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Abstract

In an open economy, the real exchange rate plays a crucial role in the transmission of external shocks to the real economy and in the propagation of monetary policy actions. The main purpose of this paper was therefore to estimate the equilibrium real exchange rate, determine the level of real exchange rate misalignment and assess its implications on the monetary policy implementation in Rwanda. The study used quarterly data covering the period 2006Q1-2021Q4 and behavioral equilibrium exchange rate (BEER) models. The models were estimated using cointegration-based estimators, particularly dynamic ordinary least squares (DOLS). The study revealed two important results. First, the results indicated that REER is influenced by economic fundamentals and alternating episodes of undervaluation and overvaluation were identified. Considering the most recent episode, the results showed that Rwanda's currency in real effective terms was undervalued by 2.3 percent in 2021 and an overvaluation of 3.4 percent in 2020, a level that is not too high to induce a negative effect on macroeconomic stability. Second, the study found that REER misalignment may not have important implications on monetary policy implementation. Nevertheless, the study recommends that the monetary authorities should continuously monitor the extent and evolution of exchange rate misalignment due to its potential impact on macroeconomic stability.

Key words: Exchange Rate Misalignment, Monetary Policy, Dynamic Ordinary Least squares.
JEL classification: F41, E52, C22

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I. Introduction

The stability of exchange rate is important in a country's monetary policy mechanism. (Edwards, 2018) suggested that central banks need to know whether the real exchange rate (RER) is (approximately) close to its long-term equilibrium value to make efficient monetary policy decisions. Significant and persistent real exchange rates misalignments, i.e. deviation of actual RER from its benchmark or equilibrium level, have implications on the country's potential economy, hence, increases its vulnerability (Jongwanich, 2009). For instance, an RER overvaluation may cause a decrease in economic growth, put pressures on exporter industries, particularly manufactures, which reduce export volumes and encourage imports and constrain export diversification, foster currency crises and political instability and conflict (Ambaw, et al., 2023). Therefore, policy makers and markets need to have knowledge on these currency misalignments, overvaluation or undervaluation, and what policy actions are in place to address these volatilities (Borowski & Couharde, 2003).

This paper deals with the relationship between exchange rates and monetary policy in Rwanda. The main purpose of this paper is to estimate the equilibrium real exchange rate, determine the level of real exchange rate misalignment, if any, and assess its implications on monetary policy implementation in Rwanda. The number of studies that examined this topic in Rwanda remains limited and have focused on measuring the level of exchange rate misalignments without attempting to relate it to monetary policy implementation while other have focused on exchange rate pass through to inflation in Rwanda.

For instance, Hitayezu & Nyalihama, (2019) examined the real exchange rate pass through to domestic prices in Rwanda while Nuwagira and Kigabo, (2014) estimated the exchange rate misalignment using quarterly data from 2000Q1 to 2012Q1 and derived a long-run Behavioral Equilibrium Exchange Rate (BEER). Similarly, Nuwagira and Muvunyi, (2016), using quarterly data spanning the period 2000Q1 to 2015Q4, analyzed the impact of the real exchange rate on the Rwandan external competitiveness, using the BEER method to determine the level of the exchange rate misalignment and tested the Marshall-Lerner condition. Both studies found evidence of exchange rates misalignments. This paper revisits the analysis but using the most recent data in order to inform policy makers and researchers on the extent of exchange rate misalignments in the light of the latest global multiple shocks that had implication on currencies of many countries including Rwanda.

This study used the reduced form equilibrium exchange rate approach, particularly the behavioral equilibrium exchange rate (BEER) model to estimate the real exchange rate misalignment, (MacDonald, 1997; Clark and MacDonald, 1998). The results from the study are as follows. First, we run a reduced-form model in which a long-run or cointegrating relationship between RERs and a set of key macroeconomic fundamentals was estimated. The results from the model indicate a

significant relationship between the RERs and the selected variables, implying that the real exchange rate is in line with economic fundamentals. Second, the reduce-form model allowed us to derive RER and REER equilibrium values, as well as to compute the corresponding level of misalignments. Our study found evidence of REER misalignments- altering episodes of overvaluation and undervaluation. However, the level of misalignment is not prolonged and is not very high to induce a negative effect on macroeconomic stability.

The structure of the rest of paper is as follows. Section 2 describes the exchange rate transmission mechanism while section 3 provides the literature review. Section 4 describes the empirical model and discusses variable measurement. Section 5 provides discussion of estimation results of equilibrium RER and RER misalignments while section 6 concludes the study.

II. Monetary Policy and Exchange Rate

Rwanda operates under a flexible exchange rate and inflation targeting monetary policy framework where the transmission of monetary policy is expected to impact the economy through various channels including interest rates and the exchange rate. Under this framework, the central bank of a country alters its policy rate with the expectations that the move will be transmitted along the yield curve, and affect the long-term interests, which ultimately impact consumption decisions by households and firms' investment decisions (Edwards, 2018). However, in recent times some studies have shown concerns that monetary policy in some countries has lost power and effectiveness as evidenced by less responsiveness of long-term interests to changes in central banks' policy rates.

These studies suggest that this weak transmission mechanism is due to the global financial markets interconnectedness, where interest rates are determined by the global interaction between savings and investment and not the decision of the local monetary policy, (Edwards, 2018; Guinigundo, 2005). The significance of exchange rate transmission mechanism may also depend on the share of domestic value added, compared with imported goods and services, in tradables. If this share is very high, changes in exchange rate have high effect on output and inflation (Mohanty & Turner, 2005). The traditional interest rate transmission mechanism may therefore be even much weaker since in such small open economies, output and inflation are sensitive to changes in the exchange rate. Consequently, the major transmission mechanism might be the exchange rate rather than the yield curve, (Edwards, 2018; Mohanty & Turner; Chow, 2005).

