for instance, maintaining the real exchange rate undervaluation requires higher savings relative to investment or lower expenditure relative to income. This can be achieved through prudent fiscal policy as part of a wider macroeconomic policy package.

Chapter 3 examines the link between real exchange rate undervaluation and economic growth in SSA countries. Its key contribution lies in the fact that it exclusively focuses on SSA countries and our data set starts in 1995 to capture the impact of structural adjustment programs and the resultant economic liberalization that was experienced by most SSA Countries on the real exchange rate. Our analysis started with generating real exchange rate volatility and real exchange rate misalignment indicators. For the real exchange rate misalignment, we constructed both the misalignment based on purchasing power parity and misalignment based on the behavioral equilibrium exchange rate (BEER) model.

In the first step, we estimated BEER model using dynamic panel cointegration based estimators, particularly DOLS. The results show that RER is influenced by economic fundamentals. The estimated coefficients together with HP filter are based on to derive sustainable values of economic fundamentals by decomposing the RER into their permanent and cyclical components and compute the misalignment indicator, especially RER undervaluation indicator. The constructed RER undervaluation is thus used in baseline growth regressions, along with relevant control variables. The obtained results provide strong evidence that the RER undervaluation fosters economic growth in SSA countries. We also checked whether the impact of RER undervaluation on economic growth in SSA countries depends on the RER undervaluation measure used by also employing Balassa-Samuelson (BS) adjusted undervaluation measure and checked whether the effect is asymmetric (non-linear). We first generated the purchasing power parity adjusted real exchange rate, which was then regressed on real per capita GDP growth to test for BS hypothesis and the results indicate that the BS hypothesis holds for SSA countries. This finding is in line with Gala (2008), Rodrik (2008),Glüzmann et al.(2012) and MacDonald and Vieira (2012) given that the we find a negative and statistically significant coefficient of per capita real GDP growth. After establishing the BS hypothesis, we proceeded to construct the RER undervaluation measure to assess whether real undervaluation of the exchange rate spurs economic growth in SSA countries. The result of BS adjusted RER undervaluation indicates that the coefficient of the BS adjusted RER undervaluation measure is positive and statistically significant, suggesting a positive effect of the real exchange rate undervaluation on economic growth. This implies that both the measure based on reduced form equilibrium exchange rate model and BS effect adjusted RER undervaluation measure significantly influence economic growth in SSA, implying that these measures are not competing but rather complementary.

Finally, checking for non-linear effects of RER undervaluation on growth by using the squared term of RER undervaluation shows that the coefficient of the squared term is positive and statistically significant, pointing to no evidence of asymmetric effects and thus non-linearity, a result that corroborates those obtained by Rodrik (2008).

However, the results of a non-linear regression based panel threshold autoregressive (PTAR) model point to a significantly positive non-linear relationship between RER undervaluation and economic growth in SSA countries. These contrasting results support the view that there is no consensus in the empirical literature on the asymmetric link between RER and economic growth given that while Rodrik (2008) finds only symmetric relationship between RER undervaluation and growth, other recent studies such as Aguirre and Calderon (2005), Béreau (2012) and Couharde and Sallenave (2013) find the existence of non-linearities in the exchange rate-growth nexus. Important policy implications emerge from the obtained empirical results. Results confirm the presence of BS effect for the selected SSA countries, suggesting that there are significant differences in prices between tradable and non-tradable sectors, pointing to the fact that the non-tradable sectors are vulnerable, a phenomenon that is linked to the unskilled labour in the non-tradable sector of the SSA countries. To mitigate these disparities in prices and wages, respective governments should put in place policies that induce productivity in the non-tradable sectors of these countries, including putting emphasis on vocational education and training. Secondly, results indicate that RER undervaluation is essential for growth, pointing to the need to revisit the exchange rate as a policy instrument given that it favors growth. However, when currencies are highly undervalued, the impact on growth becomes minimal. For instance for SSA countries that have large foreign denominated liabilities such as external debts, extremely undervalued currencies impede growth, nonetheless policies that sustain the exchange rate at a competitive level determined by forces of demand and supply and limit RER volatility should be pursued as part of the broader macroeconomic stability package conducive to productivity and growth.

