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Foreword

It is with great pleasure that the National Bank of Rwanda publishes a booklet combining two (2) issues of volume twenty (20) of the BNR Economic Review. The BNR Economic Review is a distinguished journal of the National Bank of Rwanda aimed at disseminating high-quality and impactful applied research produced by both BNR staff and other interested researchers around the world. The focus on applied research is meant to contribute to evidence-based formulation and implementation of economic policies, especially in Rwanda. The two issues of this volume, published in June and November 2023, respectively, are available online at the African Journal Online (AJOL). Also, this booklet, combining the two issues, is available online at the BNR website.

In this volume, contributing researchers investigate different channels of the monetary policy transmission mechanism in Rwanda, focusing on the interest rate, exchange rate, and bank lending channels. These studies are imperative and continuous given their importance in unpacking how monetary policy actions affect the real economy, allowing a central bank to assess the overall effectiveness of its policy measures and whether the intended outcomes of monetary policy are being achieved. This, therefore, underscores the NBR's commitment to serve the Rwandan population by actively contributing to the overall macroeconomic stability.

In addition to price stability, the National Bank of Rwanda has a mandate of fostering financial stability. Cognizant of the considerable impact of non-performing loans (NPLs) on both financial and macroeconomic stability, one article in this volume assessed macroeconomic and bank-level factors that drive NPLs in Rwandan banking sector. Insights from the study are expected to contribute to the formulation of targeted policies to mitigate risks and maintain a stable and sound banking sector.

Recognizing the unprecedented COVID-19 shock and its multifaceted impacts on the Rwandan economy, one paper documents the weekly index of economic activities, a crucial tool in tracking the pandemic's economic impact in Rwanda. Using the experience of Rwanda, the paper highlights how high-frequency real-time data can contribute to the mitigation of an abrupt shock, such as the CoVID-19. Focusing on the same period, another paper examines the drivers of inflation during the pandemic using monthly disaggregated consumption data for Rwanda. The paper concludes that the persistence and volatility in inflation during the pandemic period was primarily driven by volatile CPI components, hence stressing the need to monitor them.

Furthermore, another article investigates the role of export diversification in correcting persistent real exchange rate misalignment in Rwanda and hence ensuring

external sector stability. The paper provides valuable insights that form the basis for designing policies that foster overall economic stability, reduce vulnerability to external shocks, and promote long-term sustainable growth.

As Rwanda navigates through the complexities of the global economic landscape, the BNR Economic Review remains an indispensable resource for fostering intellectual exchange and advancing our collective understanding of the economic forces at play. We commend the authors for their rigorous research and the editorial team for their commitment to maintaining the high standards that have come to define this esteemed journal.

We trust that the diverse range of topics covered in this volume will spark further exploration and discussion, inspiring new avenues for research and contributing to the ongoing dialogue on Rwanda's economic developments. May this edition serve as a valuable resource for scholars, policymakers, and all those vested in the prosperity of our nation.

RWANGOMBWA John
Governor

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INTEREST RATE PASS-THROUGH IN RWANDA

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Abstract

This paper aims to assess whether there has been an improvement in the interest rate pass-through in Rwanda following the adoption of a price-based monetary policy framework since January 2019, bearing in mind recent financial sector developments and improvements in monetary policy formulation and implementation. Empirical estimations based on the entire estimation sample[1] show that there is incomplete but statistically significant long-run pass-through from the interbank rate, the repo rate, and the 13-week and 26-week T-bills rates to the deposit rates of 1, 2, 6, and 12 months, respectively. The estimations of the pass-through from policy rates to the lending rates are generally counter-intuitive, suggesting that the former are driven by other structural issues in the loan market, especially the banks' high-cost structure and the loan market power. Our empirical estimations also show that the interest rate pass-through from various proxies of policy rates to the market rates has generally declined since January 2019 (Appendix B & table 5) compared to the sample before, and this can be attributed to the fact that the sample is still small yet the recent period has also been affected by shocks, notably COVID-19, the Russia-Ukraine war and domestic weather shocks. The main policy recommendation is that existing initiatives should be strengthened, and new ones developed to help improve the Monetary Policy Transmission Mechanism.

Key words: **Interest rate channel, Transmission mechanism, Monetary policy.**

JEL Classification: **E52, L14**.

[1] Estimation samples for the pass-through to other interest rates from: the Repo rate (January 2008 - June 2022); CBR (January 2005 - June 2022); Interbank (January 2004 - June 2022); 4, 13 and 26 weeks T-bills rates (January 2004 - June 2022); 52-week T-bills (January 2005 - June 2022); Weighted T-bills rate (January 2008 - June 2022).

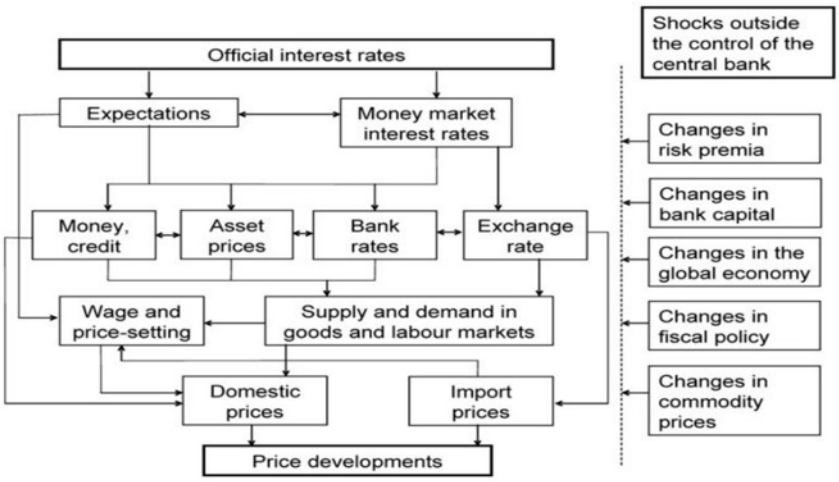
1. Introduction

Generally, the main objective of central banks while conducting monetary policy is to be able to affect aggregate demand in an economy and, hence, inflation. This is achieved when the Monetary Policy Transmission Mechanism (MPTM) is efficient. An efficient MPTM occurs when the actions of monetary authorities affect liquidity conditions, which in turn affects economic agents' aggregate consumption and investment decisions. Thus, the MPTM explains how monetary policy actions affect aggregate demand, economic activities, and the general price level. The speed and magnitude with which monetary policy actions affect output and inflation often vary from country to country depending on factors such as financial sector development and the degree of formalization of the economy.

The effectiveness of monetary policy, therefore, has two stages. The first stage is the "interest rate pass- through", which is about how changes in the CBR affect other interest rates in the economy. The second stage is how the real economy (i.e. aggregate demand and inflation) are affected due to monetary policy actions. Due to the first stage, there are changes in liquidity conditions in the economy, leading to changes in consumption and investment decisions, ultimately affecting aggregate demand and inflation. These two stages constitute what is known in the literature as the interest rate channel of monetary policy, which explains how changes in an economy's interest rates affect both aggregate demand and inflation via their effect on the demand for credit and available income of borrowers and lenders.

These two stages constitute what is known in the literature as the interest rate channel of monetary policy, which explains how changes in an economy's interest rates affect both aggregate demand and inflation via their effect on the demand for credit and available income of borrowers and lenders. Other channels of MPTM include the asset price channel, exchange rate channel, and bank lending channel, whose discussion is beyond the scope of this study. The MPTM channels are broadly summarized in Figure 1. This study examines how effective the interest rate channel in Rwanda is by focusing on the interest rate pass-through.

Figure 1: Channels of Monetary Policy Transmission



Source: European Central Bank

Focusing on the interest rate pass-through, theoretical literature shows that the stickiness of interest rates is generally explained by four theories, namely: agency costs (Stiglitz & Weiss, 1981), adjustment costs (Cottarelli & Kourelis, 1994), switching costs (Klemperer, 1987), and risk sharing (Fried & Howitt, 1980). Additionally, most theoretical and empirical works have concluded that the interest rate pass-through is generally influenced by financial sector development, the degree of competition in the banking system, the level of operating costs incurred by banks and general macroeconomic stability (i.e., exchange rate and inflation stability).

The main objective of this paper is to assess the MPTM in Rwanda, focusing on the interest rate channel and providing policy recommendations. The current study builds on Kigabo (2021) and extends the sample until June 2022. While Kigabo (2021) captured some changes related to an interest rate-based monetary policy framework, such as improved daily liquidity management by the Financial Markets Operations Committee (FMOC) guided by enhanced liquidity forecasting, this study captures recent changes, such as the downward revision of the corridor within which the interbank rate fluctuates (from CBR ±2% to CBR ±1%since July 2020) since July 2020), takes into account the lags in the transmission mechanism, the challenges emanating from recent shocks (COVID-19 and Russia-Ukraine war), and partially the effect of a prolonged tightening cycle since February 2022.

The main mandate of the National Bank of Rwanda is to maintain price stability and, hence, contribute to overall sustainable macroeconomic stability. For a period of two

decades, ending in December 2018, the NBR conducted its monetary policy under the money-targeting framework. However, the NBR adopted a price-based monetary policy regime in January 2019. Under this new regime, the NBR sets its Central Bank Rate (CBR) so as to affect the interbank rate and other short-term interest rates in the economy. It is believed that the MPTM improves when the interbank is close to the CBR as this will affect the liquidity position of banks and hence lead to the desired changes in other interest rates, especially deposit and lending rates (Kigabo, 2021). Specifically, this paper re-estimates the magnitude of the interest rate pass-through and compares the findings with recent empirical studies on Rwanda to see if there have been improvements.

After the introduction, covered in section one, the rest of the paper is organized as follows: section two gives an overview of monetary policy in Rwanda, section three covers the theoretical and empirical literature, section four explains the methodology used in this paper, section five focuses on the discussion of both descriptive and empirical results, while section six gives the conclusion and policy recommendations.

2. Literature review

2.1 Theoretical literature

In this chapter, we review both empirical and theoretical literature regarding the factors that can make the interest rate pass-through either complete or incomplete, drawing on cross-country findings. Most empirical work on the interest rate pass-through focuses on estimating the degree and speed of adjustment of the retail rates following changes in the official rate. The general consensus from these studies is that the interest rate pass-through is incomplete, especially in developing countries (De Bondt, 2002) where a non-competitive banking sector may not fully pass through or may delay the transmission of the changes in the monetary policy rate to borrowers. While the interest rate pass-through tends to be low in the short run, it progressively increases in the long-run toward complete pass-through. The incomplete pass-through from the policy rate to the lending rate may be due to the stickiness of the latter.

The stickiness in lending rates has generally been explained by four theories: agency costs (Stiglitz & Weiss, 1981), adjustment costs (Cottarelli & Kourelis, 1994), switching costs (Klemperer, 1987), and risk sharing (Fried & Howitt, 1980). Cottarelli and Kourelis (1994) argue that the structure of the financial system influences the stickiness of interest rates. More specifically, the presence of barriers to entry in the banking sector

hinders competition among banks and negatively affects the adjustment of interest rates to a change in the policy rate. Similarly, Mojon (2000) argued that competition among banks significantly improves the interest rate pass-through. Borio and Fritz (1995) also suggest that under a perfectly competitive loan market, the interest rate pass-through would be complete, contrary to monopolistic and oligopolistic markets where the degree of interest rate pass-through would be much smaller. Collectively, all these papers agree that the degree of competition affects the level and speed of adjustment of interest rates to a change in the policy rate.

According to (Saborowski & Weber, 2013), financial development plays a significant influence on interest rate transmission, with the development of the money market for short-term instruments like certificates of deposits (CDs) and Treasury bills playing a huge role in the flexibility of lending rates (Cottarelli & Kourelis, 1994). On the contrary, banks' operating costs impede the interest rate mechanism, as suggested by Mojon (2000). He argues that the higher the staff costs, the smaller the degree of pass-through in setting credit rates. Likewise, Sorensen (2006) find a negative relationship between bank funding costs and the pass-through. Sorensen (2006) discuss the negative relationship observed between excess liquidity/excess capital and the pass-through. They argue that excess liquidity or capital can serve as a buffer against market variations, leading to a slow and small level of interest rate adjustments. Contrary to credit risk, they found that the more loans the banks give, the faster the adjustment. This implies that in a competitive environment, banks take more risk in giving out loans, making banks more vulnerable to changes in interest rates.

Medina, Carri n-Men ndez, and Frantischek (2011) attribute cross-country differences in interest rate pass-through on the exchange rate regime, with high pass-through expected for the case of flexible exchange rate regimes. Similar to Saborowski and Weber (2013), they argue that countries with a tight exchange rate regime can have a 40% long-run pass-through, lower than 60% for the countries with a flexible exchange rate regime. Another important determinant of the pass-through is the conduct of monetary policy. Borio and Fritz (1995) capture this factor by analyzing the role of infrequently changed rates on official standing facilities, arguing that this serves as a signal about future interest rates or a policy change. They argue that the signal associated with a change in policy rates is very relevant to the speed and level of the pass- through. Mojon (2000) agrees that the conduct of monetary policy matters in determining the interest rate pass-through. The latter is measured using money market rates (MMR) volatility and inflation,

and the MMR volatility is expected to have a negative impact on the pass-through, whereas the effect of inflation can have a positive impact.

2.2. Empirical literature

Empirical work around the interest rate pass-through has been growing over time, but the majority focuses on advanced economies. The results of these different studies have found that the level and speed of the adjustment of interest rates varies across countries and depends on the type of interest rates used. Some studies go an extra step to analyze the presence of asymmetric adjustment. Several studies on the adjustment of interest rates have been conducted for the Euro area. Kwapil and Scharler (2009) worked on the Euro area and the USA, using both the Engle-Granger cointegrating relationship and ARDL, using monthly data for the period of 1995 to 2003. They used the three-month money market rate as the policy rate and examined how this is transmitted to the various deposit and lending rates and to their respective weighted averages. They found that for the Euro area, the pass-through is incomplete but higher in the long-run than in the short run and that it is higher for lending rates than the deposit rates.

H Isewig, Mayer, and Wollmersh user (2009), studied the Euro area using quarterly data from 1999 to 2002, using the new Keynesian DSGE model. They used the nominal short-term Euro interbank offered rate (EURIBOR) as the policy rate and examined how this affects changes in the retail bank lending rates. Their main conclusion is that the pass-through is incomplete in the short run. Sudo and Teranishi (2008) conducted a study on 12 Euro countries, using an Error Correction Model (ECM) for a more recent period of 2003 to 2008 monthly frequency. They examined the degree of transmission of the ECB policy rate to the bank loan interest rates and found that the level of stickiness differs across countries but ranges from 0.2 to 0.8 in the short-run, leaving to conclude that the pass-through is incomplete.

For the USA, Neumark and Sharpe (1992) use Ordinary Least Squares (OLS), a partial adjustment model and a switching model of partial adjustment on monthly panel data from 1983 to 1987. The study covers 255 banks, and the results indicate that there is the presence of asymmetric adjustment, whereby banks adjust deposit rates downward quicker when above the equilibrium than upward when below the equilibrium. Similarly, Hannan and Berger (1991) using multinomial logit estimation on a sample from 1983 to 1986 found the presence of asymmetric adjustment. Deposit rates adjust faster when there is a decrease than an increase in the policy rate.

Various studies found a nearly complete pass-through in deposit rates in the USA and Asia. For example, Huang and Wang (2009)'s recent study on the USA and some Asian countries, using monthly data from 1988 to 2000 to estimate an asymmetric threshold cointegration model and an EC-EGARCH (1,1) model, found that both in the short and long-run the pass-through to deposit and lending rate is close to one. Comparatively, Kwapil and Scharler (2009) looking at monthly data from 1995 to early 2003, with the use of Engle-Granger cointegrating relationship and autoregressive distributed lag model (ARDL), found a nearly complete pass-through for deposit but not for lending rates, both in the short and long-run for the USA. Interestingly, they did not find the presence of asymmetric adjustment for the USA.

Cottarelli and Kourelis (1994) focused on 31 industrial and developing countries, using monthly data to measure the degree of lending rates stickiness by the use of simple dynamic models. In the first step, lending rates (prime, non-prime, and average rates) are regressed on lagged money market rates (T-bill rates or interbank rates) and discount rates. It is found that the degree of lending rate stickiness differs across countries, with some countries having close to one and others nearly zero. In the second step, they try to explain the differences in the degrees of stickiness across countries by regressing a cross-section of impact multipliers against a set of variables that indicate different features of the financial system. Five factors are found to be more relevant in reducing lending rates stickiness. A developed market for short-term monetary instruments, absence of constraints on capital movements, absence of bank competition constraints such as barriers to entry, private sector ownership of the banking sector, and stability in the money market rates.

Tieman (2004) conducts a study on transition economies, comparing Romania with other European economies, using monthly data from 1995 to 2004. His study looks at short and long-term deposit and lending rates and the central bank policy rate using the error correction model. He finds that the pass-through is slow and incomplete in all interest rates, but the pass-through is greater and faster for the deposit rates than lending rates.

A number of studies have empirically studied the magnitude of interest rate pass-through in developing countries, especially from the policy rate to the lending and deposit rates. For the case of South Africa, (De Angelis, Aziakpono, & Faure, 2005) study the pass-through using an Engle-Granger cointegration method and Error Correction model

(ECM), while (Guisan et al., 2005) used mixed dynamic model, for a sample of monthly data March 1998 to September 2001 and from September 2001 to November 2004. For the policy rate, they use the repo rate and look at prime interbank rate, prime lending rate, and negotiable certificates of deposit (NCD) rate. They found that in the long-run the pass-through is nearly complete for all interest rates, but was higher during the first period during the first repo system. Likewise, Aziakpono and Wilson (2013, 2015) found that in the long-run the pass-through are very high and the speed is very fast. They use is EG cointegration and ECM and asymmetric ECM on monthly data from 1973 to 2004, but they use the repo rate instead of the policy rate.

Using bank-level quarterly data for the 2006Q2 -2016Q4 period, (Bennouna, 2019) showed that the pass- through from the policy rate to the different lending rates varied between 0.02 and 0.99 in Morocco. Using monthly data for the 2009-2015 period, the pass-through was estimated to be between 0.02 and 0.089 for the deposit rates and between 0.01 to 0.09 for the lending rates in Malawi (Chiumia & Palamuleni, 2019). For Mongolia, Doojav and Kalirajan (2016) estimated the pass-through to the lending rate to range between 0.1 and 0.9 and 0.73 to 0.77 for the deposit rates. High pass-through was estimated for the case of the Dominican Republic, standing between 0.94 and 2.66 for the lending rates and between 0.73 to 1.65 for the deposit rates (And jar-Scheker, 2012; Escudero, Gonzalez-Rozada, & Sola, 2014).

Using the 7-day interbank rate as a policy rate for the case of Uganda, Apaa (2014) found that the pass-through to the lending rate stood at 0.43 for the entire, was insignificant before the adoption of the Inflation Targeting Light (ITL) framework and 0.3 in the sample after the adoption of the ITL. Generally, the pass-through to time deposits ranged between 0.56 and 0.6, whereas the interbank rate affected most interest rates in the post-ITL period, suggesting that the interest rate pass-through is more suitable for inflation-targeting regimes. Generally, similar findings were obtained for the case of Kenya by Misati, Nya- mongo, and Kamau (2011), who argued that there is incomplete pass-through from policy rates to other interest rates in both the short and the long-run.