The exchange rate transmission mechanism suggests that an increase in a central bank policy rate appreciates the local currency through the which in turn yields downward pressures through the law of one price for tradable goods, making imported goods and services relatively cheap, resulting into a decrease in inflationary pressures in the domestic economy. On the other hand, a currency depreciation will generate upward pressures as imports become more expensive and less

competitive against goods produced by domestic producers. Therefore, if monetary policy is evidenced to be transmitted through exchange rate changes, central banks worldwide will need to take into account the exchange rate when formulating their monetary policy. Particularly, central banks should be concerned whether the real exchange rate is close to equilibrium, or if it is misaligned. (Edwards, 2018) argues that if a country currency is misaligned, monetary policy actions triggered by inflation considerations may exacerbate this disequilibrium. In light of this view, understanding the extent of exchange rate in Rwanda is crucial for policy makers.

III. Literature Review

Several empirical studies have been undertaken to estimate the long-run equilibrium and the associated RER misalignment. These studies have mostly followed techniques related to reduced form real exchange rate equilibrium (ERER) models such as fundamental equilibrium exchange rate (FEER) and Behavioral equilibrium exchange rate (BEER). Some have used single equation approach, while others employed the cross-section and panel frameworks.

Chin & Prasad, (2003) employed the macroeconomic balance (MB) approach to determine the factors that directly and indirectly affect the current account fluctuations. They used cross-section and panel data models of 18 industrial and 71 developing countries, and the results show that the current account deficit is positively related to fiscal balance and international investment position deficit. The results showed a positive relationship between foreign financial flows and current account deficit for developing countries dependent on these inflows. On the other hand, the countries' level of openness tends to negatively affect the current account balance.

Borowski & Couharde, (2003) examined the macroeconomic balances between major countries vis-à-vis their exchanges rate to establish the extent of fluctuations in the medium term since large fluctuations can cause world macroeconomic instability. The study applied the fundamental equilibrium exchange rate approach, using 1995 as the baseline, with the medium-projection up to 2000 to establish equilibrium exchange rate in selected industrial countries, and the results showed, that adjustment of the Dollars, Yen and Euro is aligned with the fundamentals.

As articulated in previous studies, a country's exchange rate should remain competitive to continue supporting its exports and ultimately its growth while ensuring that it remains consistent with macroeconomic objectives in the medium term (Williamson, 2008). In light of this view, in a given country there exists an equilibrium real exchange rate (ERER) that satisfies its macroeconomic balance. Hence, any deviation of the RER from its equilibrium hampers internal balance and sustainability of the external balance (Rodrik, 2008).

Other studies, however, have provided theoretical and empirical evidence indicating that, not all deviations from the ERER could negatively affect growth and exports. Indeed, (Rodrik, 2008)

showed that while RER overvaluation harms growth and current account balance, the RER undervaluation improves these variables, mostly in developing countries. Notably, Nouira et al., (2011) found evidence supporting the view of (Rodrik, 2008) and based on a sample of 52 developing countries and the REER model, the authors showed that such countries deliberately choose the policy of keeping their exchange rate undervalued in order to strengthen the price competitiveness in their manufacturing exports sector.

Zhang, (2002) estimated the behavioural equilibrium exchange rate (BEER) in Hong Kong and China for the period 1984-1988 and included four economic fundamentals, namely terms of trade (TOT), net exports/GDP, private investment and trade openness in their specification. They found that RER was overvalued during the period 1983Q3-1985Q2, and in 1984Q1, at around 20 percent. After the second half of 1985, the currency tended to adjust back towards the equilibrium. Leung & Ng, (2007) also estimated the equilibrium RER for Hong Kong and China, covering the period 1987-2006. Using key economic fundamentals such as productivity, terms of trade, and government consumption as share of GDP, they found a modest undervaluation of the real exchange rate in the late 1990s.

Frankel, (2005) employed fundamental equilibrium exchange rate (FEER) approach to compute the equilibrium exchange rate and the exchange rate misalignment in China and found that in 2000, the RER was undervalued by 35 percent. Cheng and Orden, (2005) used the BEER framework to estimate RER misalignment in India during the period 1975-2002. The RER was overvalued during the 1980-1990 and in 1990 and the overvaluation was more than 10 percent, however, in the aftermath of 1991 crisis, the RER adjusted towards the equilibrium.

Bénassy-Quéré, et al., (2008) used panel data methodology to estimate the misalignments of bilateral and multilateral real effective exchange rates of G20 currencies. The results showed that the currencies of five Asian countries were overly undervalued at the beginning of 2006. These results also indicated that lack of exchange rate adjustment in Asian countries amplified this impact. In addition, the bilateral misalignments between the United States and the other countries depend mainly on misalignments of the exchange rate of all countries.

Baffers, et al., (1999) estimated the RER and the degree of misalignment of countries such as Cote d'Ivoire and Burkina Faso using the single-equation model consistent with previous work, (Edwards, 1989; Devarajan, et al., 1993; Elbadawi & Soto, 1994). The study adopted a three-pronged methodology. An estimate of the long-term relationship, an estimation of the model parameters and the computation of degree of misalignment and concluded that devaluing the currency depends on the fundamentals and that the degree of misalignment of the RER and the speed of the internal and external adjustment mechanisms seem to restore the macroeconomic balance.

Lossifov & Loukoianova, (2007) examined the factors that influence the equilibrium exchange rate in Ghana. They followed a vector error correction model (VECM). The results indicated that the long-term variations in the real exchange rate are explained by the real GDP growth rate, the interest rate differential as well as the world prices of the exported raw materials. These results also showed that when the RER deviates from its equilibrium trajectory, it reverts back to it after 2 and 3 years.

Couharde, et al., (2011) estimated the currency misalignment of the CFA zone countries and assessed how their real effective exchange rates converged to their equilibrium level between 1985 and 2007. To attain this, they estimated the long-run relationship between actual effective exchange rates and their economic fundamentals through panel cointegration techniques, particularly, the ordinary dynamic-least-squares based on previous studies (Kao & Chiang; Mark & Sul, 2003). The results from their study found that the real appreciation of CFA zone countries in 2000s didn't translate into a real overvaluation, with exceptions of some countries. They also found that the adjustment of the REER towards the equilibrium levels differ among the CAF zone countries.