Chapter 4 focuses on modeling non-linear dynamics in the real exchange rate in Rwanda using regime switching models. The study is country specific and it is an area that has not been explored for the case of Rwanda. Its novelty lies in the use of model confidence set procedure to evaluate the predictive ability of competing models, a procedure that is quite new in forecast performance evaluation, particularly in the case of Rwanda, thus the conclusions of this study extend the existing stock of literature. Our empirical analysis began with the estimation of the linear model (Autoregressive Integrated Moving Average) as the benchmark model and proceeded with the estimation of the competing non-linear models. We performed both the in-sample and out-of-sample forecast evaluations of these models. The results of the ARIMA model show that the coefficient is positive and statistically significant and the AR, MA and sigma components are also positive and statistically significant, confirming that the model is well specified. The results of the TAR model show that the parameter estimates for the two regimes is 4.36, with the asymptotic confidence interval ranging between 4.34 and 4.36, pointing to the evidence of two regime specification. For the Markov Switching autoregressive model, the parameter estimates for the state dependent intercepts are 4.33 and 4.42 for state 1 and state 2, respectively. These results are consistent with the TAR estimates. The results of expected duration indicate that the appreciation regime lasts for 25.4 quarters on average and the depreciation regime lasts for 13.69 quarters, suggesting that the appreciation regime dominates its counterpart (depreciation) in most data points within our sample. Regarding the forecasting ability of models, the results indicate that in terms of in-sample forecasting the TAR model outperforms the ARIMA, which is a linear model, while TAR and MS-AR models, non-linear models, emerge the best in the out-of-sample forecasting. The empirical implication arising out of these results is that Rwanda's real exchange rate dynamics can be best characterized as non-linear and, thus, non-linear models, particularly TAR and MS-AR are the appropriate models to predict real exchange rate patterns.

5.2 Limitations and Areas for Further Research

The major limitation of this study relates to lack of all the required data, leading to a narrow cross-sectional dimension of the data set that we used to estimate the panel regression models specified in chapters 2 and 3. The estimated effect of RER undervaluation and RER volatility on trade and economic growth could have been more robust had we included a wider range of low and middle income SSA countries.

Further research could capitalize on this limitation by expanding the data set by not only increasing the number of countries, but also disagregating SSA countries by their income levels. Future research should also examine the growth effects of exchange rate regimes in SSA countries, given that some countries have allowed their exchange rates to float, while other, especially those that belong to currency boards, have their currencies pegged to major international currencies.

Firm level export and import data are yet to be explored for the case of SSA, therefore assessing the effect of RER changes on trade in the context of firm heterogeneity by particularly exploring intensive and extensive margin channels could be another important venue for future research. This could be examined, subject to data availability in order to draw robust conclusions on the role of exchange rate variability on trade flows in SSA countries. In addition, characterizing exchange rate volatility by checking whether there is presence of structural breaks, especially those pertaining to foreign exchange market reforms such as changes in the foreign exchange transactions, could be an important area for further research.

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Appendices to Chapter Two

Appendix A

Table A1:Definition of variables and sources

Variable	**Description**	**source**
Real exchange rate	Constructed as $Reer = \sum_{t=1}^{k}(Neer_{it}) \times \frac{p_{it^{\star}}}{p_{it}}$	Bruegel Reer database (Darvas, 2012a)
Terms of trade (TOT)	The ratio of the export price index to the import price index	WDI
openness	Constructed as the sum of total value of exports and total imports relative to GDP, $Open_{it} = \frac{X_{it}+M_{it}}{y_{it}}$	WDI
Productivity	proxied by percapita GDP	WEO
Government expenditure	GDP share of total government expenditure at current prices (in USD)	WEO
Nfa	The ratio of net foreign assets relative to GDP at current prices (in USD)	WDI
Fdi	Foreign direct investment net inflows as a percentage of GDP	WIR and WDI
Ex	Total value of goods exported, free on board value (in USD)	WDI
Im	Total value of goods imported, cost freight insurance value (in USD)	WDI
Wgdp	World gross domestic product , current prices (USD)	WEO
Gdp	Gross domestic product, current prices (in USD)	WEO
Exchvol	exchange rate volatility indicator , which is the conditional variance based on a GARCH specification, $\sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_i \epsilon_{t-1}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2$	Author's computation using stata 15