For the case of Rwanda, Kigabo and Mwenese (2016) found that the pass-through was incomplete for deposit rates ranging between 0.14 and 0.45 in the long-run, whereas, in the short-run it is even smaller, standing at around 0.15. For lending rates, they found an even smaller degree of pass-through, standing at around 0.06. Similarly, Rutayisire (2017) estimates the pass-through using a transformed ADL model on monthly data from

2008 to 2016. He finds that the adjustment of deposit rates is very small and slow, and there is the presence of asymmetric adjustment. This implies that banks will adjust deposit rates downward faster than upward. Additionally, He confirms that the pass-through to lending rates is also incomplete both in the short and long-run.

Using monthly data for the 2016:1 – 2018:6 period, Kigabo and Kamanzi (2018) estimated the pass- through from the repo rate to the interbank rate at 0.04 in the short-run and 0.03 in the long-run. Using monthly data for the 2015:1 – 2018:8 period, the short-term and long-term pass-through from the interbank rate to the weighted deposit rate was estimated at 0.03 and 0.02, respectively. Similarly, it stood at 0.22 and 0.24 for the 1-month deposit rates and at 0.2 and 0.16 for the 12-month deposit rates. When a larger sample (monthly data, 2004:1-2018:6) is used, the pass-through from the T-bills rate (weighted average and all maturities) to the deposit rates (weighted average and all maturities) weakens, with long-run & short-run coefficients ranging between 0.01 and 0.1. Similar results are obtained when the 2008:1 – 2018:6 sample is used. In all the sub-samples, the pass-through from all proxies of the policy rate to the lending rate is counter-intuitive, with relationships mostly being negative and significant.

In a recent study, Kigabo (2021) analyses the pass-through: (1) from repo rates to money market rates (interbank rate, T-bills rates for all maturities and its weighted average); (2) from interbank rates to Treasury bill rates of different maturities; and (3) from money market rates to banking rates (deposit rates and lending rates) as well as the link between deposit rates and lending rates. Findings show that there is a complete long-run pass-through from the repo rate to the interbank rate and T-bills rates for 4, 13 and 26 weeks, respectively. In the short run, there is a significant, albeit low, pass-through from the repo rate to the interbank rate (with a coefficient of 0.4) and the 13-week T-bills rate (with a coefficient of 0.28). The pass-through from the interbank rate to the treasury bills rates is quite high, ranging between 0.9 and 1.09, with complete pass-through to 4 and 13-week T-bills rates. The short-run pass-through from repo to T-bills rates is significant but quite weak, ranging between 0.32 and 0.5. Lastly, there is a low/incomplete pass-through from the T-bills rates to the lending and deposit rates, significant in the long-run but insignificant in the short run.

For the case of deposit rates, Kigabo (2021) found a low and significant pass-through from the weighted T-bills rate to the weighted deposit rate and from the 26-week T-bills rate to the 1-month deposit rate. Regarding the lending rates, a significant but low effect

is found from the weighted deposit rate to the weighted lending rate, from the 3 and 6 months deposit rate to the weighted lending rate, from the six-month deposit rate to the short-term and long-term lending rates, from the weighted deposit rate to the long-term lending rate and from the 52 weeks T-bills rate to the weighted lending rate. The studies on Rwanda that estimated the level of interest rate pass-through stopped before adopting a price-based monetary policy and, therefore, do not capture recent developments in the money market and financial system developments. This study will extend the sample to June 2022 and cover a broad interest rate range.

2.3 Overview of monetary policy in Rwanda

Since its creation in 1964, the National Bank of Rwanda has implemented its monetary policy under different regimes. Between 1964 and 1990, the NBR used direct monetary policy instruments to regulate money supply but switched to indirect, market-based instruments in 1990 following the liberalization of the economy. Nonetheless, a clear monetary policy regime started in 1997, when the NBR started implementing its monetary policy under the monetary targeting framework, with reserve money (i.e. base money) used as an operating target, broad money (M3) as an intermediate target and inflation as the ultimate target. Under this regime, changes in reserve money affected the money supply (M3), which affected the inflation and output levels. By reaching the desired level of M3, the central bank could attain its ultimate goal of price stability. As explained by Kigabo and Irankunda (2012), the transmission mechanism under the monetary targeting framework started from base money to inflation via money supply: the NBR used its monetary policy instruments to influence the level of reserve money so as to affect money supply with an ultimate objective of affecting inflation.

For this transmission mechanism to work, two strong assumptions need to be satisfied: (1) Money supply and inflation should be strongly related, such that changes in M3 can lead to desired changes in inflation; (2) the NBR should be able to control the money supply, and this is only possible if there is a long-run, stable and predictable relationship between M3 and reserve money. From the supply side, strict money targeting was found to be cumbersome due to increased and frequent deviations of actual base money stocks from their target values. In addition, the NBR had limited control over the money supply given the significant share of currency in circulation in base money and the fact that the NBR could not control the former via the usual open market operations.

From the demand side, the effectiveness of the reserve money targeting program was also premised on the assumption of a stable money demand function such that NBR interventions focus on reducing deviations of M3 from its target and, therefore, push it closer to the estimated money demand level. Thus, the estimation of money demand should be accurate, stable and predictable. According to the quantity theory of money and recent empirical literature, the stability of the money demand function depends on the assumption that the velocity of money is either constant or grows at a constant, predictable rate. However, empirical work on Rwanda indicated that the velocity of money was not constant and was not growing at a constant rate, implying instability of money demand and often leading to the disequilibrium between the demand and supply of money, thus posing challenges to the effectiveness of monetary policy in Rwanda (Kigabo, 2021). Just like in Rwanda, the instability of the money multiplier, money velocity, and money demand function has been reported in many developing countries (Adam & Kessy, 2010).

As a result, the NBR introduced a flexible system in 2012, under which target misses were tolerated within the ±2% band around the central reserve money target. More reforms were introduced to this flexible regime, especially since 2008, which marked the beginning of the transition to a price-based monetary policy framework. In 2008, the Key Repo Rate (KRR) was introduced. Since then, the MPC has decided on the level of the KRR every quarter and communicated this to the market, just as a signaling tool of the monetary policy stance. The NBR also adjusted its Open Market Operations (OMOs) by introducing repo operations to replace the overnight facility and 7-day auctions. To help commercial banks manage liquidity, the NBR also introduced an interbank interest rate corridor system.

After the transition period, the National Bank of Rwanda adopted the price-based monetary policy regime in January 2019, which mainly emphasizes the importance of the interest rate channel of the monetary policy transmission mechanism. Under this regime, the National Bank of Rwanda sets the Central Bank Rate (CBR) to affect the short-term interest rates, mainly the 7-day-interbank rate, which ultimately affects other interest rates in the economy, notably the lending and deposit rates. The changes in interest rates then influence liquidity conditions and thereafter affect aggregate demand and prices if the transmission mechanism is effective. Thus, the effectiveness of the interest-rate-based policy regime hinges on the effectiveness of the interest rate pass-through.

According to Kigabo (2021), the analysis of the effectiveness of the interest rate channel is often done in two stages. The first stage focuses on assessing the interest rate pass-through to check how policy-controlled short-term interest rates affect both money market interest rates and banks' retail rates. Most of the empirical literature focuses on determining the magnitude and symmetry of the pass-through. Generally, it concludes that there is incomplete pass-through in developing countries, where a 1% increase in the policy rate leads to a less than 1% increase in the money market or retail rate. The second stage consists of examining the effectiveness of the whole monetary policy transmission mechanism, focusing on examining how monetary policy actions, such as changes in the policy rates, affect aggregate demand and price levels in an economy (Samba & Yan, 2010; Apaa, 2014; Kigabo, 2021).

3. Data and Methodology

All the monthly interest rate data used in this study were obtained from the National Bank of Rwanda (NBR). Data for the CBR start in January 2005, while that of the repo rate starts in January 2008. The starting period for other interest rates data is January 2004 for the interbank rate, treasury bills rate (4, 13, 26, and 52-week maturities), the deposit rate (average, and 1, 3, 6, 12 months maturities), and lending rates for all maturities (i.e., short-term, medium-term and long-term). Dejure, the CBR is the policy rate, while the repo is the de facto policy rate. The end of the sample for all interest rates is June 2022. The estimation samples, therefore, vary with respect to the proxy of the policy rate and the market rate used[2].

Regarding the methodology, empirical analysis of the interest rate pass-through is dominated by bi- variate regression analyses, assessing the sensitivity of the market rate to the changes in the policy rate, and this explains why most empirical studies are predominated by single-equation modelling (Chionis & Leon, 2006). The standard empirical models used in the interest-rate pass-through literature are the Autoregressive Distributed Lag (ARDL) models and bi-variate Engle-Granger cointegration. The Engle-Granger two-step procedure consists of first estimating a levels OLS model:

[2] Estimation samples for the pass-through to other interest rates from: the Repo rate (January 2008 - June 2022); CBR (January 2005 - June 2022); Interbank (January 2004 - June 2022); 4, 13 and 26 weeks T-bills rates (January 2004 - June 2022); 52-week T-bills (January 2005 - June 2022); Weighted T-bills rate (January 2008 - June 2022).

$$y_t = \alpha_1 + x_t'\beta + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where (y_t, x_t') is a vector of I(1) variables, representing the market rate (y_t) and policy rate (x), α is an intercept that indicates a mark-up or mark-down on the market or retail rate to reflect market conditions. It is important to test whether or not the stochastic error term (ε_t) is stationary. If not stationary[3], then the OLS estimation of equation 1 gives spurious results. However, if stationary, then a long-run regression (equation 1) is valid, and a short-term regression (equation 2) can also be estimated, to give the long-run and short-run level of the interest rate pass-through. Equation 1 is the long-run model, whereas Equation 2 is the Error Correction Model (ECM).

$$\Delta y_t = \alpha_2 + \gamma\hat{\varepsilon}_{t-1} + \sum_i^{p-1} \varphi_{xj}\Delta x_{t-j} + u_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots . (2)$$

Where y_t and x_t are as defined above, $\hat{\varepsilon}_{t-1}$ is the lag of the estimated residuals obtained from equation 1, and u_t is the error term in the ECM. The ECM shows short-run adjustments to eliminate the disequilibrium, moving towards attaining the long-run equilibrium. Thus, under the Engle-Granger model, it is essential that γ is negative and statistically significant, to ensure that the series are cointegrated. We thus test whether the $-1 \leq \gamma < 0$ assumption is valid[4]. Some empirical studies, such as Kigabo (2021), combine equations 1 and 2 into a single-step estimation procedure, but the results and interpretations are similar. Before using the Engle-Granger model, one must ensure that the variables are all I(1). The main drawback of this methodology is that it does not accommodate other control variables, which may lead to an overestimation of the interest rate pass-through. In this study, we use the Engle-Granger methodology to enable the comparison of our results with those of Kigabo (2021). In addition, robustness checks indicated that the results of the ARDL and the Engle-Granger methodologies are generally the same.

4. Discussion of descriptive and empirical results

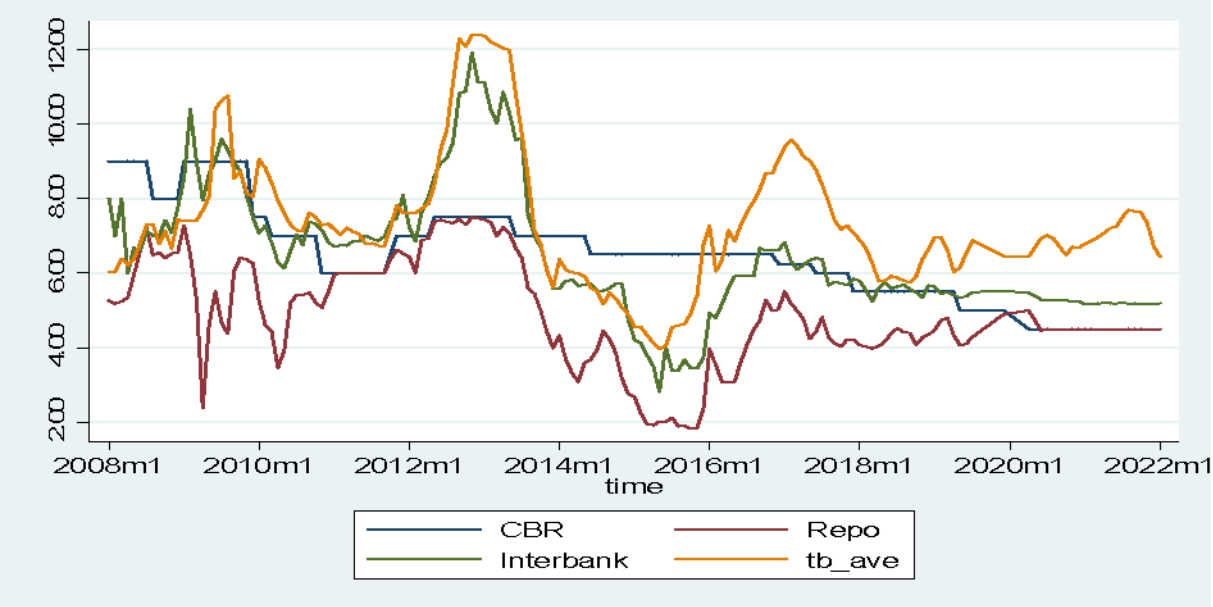
Since July 2020, the CBR and the repo have been harmonized (i.e. the two are now equal). The first interesting empirical task will be to check if the CBR has been comoving with the

[3] Stationarity tests indicate that the variables are all I(1): see appendix 1.

[4] In all the estimations, this assumption is satisfied, hence confirming that the series are cointegrated.

repo and interbank rates. Despite the sluggishness in the CBR, there is broad co-movement between the three interest rates, with more co-movement observed between the repo rate and the interbank rate (Figure 2).

Figure 2: Co-movement between the policy and money market rates



Source: Authors' estimation

Looking at the correlation coefficients in table 1, it is clear that the de facto policy rate (i.e. the repo rate) is highly and positively correlated with the interbank rate and the T-bills rates (weighted average and all maturities). The interbank rate is also positively and highly correlated with the T-bills rates (all maturities). Therefore, the repo rate, interbank rate and T-bills rates can and have been used as proxies for the policy rate in most of the recent empirical literature on Rwanda (Kigabo & Kamanzi, 2018; Vlček, Pranovich, Hitayezu, Mwenese, & Nyalihama, 2020; Kigabo, 2021).

Table 1: Correlation between policy and money market rates

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	cbr	1.000							
(2)	repo	0.364	1.000						
(3)	Interb	0.602	0.825	1.000					
(4)	tb_4wk	0.315	0.786	0.837	1.000				
(5)	tb_13wk	0.356	0.739	0.869	0.923	1.000			
(6)	tb_26wk	0.257	0.645	0.771	0.817	0.906	1.000		
(7)	tb_52	-0.075	0.434	0.533	0.728	0.784	0.780	1.000	
(8)	tb_ave	0.303	0.685	0.833	0.901	0.979	0.911	0.836	1.000

Source: Authors' estimation

Regarding the correlation between the deposit rates (average and all maturities) and the various proxies for the policy rates, the correlations in table 2 are positive but quite low, which may indicate weak pass-through from these respective policy rates to the deposit rates. Generally, the correlations are higher between deposit and T-bills rates than between deposit and repo rates.

Table 2: Correlation between policy rates and deposit rates

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1)	dr_1m	1.000											
(2)	dr_3m	0.326	1.000										
(3)	dr_6m	0.322	0.665	1.000									
(4)	dr_12m	0.194	0.630	0.655	1.000								
(5)	dr_ave	0.199	0.661	0.698	0.882	1.000							
(6)	repo	0.195	0.294	0.148	0.144	0.101	1.000						
(7)	Interb	0.260	0.518	0.382	0.393	0.320	0.825	1.000					
(8)	tb_4wk	0.134	0.472	0.306	0.343	0.350	0.786	0.837	1.000				
(9)	tb_13wk	0.171	0.518	0.356	0.415	0.420	0.739	0.869	0.923	1.000			
(10)	tb_26wk	0.203	0.474	0.322	0.429	0.450	0.645	0.771	0.817	0.906	1.000		
(11)	tb_52	0.131	0.494	0.357	0.457	0.531	0.434	0.533	0.728	0.784	0.780	1.000	
(12)	tb_ave	0.180	0.532	0.359	0.437	0.455	0.685	0.833	0.901	0.979	0.911	0.836	1.000

According to Appendix A, the Augmented Dickey-Fuller (ADF) test shows that all the variables are I(1)[5],and thus, the empirical approach of Kigabo (2021) can be conveniently used by re-estimating the interest rate pass-through for the case of Rwanda, both in the short-run and long-run. Short-run estimations (table3) show that there is a weak but statistically significant pass-through only from the 13-week T-bills rate (tb_13wk) to the 3-month deposit rate (dr_3m). Other estimations are not statistically significant[6].

Table 3: Short-term pass-through from proxies of policy rates to the deposit rates

		dr_1m	dr_3m	dr_6m	dr_12m
Interb	Cons	-0.0	0.0	-0.0	0.0
	coeff	-0.03	-0.04	-0.1	0.08
	Ut-1	-0.7***	-0.4***	0.4***	-0.3***
Repo	Const	0.04	0.02	0.04	0.011
	coef	0.04	0.07	-0.041	-0.14
	Ut-1	-0.6***	-0.3***	-0.3***	-0.2***
tb_4wk	Const	-0.00	0.008	-0.00	0.006
	coef	-0.019	0.058	-0.069	0.00724
	Ut-1	-0.713***	-0.452***	-0.425***	-0.299***
tb_13wk	Cons	0.006	0.0116	0.00798	0.00696
	Coef	0.04	0.372**	-0.217	0.00426
	Ut-1	-0.5***	-0.3***	-0.3***	-0.2***
tb_26wk	Cons	-0.00	0.0	5.7	0.0
	Coef	0.09	0.153	-0.04	0.09
	Ut-1	-0.7***	-0.427***	-0.4***	-0.318***
tb_52wk	Cons	-0.00	0.0	0.0	0.0
	Coef	0.00222	0.2	-0.06	0.09
	Ut-1	-0.7***	-0.4***	-0.4***	0.06

Note: * p<0.05, ** p<0.01, *** p<0.001

[5]Appendix A gives ADF tests for the entire sample. However, the same conclusions were reached for the sub-samples.

[6] Note that Ut-1 stands for the error correction term.

In the long-run estimations (table 4), there is a weak and statistically significant pass-through from the interbank rate, the repo rate, 4-week, 13-week and 26-week T-bills rates to the deposit rates of 1, 2,6 and 12 months maturity, respectively. The pass-through from the 52 T-bills rate is weak and only significant if it is to the 3, 6 and 12-month deposit rates.