With regard to country specific studies, Nuwagira and Muvunyi, (2016) studied the impact of the real exchange rate on the Rwandan external competitiveness, using the Behavioral Equilibrium Exchange Rate (BEER) method to determine the level of the exchange rate misalignment and the Marshall-Lerner condition. The long-run BEER drew a relationship between the REER with the economic fundamentals highlighting some of the factors that influence RER under-valuation. These factors include the increase in government expenditure and the decrease of terms of trade while other factors, mainly the increase in foreign financial inflows and the supply side of output explain RER over-valuation. In addition, the study found that the Marshall-Lerner condition for Rwanda does not hold given that the improvement in trade balance relies so much on foreign demand than exchange rate depreciation.

In addition, Nuwagira & Kigabo, (2014) examined the RER misalignment using quarterly data spanning the period 2000Q1 to 2012Q4 using the BEER approach. Their results indicate the existence of episodes of overvaluation and undervaluation with the level of misalignment ranging between 0.04% and 2.3%. Therefore, the issue could have become more important in recent years as many economies' vulnerabilities rose due to the coronavirus pandemic and prolonged low international commodity prices, which weighed on the external sector performance.

Muvunyi, et al., (2019) used the external sustainability approach to evaluate the Rwandan current account deficit vulnerability to the level of net foreign assets, on a sample covering up to 2017 (the benchmark), and considering 2018 – 2021 as medium-term projections. The results showed that the current account gap at the benchmark was higher, but it would go lower based on the medium-term projections, suggesting a small RER adjustment in order to close the gap.

IV. Methodology

4.1 Theoretical Models

This subsection presents the key theoretical approaches in determining the equilibrium exchange rate and its misalignment. The equilibrium real exchange rate is based on three major theories, namely the purchasing power parity (PPP), the uncovered interest rate parity (UIP) and the reduced form equilibrium real exchange rate, (Jongwanich, 2009).

4.1.1 Purchasing Power Parity Model

The first theoretical approach is premised on the purchasing power parity, which conjectures that exchange rate variation between two currencies over a given period of time is influenced by the change in the two countries' relative price levels. The application of the PPP involves 2 steps: i) a RER index of the base year also referred to as equilibrium year and subsequent years is calculated and then ii) a comparison is made between the RER of the current period and that of the base period or equilibrium year. If the two RER deviate, then the currency is said to be misaligned. Under this approach, when the cost of a basket of goods in a common currency is equalized across countries and the same basket enters each country's market with the weights, then the equilibrium RER is determined as:

$RER^* = e * \frac{p^*}{p} = 1$ ..... (1), where RER^* is equilibrium RER, e is the nominal exchange rate, p^* is the price, and p is the domestic price. The equation specified in (1) is known as the absolute PPP, which relies on the assumption of the law of one price. However, the law of one price is challenged on several grounds. Firstly, the spot price of a given good will not necessarily be equal in different locations given the time it takes to move commodities from one location to another. The basket of commodities across countries tend to be different and the price measures are not likely to be constructed in terms of absolute prices, these shortcomings led to the introduction of relative PPP, given by:

$RER^* = e * \frac{p^*}{p} = \theta$ ..... (2), where θ is a constant, reflecting the barriers to trade and the differences in basket compositions.

While both the absolute and relative measures suggest that equilibrium RER is constant over time, a host of empirical studies dispute the validity of these theories. On the empirical front, the mean reversion to PPP is not observed in data. Theoretically, the critique of PPP emerge from two major causes. Firstly, the increased importance of manufactured tradable goods, which are differentiated has led to finite elasticities of demand under imperfect competition. In addition, transport costs,

trade restrictions and taxes may alter the price of tradable goods across countries. Secondly, differences in production, consumer tastes and preferences and factor endowments across countries dispels the law of one price, suggested by the PPP theory. The deficiency of the PPP approach has led to the emergence of theoretical alternative approaches to assessing factors influencing movements in equilibrium RER including uncovered interest rate parity and equilibrium exchange rate models.

4.1.2 Uncovered Interest Rate Parity

The second strand of theoretical model to the determination of equilibrium real exchange rate is the uncovered interest parity (UIP), which suggests that the difference in interest rates between two countries equals the relative change in exchange rates over the same period to equilibrate international financial market. The UIP also involves 2 steps: i) a reduced form for the real exchange rate with economic "fundamentals" is derived and estimated and ii) then the estimated coefficients together with the economic fundamentals is used in calculating the equilibrium RER. The UIP condition is given by:

$\mathrm{E}_t\left(e_{t+1}\right)-e_t=i_t-i_i^*$ ..... (3), where $\mathrm{E}_t\left(e_{t+1}\right)$ denotes the nominal value of exchange rate in period t for t+1, i and i^* are domestic and foreign nominal interest rates, respectively.

To convert nominal interest rate to real interest parity, we subtract the expected inflation differential on both sides of equation 3 and obtain:

$E_t\left(rer_{t+1}\right)-\left(rer_t\right)=r_t-r_t^*$ ..... (4)

By rearranging equation (4), the observed exchange rate is represented as a function of the expected value of real exchange rate $E_t\left(rer_{t+1}\right)$ and the current real interest rate differential $rer_t=E_t\left(rer_{t+1}\right)=(r_t-r_t^*)$. Following Clark & MacDonald, (1998), the unobservable expectations of the real exchange rate $E_t\left(rer_{t+1}\right)$ is influenced by a vector of economic fundamentals. These include terms of trade, productivity differential (PROD), net foreign assets (NFA), and government expenditure, thus the equilibrium real exchange rate is expressed as a function of economic fundamentals and the interest rate differential

$erer=f\left(tot,prod,nfa,gov,r-r^*\right)$ ..... (5)

4.1.3 Equilibrium Exchange Rate Model

The third strand of theoretical approach to the determination of RER is based on the notion of equilibrium, particularly the consistence in internal and external balance over the medium to long

term, a phenomenon known in literature as fundamental equilibrium exchange rate (FEER) proposed by (Williamson, 1994). The internal balance is attained when the economy is operating at fully capacity/employment, with low inflationary pressures. The external balance is characterized as sustainable balance of payments position over the medium term. It calculates the difference between the actual current account and the balance that would stabilize the net foreign assets. This approach involves estimating a sustainable current account balance and then computing the level of RER that is consistent with that particular current account deficit.