Reerhp	exchange rate misalignment indicator given $Mis_{it} = reer_{it} - ereer_{it}$	Author's computation using stata 15

Table A2: Ilzetzki, Reinhart and Rogoff (2019) Classification of ERR

Codes	**Fine classifications**
1.	No separate legal tender or currency union
2.	Pre announced peg or currency board arrangement
3.	Pre announced horizontal band that is narrower than or equal to +/-2%
4.	De facto peg
5.	Pre announced crawling peg; de facto moving band narrower than or equal to +/-1%
6.	Pre announced crawling band that is narrower than or equal to +/-2% or de facto horizontal band that is narrower than or equal to +/-2%
7.	De facto crawling peg
8.	De facto crawling band that is narrower than or equal to +/-2%
9.	Pre announced crawling band that is wider than or equal to +/-2%
10.	De facto crawling band that is narrower than or equal to +/-5%
11.	Moving band that is narrower than or equal to +/-2% (i.e., allows for both appreciation and depreciation over time)
12.	De facto moving band +/-5%/ Managed floating
13.	Freely floating
14.	Freely falling
15.	Dual market in which parallel market data is missing.

Table A3: Results of BEER estimation

Dependent variable: Real exchange rate (lreer)				
Variables	**OLS (1)**	**FE (2)**	**Diff-GMM (3)**	**Sys-GMM (4)**
Llreer	0.824***	0.678***	0.531***	0.646***
	(0.031)	(0.047)	(4.100)	(5.945)
lgov_gdp	-0.025	0.035	0.074	-0.111***
	(0.017)	(0.043)	(1.016)	(-2.872)
lopen	0.013	0.005	-0.153*	-0.022
	(0.015)	(0.028)	(-1.899)	(-0.359)
ltot	-0.005	-0.027	0.090	-0.034
	(0.025)	(0.017)	(1.500)	(-0.567)
lrgdppc	0.012	0.232***	0.359***	0.111*
	(0.009)	(0.059)	(4.292)	(1.958)
nfa_gdp	-0.104	-0.171***	-0.208***	-0.198***
	(0.065)	(0.031)	(-4.978)	(-5.091)
obs	503	503	480	503
R-squared	0.76	0.76		
Instruments			45	52
AR(1)			0.005	0.002
AR(2)			0.119	0.109
Sargan test			0.000	0.000

Notes: *** p<0.01, ** p<0.05, *p<0.1 . denote statistical significance level at 1, 5 and 10 percent. Robust standard errors are reported in parentheses. We report p-values for "AR(1)" and "AR(2)" and "Hansen test".