Table 4: Long-term pass-through from proxies of policy rates to the deposit rates

		dr_1m	dr_3m	dr_6m	dr_12m
Interbank	**Cons**	2.6***	2.4***	4.5***	6.8***
	Coef	0.2***	0.5***	0.4***	0.3***
Repo	**Cons**	3.2***	4.3***	6.5***	8.1**
	Coef	0.3***	0.73***	0.6***	0.4***
tb_4wk	Cons	3.4***	3.2***	5.3***	7.3***
	Coef	0.1*	0.4***	0.3***	0.2***
tb_13wk	**Cons**	3.4***	3.3***	5.5***	7.0***
	Coef	0.1***	0.4***	0.2***	0.2***
tb_26wk	**Cons**	2.9***	2.8***	5.0***	6.6***
	Coef	0.2**	0.4***	0.3***	0.2***
tb_52wk	**Cons**	3.2***	2.0***	4.352***	6.0***
	Coef	0.1	0.4***	0.36***	0.3***
	N	174	174	174	174

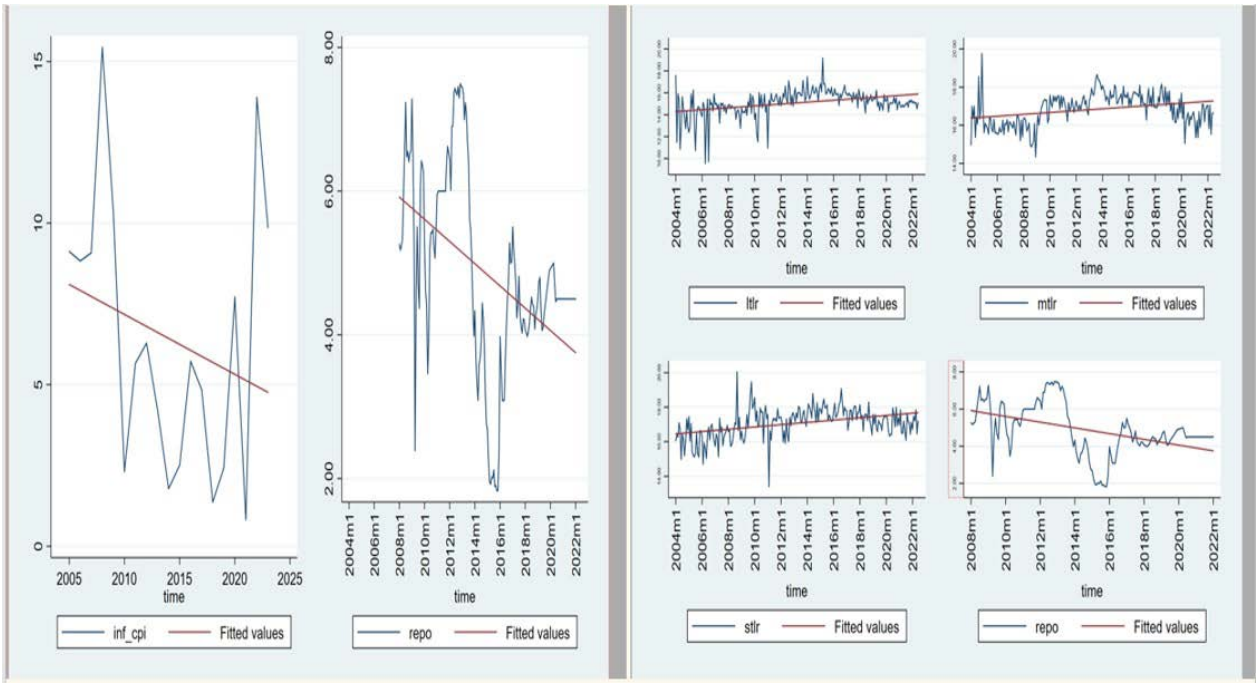
Note: * p<0.05, ** p<0.01, *** p<0.001

Source: Authors' estimation

In all the estimations (not reported here), the pass-through from different proxies of the policy rate to the lending rate (weighted average, short-term, medium-term and long-term) gave counter-intuitive results with unexpectedly negative relationships. As shown in Appendix C, it takes 7 months, 21 months, and 22 months for medium-term, short-term, and long-term lending rates to be positively correlated with the repo rate, respectively.

As indicated in Figure 3, both headline inflation and the repo rate have been generally and consistently trending downwards, while the lending rates have generally been trending upwards, which could be an ex- planation for the observed negative relationships between the policy rates and the lending rates.

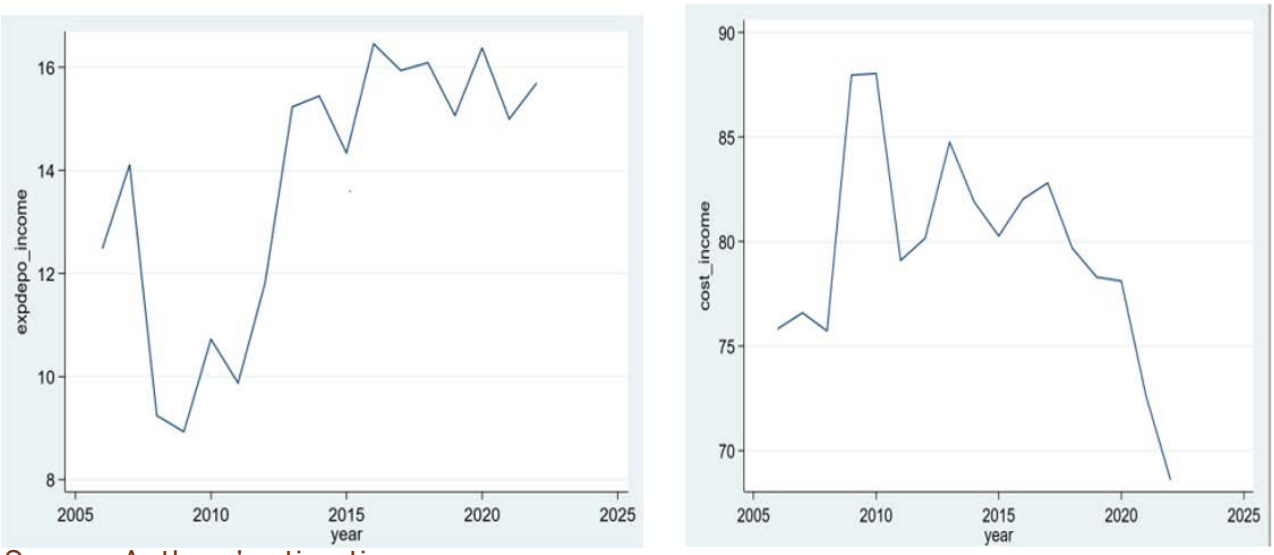
Figure 3: General trend in the lending rates, inflation and policy rate



Source: Authors' estimation

Also, the lending rate has been observed to be quite sticky and at a higher level compared to the deposit rate given that the banks still incur high operating costs, the credit risk is still high, there is monopoly power in the deposit market where big depositors negotiate for higher interest rates and hence push up the cost of funds, there is low competition in the loans market, among others (Karangwa & Nyalihama, 2014; Kigabo, 2021). Though the discussion of the reasons for the stickiness in lending rates is beyond the scope of this paper, a few examples can be cited. For example, the expenditure on deposits as a share of total income is quite high (figure 4), implying a high cost of funds. The share of total costs to income has declined over time, but it remains close to 70.

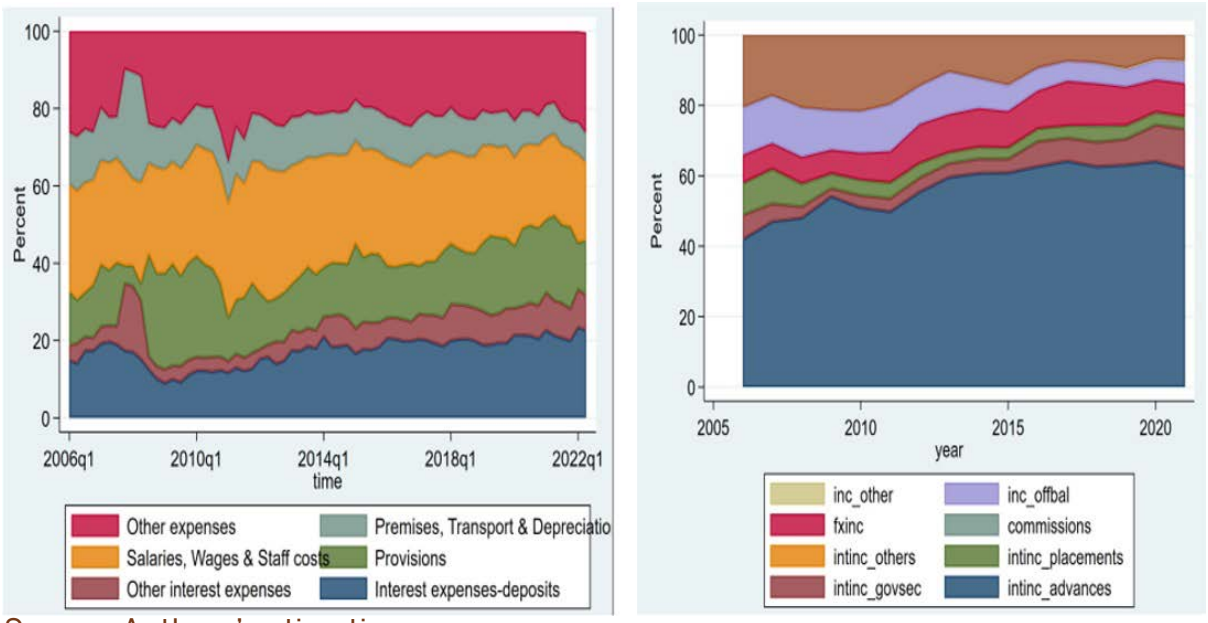
Figure 4: Cost of funds and total costs of commercial banks



Source: Authors' estimation

The main source of income for commercial banks is interest income from loans and advances (intinc_advances). The lack of a diversified portfolio may imply that commercial banks tend to maintain higher lending rates to remain profitable. Also, the operating costs of banks remain quite high, mainly pushed up by salaries, wages and staff costs, interest expenses on deposits, loan loss provisions and other expenses.

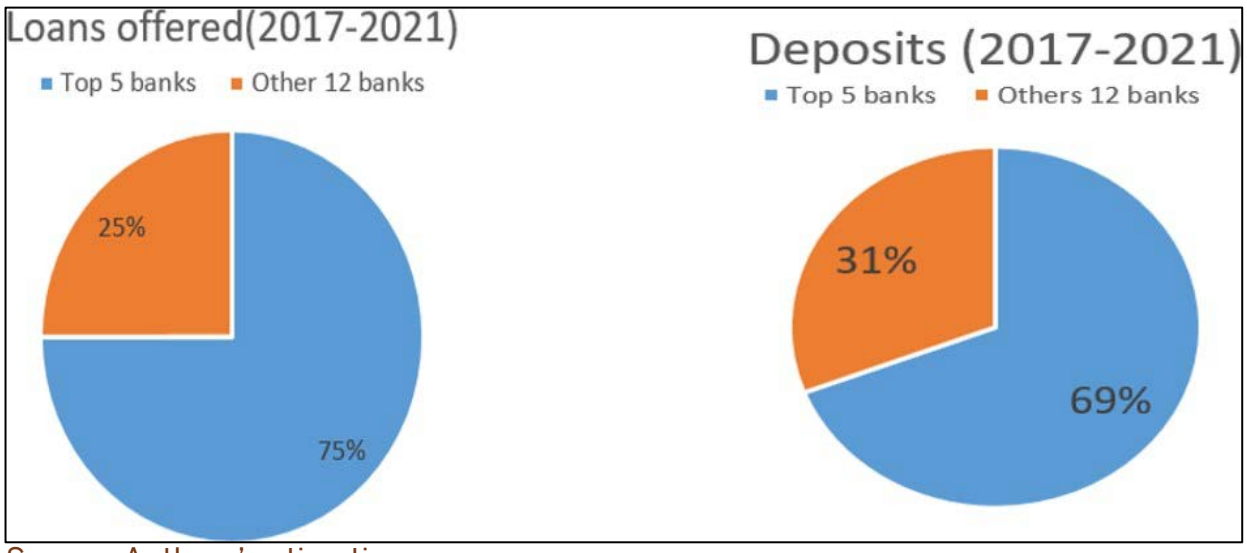
Figure 5: Decomposition of operating costs of commercial banks



Source: Authors' estimation

There is less competition among commercial banks in Rwanda, where only a few banks dominate the loan and deposit markets, hence impeding the interest rate pass-through.

Figure 6: Share in loans and deposits market.



Source: Authors' estimation

In both the Kigabo (2021) paper and this current study, there is a strong and complete long-run pass- through from the repo rate to the interbank rate, from the repo rate to the

4-week T-bills rate, from the repo rate to the 13-week T-bills rate, and from the interbank to the 4-week T-bills rate. The pass-through from the repo to 26 weeks T-bills and from the interbank rate to the 13 weeks T-bills rate has declined (from complete pass-through) but remains strong and statistically significant. Also, the pass-through from the interbank rate to the weighted T-bills rate and from the interbank to the 26-week T-bills rate has declined but remains quite strong. Though still weak, there has been some slight improvement in the pass-through from the 26-week T-bills rate to the 1-month deposit rate and from the 3-month deposit rate to the weighted lending rate. Overall, the (Kigabo, 2021) estimations are statistically significant at 5%, which has improved to 1% in the current estimations. However, the corresponding short-term pass-through is generally weak.

To confirm whether the interest rate pass-through has declined since January 2019, compared to the sample before, we re-run estimations after adding a dummy variable on the various bi-variate regressions. We define the dummy as equal to 1 for the sample since January 2019 and 0 otherwise. Results in Appendix B show that the interest rate pass-through has generally declined since the NBR's adoption of the price-based monetary policy framework[7]. While this could be attributed to the fact that the recent past has been hugely affected by the shocks (COVID-19, Russia-Ukraine war & adverse weather), the small size of the sample cannot also be disregarded. Thus, it is important to always update the estimations from time to time.

[7] The exception is that the pass-through from the weighted interbank rate to the weighted deposit rate has increased in the January 2019 - June 2022 sample.

Table 5: Benchmarking empirical findings.

Pass-through from	Kigabo (2021) Jan 2008 – May 2020		Current study Jan 2008 – June 2022	
	Long-T	Short-T	Long-T	Short-T
Repo to interb	1.09**	0.40**	1.03***	0.39***
Repo to TB_4W	1.18**	0.21	1.09***	0.19
Repo to 1TB_13W	1.16**	0.28**	1.06***	0.28***
Repo to TB_26W	1.01**	0.13	0.90***	0.11
Interbank to WTB	0.9**	0.40**	0.84***	0.40***
Interbank to TB_4W	1.03**	0.50**	1.04***	0.62***
Interbank to TB_13W	1.09**	0.47**	0.87***	0.49***
Interbank to TB_26W	0.94**	0.32**	0.84***	0.45***
WTB to WDR	0.29**	0.05	0.29***	0.04
TB26 to DR1	0.16**	0.09	0.28***	0.08
DR3 to WLR	0.11**	0.005	0.15**	0.20

Note: * p<0.05, ** p<0.01, *** p<0.001

5. Conclusion and recommendation

For monetary policy to be effective, policy decisions should be translated into policy actions that can affect inflation and output. This requires the effectiveness of the monetary policy transmission mechanism (MPTM), which includes several channels, such as the interest rate channel, the bank lending channel, the asset price channel and the exchange rate channel. This paper analyses the effectiveness of the interest rate channel, focusing on the pass-through from policy rates to the lending and deposit rates. We use data from January 2008 to June 2022 and use both simple descriptive analysis and an empirical strategy employed by Kigabo (2021). Our results are generally robust and align with those obtained by Kigabo (2021). The pass-through is, however, slightly lower in our estimations but is also more statistically significant compared to Kigabo (2021). Also, our estimations show improved pass-through from the 26-week to the 1-month deposit rate and from the 3-month deposit rate to the weighted lending rate. Our estimations show a weak but statistically significant short-run pass-through from the 13-week T-bills to the 3-month deposit rate. In the long-run, there is weak and statistically significant pass-through from the interbank rate, the repo rate, and the 13-week and 26-week T-bills rates to the deposit rates of 1, 2, 6 and 12 months, respectively.

The estimations of the pass-through from policy rates to the lending rates are generally counter-intuitive as lending rates have been moving in opposite directions with the policy

rate and monetary policy objective. The challenges impeding effective MPTM include low financial sector development and the still high level of informality of the Rwandan economy (Kigabo, 2021). Also, the lending rate has been observed to be quite sticky and at a higher level compared to the deposit rate given that the banks still incur high operating costs, the credit risk is still high, there is monopoly power in the deposit market where big depositors negotiate for higher interest rates and hence push up the cost of funds, there is low competition in the loans market, among others (Karangwa & Nyalihama, 2014; Kigabo, 2021).

Given the relatively weakening interest rate pass-through to deposit rates, this paper recommends thoroughly analyzing the dynamics in the deposit market. Given the counter-intuitive results regarding the pass-through to the lending rates, we recommend a detailed loan market analysis. We suggest that a similar analysis be conducted from time to time using updated data to check if there has been an improvement in the interest rate pass-through, which is required for the efficient functioning of the interest rate channel. NBR should continue working with other stakeholders to increase financial sector development and implement other policies aimed at attaining the desired structural transformation of the Rwandan economy, as this can potentially lead to the improvement of the MPTM. There is a need to encourage banks to devise mechanisms for diversifying their portfolios, cutting their operating costs and embracing competition in both the loans and deposit markets. This can be done via different engagements, taking appropriate supervisory measures and moral suasion.