The determination of FEER model builds on the current account position (CA) as a function of rer^* as well as domestic and foreign output at full employment $\left(y^{d*}, y^{f*}\right)$. The CA is then equal to the level of equilibrium capital account over the medium term $\left(CAP^*\right)$. This equation can be expressed as depicted in equation (6)

$CA = f(rer^*, yd*, y^{f*}) = CAP^*$ ……………………………………….. (6).

Given the level of domestic and foreign output at full employment $\left(y^{d*}, y^{f*}\right)$ and the equilibrium capital account $\left(CAP^*\right)$, then the fundamental RER is derived as follows:

$rer^* = f\left(CAP^*, yd*, y^{f*}\right)$ ………………………………… (7)

However**,** this approach is influenced by normative assumptions about the notion of ideal economic conditions of internal and external balance, which in actual sense are not attainable. Secondly, its calculation requires the estimation of trade elasticities with respect to exchange rate, which in most cases are less accurate given that different functional forms of current account equations could lead to different trade elasticities. To overcome this, we adopt the behavioural equilibrium exchange rate (BEER) due to the fact that, it is not a normative measure as it does not necessitate making assumptions on the sustainable internal and external balance over the long-run. The equilibrium real exchange rate under BEER approach is thus in line with economic fundamentals.

4.2 Empirical Model

To estimate the real exchange rate misalignment, we follow the reduced form equilibrium exchange rate approach, particularly the behavioural equilibrium exchange rate (BEER) model consistent with previous work, (MacDonald, 1997; Clark and MacDonald, 1998). This is an empirical approach that is based on economic fundamentals that influence real exchange rate behaviour. To obtain the measures of real exchange rate misalignment, we compute the deviation of actual real exchange rate from its equilibrium value and this deviation is known in literature as exchange rate misalignment. Its empirical assessment is challenging given that the equilibrium real exchange rate is unobservable, thus the starting point in addressing this is to define the concepts of real exchange rate and equilibrium real exchange rate.

The RER is the domestic relative price of traded to non-traded goods, expressed as $rer = E * \frac{p_t^*}{p_n}$, where E is the nominal exchange rate, p_t and p_n are prices of tradables and non-tradables, respectively. Nurkse, (1945), defined ERER as the value of RER that induces both the internal and external equilibrium, given sustainable values of relevant variables for achieving this objective.

Despite the fact that BEER approach is part of the complementary approaches proposed by the IMF's consultative group on exchange rate issues (CGER), it is chosen over other approaches such as Macroeconomic balance (MB) and external sustainability (ES) due to the fact that it is more pragmatic given that it directly computes an equilibrium exchange rate for each country as a function of medium to long term fundamentals of the real exchange rate. It therefore does not require to make assumptions on the long-run values of economic fundamentals, while the other two approaches are highly influenced by normative assumptions. Indeed, Thorstensen et al., (2014) contend that the BEER approach minimizes the subjectivity in the estimation of equilibrium RER and its misalignment by using a set of economic fundamentals that explain real exchange rate behaviour. Secondly, the macroeconomic balance approach does not take into account long-run stock effects via the net foreign position and the stock of capital. This paper uses takes into account economic fundamentals consistent with previous studies (Berg & Miao, 2010; Vieira & MacDonald, 2012). Our empirical model is thus specified as:

$$reer_t = \alpha + \alpha_1 tot_t + \alpha_2 open_t + \alpha_3 nfa_t + \alpha_4 prod_t + \alpha_5 gov_t + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

Where $t = 1....,T$ denote time period, $reer_t$ is the real effective exchange rate, tot_t are the terms of trade, $open_t$ is the degree of trade openness, nfa_t is net foreign assets, $prod_t$ is productivity proxied by real per capita gross domestic product, gov_t is government consumption as percentage of GDP, $\alpha = (1,....,5)$ are parameters to be estimated and ε_t is the error term.

The procedure to estimate the equilibrium real exchange rate is implemented in five steps. Firstly, in line with conventional practice in econometrics, we test for unit root to determine the order of integration of used variables. Secondly, we estimate single equation cointegration based on reduced rank regression approach due confirm the presence of cointegrating relations (Johansen, 1988). Thirdly, we estimate the long run parameters of equilibrium RER using single equation cointegration based estimators such as dynamic ordinary least squares (DOLS) model. Fourthly, derive sustainable values of economic fundamentals of RER by decomposing RER into their permanent and cyclical components, implemented via Hodrik-Prescott (HP) filter and compute the misalignment measure, given by $Mis_t = reer_t - ereer_t$, where $ereer_t$ is the equilibrium real exchange rate and where positive (negative) values of Mis_t indicate undervaluation

(overvaluation). Finally, we incorporate the RER misalignment indicator in the monetary reaction function to check for the impact of RER misalignment on monetary policy implementation.

4.3 Estimation Strategy

To estimate the relationship specified in equation (1), we apply single equation dynamic ordinary least squares estimator, (Stock & Watson, 1993; Kao and Chiang, 2000; Mark and Sul, 2003). This approach improves OLS by addressing the problem of small sample bias and dynamic sources of bias owing to the fact that it corrects for endogeneity by adding leads and lags. Indeed, Kao and Chiang, (2000) argue that DOLS is robust in small samples, a result that is confirmed by Rahman, (2017) using Monte Carlo simulations. This estimation technique is used, along with complementary estimators such as fully modified ordinary least squares (FMOLS) and canonical cointegration regression (CCR).