Source:Author's computation using Stata

Figure A1: Estimated lreer misalignment

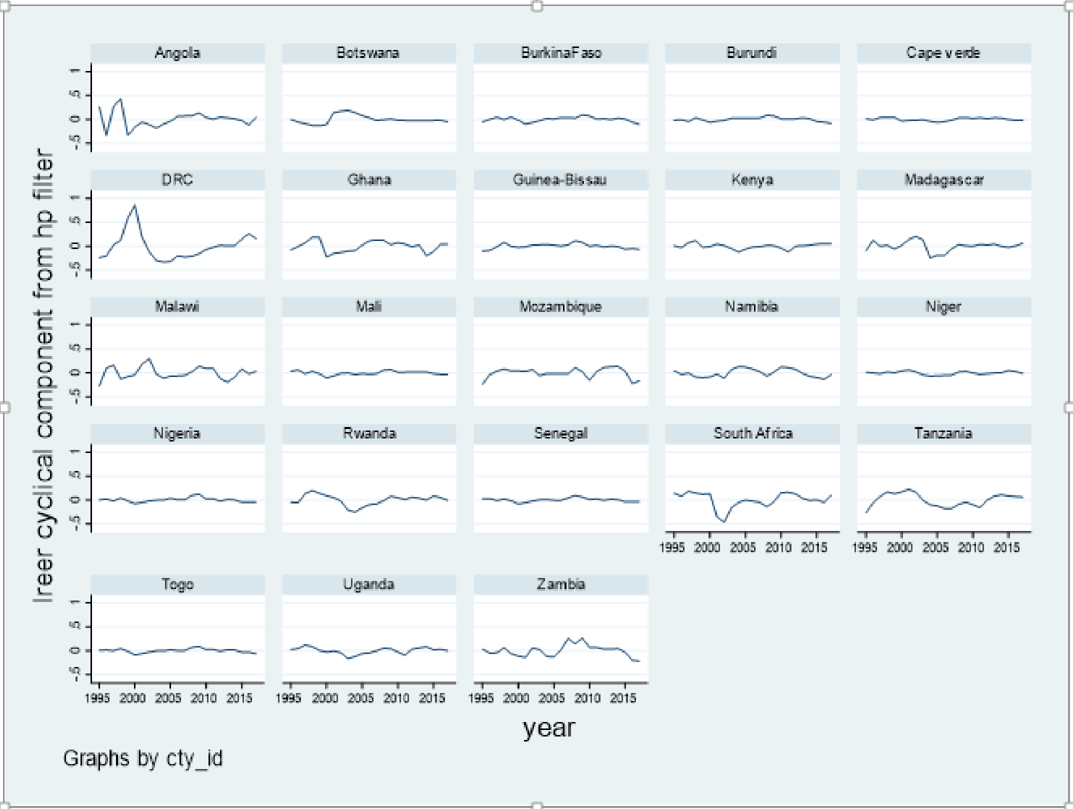


Table A4 : Excluding Outlier Countries: Angola

Variables	**Exports**			**Imports**		
	OLS (1)	FE (2)	BC-LSDV (3)	OLS (4)	FE (5)	BC-LSDV (6)
L.lexp	0.976***	0.586***	0.614***			
	(0.008)	(0.048)	(20.728)			
L.lim				0.522***	0.215***	0.226***
				(0.048)	(0.038)	(10.900)
Underval	0.008	0.029*	0.029*	-0.127	-0.92	-0.093**
	(0.022)	(0.016)	(1.702)	(0.085)	(0.062)	(-2.100)
Vol	-0.002	-0.000	-0.000	0.004	0.003	0.003*
	(0.003)	(0.002)	(-0.108)	(0.003)	(0.002)	(1.753)
Lopen	0.092***	0.546***	0.536***	0.504***	0.880***	0.872***
	(0.028)	(0.071)	(12.316)	(0.054)	(0.056)	(38.532)
Ltot	0.058**	0.046	0.040	0.036	-0.063	-0.062***
	(0.033)	(0.066)	(1.202)	(0.041)	(0.041)	(-3.579)
Lwgdp	-0.053	0.206**	0.168***			
	(0.040)	(0.078)	(2.948)			
Lrgdp				0.443***	0.721***	0.707***
				(0.046)	(0.053)	(23.013)
Fdi	0.000**	0.000	0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(-0.101)
Obs	484	484	484	484	484	484
R-squared	0.98	0.95		0.99	0.98	
AR(1)			0.0000			0.0000
AR(2)			0.9077			0.6545

*** p<0.01, ** p<0.05, *p<0.1. Dependent variables are logs of exports and imports. For BC-LSDV, bias-corrected version of estimates are reported. Bias is initialized by Arellano-Bond (1991) estimator and bootstrapped standard errors using 50 iterations. P-values for ”AR(1)” and ”AR (2)” are reported. we exclude Angola.