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Appendix A. Stationarity tests

Figure 7: Stationarity test

Period	Variable	ADF 1st Diff Statistic
Entire Period	tb_4wk	18.63***
Entire Period	tb_13wk	8.9***
Entire Period	tb_26wk	16.93***
Entire Period	tb_52	9.87***
Entire Period	INTERB	7.18***
Entire Period	CBR	12.78***
Entire Period	dr_1m	8.23***
Entire Period	dr_3m	10.75***
Entire Period	dr_6m	11.6***
Entire Period	dr_12m	10.21***
Entire Period	stlr	7.44***
Entire Period	mtlr	10.74***
Entire Period	ltlr	8.43***
Entire Period	REPO	10.52***
Entire Period	dr_ave	13.37***
Entire Period	lend_ave	7.81***
Entire Period	tb_ave	9.5***

Appendix B. Time-varying estimations

Repo to:	Slope	Dummy	Interbank to:	Slope	Dummy
dr_ave	0.06941	-0.24614	dr_ave	0.21668***	0.05131
lend_ave	-0.11717***	-0.64644***	lend_ave	-0.06729***	-0.71818***
dr_1m	0.16592*	-0.76078***	dr_1m	0.19700***	-0.51252*
dr_3m	0.28723***	-1.40296***	dr_3m	0.45173***	-0.81358***
dr_6m	0.13079	-1.28443***	dr_6m	0.34566***	-0.81425***
dr_12m	0.11875*	-0.49349**	dr_12m	0.28547***	-0.1075
stlr	-0.12538***	-0.34845***	ltlr	-0.08974**	-0.45081***
mtlr	-0.16266***	-0.67660***	mtlr	-0.07721**	-0.75284***
ltlr	-0.17800***	-0.38726**	ltlr	-0.14347***	-0.55572***
CBR to:	**Slope**	**Dummy**	**tb_ave**	**Slope**	**Dummy**
dr_ave	-0.08321	-0.44063	dr_ave	0.28784***	-0.07061
lend_ave	-0.14905***	-0.94274***	lend_ave	-0.01253	-0.62946***
dr_1m	0.14761	-0.47811	dr_1m	0.14244**	-0.70230**
dr_3m	0.09913	-1.25104***	dr_3m	0.46959***	-1.15413***
dr_6m	0.16634	-0.95378**	dr_6m	0.33508***	-1.09088***
dr_12m	0.10159	-0.29991	dr_12m	0.30817***	-0.31515
stlr	-0.14038**	-0.62428***	stlr	-0.02202	-0.33598**
mtlr	-0.30330***	-1.29587***	mtlr	-0.00712	-0.64623***
ltlr	-0.27683***	-0.94611***	ltlr	-0.07693*	-0.39977**

Appendix C. Correlations between the repo and lending rates

	repo	L. repo	L2. repo	L3. repo	L4. repo	L5. repo	L6. repo	L7. repo	L8. repo	L9. repo	L10. repo	L11. repo
repo												
--.	1.0000											
L1.	0.9684	1.0000										
L2.	0.9220	0.9687	1.0000									
L3.	0.8752	0.9224	0.9686	1.0000								
L4.	0.8202	0.8680	0.9147	0.9635	1.0000							
L5.	0.7799	0.8158	0.8636	0.9123	0.9637	1.0000						
L6.	0.7502	0.7798	0.8157	0.8642	0.9103	0.9625	1.0000					
L7.	0.7068	0.7453	0.7747	0.8125	0.8641	0.9105	0.9612	1.0000				
L8.	0.6452	0.6814	0.7189	0.7529	0.8073	0.8563	0.8942	0.9526	1.0000			
L9.	0.6078	0.6444	0.6803	0.7184	0.7513	0.8071	0.8567	0.8934	0.9378	1.0000		
L10.	0.5564	0.6112	0.6473	0.6819	0.7115	0.7474	0.8071	0.8513	0.8647	0.9355	1.0000	
L11.	0.5091	0.5617	0.6158	0.6493	0.6703	0.7031	0.7450	0.7968	0.8122	0.8594	0.9356	1.0000
L12.	0.4692	0.5135	0.5657	0.6182	0.6429	0.6664	0.7033	0.7400	0.7697	0.8106	0.8608	0.9355
L13.	0.4114	0.4738	0.5178	0.5685	0.6123	0.6392	0.6668	0.6987	0.7145	0.7685	0.8124	0.8616
L14.	0.3471	0.4159	0.4778	0.5204	0.5633	0.6094	0.6400	0.6629	0.6754	0.7137	0.7702	0.8134
L15.	0.3001	0.3524	0.4203	0.4805	0.5148	0.5605	0.6105	0.6359	0.6387	0.6744	0.7159	0.7723
L16.	0.2615	0.3053	0.3567	0.4229	0.4753	0.5126	0.5620	0.6069	0.6132	0.6380	0.6766	0.7183
L17.	0.2253	0.2697	0.3125	0.3610	0.4148	0.4709	0.5138	0.5555	0.5758	0.6109	0.6416	0.6825
L18.	0.1833	0.2310	0.2747	0.3156	0.3560	0.4129	0.4728	0.5103	0.5333	0.5752	0.6136	0.6452
L19.	0.1322	0.1862	0.2333	0.2759	0.3126	0.3555	0.4146	0.4711	0.4956	0.5332	0.5759	0.6138
L20.	0.0823	0.1321	0.1855	0.2323	0.2744	0.3127	0.3561	0.4139	0.4627	0.4951	0.5313	0.5720
L21.	0.0347	0.0818	0.1310	0.1841	0.2309	0.2745	0.3131	0.3554	0.4070	0.4621	0.4927	0.5269
L22.	0.0043	0.0337	0.0800	0.1289	0.1825	0.2312	0.2748	0.3124	0.3495	0.4060	0.4592	0.4881
L23.	-0.0140	0.0039	0.0325	0.0784	0.1272	0.1827	0.2316	0.2740	0.3063	0.3486	0.4037	0.4555
stlr	-0.3094	-0.3001	-0.3141	-0.2942	-0.2772	-0.2517	-0.2237	-0.2129	-0.2153	-0.1731	-0.1143	-0.1146
mtlr	-0.1878	-0.1543	-0.1343	-0.0858	-0.0409	-0.0123	-0.0024	0.0503	0.0919	0.0745	0.0990	0.1136
ltlr	-0.1852	-0.2020	-0.2012	-0.2242	-0.2241	-0.1888	-0.1543	-0.0854	-0.0090	0.0066	-0.0330	-0.0276

	L12. repo	L13. repo	L14. repo	L15. repo	L16. repo	L17. repo	L18. repo	L19. repo	L20. repo	L21. repo	L22. repo	L23. repo
L12.	1.0000											
L13.	0.9361	1.0000										
L14.	0.8627	0.9366	1.0000									
L15.	0.8150	0.8640	0.9372	1.0000								
L16.	0.7742	0.8168	0.8651	0.9376	1.0000							
L17.	0.7216	0.7768	0.8181	0.8659	0.9373	1.0000						
L18.	0.6852	0.7241	0.7785	0.8193	0.8666	0.9372	1.0000					
L19.	0.6462	0.6863	0.7248	0.7785	0.8192	0.8647	0.9366	1.0000				
L20.	0.6121	0.6447	0.6847	0.7226	0.7763	0.8140	0.8622	0.9359	1.0000			
L21.	0.5699	0.6102	0.6428	0.6821	0.7200	0.7706	0.8111	0.8612	0.9358	1.0000		
L22.	0.5246	0.5678	0.6080	0.6398	0.6790	0.7139	0.7673	0.8097	0.8608	0.9357	1.0000	
L23.	0.4863	0.5230	0.5661	0.6054	0.6372	0.6737	0.7110	0.7661	0.8093	0.8605	0.9355	1.0000
stlr	-0.0963	-0.1148	-0.1665	-0.1886	-0.1654	-0.0905	-0.0468	-0.0569	-0.0486	-0.0031	0.1078	0.0830
mtlr	0.1279	0.1236	0.1313	0.1598	0.1303	0.1323	0.1727	0.1679	0.1901	0.2055	0.2089	0.2082
ltlr	-0.0543	-0.1456	-0.1465	-0.1434	-0.0931	-0.0617	-0.0473	-0.0419	-0.0033	0.0664	0.0364	0.0491

	stlr	mtlr	ltlr
stlr	1.0000		
mtlr	0.1453	1.0000	
ltlr	0.0825	0.1502	1.0000

EXCHANGE RATE CHANNEL OF MONETARY POLICY TRANSMISSION MECHANISM IN RWANDA

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Abstract

Understanding the channels of the monetary policy transmission mechanism is crucial for the proper implementation of monetary policy. For low-income countries and Rwanda in particular with recent history of economic reforms including modernization in the monetary policy framework and ongoing financial sector development, there are questions on the strength of monetary policy transmission and which channels actually work. This study aims at assessing the exchange rate channel in the case of Rwanda. Using quarterly data from 2006 to 2022, empirical results reveal that the transmission of monetary policy via the exchange rate channel exists. First, evidence confirms the first stage of transmission, as an increase in Central Bank Rate influences the exchange rate by reducing the rate of the depreciation of Franc Rwandais. Furthermore, results from Bayesian VAR estimation suggest that this transmission work mostly via the direct channel as this effect from policy rate on the Franc Rwandais exchange rate is transmitted to inflation and the peak impact is attained after four quarters. Meanwhile, the indirect channel, which implies the effect of monetary policy on inflation via effect of exchange rate on output, is quasi-ineffective, as the output response, though in the right direction, is not statistically significant. We argue that this is likely due to the limited impact of exchange rate movement on export sector and subsequently the current account, thus ongoing economic structural reforms, financial sector development, and policy implementation would be critical for enhancing the potency of NBR monetary policy.

Key Words: Monetary policy, transmission mechanism, exchange rate channel.

JEL Classification Numbers: E52, E31, F31.

1. Introduction

Monetary policy, one of the most important macroeconomic policies, influences economic activity and inflation through various channels. Understanding the channels of the monetary policy transmission mechanism and how it affects other macroeconomic variables is critical for the proper implementation of monetary policy. Central banks across the globe are interested in assessing how their policies and actions are transmitted to the economy and how long it takes for them to make an impact. The vast theoretical and empirical literature over many years ago also illustrates the importance of this topic.

Indeed, the literature has been instrumental in revealing the relative importance of different channels of monetary policy transmission, as well as estimates of the size and timing of the impact of the monetary policy action on output and prices for different economies across time, and these insights improved the understanding of monetary policy transmission mechanism and were crucial for policymaking because they help in making the right decisions regarding notably the degree and timing of policy action for an effective monetary policy.

Interest rates, credit, asset prices, and exchange rate channels are the four key avenues through which monetary policy is transmitted (Ouchchikh, 2018). Numerous studies have explored the functioning of these channels. However, the majority of them have been conducted in advanced countries, and evidence show the existence of cross-country heterogeneity in monetary policy transmission mechanism (e.g., Berben, Locarno, Morgan, and Vall s (2004), Montiel, Spilimbergo, and Mishra (2010), and Grandi (2019)). For developing economies, Montiel et al. (2010) argue that the monetary policy transmission mechanism could differ from advanced economies due to, among others, weak institutional frameworks, reduced role of securities markets, imperfect competition in the banking sector and the high cost of bank lending to the private sector.

In the meantime, developing countries have experienced noticeable improvements in many macroeconomic areas including the structure of their economies, more liberalization and development in financial markets, and modernization in economic policymaking including monetary policy frameworks among others. Nevertheless, challenges remain amid recurrent shocks at a global and local level and emerging uncertain- ties. Besides, as developing countries are at different stages of development, the transmission mechanism of monetary policy may differ.

The transmission mechanism of monetary policy in Rwanda has previously been studied (e.g. Davoodi, Dixit, and Pinter (2013), Berg, Charry, Portillo, and Vlcek (2013) and Mugisha (2018)) and showed some evidence of the interest rate, bank lending, and exchange channels while other studies such as Berg et al. (2013) highlighted some impediments on transmission such as policy regime and illiquid and underdeveloped financial markets. However, all these studies were conducted before the National Bank of Rwanda adopted the new monetary policy framework. This transition involved a shift in the intermediate target from broad monetary aggregate (M3) to the interbank rate, necessitating a re-examination of the transmission mechanism.

Furthermore, these previous studies did not explore any channel in-depth, providing a complete comprehension of that channel. Regarding exchange rate channel in particular, no previous study on Rwanda has attempted to contrast direct and indirect channels, and yet previous studies on exchange rate pass-through in Rwanda (e.g., Nuwagira (2015) and Hitayezu and Nyalihama (2019)) suggested a non-trivial influence of FRW depreciation on CPI inflation.

Against this backdrop, this study examines monetary policy transmission through the exchange rate channel in the case of Rwanda. Firstly, it evaluates the first stage of transmission, that is, whether monetary policy impulses affect exchange rates, using various models. Secondly, it evaluates the whole channel using the structural VAR framework and compares the strength of direct and indirect channels.

Identification of monetary policy shock has often been a challenge, especially in developing markets without advanced financial markets and this prevents the use of some identification schemes. Regarding the whole transmission channel, this study builds on the past literature especially studies which used a VAR framework and uses recursive identification and Bayesian estimation, which has many advantages especially when the sample period is relatively short. Regarding the first stage of transmission, this study adopted two approaches. One is based on the traditional UIP condition adapted to Rwanda realities. The second one is based on small VAR to address the possibility of simultaneity between interest rate and exchange rate as highlighted by Alper, Ardic, and Fendoglu (2009).

Results generally support the existence of the exchange rate channel in Rwanda. First, empirical evidence of the effect of policy impulse on the exchange rate suggests that the first stage of transmission exists, albeit with a partial pass-through. Secondly, the results

show further evidence of transmission via the direct channel, where the effect of policy rate shock on the exchange rate is directly transmitted to inflation, and the peak impact is attained after four quarters. However, the indirect channel is quasi-ineffective, as the output response, though in the right direction, was not statistically significant.

The remainder of this study is as follows: the next chapter reviews the existing literature. Chapter 3 outlines the methodology including models, data, and identification strategy. Chapter 4 presents and discusses the empirical results and chapter 5 concludes.

2. Review of the Literature

This part mostly reviews previous studies on exchange rate channel. Recall that the empirical analysis focuses on whether and how monetary policy interventions affect FRW exchange rate as the first stage in the whole exchange rate channel of monetary policy transmission. Secondly, the transmission in the whole channel including both direct and indirect channels is assessed. Therefore, this literature review covers both areas.

On the first stage of transmission, this study assesses the uncovered interest parity (henceforth, UIP) condition in Rwanda as the main framework via which exchange rate dynamics are analyzed in new Keynesian monetary policy models. Considering that earlier studies on UIP conditions have yielded dismal results and the strong assumptions surrounding it, the first stage of transmission is also assessed via VAR framework.

The second part encompasses the whole transmission channels notably how exchange rate movement affects domestic price inflation in a direct way, or indirectly via its effect on output and ultimately domestic price inflation in line with the Phillips curve.

Before discussing the literature, it is important to illustrate with figures, both direct and indirect exchange rate channels.

2.1. Conceptual framework

Figure 1 below depicts monetary policy transmission via the direct exchange rate channel. The channel operates through import prices. The transmission is rapid, and the impacts on prices (inflation) are immediate. From top to bottom, a change in the central bank rate directly affects market rates, then the exchange rate, which influences import costs, and finally, the total consumer price index components change.

Figure 1: Monetary Policy transmission, exchange rate channel (direct):

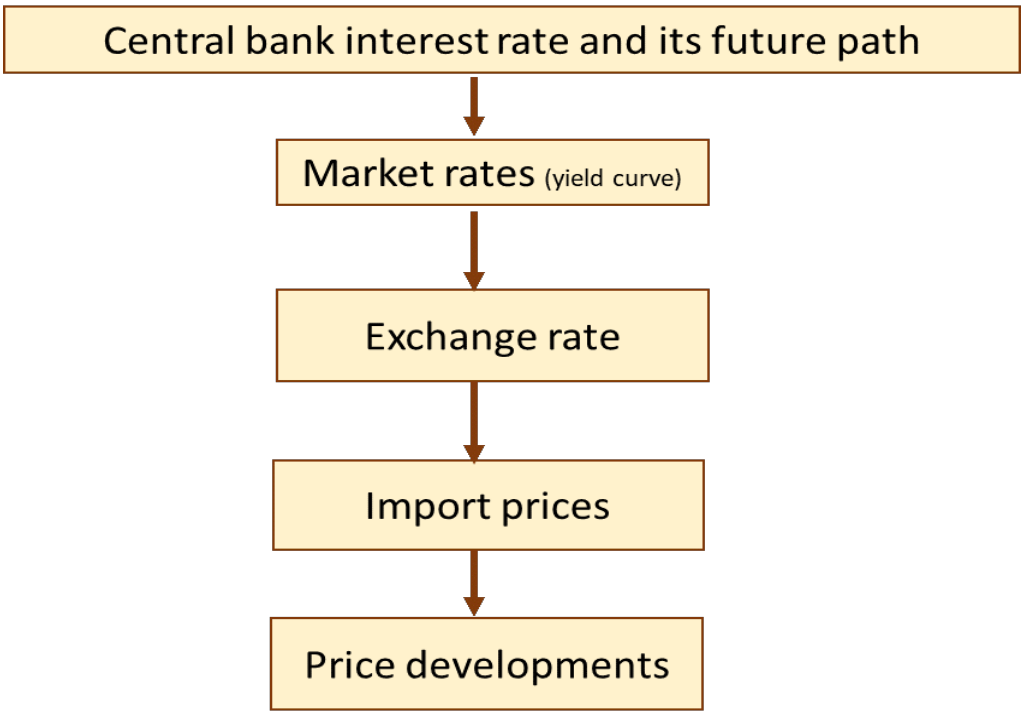
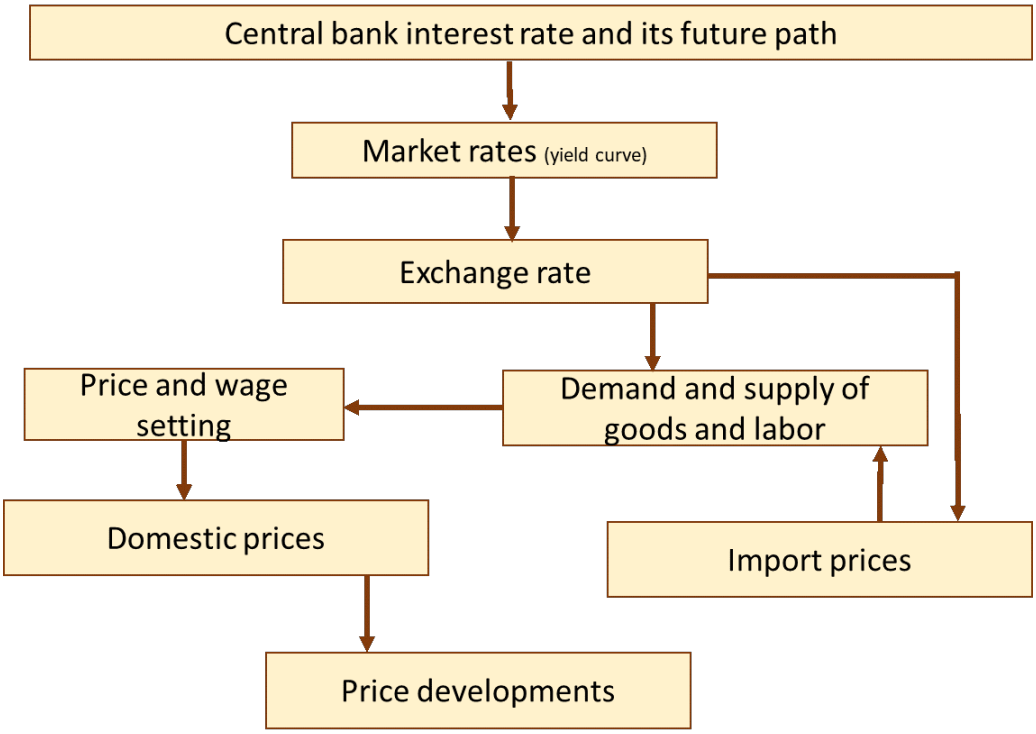


Figure 2 below illustrates the monetary policy transmission through the indirect exchange rate channel. In contrast to Figure 1, this channel operates via the influence on economic activity (demand and supply of goods and labor). The transmission is slow and has an indirect effect on prices (inflation). From top to bottom, a change in the central bank rate has an immediate impact on market rates, which affects the exchange rate. Exchange rate variations impact exports and imports following a substitution between foreign and domestic products and services. This impacts the overall demand and supply of goods, services, labor, and related prices. Finally, the components of the aggregate consumer price index change.

Figure 2: Monetary Policy transmission, exchange rate channel (indirect)



The following section reviews the literature on the first stage of transmission, focusing on the literature on the relationship between interest rate and exchange rate via UIP condition, its theoretical foundations, and results from some empirical studies.

2.2 Literature on the relationship between interest rate and exchange rate

In the new Keynesian monetary policy framework, the relationship between exchange rate and interest rates hinges on the UIP condition. The UIP is a no-arbitrage condition that tries to explain the relationship between the differential between the interest rate on an asset denominated in one currency and the interest rate on the same asset denominated in another currency and the expected change in the spot exchange rate between the two currencies (Isard, 2006).

The UIP concept is based on another close concept of covered interest parity (henceforth, CIP). The CIP postulates that an investor is indifferent between investing in an asset denominated in his country's currency with an expected return in the form of

interest rate. r_d and converting the sum into foreign currency at a future date and investing in foreign assets with interest r_f and converting it into domestic currency.