4.4 Definition Variables and Data Sources

The series in equation (1) are constructed as follows. The real exchange rate is the inflation adjusted and trade weighted nominal exchange rate, computed by multiplying the nominal effective exchange rate by the ratio of foreign price to domestic price, given by $reer_t = \sum_{t=1}^{k} neer_{it} * \frac{p^*}{p}$. [1] The real exchange rate misalignment indicator is the exchange rate deviation from the equilibrium level based on Hodrick-Prescott (HP) filter, constructed as $Mis = reer_t - ereer_t$. Net foreign assets is calculated as difference between assets and liabilities $nfa = total\ Assets - total\ liabilities$, (Lane & Gian Milesi-Ferretti, 2007). Relative productivity proxied by real per capita GDP is calculated as nominal GDP divided by the total population and its growth rate is given by $ngdppc\_gr = ngdppc - ngdppc_{t-1} - 1.$

Terms of trade is the ratio between a country's export prices and its import prices, computed as $tot = \frac{\exp ort\ prices}{import\ prices} * 100$

Government expenditure is the total government expenditure, including recurrent and capital spending divided by GDP. Openness is measured as the sum of exports and imports divided by GDP, calculated as $open = \frac{x + m}{gdp}$. All the series are expressed in natural logarithms. We use quarterly data, covering the period 2006Q1-2021Q4 and data is sourced from World Bank's world economic outlook database (WEO), National Institute of Statistic of Rwanda and National Bank of Rwanda database.

[1] The estimated models used real effective exchange rate as the indicator of exchange rate. Evolution of bilateral and weighted exchange rates for Rwanda is presented in Annex 2a and 2b.

V. Discussion of Results

5.1 Results of Behavioral Exchange Rate Model

Prior to estimating the reduced form real exchange rate equilibrium model, we checked for the stochastic properties of data and found that except for the terms of trade, all other variables are integrated of order one (see Annex 1).

Table 1 presents the results of the reduced form model based on various single equation cointegration estimators. It this study, the main focus is on DOLS. We estimated the long-run relationship between real effective exchange rate and a set of economic fundamentals. The estimated coefficients are presented in columns (2) -(4). All variables included in our empirical specification are statistically significant, with correct signs, implying that the real exchange rate is in line with economic fundamentals.

The coefficient of openness is positive and statistically significant, this implies that trade-liberalizing reforms tend to depreciate the equilibrium RER. From the results in table 1, a 10 percent rise in openness brings about 1.5 percent depreciation in REER. In addition, the coefficient of terms of trade is positive and statistically significant, supporting the hypothesis that the substitution effect overwhelms the income effect in Rwanda. Similar results on the domination of substitution effect over income effect was found by Bahati and Sebera, (2020). The coefficient of NFA is positive and statistically significant, implying that higher net foreign assets induce real exchange rate depreciation given that a depreciated currency is required to restore the external balance for countries like Rwanda that experience current account deficits. As a matter of fact, Rwanda continues to run current account deficits despite the fact it has received substantial amounts of capital inflows, which would have otherwise rendered Rwanda to afford a more appreciated REER, while retaining the ability to restore the external balance through financing the associated current account deficits. However, these financial flows have not been enough to offset the current account deficit. In their analysis on the response of real exchange rate on different types of capital flows, (Bahati & Sebera, 2020) found total capital flows is associated with a currency depreciation as FDI and other private flows have a higher tradable bias compared to public inflows and remittances. The coefficient on government expenditure was also positive and statistically significant, suggesting that government consumption is biased towards tradables. From the results, the RER would depreciate by 0.7 percent following a 1 percent increase in government consumption.

By contrast, the coefficient of productivity is correctly signed but not significant in the first specification and correctly signed and statistically significant in the second and third

specifications, suggesting that productivity increase relative to trading partners induces real exchange rate appreciation, a phenomenon well known in literature as "Balassa- Samuelson effect". These results are consistent with the theory and the results of empirical studies for different countries, (Nuwagira and Muvunyi, 2016; Bukovšak, et al., 2020).

Table 1: BEER Estimation Result

Variables	DOLS	FMOLS	CCR
Openness	0.15*	0.27***	0.30***
	(0.08)	(0.08)	(0.09)
Terms of trade	0.30**	0.19	0.41***
	(0.12)	(0.13)	(0.05)
Net Foreign Assets	0.14**	0.19**	0.20**
	(0.06)	(0.07)	(0.08)
Government Expenditure	0.72***	0.81***	0.73**
	(0.07)	(0.08)	(0.07)
Productivity	-0.09	-0.13**	-0.17**
	(0.07)	(0.07)	(0.07)
Constant	0.52	0.41	(0.33)
	(0.56)	(0.67)	(0.64)
Observations	64	64	64
R-squared	0.87	0.68	0.72