Source:Author’s computation using Stata 15

Table A5 : Excluding Outlier Countries: Nigeria

Variables	**Exports**			**Imports**		
	OLS	FE	BC-LSDV	OLS	FE	BC-LSDV
	(1)	(2)	(3)	(4)	(5)	(6)
L.lexp	0.977***	0.591***	0.617***			
	(0.008)	(0.045)	(26.026)			
L.lim				0.582***	0.215***	0.225***
				(0.070)	(0.039)	(11.344)
Underval	0.011	0.030*	0.030*	-0.131	-0.085	-0.087**
	(0.022)	(0.016)	(1.948)	(0.090)	(0.056)	(-2.347)
Vol	-0.002	-0.000	-0.000	0.003	0.002	0.002
	(0.003)	(0.002)	(-0.145)	(0.002)	(0.002)	(1.298)
Lopen	0.101***	0.546***	0.536***	0.412***	0.884***	0.876***
	(0.033)	(0.073)	(10.219)	(0.071)	(0.055)	(34.115)
Ltot	0.065*	0.043	0.036	0.012	-0.063	-0.087***
	(0.033)	(0.067)	(0.900)	(0.039)	(0.056)	(-4.287)
Lwgdp	-0.057	0.204**	0.167***			
	(0.043)	(0.082)	(3.436)			
Lrgdp				0.376***	0.703***	0.689***
				(0.072)	(0.055)	(21.311)
Fdi	0.000	-0.000	-0.000	0.000**	0.000	0.000*
	(0.000)	(0.000)	(-0.465)	(0.000)	(0.000)	(1.678)
Obs	484	484	484	484	484	484
R-squared	0.98	0.95		0.99	0.98	
AR(1)			0.0000			0.0000
AR(2)			0.9077			0.5498

*** p<0.01, ** p<0.05, *p<0.1. Dependent variables are logs of exports and imports. For BC-LSDV, bias-corrected version of estimates are reported. Bias is initialized by Arellano-Bond (1991) estimator and bootstrapped standard errors using 50 iterations. P-values for "AR(1)" and "AR (2)" are reported. We exclude Nigeria

Source:Author's computation using Stata 15

Table A6: Excluding Outlier Countries: South Africa

Variables	Exports			Imports		
	OLS	FE	BC-LSDV	OLS	FE	BC-LSDV
	(1)	(2)	(3)	(4)	(5)	(6)
L.lexp	0.978***	0.568***	0.593***			
	(0.008)	(0.045)	(26.026)			
L.lim				0.585***	0.232***	0.244***
				(0.061)	(0.035)	(11.244)
Underval	0.009	0.032*	0.031**	-0.145	-0.108*	-0.10***
	(0.022)	(0.017)	(2.135)	(0.096)	(0.060)	(-2.852)
Vol	-0.004	-0.001	-0.000	0.003	0.003	0.003**
	(0.004)	(0.003)	(-0.417)	(0.002)	(0.002)	(2.041)
Lopen	0.097***	0.566***	0.556***	0.428***	0.851***	0.843***
	(0.028)	(0.074)	(10.772)	(0.068)	(0.053)	(32.177)
Ltot	0.075**	0.068	0.060	0.015	-0.092*	-0.091***
	(0.033)	(0.070)	(1.622)	(0.039)	(0.051)	(-4.456)
Lwgdp	-0.066	0.224**	0.189***			
	(0.044)	(0.084)	(3.505)			
Lrgdp				0.361***	0.707***	0.691***
				(0.056)	(0.053)	(18.839)
Fdi	0.000	-0.000	-0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(-0.401)	(0.000)	(0.000)	(1.622)
Obs	484	484	484	484	484	484
R-squared	0.98	0.95		0.98	0.98	
AR(1)			0.0000			0.0000
AR(2)			0.9070			0.3190

*** p<0.01, ** p<0.05, *p<0.1. Dependent variables are logs of exports and imports. For BC-LSDV, bias-corrected version of estimates are reported. Bias is initialized by Arellano-Bond (1991) estimator and bootstrapped standard errors using 50 iterations. P-values for "AR(1)" and "AR (2)" are reported. We exclude South Africa