UIP condition hinges on interest arbitrage. Assumptions underlying the UIP condition include notably that assets are identical in terms of maturity, liquidity, and default risks, absence or negligible transaction costs, and funds placed do not influence interest rate. Besides, UIP assumes exchange rate flexibility, perfect capital mobility, and perfect asset substitutability and that agents have rational expectations and are risk neutral. (Gandolfo, 2016)

Nevertheless, UIP has a number of challenges. The main is a lack of empirical evidence, especially in studies on developed countries. In fact, while UIP postulates that the currency of a country with a higher interest rate will tend to depreciate, most empirical studies have refuted that, and some have rather shown a currency appreciation (Flood & Rose, 2001).

One of the reasons suggested by Flood & Rose (2001) is that most of the empirical tests of UIP were on countries with low inflation and flexible exchange rate regime and that for countries with higher inflation and exchange rate volatility or with lower financial depth, UIP can hold.

The empirical results from Flood & Rose (2001) show that for some countries, there are some signs of a UIP relationship as higher interest rates led to currency depreciation, although it was not a one-to-one relationship. Besides, country results were heterogeneous. Specifically, evidence of UIP condition was absent in countries with fixed exchange rate regimes.

Alper et al. (2007) argued that this absence of empirical evidence of UIP can be attributed to the fact that the two main assumptions in estimating the UIP conditions, namely the rationality of agents and the absence of risk aversion, do not hold. In addition to other factors such as transaction costs, less developed financial markets, weaker institutions and macroeconomic fundamentals, and the possibility of central bank interventions, among others. Besides, differences in liquidity and credit risks between domestic and foreign assets would also affect UIP condition.

In particular, central bank interventions may also affect the UIP condition as the central bank interventions to influence exchange rate movement using the policy rate imply

simultaneity between the expected changes in the exchange rate and interest rate differentials. According to Alper, et al. (2007), this simultaneity would lead to a lower or even negative coefficient beta 1.

Earlier empirical studies on UIP generally found no evidence of UIP condition (e.g. Froot & Thaler, 1990). These studies found that coefficients on interest rate differential were less than 1 and even negative in some cases. This wrong direction in a change in the exchange rate is usually called the "forward premium puzzle". Other earlier studies estimated the equation, including the proxy of risk premium. Taylor (1995) conducted a survey of some of these studies and showed that the models with the risk premium failed to find evidence of UIP conditions.

According to Alper, et al. (2007), most recent studies using more advanced quantitative techniques have come up with more UIP-compatible results. For instance, evidence of UIP was obtained in studies using short-term horizons like intra-day frequency (e.g., Chaboud & Wright (2005)) and also for more than 1-year horizon (e.g., Chinn (2006)). Other studies (e.g., Choi & Zivot (2007)) highlighted the importance of considering structural breaks in estimating the UIP equations and showed that considering structural breaks significantly improve the forward premium bias.

To address the simultaneity issue discussed above, a number of studies on the transmission from monetary policy impulse to exchange rate have used structural models such as VARs and DSGE. Some of these intended to analyze the whole exchange rate channel, which is how monetary policy affects inflation via exchange, while others aimed only at the first stage of transmission, which is the effect of monetary policy shock on the exchange rate.

Similar to studies on UIP, empirical results highlighted a number of factors that influence the potency of the exchange rate channel, including the level of economic development, liquidity, institutional strengths, and level of financial development, among others (Hnatkovska, et al., 2016).

For instance, Hnatkovska, et al. (2016) study pointed out the difference between developed and developing countries regarding the response of exchange rate to monetary policy tightening, whereas in developed countries, the exchange rate appreciated contrary to developing countries. (Eichenbaum & Evans, 1993) results for the US were in the same line, and their approach was to some extent similar to

Hnatkovska, et al. (2016), especially on identification as they used orthogonalized innovations in their VAR models. However, they considered alternative indicators of US monetary policy, namely the federal funds rate, the ratio of non-borrowed to total reserves and the Romer and Romer index. Other studies on developed countries (e.g., Kim & Roubini (2000)) have also yielded the same results.

Nevertheless, Cormun and De Leo (2017) highlighted the role of recursive identification in VARs as one of the reasons behind the puzzle of depreciation after monetary policy tightening. They argued that recursive identification confounds the effect of monetary policy shocks on the effect of news about the US business cycle and leads to the puzzle of depreciation after policy tightening. In their approach, they isolated the monetary policy response to US news to identify pure monetary policy shock in developing countries. The results show that the puzzle disappeared as a monetary policy tightening led to exchange rate appreciation.

2.3 Literature on the whole exchange rate channel

Regarding studies on the transmission channel, the literature on direct and indirect channels is vast. Apart from the DSGE approach, the structural VAR approach has been extensively used across different country cases, though the identification scheme could differ depending on the context. Variables used were more or less the same and included notably a measure of economic activity (real GDP or industrial production), a measure of price inflation, an indicator of monetary policy (policy interest rate or monetary aggregates), and the exchange rate (nominal, or nominal effective). Empirical evidence across numerous studies shows that transmission could be contingent on a number of factors, including the monetary policy framework, the exchange rate regime, the level of dollarization, and the level of financial development.

Regarding the exchange rate regime as one of the important factors to be taken into account in studies on monetary policy transmission. Mishra, et al. (2012) discussed some characteristics of emerging and developing countries that may impair the transmission mechanism via the exchange rate channel, including the fact that in these countries, the central bank's intervention in the exchange rate market is more likely. Previously, Goeltom (2008) study for Indonesia had shown that the exchange rate regime was crucial as during the period when the exchange rate was managed, the transmission via the exchange rate channel was weak, and when Indonesia adopted a floating exchange

rate, the transmission got more significant, especially via the direct channel. The possibility of an adverse effect of exchange rate management on transmission via the exchange rate channel was also highlighted by Berg, et al. (2013) in the case of East African Countries, including Rwanda.

Another important factor is the level of dollarization, as highlighted by Bordon (2010) in their study on Armenia. Using a Markov switching VAR to identify structural break separating the period before and after the adoption of inflation targeting and the period before and after dollarization. They analyzed different transmission channels; in particular, their results point out the strengthening of the exchange rate channel during the period of low dollarization. One of the explanations for this is the adverse effect of depreciation on agents' balance sheets, leading to lower aggregate demand.

Indeed, the policy framework would heavily influence the transmission mechanism, notably the adoption of inflation targeting-like frameworks, as indicated by evidence from studies on 40 emerging and developing countries (e.g. Brandao-Marques, et al.,2020) and on 4 East African Countries (e.g. Berg, et al. (2013)). On this one, Berg, et al. (2013) showed that in 4 East African Community countries, namely Kenya, Uganda, Tanzania and Rwanda, monetary policy framework impacted the transmission of monetary policy shock and across different channels, notably interest rate, bank lending, and exchange rate channel. Using the narrative approach la Romer and Romer, they argued that transmission was relatively more evident in Uganda and Kenya, where regimes were similar to inflation targeting lite, contrary to Tanzania and Rwanda, which, at that time, had a less clear stance of their monetary policy according to the authors. Regarding the exchange rate channel in particular, they highlighted that central banks' intervention in the forex market to smooth the exchange rate volatility could have impeded the transmission via the exchange rate channel in Rwanda. For the case of the three other countries, the transmission via a direct exchange rate channel was evident.

Other non-trivial factors include the level of financial development, central bank independence and transparency Brandao-Marques, et al. (2020).

The identification of monetary policy shock has always been crucial in studies on monetary policy transmission mechanisms. On one side, most of the studies using the VAR framework identified monetary policy shock based on the Taylor rule relationship (removing the effect of output and inflation from the policy indicator), sometimes using recursive identification despite its shortcomings highlighted in previous sections. On the

other side, the Romer and Romer narrative approach to identifying monetary policy shock is one of the alternatives to identification via structural VARs. In addition to the study by Berg, et al. (2013) discussed in the previous section, another example using the Romer and Romer narrative approach is the study by De Fiore (1998) for the case of Israel, where the exchange rate channel as well as bank lending channel were found to be important and active.

Study by Brandao-Marques, et al. (2020) on 40 emerging and developing economies used Taylor rule residual to identify monetary policy shock. They used the local projection method to consider the interactions and the possibility of non-linearities. Their model included the interaction of interest rate and nominal exchange rate, and the results suggested that the exchange rate amplifies the transmission of monetary policy shocks. Secondly, evidence of transmission via direct exchange rate channel as a contraction led to appreciation in the nominal effective exchange rate and a decline in prices.

In summary, studies with macro data used mostly VARs and DSGEs. For open developed economies with developed financial markets, most of the studies found evidence of transmission via the exchange rate channel (e.g., Franta, et al. (2014) for the Czech Republic, Kearns & Manners (2006) for the case of Australia, New Zealand, Canada, and the UK). A number of studies on emerging economies generally found evidence of the transmission (e.g., Fetai & Izet (2010) for Macedonia).

For developing economies, empirical evidence is mixed with the transmission but at a different degree. For instance, transmission via the exchange rate channel was found in Kenya by Davoodi, et al. (2013) and in Namibia by Sheefeni (2017), while results from other studies suggested limited transmission for Bangladesh (Ahmed & Islam, 2004), Uganda (Mugume, 2012) and Morocco (Ouchchikh, 2018).

The present study borrows from the previous studies discussed above while considering the realities of the Rwandan economy. Regarding the first stage of transmission, we adopt two approaches. First, considering the current policy framework, we assessed the relationship between interest rate and exchange rate within the UIP framework and took a more recent sample period, corresponding to the period when the NBR started to steer short-term interest rate. The risk premium will be proxied using the difference between the yields of 10Y Eurobonds with 10Y US T bonds. This first stage is assessed via single equation estimation as well as via the VAR framework. This VAR framework helps to deal with the simultaneity issues arising from the fact that monetary authorities may react to

exchange rate movements using policy interest rate. The VARs will also include alternative indicators of monetary policy, such as monetary aggregates, considering reforms made in monetary policy frameworks where, in the past, NBR used a monetary targeting framework before moving to a price-based monetary policy framework.

Secondly, we will analyze the whole MTM within structural VAR, which has the advantage of considering many variables that may affect transmission from policy variable to exchange rate in line with the past studies summarized in the previous section.

3. Methodology

3.1 First stage of transmission

As mentioned in the previous section, the first stage of transmission is analyzed via the traditional UIP framework and VAR framework. The UIP assumes rational expectations; hence, the expected exchange rate at t+1 is equal to its realization.

These assumptions lead to the following equation:

$$s_{t+1} - s_t = b_0 + b_1(r_t - r^*) + u_{t+1} \dots\dots\dots (1)$$

This involves testing whether the error term is unbiased and orthogonal to information available at time t and joint test whether b0=0 and b1=1.

Besides, this can be tested at different horizons. It is important to note that empirical evidence has mostly rejected the two hypotheses at shorter horizons, while some favourable evidence was found at longer horizons.

In line with Meredith and Chinn (1998), equation 5 can also be used to test for rational expectations in addition to the UIP condition. Under the assumption that the error term, which combines both risk premia and errors, is orthogonal, b1 should be equal to 1. Besides, Meredith & Chinn (1998) argued that even b0 different from 0 can still be consistent with UIP if we assume that some investors are not risk neutral, and the constant may represent a time-invariant risk premium.

Failure to find evidence of unbiasedness has led to different proposals to explain that bias. One is the existence of varying country risk premium, given that market participants are less likely to be risk-neutral.

Another important one is the simultaneity between interest rate and exchange rate as monetary policy decisions on policy interest rate could take into account exchange rate movements.

To address the issue of simultaneity and considering the fact that the journey of monetary policy framework modernization involved evolution in monetary policy instruments, several bivariate VARs have been estimated, ranging from using the repo rate and reserve money as proxies of monetary policy and, alternatively indicators of the FRW exchange rate, namely the FRW USD exchange rate and NEER. These include:

- Bivariate VAR with interest rate differential and log exchange rate;
- The same VAR model augmented with country risk premium;
- Bivariate VAR with reserve money/excess reserve with the exchange rate.

3.2 The whole exchange rate channel

To examine the whole exchange rate channel in Rwanda, a Bayesian VAR model was applied. From the literature, Bayesian methods have proven useful in estimating straightforward reduced-form VAR and dealing with issues of lack of long series and risk of over-parameterization. The BVAR models started since Doan et al. (1984) work based on Minnesota prior, which includes the prior mean of the VAR parameters to zero, and with a prior variance depending on two hyper parameters. This model estimation gives a good way of dealing with the issue of over-parameterization by integrating the past attained information.

Minnesota priors developed by Doan et al. (1984) and Litterman (1986) include approximating the variance-covariance matrix, Σ, with an estimate $\hat{\Sigma}$. Therefore, priors need to be formed only for α, which considers this form:

$$\alpha \sim N(\bar{\alpha}_{Mn}, \bar{V}_{Mn}) \quad \text{...(2)}$$

The Minnesota prior includes setting the elements of the parameter-prior $\bar{\alpha}_{Mn}$ and the covariance-prior $\bar{V}_{Mn}$. Still, the Minnesota prior considers the prior variance-covariance

matrix, where $\bar{V}_{Mn}$ refers to the diagonal, meaning that there is no association among the coefficients of the different Vector Autoregressive equations. Besides, the diagonal elements of the prior variance-covariance matrix are such that the most current lags of a variable are likely to cover more information about the variable's recent value than previous lags. Furthermore, lags of other variables are expected to have less information than lags of own variables.

The benefit of the Minnesota prior is that the subsequent posterior of the parameter vector α has a normal distribution. This permits us to compute the posterior mean of the estimates without having to recourse to different sampling techniques, which also decreases computational time significantly. The recursive identification scheme used for the benchmark SVAR is conserved in the Bayesian VAR description.

Thus, our BVAR specification is presented in the form below:

BVAR includes n variables and p lags

$$y_t = c + A(L)y_{t-1} + e_t \quad ; \quad E(e_t e_t') = \varepsilon_t \qquad (3)$$

Y_t is $Kx1$ vector of endogenous variables in period t, A_i is the coefficient matrix matching to the ith lag of y_t ,c is the constant deterministic term, and ε is an error term with zero mean and variance-covariance. Furthermore, the number of parameters in c and A is n(1+np). In addition to autoregressive adjustment throughout the prior settings, some other adjustments of the degree of the overall tightness hyper-parameter, the relative cross-variable weight hyper-parameter, the lag decay hyper-parameter and the exogenous variables hyper-parameter were vital to be identified. Generally, Bayesian coefficient estimates combine information in the prior with evidence from the data. It captures changes in beliefs about parameters and priors, which means initial beliefs (e.g., before data are seen), while the posterior means new beliefs (initial beliefs + evidence from data). The BVAR estimation focused on the equation made by food inflation, GDP non-agriculture, headline inflation, credit to the private sector, nominal exchange rate and policy rate.

By applying the Minnesota prior to equation on equation (2), the values for the prior are: l1=0.3, l2=0.8, l3=1.5, and mu1=100, to represent the overall tightness hyper-parameter,

the relative cross-variable weight hyper-parameter, the lag decay hyper-parameter, the exogenous variables hyper-parameter, respectively.

3.3. Data and motivation

This section describes data used for both the first stage of transmission and the whole transmission channel. Starting with the first stage, specifically on the UIP, the expected exchange rate is equal to the realized one as data on expectations are not available. Interest rates are alternatively, interbank rate or the T-bills rate. Country risk premium is proxied by the spread between the yield of Rwanda 10 years Eurobond and the 10 years US Bond. The data on these two variables are obtained from Bloomberg.

Regarding the whole transmission channel, some of the macroeconomic indicators are selected based on their significance on the domestic economy, and theoretical literature, which are considered in the analysis including international food prices, domestic economy proxied by non-agriculture output, headline inflation, credit to the private sector, nominal exchange rate and policy rate which is a weighted average of repo and reverse repo. International food prices are sourced from World Bank; non-agriculture output and headline inflation from National Institute of Statistics of Rwanda and the rest are obtained from National Bank of Rwanda.

The study uses quarterly data from 2006Q1 until 2022Q2, and these were treated to facilitate the interpretations and have good estimates with precision to guide policymakers especially when it comes to monetary policy decision-making. Data are seasonally adjusted and transformed into log difference. Thus, all series were stationary. On the UIP condition, data used are monthly and the sample began in 2013 when the NBR started to pursue flexible monetary targeting with the aim of steering the interest rate in preparation to move to an interest rate-based monetary policy framework.

Regarding the identification strategy, on the Bayesian VAR, we apply recursive identification with Cholesky decomposition in line with some past literature on monetary policy transmission (e.g. (Eichenbaum and Evans (1993), Davoodi et al. (2013)) and considering the reality of the Rwandan economy.

This identification scheme requires a specific ordering of variables, starting from the most exogenous onwards. Thus, variables were ordered starting with global food prices, followed by non-agriculture GDP, headline inflation, credit to the private sector, nominal

exchange rate of FRW against USD, and policy rate proxied by weighted average of interest rate on repo and reverse repo operations. The policy rate is ordered last as it has been the main monetary policy instrument since the end of 2012 when NBR started to use flexible monetary targeting. This allows for controlling innovations in other variables ordered ahead and this is in line with the policy framework where the policy rate is endogenous to those macroeconomic variables.

4. Results

4.1 Estimation results

Equation 1 was estimated using the least square methods and results show no evidence of UIP as the co- efficient of interest rate differential was not statistically different from zero. The alternative specification which included the risk premium as the additional independent variable also didn't yield evidence of UIP in Rwanda. Results from a simple VAR model with interest rate differential and change in log of FRW exchange rate also did not provide empirical evidence of UIP relationship in Rwanda. However, knowing the issue of endogeneity between interest rate and exchange rate, this would not necessarily imply the absence of a relationship between interest rate differential and exchange rate.

Meanwhile, a simple bivariate VAR estimation with the policy rate and the change in log of FRW ex- change rate show rather some signs of transmission in the first stage. The increase in repo rate leads to a deceleration in depreciation as expected, while an increase in the rate of change in reserve money leads to more depreciation although not statistically significant. Considering the NEER as an alternative indicator for the exchange rate, its reaction to either the shock on repo rate is in the right direction as an increase in policy rate lead to a deceleration in depreciation, however, it is not statistically significant.