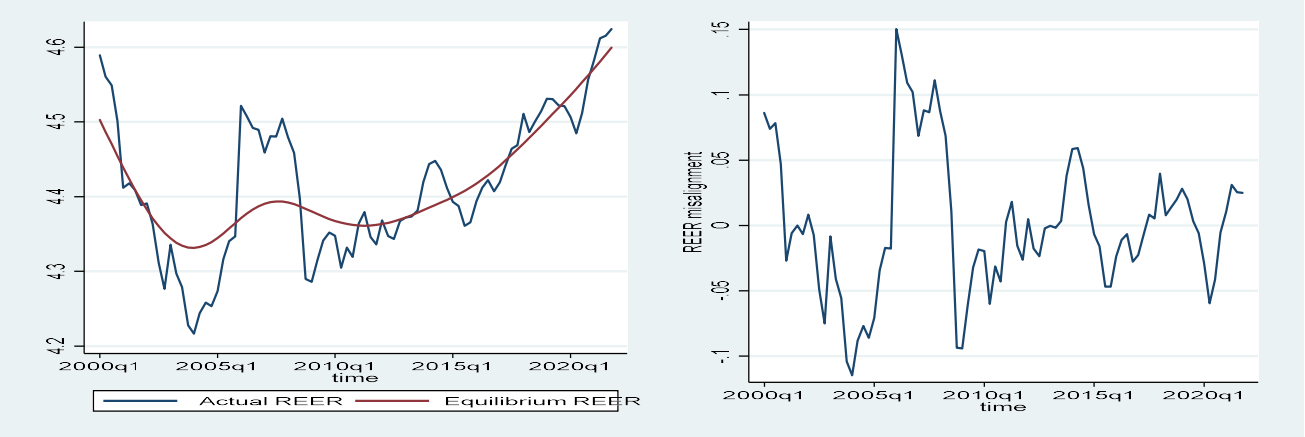
Note: Standard errors in parentheses. *, ** and *** denote significant at 0.1%, 0.05% and 0.01%, respectively. The lag interval is set to 1 as suggested by Schwarz and Hann-Quinn information criteria.
Source: Authors' estimations

5.2 Exchange Rate Misalignment in Rwanda

The estimated results of the main model, coupled with the Hodrick & Prescott, (1997), HP filter is used to derive the equilibrium values of economic fundamentals, whereby HP filter decomposes REER into their permanent and cyclical components and thus the level of misalignment is calculated as the difference between the actual real effective exchange rate and the equilibrium real effective exchange rate, which is the permanent component. Figure 1 below depicts the level of misalignment over the entire sample period. From the figure, different but alternating episodes of overvaluation and undervaluation are observable. It can further be observed that the level of misalignment is not prolonged and not very high. Considering the last episode, Rwanda's real effective exchange rate is undervalued by 2.3 percent, suggesting that Rwandan franc should appreciate by 2.3 percent in real effective terms to restore REER to its sustainable levels. Broadly

speaking, this level of misalignment is not too high and the associated real exchange rate misalignment episodes are not persistent to induce a negative effect on external sector competitiveness. The low levels of misalignment would be explained by the fact that inflation and exchange rate depreciation remained small in the last one decade. Specifically, during this period inflation averaged 3.8 percent while REER misalignment averaged 2.2 percent, thus monetary policy was largely accommodative.

Figure 1: Evolution in REER Misalignment in Rwanda



Source: Authors' estimations

Note: An increase (decrease) in RER is referred to as depreciation (appreciation). When the actual RER exceeds the equilibrium level, this refers to undervaluation.

5.3 REER Misalignment and Monetary Policy Implementation

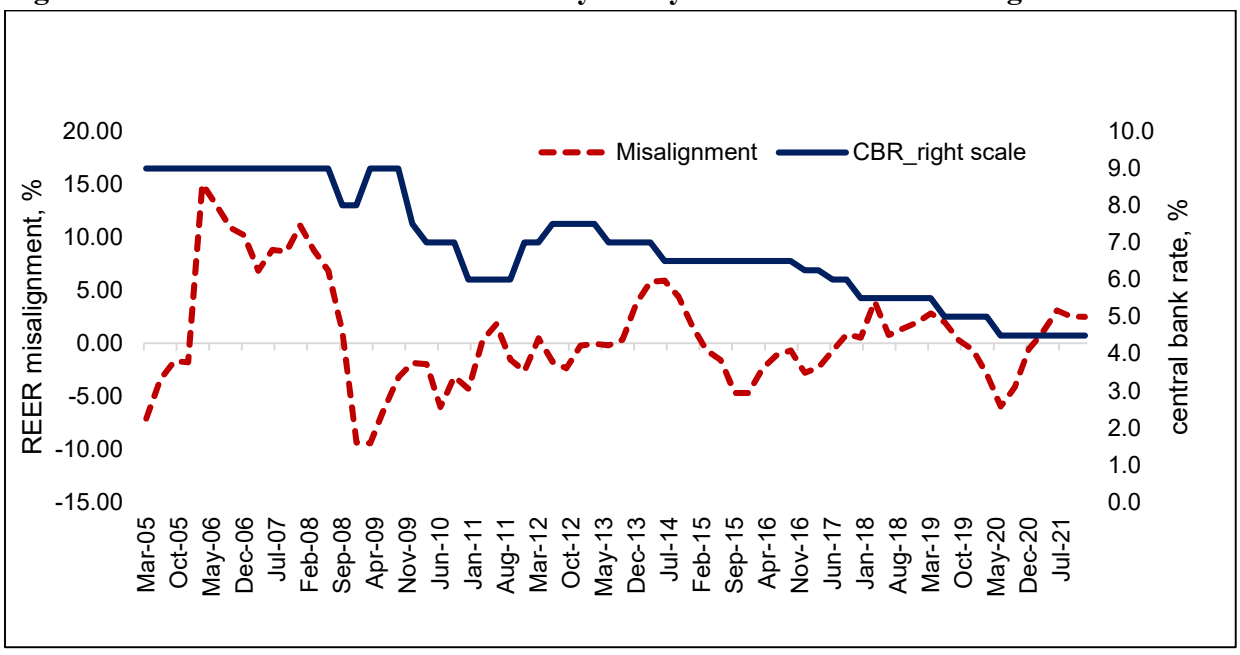
After obtaining the equilibrium level of real exchange rate and its associated real exchange rate misalignment as well as identifying the alternating episodes of overvaluation and undervaluation, we proceed with the assessment of the implication of REER misalignment on monetary policy implementation in Rwanda. This is informed by the fact that the REER and its deviation from sustainable levels plays a cardinal role in the transmission of external shocks to the domestic economy and in the propagation of monetary policy actions. The key channel that is well documented in literature is the direct effect of real exchange rate on inflation. Households consume not only domestically produced goods, but also imported goods, which are part of the consumer price index basket and as such the depreciation in exchange rate affect the domestic currency price of imported goods. REER depreciation erodes the value of domestic currency, thereby leading to an increase in inflation, thus if the resultant inflation expectations are not adequately anchored, the increase in imported goods prices feeds through to other domestic prices in the economy, inducing rampant increase in general price levels. Indeed, evidence from the empirical literature indicate that persistent REER misalignment have been associated with many of the crises that have been

experienced in the emerging and developing economies, suggesting that monetary authorities should closely track its evolution.