Source:Author's computation using Stata 15

Appendices to Chapter Three

Appendix B

Table B1:Definition of variables and sources

Variable	Description	source
Real exchange rate	Constructed as $Reer = \sum_{t=1}^{k}(Neer_{it}) \times \frac{p_{it\star}}{p_{it}}$	Bruegel Reer database (Darvas, 2012a)
Terms of trade (TOT)	The ratio of the export price index to the import price index	WDI
openness	Constructed as the sum of total value of exports and total imports relative to GDP, $Open_{it} = \frac{X_{it}+M_{it}}{y_{it}}$	WDI
Productivity	proxied by real per capita GDP	WEO
Government expenditure	GDP share of total government expenditure at current prices (in USD)	WEO
Nfa	The ratio of net foreign assets relative to GDP at current prices (in USD)	WDI
Rgdppc	Real GDP per capita growth, $lrgdppc\_gr = lrgdppc - lrgdppc[\_n-1]/(lrgdppc[\_n-1]*(year - year[\_n-1]))$.	WDI
Investment	Investment to GDP share	WDI
Inflation	Average change in consumer price index, computed as $Inf = (\frac{CPI_{it}-CPI_{it-1}}{CPI_{it-1}}) \times 100$	WEO
population	population ,in Millions	WEO
Gdp	Gross domestic product, current prices (in USD)	WEO
Exchvol	exchange rate volatility indicator , which is the conditional variance based on a GARCH specification, $\sigma_t^2 = \omega + \sum_{i=1}^{p}\alpha_i\epsilon_{t-1}^2 + \sum_{j=1}^{q}\beta_j\sigma_{t-j}^2$	Author's computation using stata 15
Reerhp	exchange rate misalignment indicator given $Mis_{it} = reer_{it} - ereer_{it}$	Author's computation using stata 15

Table B2: Cross-Sectional Dependence Tests

Tests	Variables					
	lreer	lrgdppc	ltot	lopen	lgov_gdp	nfa_gdp
Lm	995.7***	2126***	1337***	2997***	703.3***	1236***
Lm adj*	83.05***	213.6***	122.5****	314.4***	49.26***	110.8***
Lm CD*	8.22***	41.21***	15***	53.14***	-0.51	19.4***
Pesaran CD	6.34***	61.80***	16.92***	66.8***	10.05***	35.44***

Notes: Null hypothesis: No cross-section dependence. *** p<0.01, ** p<0.05, *p<0.1 denote statistical significance level at 1, 5 and 10 percent respectively. LM is Breusch-Pagan (1980) based lagrange multiplier test, LM CD* is the Pesaran (2004) scaled lagrange multiplier test, LM adj* is the bias-corrected scaled lagrange multiplier test by Baltagi et al. (2012), and Pesaran CD is the cross-section dependence lagrange multiplier test by Pesaran (2007).

Source:Author's computation using Stata 15

Table B3: Slope Homogeneity Test

Ho: Slope coefficients are homogeneous		
Test	**D statistic**	**P-value**
D test	15.5***	0.000
D adj test	18.59***	0.000

Notes: *** p<0.01, ** p<0.05, *p<0.1 denote the significance level at 1, 5 and 10 percent.

Source:Author's computation using Stata 15

Table B4: Results of Cross-sectionally ADF Test

		Level		
Variables	**CADF***	**Critical Values**		
		1%	5%	10%
lreer	2.33	4 2.58	4 2.66	4 2.81
lrgdppc	2.94***	4 2.58	42.66	4 2.81
ltot	2.47	42.58	42.66	42.81
lopen	3.18***	4 2.58	42.66	4 2.81
lgov_gdp	2.38	42.58	42.66	4 2.81
nfa_gdp	2.07	4 2.58	4 2.66	42.81
		First Difference		
lreer	4.42***	4 2.58	4 2.66	42.81
ltot	4.29***	4 2.58	42.66	42.81
lgov_gdp	4.71***	42.58	42.66	42.81
nfa_gdp	4.12***	4 2.58	4 2.66	42.81

Notes: *** p<0.01, ** p<0.05, *p<0.1 represent statistical significance level at 1,5, and 10 percent. CADF* is the cross- sectionally augmented Dickey-Fuller test statistic.