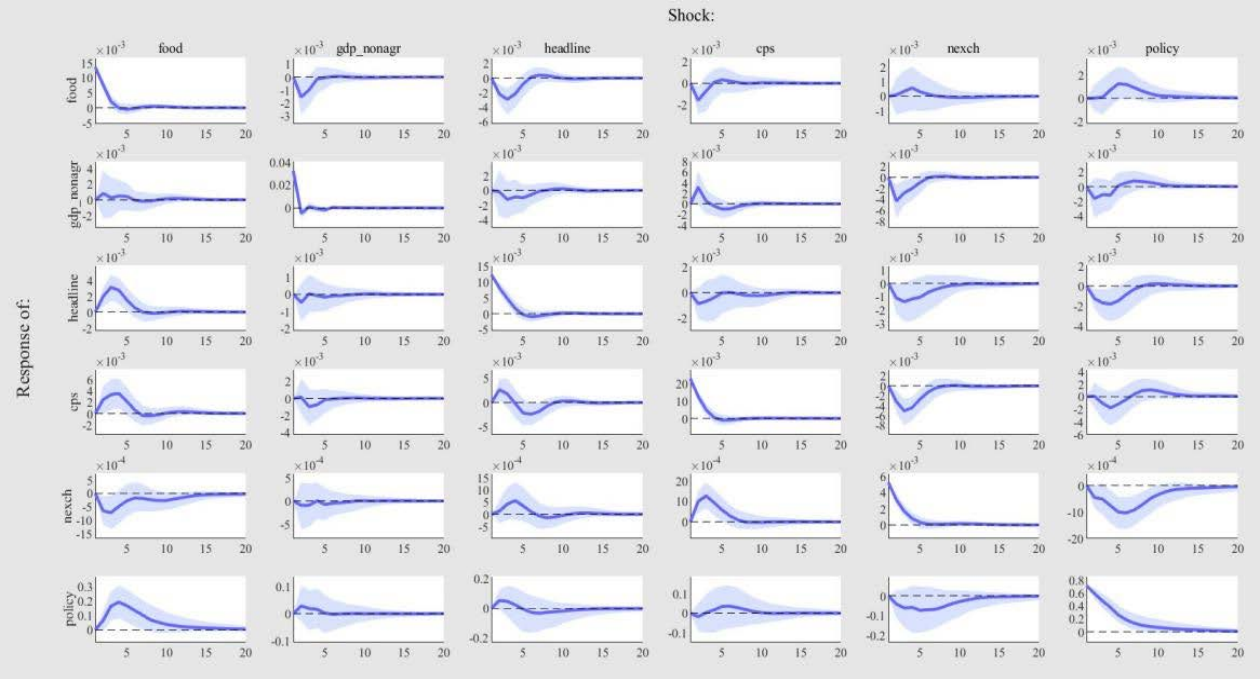
Regarding the whole transmission channel, results from the Bayesian VAR estimation described in the previous section, indicate the presence of transmission via direct channel. An increase in policy rate leads to a deceleration of the FRW

depreciation and headline CPI inflation. The effect on headline inflation starts to appear in the next quarter and peaks in the 4th quarter as shown in the next figure. In addition, the transmission is incomplete as the dynamic pass-through elasticity is very low (-0.0012).

Nevertheless, there is no solid evidence of an indirect channel. In fact, there are encouraging signs as the reaction of the output is in the right direction as the appreciation of the exchange rate leads to a decline in the output, but not statistically significant; This may be due to the limited impact of the changes in relative prices on net exports and output (lower price elasticity of import and export).

In terms of speeds of transmission, prices react relatively more quickly to the initial impact of a monetary policy shock and after reaching the maximum in the fourth quarter, the impact of these shocks becomes weaker over time and produces less persistent effects on prices. This is relatively quicker compared to other case studies such as the study of Franta et al. (2014) showed that the extreme impact of a monetary policy shock on prices/inflation occurs approximately four to eight quarters after the shock in Czech Republic.

Figure 3: Impulse response function from Bayesian VAR estimation



Source: Author's computation

4.2 Discussion of results

Previous studies on Rwanda (Berg et al. (2013) and Davoodi et al. (2013)) had not found evidence of an ex- change rate channel of monetary policy transmission. Important to note that the sample period was mostly prior to monetary policy reforms. Berg et al. (2013) argued that it was hard to disentangle the channel due to the prevailing exchange rate policy regime during the decade 2000-2010.

Our findings suggest that with reforms in policymaking and monetary policy framework in particular, the exchange rate channel has become potent in monetary policy transmission in Rwanda. Nevertheless, the bulk of evidence points out to the direct channel where the effect on the exchange rate is directly transmit- ted to price inflation while the effect via the indirect channel is quasi-absent as the impact on output is not statistically significant though in the right direction. The absence of an indirect channel can be associated to among others the inelasticity of tradable goods, services, and factors of production in Rwanda. Nuwagira and Muvunyi (2016) found some impact of change in the exchange rate on the current account in Rwanda. However, the export sector was less sensitive to changes in exchange rates. This is mostly due to the structure of Rwanda's exports which has

historically been dominated by commodities such as minerals, tea, and coffee whose prices and demand are more dependent on the global economic situation.

On this, ongoing initiative to diversify Rwanda exports could lead to more responsiveness of exports on change in FRW exchange rate and subsequently more potent exchange rate channel. Due to data unavailability, we could not properly analyze whether these initiatives undertaken in the last 5 years have led to some improvements. Future analysis would shed more light on this.

4.3 Robustness check

We checked the robustness of our results by estimating the same version of VAR model but using maximum likelihood estimation and with recursive identification of monetary policy shock and the change in log of FRW nominal exchange rate instead of the nominal effective exchange rate.

Results were generally in line with the Bayesian estimation discussed above, with minor exceptions. One is the response of FRW exchange rate depreciation on policy shock. Though it is in the right direction, it seems to appear in the 3rd and 4th quarter after the policy shock. This may be attributed to the fact that maximum likelihood estimation gives more weight to information from data compared to Bayesian estimation and our sample period includes the period prior to 2013 monetary policy reforms where the repo rate was not always reflecting the policy rate and the nominal FRW exchange rate was relatively less flexible as it currently is. Another exception is the reaction of output gap to shock on repo rate, which is statistically significant this time contrary to the case of Bayesian estimation.

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5. Conclusion and policy recommendation

The effective implementation of monetary policy requires to understanding of the channels of the trans- mission mechanism for monetary policy and how it influences other macroeconomic variables. This study assessed how the monetary policy is transmitted through the exchange rate channel in the case of Rwanda. The examination of this channel was performed using bivariate VARs to examine the first stage and Bayesian VARs models to evaluate the whole channel. Empirical results revealed that in Rwanda, the transmission of the monetary policy via the exchange rate channel exists.

First, there is evidence of the first stage of transmission, which is the effect of policy impulse on the exchange rate. Secondly, the results show further evidence of transmission via the direct channel, where the effect of policy rate shock on exchange rate is directly transmitted to inflation, and the peak impact is attained after four quarters. However, the indirect channel is ineffective, as the output response, though in the right direction, was not statistically significant.

Taking stock of these results, the effectiveness of NBR policy move is reinforced by subsequent change in FRW exchange rate and this can be crucial in achieving price stability. Besides, the current analysis of monetary conditions which combines both policy rate and exchange rate provides a better picture especially in terms of future inflation path. Therefore, NBR interventions to tame exchange rate volatility via selling or buying of foreign currencies to the market, can be equally important in the current framework, if this is not excessive to alter the trend of exchange rate depreciation and take into consideration the level of reserves.

The quasi-absence of the indirect channel is a reminder that economic structural reforms that could boost productivity in tradable sector and reduce Rwanda's external imbalance, as well as financial sector development, and policy implementation must continue.

Lastly, with past evidence of bank lending channels in Rwanda, both channels can supplement each other and reinforce NBR policy transmission. Further research is needed with the enriched dataset to continue monitoring the functioning of the transmission mechanism in Rwanda and support evidence-based decision- making.

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Appendices

Appendix A: OLS estimation of UIP equation

Dependent Variable:
DL_RWF_USD Method: Least
Squares
Date: 08/03/23 Time: 11:53
Sample (adjusted): 2013M05 2022M06
Included observations: 110 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INTEREST_DIFF	-0.01263	0.020046	-0.63014	0.5299
C	0.475307	0.075065	6.331937	0

R-squared	0.003663	Mean dependent var	0.430273
Adjusted R-squared	-0.00556	S.D. dependent var	0.240202
S.E. of regression	0.240869	Akaike info criterion	0.008888
Sum squared resid	6.265937	Schwarz criterion	0.057988
Log likelihood	1.511138	Hannan-Quinn criter.	0.028803
F-statistic	0.397078	Durbin-Watson stat	0.592477
Prob(F-statistic)	0.529933		

Appendix B: OLS estimation of UIP equation with risk premium

Dependent Variable:
DL_RWF_USD Method:
Least Squares
Date: 08/03/23 Time: 11:53
Sample (adjusted): 2013M05 2022M06
Included observations: 110 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INTEREST_DIFF	-0.01263	0.020046	-0.63014	0.5299
C	0.475307	0.075065	6.331937	0
Adjusted R-squared	-0.00556	S.D. dependent var		0.240202
S.E. of regression	0.240869	Akaike info criterion		0.008888
Sum squared resid	6.265937	Schwarz criterion		0.057988
Log likelihood	1.511138	Hannan-Quinn criter.		0.028803
F-statistic	0.397078	Durbin-Watson stat		0.592477

NEW LOOK AT THE BANK LENDING CHANNEL OF THE MONETARY POLICY TRANSMISSION MECHANISM IN RWANDA

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Abstract

This paper investigates the existence of the bank-lending channel in the transmission of monetary policy in Rwanda for the period 2014Q1 to 2022Q4. We directly estimate the loan-supply equation using the recently developed bootstrap bias-corrected Least square Dummy Variable (BC-LSDV) technique. The findings indicate that there is evidence of an operational bank lending channel in Rwanda. The interaction term between central bank indicator with capital and liquidity does not appear to be a relevant factor in determining the differential impact of monetary policy on the lending behavior of banks. Further, segregating banks by size, we find that the effect of monetary policy is more pronounced for the medium-sized banks compared to larger sized banks. The findings provide support for the central bank's recent move from monetary targeting to price-based monetary policy to strengthen the effectiveness of the monetary policy. It is therefore important that the National Bank of Rwanda should explore the set of tools in its purview to ensure that policy changes affect loan portfolios of the entire bank system as intended.

Key Words: Monetary policy transmission mechanism, Bank lending channel, Panel data bootstrap bias-corrected least square Dummy variable

JEL Classification Numbers*: C33, E44, E52, G21*

1. Introduction

The mechanism through which monetary policy is propagated to the real economy remains a puzzle in monetary policy analysis. Extensive studies such as Jamel Boukhatem & Mouldi Djelassi (2022), Disyatat(2010,) and Chileshe(2018) have recently investigated the role played by banks in the monetary policy transmission mechanism aimed at uncovering a bank lending channel and assessing their relative significance in monetary policy. The monetary policy channels[8] behave differently across countries, widely due to variations in the level of financial sector development, and macroeconomic and structural conditions, among other factors. The perception of the mechanism through which monetary policy decisions are propagated becomes essential in achieving the central bank's ultimate objectives of price and macroeconomic stability, which would be particularly important for the National Bank of Rwanda.

In Rwanda, the financial system is dominated by banking institutions, leaving banks as the main sources of funding for individuals and businesses. According to studies such as Cottalerri and Kourelis (1994), it has been observed that financial markets in developing countries exhibit lower changes in lending rates. As a result, the effectiveness of the monetary policy transmission mechanism is limited, and its impact is more noticeable in developed countries with developed financial systems. Bernanke and Gertler (1995) demonstrated that the possible effect of monetary policy on the supply of loans from the banking system highlighting the important role that banks play in the economy by facilitating savings– investment process known in the literature as the bank-lending channel. For example, an expansionary monetary policy injects new reserves into the banking system, which in turn triggers banks into raising the supply of loans, which in turn leads to an increase in investment spending and economic growth.

Literature shows that undeveloped financial markets and a rigid exchange rate regime leave little room for the interest rate to play a role in the monetary transmission mechanism, which requires more studies on the bank lending channel not only to have a better choice of intermediate targets but also to act as a basic channel for monetary policy decisions to influence economic activity. In particular, if the lending channel is an important part of the transmission mechanism, then the banks' asset items should be the focus of more attention. The importance of the lending channel depends on the extent to which banks adjust their loan supply following changes in bank reserves as a reaction function to central bank decisions.

[8] Interest rate, bank lending, exchange rate, expectations, and asset price channels

In such circumstances, there is little scope for the functioning of the conventional interest rate channel, because alternative channels are likely to be weak, and banks are by far the dominant formal financial intermediaries in developing economies (Mishra et al., 2012).

While the previous empirical studies widely use time series techniques to examine the effectiveness of the interest rate channel of monetary policy in Rwanda, the more recent research tend to focus on individual bank behaviour using panel data models. The only study specifically on the bank lending channel of monetary policy transmission in Rwanda conducted by Kamanzi et al.(2019) showed that the bank loan supply rises in response to expansionary monetary policy, although its effect remains limited.

The objective of this paper is to assess the existence of the bank lending channels of monetary policy transmission in Rwanda by utilizing disaggregated bank-level data and exploiting the heterogeneity of banks' responses to monetary policy decisions. The testing of the bank lending channel has gained importance not only due to the recent shift of monetary policy framework but also, the significant structural change witnessed by the Rwandan banking sector in both operation and regulation. This study departs from previous studies, particularly the study done by Kamanzi et al. (2019) on a specific case of Rwanda using the Generalized Method of Moments (GMM). The problem with the GMM estimator is that it is usually suitable for large cross-section units and can be severely biased and imprecise in panel data with a small number of cross-sectional units similar to the current study. Following the shortcomings of the GMM estimator, we apply the recently developed bootstrap bias-corrected LSDV estimator proposed by De Vos et al. (2015) which is shown to have superior small-sample properties compared to GMM estimators and maintain relatively small coefficient uncertainty while removing most of the bias. In addition, it allows for heteroscedasticity and has the potential to be applicable in non-standard cases through adequate modification of the bootstrap resampling scheme.

The rest of this study is organized as follows. Section 2 describes the Literature Review. Section 3 presents the Rwandan sector. Section 4 indicates **E**conometric Framework and Data Issues, while Section 5 reports the empirical results and Section 6 describes the conclusion.

2. Literature Review

2.1 Theoretical Framework

Bernanke and Gertler (1995) provide a comprehensive theoretical framework that explains the bank lending channel and its role in the transmission of monetary policy. The authors highlight the significance of banks as financial intermediaries and their unique role in the credit creation process. In this study, we present an alternative view of the bank lending channel within the IS/LM framework. This alternative perspective enhances our understanding of the bank lending channel's role and contributes to a more nuanced analysis of monetary policy's impact on the economy. On the one hand, the model will help us to understand the identifying restrictions underlying the econometric approach, followed in the empirical literature to uncover the lending channel, and, on the other hand, will enable us to define a testing strategy. The model draws heavily on Bernanke and Blinder (1988) and departs from their model in the way money supply modeled and monetary policy is implemented.

Let us assume that we have an economy with three different agents or sectors and four assets. The agents are the non-banking sector, the banking sector, and the central bank. The central bank sets monetary policy either by changing the reserve requirement ratio, setting the discount interest rate, or controlling the bond rate by conducting open market operations. In either case, banks react by changing the amount of reserves as well as the other items on their balance sheets. In our model, we explicitly assume that the central bank sets monetary policy by changing the discount rate or the money market rate, but the model can easily be adapted to deal with other monetary policy instruments. The four assets are deposits held by the private sector with banks, loans granted by banks to the private sector, reserves held by banks for legal and liquidity reasons and bonds held by banks for liquidity reasons and by the non-financial sector for liquidity and or portfolio motives. For the money market, we assume a conventional LM curve[9]. The demand for money (in the form of deposits held with a typical bank) by the non-monetary sector is the conventional money demand function:

[9] The curvature of the conventional LM curve represents the shape or slope of the relationship between the interest rate and the level of real income or output. It is typically upward sloping with a moderate degree of curvature, indicating that as the interest rate increases, the impact on income or output diminishes. Factors such as money supply and money demand dynamics contribute to the curvature. However, the curvature can vary depending on assumptions and model specifications.

$$d_t^d = \alpha_0 + \underset{(+)}{\alpha_1 y_t} + \underset{(-)}{\alpha_2 \pi_t} + \underset{(-)}{\alpha_3 i_t} \quad \text{.....(2.1)}$$

where d_t^d stands for the nominal deposits held by the private sector at a typical bank, y_t, a scale variable (for instance real GDP), π_t the inflation rate, and i_t the interest rate on bonds. Below each coefficient in equation (2.1) is the corresponding expected sign according to the conventional economic theory.

We write the (real) money supply as

$$d_t^s = \beta_0 + \underset{(+)}{\beta_1 R_t} + \underset{(+)}{\beta_2 l_t} + \underset{(+)}{\beta_3 i_t} + \underset{(-)}{\beta_4 r_t} \quad \text{.....(2.2)}$$

where R_t stands for the bank reserves, l_t for the interest rate on loans, i_t for the interest rate on bonds, and r_t for the relevant monetary policy interest rate controlled by the central bank. We note that equation (2.2) should be perceived as a simplification of the textbook equation, according to which the money supply is equal to bank reserves times the money multiplier, which, in turn, is a function of l_t, i_t, r_t and the required reserve ratio (assumed constant for simplicity).

In equilibrium equations (2.1) and (2.2) determine the equilibrium interest l_t and the equilibrium quantity of money for given y_t, π_t, l_t and r_t. Let us now focus on the credit market. The loan demand by the non-banking sector may be specified as

$$c_t^d = \delta_0 + \underset{(+)}{\delta_1 y_t} + \underset{(-)}{\delta_2 \pi_t} + \underset{(-)}{\delta_3 l_t} + \underset{(+)}{\delta_4 l_t} \quad \text{.....(2.3)}$$

where y_t captures the transactions' demand for credit, π_t the uncertainty in the economy, and i_t the possibility of the private sector having access to sources of funding that are not perfect substitutes for bank loans. The null $\delta_3 \neq 0$ captures the idea that borrowers cannot fully insulate their real spending from changes in the availability of bank credit.

For the loan supply, we have

$$c_t^s = \gamma_0 + \underset{(+)}{\gamma_1 d_t} + \underset{(-)}{\gamma_2 \pi_t} + \underset{(+)}{\gamma_3 l_t} + \underset{(-)}{\gamma_4 i_t} \quad \text{.....(2.4)}$$

It is assumed that loan supply depends on the level of total deposits held by the private sector with the banks, on the inflation rate as a measure of uncertainty in the economy as well as on the loan and bond interest rates (Bernanke and Blinder,1988). Assets held by banks in the form of bonds are seen as substitutes for loans, held mainly for liquidity reasons. The null $\gamma_1 \neq 0$ in (2.4) captures the idea that banks cannot shield their loan portfolios from changes in monetary policy, i.e., from changes in deposits brought about by monetary policy, and plays a central role in our analysis. Also important is the coefficient γ_3 as it determines the slope of the supply curve[10]. Equilibrium in the credit market will determine the equilibrium loan interest rate, l_t, and the equilibrium quantity of real bank credit, C_t^s for given y_t, C_t^d, π_t and i_t. Finally, plugging the equilibrium values for i_t and C_t^d obtained from the money market into the equilibrium equations for l_t and C_t^s, we find the reduced form equations for l_t and C_t^s as a function of the exogenous variables of the model: R_t, y_t, π_t and r_t.

The lending channel operates through shifts in the loan supply curve in response to changes in monetary policy. To see how it operates in our model, let us assume, for instance, that the central bank increases the discount rate, r_t. This will reduce the equilibrium quantity of money in the economy, i.e., deposits in our model, through the interaction between money supply and money demand schedules i.e., (2.1) and (2.2).In turn, the drop in deposits held by the private sector with the banks shifts the loan supply schedule upwards if $\gamma_1 \succ 0$ in (2.4). It is this additional transmission mechanism – the upward shift in the supply of loans – which is known in the literature as the bank-lending channel.

As mentioned above, at the micro level the existence of a lending channel rests on the assumption that banks cannot easily replace lost deposits with other sources of funds, such as certificates of deposits or new equity issues, or by selling securities.

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[10] The slope of the loan supply curve indicates the responsiveness of loan supply to changes in the interest rate. A steeper slope suggests a higher cost of borrowing and a more elastic loan supply, while a flatter slope indicates a lower cost of borrowing and a less elastic loan supply. The slope provides insights into how lenders adjust their lending behavior in response to interest rate changes, influencing credit conditions and economic activity.

Otherwise, we would expect γ_1 not to be significantly different from zero. Of course, for the upward shift to occur the supply curve cannot be horizontal. In other words, we need the additional assumption that γ_3 (2.4) is finite. To test the existence of the credit channel and evaluate its importance we need to estimate γ_1 and γ_3 in equation (2.4), test whether γ_1 is positive and significantly different from zero and that γ_3 is not very large. The credit channel is more important the larger γ_1 and the smaller γ_3 .