From the figure 1, taking the entire sample period, the episodes of real exchange rate misalignment point to a not too high level of REER misalignment, implying that exchange rate has evolved close to the equilibrium, which has prevented Rwanda from currency and banking crises and the associated high costs to the real economy coming from balance sheet effect. This has been due to the fact that the central bank has from time to time intervened in foreign exchange market to smoothen exchange rate volatility.

To show the implication of REER misalignment on monetary policy implementation in Rwanda, we follow two approaches. First, we link the evolution of Rwandan REER misalignment and Rwanda's central bank policy rate between Jan-2005 and December 2021 (Figure 2). As can be observed, there might be a link between exchange rate and central bankers' decisions with respect to policy, particularly during episodes of high REER undervaluation. For instance, the figure shows that following a REER undervaluation in 2006Q1-2008Q3 at around 10 percent which peaked at around 15 percent in 2006Q1 combined with episodes of high inflation, the central bank increased its policy rate by 1 percentage point in early 2009. The currency then adjusted back towards the equilibrium and has remained relatively close to its equilibrium level, except for some years, 2009, 2014-2015 and 2020 buoyed by terms of trade shocks. Figure 2 shows that the REER undervaluation preceded or was associated with rising domestic prices.

Figure 2: Evolution of Rwanda's Monetary Policy Rate and REER Misalignment



Source: National Bank of Rwanda and Authors' calculation

The second approach consisted of estimating the effect of real exchange rate misalignment on the implementation of monetary policy in Rwanda using both linear autoregressive distributed lag (ARDL) and non-ARDL (NARDL), akin to Bahmani-Oskooee et al., (2019). The linear model assumes a linear effect of real exchange rate misalignment on central bank rate and is specified below, (Pesaran et al., 2001):

$$\Delta ir_t = \theta + \sum_{j=1}^{n} \varphi_j \Delta ir_{t-j} + \sum_{j=1}^{n} \gamma_j \Delta mis_{t-1} + \sum_{j=1}^{n} \rho_0 ir_{t-1} + \sum_{j=1}^{n} \rho_1 mis_{t-1} + \varepsilon_t \quad (1)$$

Where; ir is the central bank policy rate proxied by the 3-months Treasury bill interest rate, mis is the real exchange rate misalignment and ε is the error term.

In the above model specification, the short-run effects are derived from the first-difference variables, whereas the long-run estimates are provided by the ρ_1 normalized on ρ_0.

To capture the asymmetric effect of real exchange rate misalignment on monetary implementation in Rwanda, the model is modified and disaggregate the real exchange rate misalignment into over-valuation and undervaluation in order to estimate their effects separately. Specifically, the study takes the positive variable for the partial sum of positive changes in the exchange rates and a thereafter a negative variable for the partial sum of negative changes in the real exchange rates is created. The positive and negative changes in the real exchange rates signify under-valuation and overvaluation of the real exchange rate respectively. The two variables are defined as:

$$undervaluation_t = \sum_j^t \Delta mis_t^+ = \sum_{j=1}^t \max(\Delta mis_j, 0) \quad \text{and}$$
$$overvaluation_t = \sum_j^t \Delta mis_t^- = \sum_{j=1}^t \min(\Delta mis_j, 0) \quad (2)$$

Therefore, the non-linear ARDL model can be expressed as follows:

$$ir_t = \theta^+ mis_t^+ + \theta^- mis_t^- + \mu_t \quad (3)$$

where θ^+ and θ^- are the asymmetric long-run equilibrium parameters associated with positive and negative changes in the real exchange rate. We then re-specify equation (1) by incorporating the two partial sum variables of the exchange rate misalignment in equation (2) and obtain the following equation:

$$\Delta ir_t = \propto + \varphi_j' \Delta ir_{t-j} + \gamma_j' \Delta mis^-{}_{t-j} + \delta_j' \Delta mis^+{}_{t-j} + \pi_0 ir_{t-1} + \pi_1 mis^-{}_{t-1} + \pi_2 mis^+{}_{t-1} + \in_t \quad (5)$$

Where $\theta^+ = \frac{\delta}{\varphi'}$ and $\theta^- = \frac{\gamma}{\varphi'}$

If the two partial sums carry the same coefficient in terms of sign and size, the effects are symmetric. Otherwise, they are asymmetric.

The results of the linear ARDL and non-linear ARDL are reported in table 2. Both models indicate that exchange rate misalignment doesn't affect monetary policy implementation in Rwanda. In the linear ARDL model, although the coefficient is not significant it is correctly signed, suggesting that an increase or undervaluation (decrease or overvaluation) in exchange rate would push the central bank to tighten (loose) its monetary policy. Similarly, in the non-linear ARDL model, the results suggest that undervaluation of the exchange rate is insignificantly associated with tight monetary policy while real exchange rate overvaluation is insignificantly linked with ease of monetary policy. In addition, both models have revealed significant effects of past monetary policy shocks on the current monetary implementation policy.