Source:Author's computation using Stata 15

Table B5: Results of Panel Cointegration Tests

Cointegration test	Test statistic	P-value
Kao test		
H_0: No cointegration-H_1: all panel are cointegrated		
Modified Dickey-Fuller	-1.61**	0.054
Dickey-Fuller	-2.82***	0.0024
Augmented Dickey-Fuller	-2.32***	0.0103
unadjusted modified Dickey-fuller	-3.50***	0.0002
unadjusted Dickey-Fuller	-3.79***	0.0001
Pedroni test		
H_0: No cointegration- H_1 : all panel are cointegrated		
Modified Phillips-Perron	5.06***	0.0000
Phillips-Perron	-2.19***	0.0142
Augmented Dickey-Fuller	-3.42***	0.0003
Westerlund test		
H_0: No cointegration-H_1: some panels are cointegrated		
Variance ratio	1.45*	0.07

Notes: *** p<0.01, ** p<0.05, *p<0.1 represent the statistical significant level at 1,5 and 10 percent respectively. H_0 and H_1 are null and alternative hypotheses respectively.

Source:Author's computation using Stata 15

Table B6 : Panel TAR Model

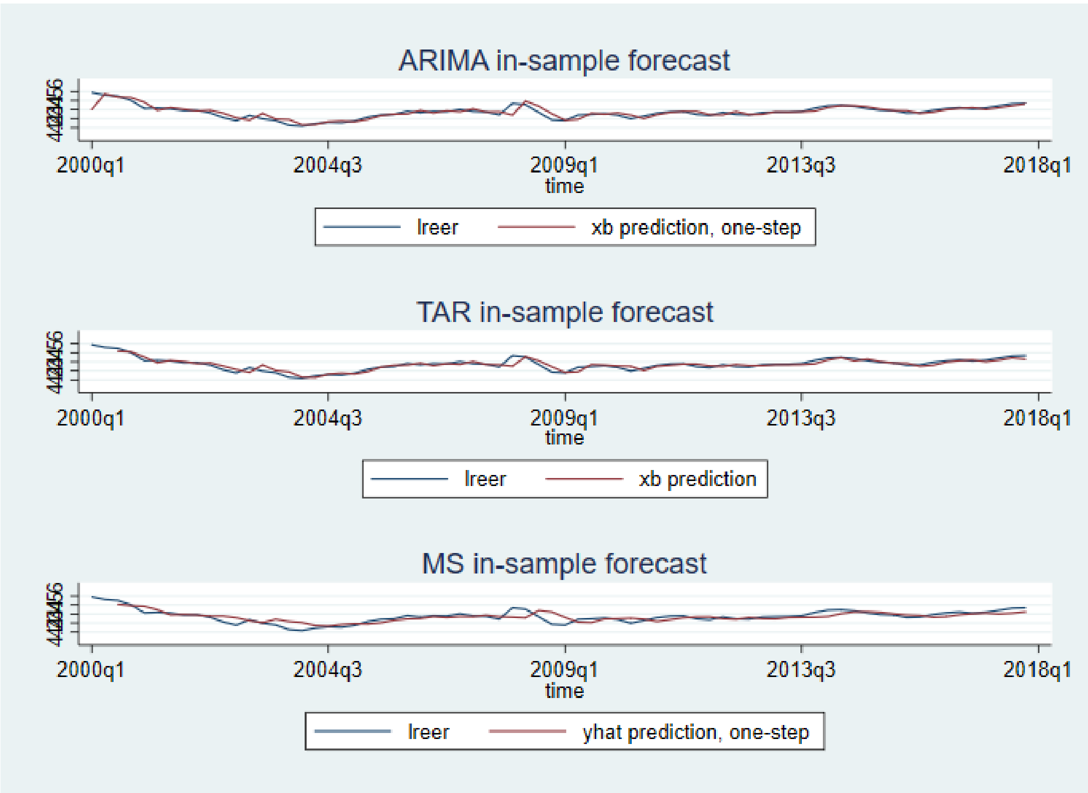
Threshold Variable: Exchange Rate Underval			
Variable	Coeff	T-Statistic	P-value
exchvol	.0081**	2.22	0.027
underval	0.828***	5.88	0.000
lgov_gdp	-0.617***	-14.45	0.000
lopen	0.597***	15.82	0.000
ltot	0.161***	3.91	0.000
pop	0 .868***	11.19	0.000
linv_gdp	.0545*	1.75	0.081
infl	-0.00009**	-2.22	0.027
Threshold	Lower	Upper	
0.0588	0.0586	0.0609	