Incorporating the bank lending channel into the IS/LM framework, have contributed to a more comprehensive understanding of the dynamics at play. These alternative perspectives have challenged traditional assumptions and enriched the analysis of how changes in monetary policy affect bank lending and the broader economy and help us to identify important variables to be used in our model specification in the rest of the study.

2.2 Empirical Review

The empirical review on the bank lending channel examines the evidence from various studies investigating the relationship between monetary policy, bank lending, and its impact on the economy. Through rigorous analysis of data, methodologies, and econometric techniques, researchers have shed light on the existence and mechanisms of the bank lending channel. This review critically evaluates the empirical findings, highlighting key results and methodological nuances. By synthesizing the empirical evidence, we gain a deeper understanding of the role played by the bank lending channel in transmitting monetary policy effects to the broader economy.

Empirical findings on the effectiveness of the bank lending channel in the monetary transmission mechanism are rather mixed. Walker (2012) investigated the existence of bank lending channels in the East African Community (EAC) namely Burundi, Kenya, Rwanda, Tanzania, and Uganda. The study applied different GMM techniques to micro-level data for the period 1993 to 2008. The results revealed stronger evidence of bank lending channels for well-capitalized banks and smaller banks as compared to better-capitalized banks and larger banks. In addition, it established that this particular outcome was of a more economically significant magnitude. The

findings alluded to the common supposition that a bank lending channel of monetary policy transmission exists for EAC economies when considered as a whole, and the study considered this as fundamental to a proposed creation of a monetary union. However, liquid asset ratios were found to be of less significance in explaining bank credit supply or the extent to which credit supply reacts to tight monetary policy.

Using GMM on bank-specific panel data, Opolot (2013) and Matousek and Solomon (2017) confirm the existence of bank lending channels in Uganda and Nigeria respectively. Both studies found that individual bank characteristics such as liquidity and capitalization influence loan supply. More liquid and highly capitalized banks in Uganda were found to react less strongly to monetary policy changes than less liquid, less capitalized banks supporting the findings by Walker (2012) for Uganda. In Nigeria however, bank characteristics were found to be more responsive to changes in money supply other than interest rates.

The Bank lending channel was also confirmed to be effective in South Africa by Siichei (2005), sing quarterly bank-level data for the period 2000Q1-2004Q4. The dynamic panel estimation methods have been utilized and the results showed that an increase in the repo rate was associated with a decrease in the supply of loans. However, the loan supply of large and highly capitalized banks was found to be more resilient to adjustments in monetary policy confirming the assertion by Bernanke and Gertler (1995)[11]. Work by Kashia and Opiela (2000), Kayshap and Stein (1997), and Kashyap and Stein (1995) also report the existence of bank lending channels with small, less liquid undercapitalized banks being most responsive to monetary policy.

Using micro-firm level data from Bank-Scope and macro country-level data from WDI databases, Amidu (2014) investigated broad determinants of credit supply in 26 sub-Saharan African (SSA) countries for the period 2000 to 2007. The study, which employed a two-step system GMM estimator, found that real interest rates significantly reduced bank lending in SSA in general but only for EAC when the study considered regional groupings. The analysis also found that bank size had significant positive effects on credit supply in ECOWAS, EAC SADC, and SSA in general. However, the results found significant adverse effects of capitalization only for ECOWAS and EAC where a capitalization reduction translated into a decrease in credit supply. Macroeconomic condition as expressed through GDP per capita

[11] Empirical studies confirm the assertion made by Bernanke and Gertler (1995) that the loan supply of large and highly capitalized banks is more resilient to adjustments in monetary policy. Well-capitalized banks demonstrate a greater ability to maintain stable lending levels even in the face of changes in interest rates. This highlights the significance of bank capitalization in the effectiveness of the bank lending channel and underscores the importance of financial stability in monetary policy transmission.

growth was found to influence bank lending significantly only in SSA in general and SADC in particular, but not for other economic blocs.

Motivated by the lack of assessment of the financial reforms, deregulation, consolidations, financial innovations, and joint payment systems, Lungu (2007) assessed the process of monetary transmission mechanism by investigating evidence of a bank lending channel in SADC during the period 1990– 2006 using data from the banking sector. The study applied a vector autoregression (VAR) model to data from all SADC countries in the sample to identify shifts in the loan supply curve in response to changes in monetary policy. The findings revealed mixed results but overall the study found evidence of the existence of a bank-lending channel in all SADC countries in the sample. Further, the study found that the take-off point for monetary policy effects differs from one country to another.

Another study on bank lending channels involved a transition economy—Poland. Specifically, Havrylehyk and Jurzyk (2005) studied the impact of monetary policy upon lending channels. The data was obtained from balance sheets of 109 banks and 5 large credit unions in Poland during times of expansionary monetary policy from 1995 to 2002. Their results generally disagree with the bank lending channel hypothesis although they find some evidence of bank lending channels based on size characteristics. The findings of the study further revealed that there were significant differences between foreign and domestic banks in their responses to changes in short-term interest rates as foreign banks reacted more strongly than domestic banks.

In the specific case of Rwanda, the study done by Kamanzi et al.(2019) showed that bank loan supply increases following an expansionary monetary policy, although its effect is still limited. Therefore, the debate on the existence of bank lending channel remains inconclusive given mixed empirical findings. It is worth emphasizing that the majority of reviewed empirical literature reports the existence of bank lending channel, more generally dependent on the health and size of the banking sector. The healthier and bigger the sector, the weaker the expected effect of monetary policy actions; the weaker the banking sector the stronger the expected impact of monetary policy movements.

3. Rwandan Banking Sector

The banking sector plays an important role as a financial intermediary and primary source of financing for the private sector. Banks are the main providers of essential financial services, and their development has been of paramount importance in

facilitating and supporting the economic growth, and transformation process in Rwanda.

The banking sector remains a dominant in the Rwandan financial sector , accounts for, on average, over 65.0 percent of the total financial sector assets in the last five years.(see Table 1) Given its significant size in the financial system the banking sector remains the largest source of financing to the broader economy. Therefore, the usefulness of monetary policy through the bank lending channel is anticipated to reflect the market structure and intensity of competition in the financial system.

Table 1. Structure of Rwandan Financial system

	Dec_10		Dec_18		Dec_19		Dec_20		Dec_21		Dec_22	
	Number	share in TA	number	share in TA	number	share in TA	Number	share in TA	Number	Share TA	number	share in TA
Banking sector	14	71.3	16	66.4	16	65.9	16	68.0	16	67.2	15	67.3
Insurers	8	10.2	16	9.7	14	9.7	15	9.3	15	9.3	17	9.4
Pension schemes	1	14.9	13	17.4	13	17.8	13	16.5	13	17.4	13	16.2
MFIs	11	3.7	459	6.0	457	6.1	457	5.6	457	5.6	457	5.8

Source: Authors' own computations

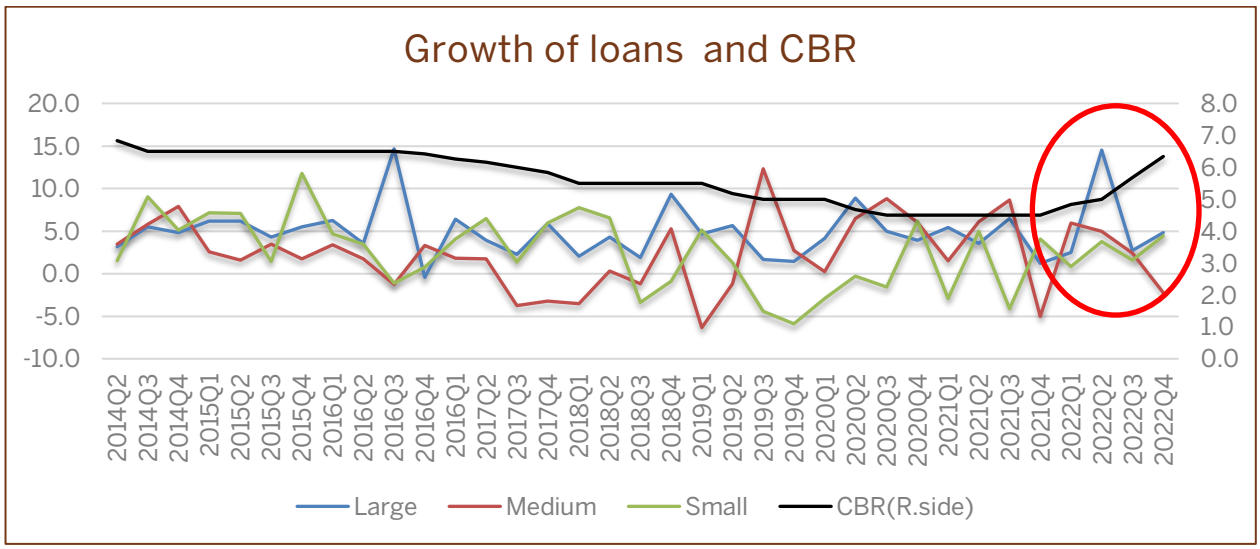
Despite an increase in the number of commercial banks during the past two decades, the Rwandan banking sector has remained highly oligopolistic in nature. The market structure indicates that the five large banks account for more than 80 percent of total loans and 77 percent of total assets of banking sector (see Table 2).

Table 2. Bank's size

Size	Count	Share of total assets	Share of total loans
Large	5	77.0%	83.0%
Medium	6	21.6%	15.0%
Small	3	1.4%	1.0%

Source: Authors' own computations

Figure 1: Growth of loans and Central Bank Rate (CBR)



Source: Authors' own computations

This figure shows the heterogeneity of banks to react on monetary policy decisions. Thus, for large banks, monetary policy effects may be attenuated by the strength of their specific bank characteristics while tight monetary policy reduce loan supply for small and medium banks (see figure 1).

4. Econometric Framework and Data Issues

4.1 Estimation strategy

This study relies on the panel data approach, where the behavior N of cross-sectional units is observed overtime, providing a solution to accommodate the joint occurrence of dynamics and unobserved individual heterogeneity in examining bank lending channels for Rwandan monetary policy. Let us consider a homogeneous dynamic panel data model of order ρ

$$y_{it} = \alpha_i + \sum_{s=1}^{\rho} \gamma_s y_{i,t-s} + x_{it}\beta + \varepsilon_{it} \quad \text{.....(4.1)}$$

With $i = 1,\ldots,N$ and $t = 1,\ldots,T$ being the cross-section and time-series dimension respectively and where y_{it} is the dependent variable, x_{it} is a $(1 \times (k-\rho))$ vector of strictly exogenous explanatory variables, where k is the total number of time-varying regressors, and α_i is an unobserved individual effect that may be correlated with x_{it} and

ε_{it} is the error term, assuming that it is serially uncorrelated, both within and over cross-sections.

To simplify the notation, we assume that the initial values $(y_{i,-(\rho-1),\ldots,}y_{io})$ are observed such that T is the actual time series dimension available for estimation. However, since Nickell (1981) showed that the Least Square Dummy Variable estimator (LSDV) is not consistent for finite t in autoregressive panel data models, several consistent instrumental variables (IV) and Generalized Method of Moments (GMM) estimators have been proposed in the econometric literature as an alternative to LSDV (see Anderson and Hsiao,1982, Arellano and Bond 1991, Arellano and Bover 1995; Blundell and Bond 1998). The IV and GMM estimators are consistent for N large, so they can be severely biased and imprecise in panel data with a small number of cross-sectional units which is our case (Kiviet 1995, Ziliak 1997; Bun and Kiviet 2006; Roodman 2009; Bun and Windmeijer 2010).

Following the shortcomings of the IV and GMM estimators, Kiviet (1995) introduced a group of bias-corrected LSDV estimators which are shown to have superior small-sample properties compared to GMM estimators and maintain relatively small coefficient uncertainty while removing most of the bias. Soon after, the bootstrap bias-corrected LSDV estimator merged in econometrics literature(see De Vos et al., 2015), with a few modifications to the Kiviet (1995) estimator, allowing for heteroscedasticity, It is similar to those of the Kiviet correction but, has the potential to be applicable in non-standard cases through an adequate modification of the bootstrap resampling scheme.

Stacking observations over time and cross-sections we gain,

$$y = W\delta + D\alpha + \varepsilon \quad \ldots\ldots(4.2)$$

Where y is the $(NT \times 1)$ vector stacking the observations

$y_{it,}W = (y_{-1,\ldots,}y_{-\rho,}X)$ y_{it}, $W = (y_{-1,\ldots,}y_{-\rho,}X)$ is the $(NT \times k)$ matrix stacking observations on the lags of the dependent variable $(y_{i,t-1,\ldots,}y_{i,t-\rho,})$ and the exogenous explanatory variables x_{it}, $\delta = (\gamma', \beta')'$ is the $k \times 1$ parameter vector of interest, and D is a $NT \times N$ dummy variable matrix calculated as $D = I_N \otimes \iota_T$

$D = I_N \otimes \iota_T$ with $T \times 1$ a vector of ones. The variance-covariance matrix ε is denoted Σ. Let

$M_D D = I_N \otimes (I_T - D(D'D)^{-1}D')$ signifies the symmetric and idempotent matrix that transforms the data into deviations from individual specific sample means $M_D D = 0$, the individual effect α can be eliminated from the model by multiplying equation (4.2) by M_D.

$$\begin{aligned} M_D y &= M_D W\delta + M_D D\alpha + M_D \varepsilon \\ \tilde{y} &= \tilde{W}\delta + \tilde{\varepsilon} \end{aligned} \quad \text{.....(4.3)}$$

$\tilde{y} = M_{Dy}$ indicates the centered dependent variable and similarly for the other variables. The least squares estimator δ in the model (4.3) defines the FE estimator:

$$\tilde{\delta} = (\tilde{W}'\tilde{W})^{-1}\tilde{W}'\tilde{y} = (W'M_D W)^{-1}W'M_D y \quad \text{.....(4.4)}$$

We further need the bootstrap algorithm to correct the bias of the FE estimator which is an extended version of the approach presented in Everaert and Pozzi (2007). The underlying idea is that the FE estimator $\hat{\delta}$ is biased but still an unknown function of the true parameter vector, which means that,

$$\mathrm{E}(\hat{\delta}|\delta,\Sigma,\mathrm{T}) = \int_{-\infty}^{+\infty} \hat{\delta} f(\hat{\delta}|\delta,\Sigma,\mathrm{T}) d\hat{\delta} \neq \delta \quad \text{.....(4.5)}$$

with E being the expected value and f the probability distribution of $\hat{\delta}$ for the given population parameter vector δ, the covariance matrix of the error terms Σ, and sample size T. If we can generate a sequence $(\hat{\delta}_1,...,\hat{\delta}_J|\delta,\Sigma,\mathrm{T})$ of J biased FE estimates $\hat{\delta}$ δ, the integral in equation (4.5) can be written as:

$$\mathrm{E}(\hat{\delta}|\delta,\Sigma,\mathrm{T}) = \lim_{J\to\infty} \frac{1}{J}\sum_{j=1}^{J} \hat{\delta}_j|\delta,\Sigma,\mathrm{T} \quad \text{.....(4.6)}$$

Equation (4.6) shows that an unbiased estimator δ can be obtained as the value $\hat{\delta}^{bc}$ that yields the FE to have a mean of $\hat{\delta}$ over the J repeated samples. Formally, $\hat{\delta}^{bc}$ is an unbiased estimator for δ if it satisfies

$$\hat{\delta} = \lim_{J\to\infty} \frac{1}{J}\sum_{j=1}^{J} \hat{\delta}_j \left|\hat{\delta}^{bc},\Sigma,\mathrm{T}\right. \quad \text{.....(4.7)}$$

The proposition in Everaert and Pozzi (2007) is that for any specific value of δ^*, the condition in equation (4.7) can be evaluated by generating J bootstrap samples from the data-generating process in equation (4.2) and applying FE to each of the samples to

obtain the sequence $(\hat{\delta}_{1,}...,\hat{\delta}_{J} \mid \delta^{*},\Sigma,\mathrm{T})$. The bias-corrected $\hat{\delta}^{bc}$ can then be obtained by searching over different parameter values δ^{*} until equation (4.7) is satisfied. Everaert and Pozzi further suggest that the search $\hat{\delta}^{bc}$ can be performed well in iterative to update the parameter vector δ^{*} used for the creation of bootstrap samples, taking the original biased FE estimate as the best initial guess $(\delta^{*}_{(0)} = \hat{\delta})$. To hold various distributional assumptions about the error term ε_{it}, our bootstrap algorithm includes several parametric error sampling and non-parametric error resampling options. All of these rely in some way on the rescaled error terms $\overset{r}{\varepsilon}_{it}$

$$\overset{r}{\varepsilon}_{it} = \hat{\varepsilon}_{it}\sqrt{\frac{NT}{NT-k-N}} \qquad \text{.....(4.8)}$$

where rescaling is necessary to correct for the fact that the estimated error terms ε_{it}, obtained in the bootstrap algorithm, have a lower variance than the population error terms $\hat{\varepsilon}_{it}$.

4.2 Empirical strategy

To assess the extent to which monetary policy may affect banks' lending behavior, we use a dynamic panel data model which is the most used in the existing stock of knowledge (see, for example, Berrospide and Edge, 2010; Brei and Gambacorta, 2014; Borio et al., 2015). We specify an empirical model to examine the effect of monetary policy on banks' loan supply while controlling for a wide range of factors possibly affecting loan supply as follows:

$$Loan_{it} = \omega_{i} + \omega_{1}cbr_{t} + \omega_{2}Z_{it} + \omega_{3}cbr_{t}Z_{it} + \omega_{4}rgdp_{t} + \omega_{5}\inf_{t} + \omega_{6}npl_{it} + \omega_{7}rgdp_{t}Z_{it} + \omega_{8}\inf_{t}Z_{it} + \varepsilon_{it}$$

where $Loan_{it}$ stands for bank loans, cbr_{t} the monetary policy rate, and Z_{it} for a measure of a bank-specific characteristic (size, liquidity, or capitalization) and where interactions appear in all the potentially relevant variables. Under our empirical specification, the fact that the estimated ω_{1} is (significantly) negative and ω_{3} is (significantly) positive is taken as evidence of the existence of the bank-lending channel. It captures the combined effect of monetary policy actions and individual bank characteristics on lending. The conventional practice is to include bank-specific characteristics such as bank size (SIZE), liquidity ratio (LIQR), and capital ratio (CAPR) in the empirical model. Key macroeconomic control variales included in the

model are real GDP ($rgdp_t$) to capture loan demand effects; the inflation rate ($\inf_t$). These two macroeconomic indicators are included in the estimator order to capture the monetary transmission mechanism. They also control for demand shocks. According to the interest rate channel, business cycle expansion increases the number of profitable projects and therefore the demand for credit.

We also include the ratio of non-performing loans to total loans (NPL) as a proxy for credit risk. We assume that the risk of loan default is mainly reflected in the proportion of realized bad loans to total loans. The increase in the proportion of realized NPLs would in turn induce banks to reduce exposure to high-risk borrowers to maintain a strong loan book. It is equally important to measure the interaction between individual bank-specific characteristics and macroeconomic factors. A positive and statistically significant interactive coefficients of bank specific characteristics and GDP indicate that ceteris paribus, boost loan demand as well as provide banks with an incentive to increase their lending, while the interaction between individual bank-specific factors with inflation may increase the likelihood of reducing the rate of loan demand.