Table 2: Results from ARDL and NARDL model

Dependent variable: monetary policy variable: ir			
Variable		**ARDL**	**NARDL**
Constant		1.15**	1.20*
		(0.45)	(1.04)
ir_{-1}		0.84***	0.80***
		(0.06)	(0.07)
mis		0.02	-
		(0.04)	-
mis_{-1}			
mis^{+}			0.01
			(0.08)
mis^{+}_{-1}			0.01
			(0.08)
mis^{-}			-0.03
			(0.09)
mis^{-}_{-1}			-0.05
			(0.13)
Diagnostics tests	$Adjusted\ R^2$	0.798	0.783
	$F-statistics$	65.53[0.00]	38.200[0.00]
	X^2_{LM}	4.69[0.0958]	5.992[0.0500]
	; χ^2_{HET}	11.225[0.0241]	12.735[0.07889]
	$Jarque-Bera(p-value)$	46.038[0.00]	52.843[0.000]
	CUSUM	stable	stable

Notes: The values in parentheses are standard errors while values in brackets are p-values. *, **, *** denote 10%, 5% and 1% significance level.χ^2_{LM} is the Lagrange Multiplier test of residual serial correlation distributed as χ^2 with n degrees of freedom; χ^2_{HET} is the Breusch-Pagan-Godfrey test of residual homoskedacity distributed as χ^2 with n degrees of freedom. RESET is Ramsey's test for misspecification.

Source: Authors' calculation

VI. Conclusions

The main objective of this paper was to estimate the equilibrium real exchange rate and misalignment and assess its implication on monetary policy implementation in Rwanda. The study used quarterly data, spanning the period 2000Q1-2021Q4. Building on the behavioral equilibrium exchange rate framework, the study estimated the relationship between the real effective exchange rate and economic fundamentals using single equation cointegration based techniques, particularly DOLS. To check for the robustness of the econometric results, complementary estimators such as FMOLS and CCR were also utilized. To derive the level of REER misalignment, the estimated equilibrium real exchange rate results were used along with Hodrick-prescott filter to obtain sustainable levels of REER and decompose REER into their permanent and cyclical components. Thus, the level of REER misalignment was calculated as the difference between the actual real effective exchange rate and the equilibrium real effective exchange rate.

The main results indicate that the real effective exchange rate is in line with the economic fundamentals. Rwanda has experienced alternating episodes of undervaluation and overvaluation over the period under review. The obtained level of REER is not too high and the identified episodes of undervaluation and overvaluation are not persistent to cause loss of competitiveness of the external sector. However, the study found that real exchange rate misalignments may not have important implications on monetary policy implementation despite Rwanda being a small open economy. Nevertheless, the study recommends that monetary authorities should continuously monitor the evolution of exchange rate misalignment due to its potential effects on macroeconomic stability.

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Annexes

Annex 1: Unit Root Test for the Variables under the BEER Model

Table 3: Unit roots test for non-stationarity (Sample: 2000Q1–2021Q4)

	Level		First Difference		Order of Integration
	Intercept	Trend	Intercept	trend	
Lrgdp	-1.21	-0.60	-8.65***	-8.70***	I(1)
Lreer	-1.60	-2.92	-7.72***	-7.92**	I(1)
Ltot	-2.47	-2.48	-3.44*	-3.53*	I(1)
Lgov	-0.74	-1.99	-3.93***	-4.45***	I(1)
Lopen	-1.67	-2.32	-11.59***	-8.05***	I(1)
Lnfa	-2.43	-2.04	-9.44***	-9.70***	I(1)

Note: *, **, ***: denote rejection of null hypothesis at 10%, 5%and 1% significance level respectively.

Source: Authors' estimations

Annex 2a: Bilateral Nominal Exchange Rate

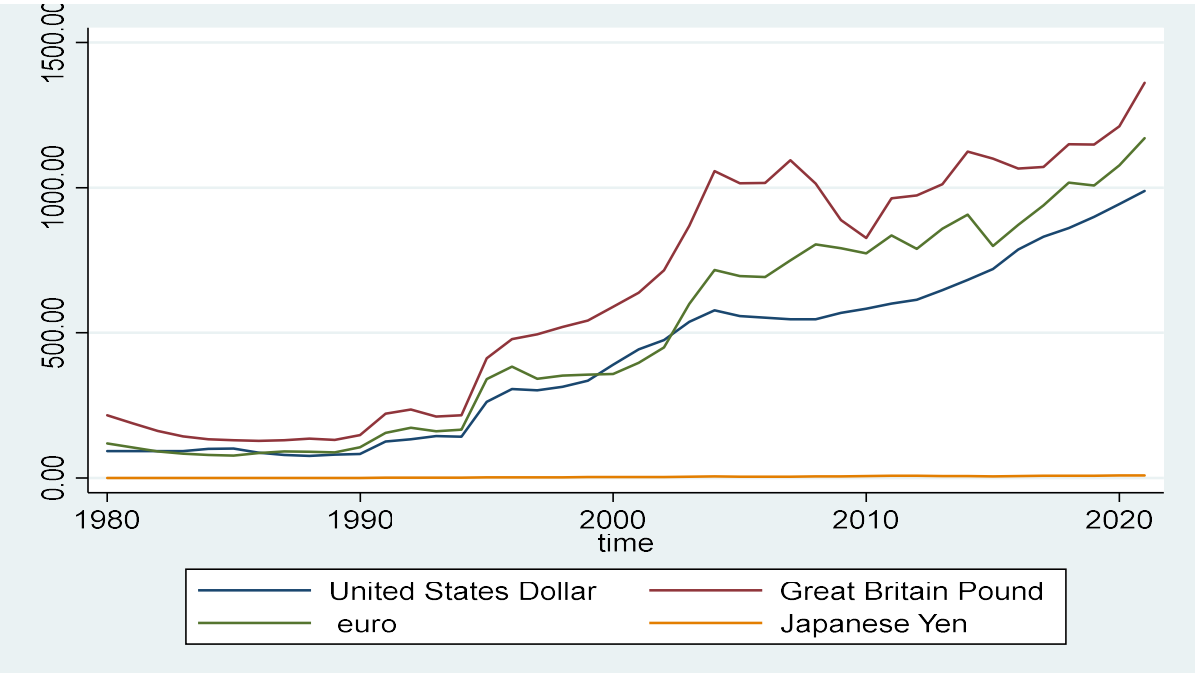

Figure 2b: Rwanda's Real Effective Exchange Rate