Source:Author's computation using Stata 15

Appendices to Chapter Four

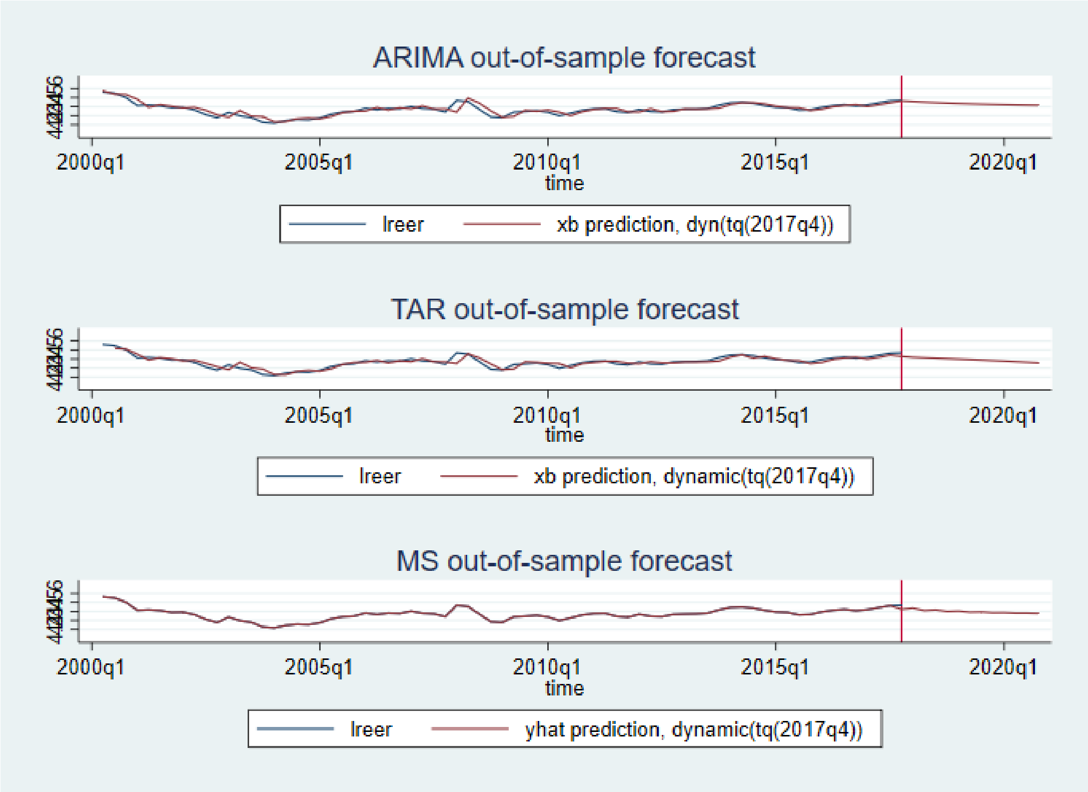
Appendix C

Figure C1: In-sample forecasting



Source: Author's Computation

Figure C2: out-of-sample forecasting



Source: Author's Computation