4.3 Data Issues

In this paper, quarterly micro-bank level and macroeconomic data spanning 2014Q1 until 2022Q4 are utilized to test the validity of the bank lending channel of monetary policy transmission in Rwanda. All variables, except those expressed in percentage, are expressed in log difference to account for the panel-data level effects. In the estimations, we use balance sheet information on a sample of 14 banks.

4.4 Empirical Evidence

This section describes some important statistics and empirical findings derived from the estimation of equation (4.9) with a panel data of 14 banks operating in Rwanda.

Table 3 provides descriptive statistics of the banking sector in Rwanda and some macroeconomic indicators. During the period between 2011Q1 and 2022Q4, the change in growth in bank loans was 2% on average. The central bank rate was around 5.7%, reflecting NBR's policy of containing inflation. There has also been significant volatility in a change in the growth rate of loans ranging from a decline of 5.1% to a growth of 4.7%. In addition, the standard deviation and the range in the change of lending growth rate are quite considerable, suggesting diverse loan growth rates. For the bank characteristics, the average growth in the size of banks has been around 0.6%, and liquidity and capitalization decreased by an average of 39% and 7% respectively. Furthermore, the table also shows that there has been substantial

variation in the growth of these bank characteristics. Key macroeconomic indicators of inflation, and real GDP growth rate are, on average, approximately 4.5% and 6.6% respectively.

Table 3: Summary statistics

VARIABLES	N	mean	sd	Min	max	skewness	Kurtosis
Dloan	482	0.0240	0.904	-5.136	4.758	-0.235	12.38
Cbr	504	5.671	0.803	4.500	7	-0.135	1.582
Dlsize	486	0.00645	0.723	-2.798	2.829	-0.102	5.403
Dliqr	484	-0.391	12.83	-51.48	42.54	-0.0408	3.752
Dcapr	486	-0.0721	12.08	-74.95	75.40	-0.249	16.77
Rgdp	490	6.557	5.346	-12.40	20.60	-1.007	6.563
Infl	504	4.570	4.558	-0.632	21.10	1.796	6.526
Dnpl	490	0.0607	7.882	-73.09	65.38	-0.423	29.40

Source: Authors' own computation

Table 4 displays the correlation coefficients for our identified variables and the matrix depicts the correlation between all the possible pairs of values. There is a negative significant correlation between the central bank rate and loan supply. The bank size is statistically correlated with bank loans and other variables of interest broadly have consistent relations which is a good indication for the empirical exercises. Most correlation coefficients are quite moderate, which suggests that multicollinearity should not be a major concern and multiple regressions should be conducted so that the results are appropriate for statistical inferences.

Table 4: Correlation matrix of variables

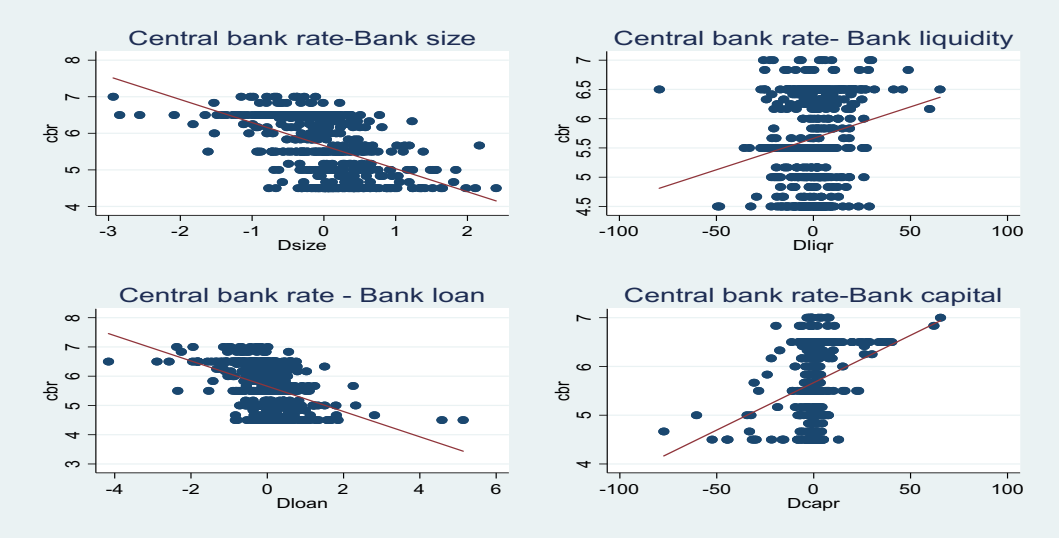
	Dloan	Cbr	Dlsize	Dliqr	Dcapr	Rgdp	infl	Dnpl
Dloan	1.00							
cbr	-0.42*** (0.00)	1.00						
Dlsize	0.89*** (0.00)	-0.53*** (0.00)	1.00					
Dliqr	-0.43*** (0.00)	0.19*** (0.00)	-0.29*** (0.00)	1.00				
Dcapr	-0.65*** (0.00)	0.27*** (0.00)	-0.56*** (0.00)	0.25*** (0.00)	1.00			
rgdp	0.01	0.05	0.00	-0.00	0.03	1.00		

	(0.89)	(0.24)	(0.96)	(0.98)	(0.52)			
infl	0.15**	0.02	0.19***	0.07	-0.05	-0.42***	1.00	
	(0.00)	(0.59)	(0.00)	(0.13)	(0.31)	(0.00)		
Dnpl	0.03	0.07	-0.00	-0.00	-0.23***	-0.14**	-0.03	1.00
	(0.52)	(0.12)	(0.92)	(0.99)	(0.00)	(0.00)	(0.52)	

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: Authors' own computation

The scatter plots and the best-fitting linear lines of the central bank rate versus the variables' bank-specific characteristics are presented in figure 2.

Figure 2: Scatter plots central bank rate with bank characteristics



Source: Authors' own computation

4.2 Full sample baseline results

The impact of monetary policy within the bank lending channel necessitates banks to modify their deposits in response to a central bank's decision. Thus, our expect signs are a negative coefficient on the indicator of central bank decision and a positive coefficient on the interactive terms for central bank decision and bank-specific characteristics, signifying that banks' indicators are the payoff for monetary policy shocks. We employ multiple models (model 1 to model 8) to assess whether the inclusion of additional variables enhances the accuracy of the estimates.

Table 5: Baseline estimation (full sample)

	Mdel1	Mdel2	Model3	Model4	Model5	Model6	Model7	Model8
Dloan(-1)	-0.139***	-0.146***	-0.284***	-0.376***	-0.166***	-0.272***	-0.376***	-0.041
	(0.040)	(0.044)	(0.048)	(0.098)	(0.047)	(0.043)	(0.098)	(0.045)
Cbr(-1)	-0.115**	-0.104*	0.013	0.051	-0.107**	0.032	0.051	-0.093*
	(0.055)	(0.056)	(0.053)	(0.072)	(0.045)	(0.059)	(0.072)	(0.051)
Dlsize	0.839***							0.859**
	(0.083)							(0.345)
Dliqr	-0.009***							-0.029
	(0.002)							(0.018)
Dcapr	-0.016***							-0.014
	(0.004)							(0.035)
rgdp	0.005*	-0.002	-0.017***					-0.001
	(0.003)	(0.003)	(0.006)					(0.002)
infl	0.006	0.004	0.016**					0.002
	(0.006)	(0.006)	(0.007)					(0.005)
Dnpl	-0.010	-0.013	-0.010	-0.010	-0.012	-0.009	-0.010	-0.011
	(0.011)	(0.014)	(0.013)	(0.019)	(0.014)	(0.015)	(0.019)	(0.013)
Cbr×size		0.129***			0.141***			-0.004
		(0.018)			(0.011)			(0.049)
cbr×liqr		0.000			-0.001***			0.004
		(0.001)			(0.000)			(0.003)
cbr×capr		-0.002			-0.003***			-0.000
		(0.001)			(0.001)			(0.005)
rgdp×size		0.011	0.077***			0.073***		0.007
		(0.007)	(0.005)			(0.005)		(0.006)
rgdp×liqr		-0.001**	-0.001***			-0.001**		-0.001*
		(0.000)	(0.000)			(0.000)		(0.000)
rgdp×capr		-0.001	-0.001			-0.001		-0.001
		(0.001)	(0.001)			(0.001)		(0.001)
infl×size		0.005		0.067***			0.067***	0.003
		(0.010)		(0.008)			(0.008)	(0.012)
infl×liqr		-0.001		-0.001***			-0.001***	-0.000
		(0.001)		(0.000)			(0.000)	(0.000)
infl×capr		0.000		-0.002			-0.002	0.001
		(0.001)		(0.001)			(0.001)	(0.001)
N	375	375	375	441	441	375	441	384
N_g	14.000	14.000	14.000	14.000	14.000	14.000	14.000	14.000

Source: Authors' own computation

The results from the baseline regression show that monetary policy has a lagged effect on banks' loan supply behavior since its coefficient is negative and statistically significant. The coefficient for bank size exhibits a positive and statistically significant relationship, aligning with the expected outcome based on prior knowledge. This suggests that greater capitalization levels are indicative of improved financial health, enabling banks to extend loans to businesses more effectively.

We do not find the expected signs for bank liquidity and capital individually, this could imply that increases in both capital and liquidity might have a strong desire to meet regulatory requirements, so as reducing lending growth. The estimated coefficients for the interactive terms between the central bank indicator and bank-specific indicators exhibit mixed results. Specifically, the interactive coefficient between the central bank indicator and bank size is positive and statistically significant, suggesting that in an environment where banks possess sufficient asset bases, the monetary policy stance encourages them to provide a greater supply of loans. However, the coefficients for other interactive terms, such as the interaction of policy rates with levels of liquidity and capital, are found to be statistically insignificant. This indicates that the interaction between these variables does not have a significant influence on the supply of loans.

Moreover, the coefficient on the scale variable real GDP is positive and statistically significant implying that an increase in economic growth will lead to an increase loan supply while the coefficient on inflation is statistically insignificant. Surprisingly, deterioration in banks' asset quality reflected in an increase in the share of non-performing loans (credit risk) does not affect banks' credit supply. This observation can be attributed to the relatively low levels of non-performing loans (NPLs) in the Rwandan banking sector. As a result, any increases in NPLs are likely to remain within the risk tolerance thresholds set by the banks.

The impact of the monetary policy stance on the supply of loans may also depend on the size of the bank, thus we isolate banks into big and medium banks to assess the impact of the monetary policy stance. The rule of thumb is that large banks tend to be much more liquid and better-capitalized than smaller banks. Thus, for large banks, monetary policy effects may be attenuated by the strength of these specific bank characteristics.

Thus, we run a regression on different sub-samples vis- -vis the benchmark equation (9) without any modifications and the results are reported in two subsequent tables 6 and 7.

Table 6: Monetary Policy and Bank lending among medium banks

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dloan(-1)	-0.182*	-0.067	-0.436***	-0.269	-0.172	-0.451***	-0.269	0.008
	(0.094)	(0.167)	(0.072)	(0.185)	(0.110)	(0.061)	(0.185)	(0.130)
cbr(-1)	-0.083	-0.059	-0.003	0.028	-0.097	-0.018	0.028	-0.099*
	(0.060)	(0.054)	(0.096)	(0.081)	(0.094)	(0.126)	(0.081)	(0.055)
Dlsize	0.753***							1.587**
	(0.158)							(0.677)
Dliqr	-0.005							0.010
	(0.005)							(0.015)
Dcapr	-0.033**							-0.057
	(0.016)							(0.055)
rgdp	-0.012	0.006	-0.010					0.005
	(0.011)	(0.021)	(0.030)					(0.005)
infl	0.006	0.038**	0.038					0.031***
	(0.018)	(0.018)	(0.038)					(0.009)
Dnpl	0.003	0.008	-0.023	-0.005	-0.001	-0.023	-0.005	0.007
	(0.011)	(0.026)	(0.044)	(0.017)	(0.015)	(0.042)	(0.017)	(0.006)
cbr×size		0.155***			0.136***			-0.095
		(0.050)			(0.023)			(0.108)
cbr×liqr		0.001			-0.001			-0.001
		(0.003)			(0.001)			(0.002)
cbr×capr		-0.008			-0.004			0.005
		(0.008)			(0.003)			(0.008)
rgdp×size		-0.017	0.041			0.045***		-0.024***
		(0.022)	(0.027)			(0.013)		(0.008)
rgdp×liqr		-0.001	-0.001			-0.000		-0.001
		(0.002)	(0.001)			(0.001)		(0.001)
rgdp×capr		0.005	-0.001			-0.002		0.004**
		(0.006)	(0.003)			(0.002)		(0.002)
infl×size		-0.028		0.027*			0.027*	-0.036
		(0.072)		(0.015)			(0.015)	(0.023)
infl×liqr		-0.001		-0.000			-0.000	-0.002
		(0.001)		(0.001)			(0.001)	(0.001)
infl×capr		-0.004		-0.005*			-0.005*	-0.004*
		(0.004)		(0.002)			(0.002)	(0.002)
N	129	129	129	162	162	129	162	132
N_g	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000

Source: Authors' own computation

The estimated results show that medium-sized banks moderately respond to monetary policy action as indicated by the statistical significance of the coefficient

on the lagged measure of monetary policy and its interaction term with bank size, this implies that medium-sized banks also apply size effects in mitigating the adverse effects of monetary policy. The deterioration in the medium banks' asset quality reflected in an increase in the share of non-performing loans (credit risk) does not reduce banks' loan supply, since its coefficient is statistically insignificant. However, liquidity levels of banks are found to be negatively related to the supply of loans and are statistically significant. The negative relationship may imply that banks may turn to their liquid assets to offer more loans, especially during periods of tight monetary policy, thus maintaining their loan portfolio. However, the more loans a bank disburses, the less the liquid assets it holds consistent with the findings by (Kabiro, 2014).

Table 7: Monetary policy and bank lending among large banks

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dloan(-1)	-0.064	-0.057	-0.217	-0.270***	-0.073**	-0.208	-0.270***	-0.027
	(0.040)	(0.061)	(0.135)	(0.065)	(0.032)	(0.139)	(0.065)	(0.029)
cbr(-1)	-0.037	-0.012	0.184**	0.119	-0.030	0.157**	0.119	-0.017
	(0.040)	(0.056)	(0.085)	(0.079)	(0.027)	(0.071)	(0.079)	(0.023)
Dlsize	0.938***							1.078***
	(0.036)							(0.204)
Dliqr	-0.009***							0.003
	(0.002)							(0.010)
Dcapr	0.011							0.013
	(0.010)							(0.043)
rgdp	0.001	0.008	-0.004					0.003**
	(0.003)	(0.006)	(0.009)					(0.002)
infl	0.005	0.019	0.029					0.013**
	(0.005)	(0.011)	(0.024)					(0.005)
Dnpl	0.006	0.006	0.006	-0.011	-0.001	0.001	-0.011	0.011**
	(0.009)	(0.011)	(0.028)	(0.023)	(0.011)	(0.025)	(0.023)	(0.005)
cbr×size		0.148***			0.155***			-0.022
		(0.025)			(0.008)			(0.032)
cbr×liqr		-0.000			-0.002***			-0.002
		(0.001)			(0.000)			(0.001)
cbr×capr		0.000			0.001			0.001
		(0.005)			(0.001)			(0.006)
rgdp×size		0.014	0.070***			0.076***		0.004
		(0.015)	(0.007)			(0.006)		(0.008)
rgdp×liqr		0.000	-0.001			-0.000		0.000
		(0.001)	(0.001)			(0.001)		(0.000)
rgdp×capr		0.001	0.003			0.004*		-0.001

		(0.003)	(0.004)			(0.002)		(0.002)
infl×size		-0.011		0.069***			0.069***	-0.017**
		(0.021)		(0.007)			(0.007)	(0.008)
infl×liqr		-0.002		-0.002***			-0.002***	-0.001
		(0.001)		(0.001)			(0.001)	(0.001)
infl×capr		-0.000		0.003			0.003	-0.001
		(0.005)		(0.004)			(0.004)	(0.003)
N	114	114	114	165	165	114	165	117
N_g	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Source: Authors' own computation

The estimated coefficient for monetary policy stance is moderately positive and significant for large banks. This could imply that the tight monetary policy condition is beneficial to big banks as they can increase their margins with higher policy rates and at the same time able to extend more loans given their adequate assets levels.

We also find that the interaction terms for liquidity and capitalization with the monetary policy indicator are insignificant, implying that monetary policy stance interacting with liquidity and capitalization for big banks does not have an impact on loan supply behavior. There could be an equity-at-risk effect, meaning that banks would have less risk-taking incentive if there is a high level of equity in the place. In other words, even when banks with high capital are capable of raising deposits, they might still refrain from making more loans. However, the interaction term between monetary policy indicator and bank size, is positive and significant, consistent with theoretical propositions buy Bernanke and Gertler (1995) and other empirical findings(see, for example studies by Walker,2012; Opolot,2013 and Matousek and Solomon,2017;Kamanzi et al.,2019).This implies that banks with large asset values can maintain their loan supply in the face of tight monetary policy conditions.

Conversely, deterioration in large banks' asset quality reflecting an increase in the share of non-performing loans (credit risk) does not reduce the appetite of large banks' loan supply. In broad consideration, the result from both sub-sample estimations is consistent with our baseline estimates (full sample).

5. Conclusion

This study examines the existence of bank lending channel in Rwanda using the bootstrap bias-corrected LSDV estimator proposed by De Vos et al.(2015) which is shown to have superior small-sample properties compared to GMM estimators and maintain relatively small coefficient uncertainty while removing most of the bias.

The results from the baseline regression (full sample) show that monetary policy affects banks' loan supply behavior since its coefficient is negative and statistically significant. The coefficient of bank size exhibits a positive and statistically significant relationship, consistent with our prior expectations. This suggests that higher levels of capitalization are associated with improved financial health, enabling banks to provide loans to businesses more effectively. We do not find the expected signs for bank liquidity and capital individually, this could imply that increases in both capital and liquidity might be strongly linked to meeting regulatory requirements, thereby reducing lending growth.

The interactive terms between central bank indicator and bank-specific indicators are somehow mixed. The interactive coefficient for central bank indicator and bank size is positive and statistically significant, implying that a tight monetary policy stance in an environment of banks with adequate assets base leads to rising loan supply. Others are statistically insignificant, meaning that the interaction of policy rates with levels of liquidity and capital does not influence the supply of loans. Moreover, the scale variable, real GDP is positive and statistically significant implying that increases in economic growth rates will lead to rising loan supply while the effect of inflation on loan supply is insignificant.

Given the landscape of the banking system in Rwanda where large banks dominate, one possible explanation for this is that the large banks are still able to expand their loan portfolio despite increases in central bank rates due to their bigger asset base. In terms of bank-specific factors, the study reveals that the asset base is statistically significant and positively related to the supply of loans. The estimated coefficient for monetary policy stance is moderately positive and significant for large banks. This could imply that the tight monetary policy condition is beneficial to big banks as they can increase their margins with higher policy rates while, at the same time, able to extend more loans given their adequate assets levels. Conversely, deterioration in large banks' asset quality reflecting an increase in the share of NPLs (credit risk) does not reduce the appetite of large banks to increase their loan supply. The findings provide support for the central bank's recent move from monetary targeting to price-based monetary policy to strengthen the effectiveness of the monetary policy.

The policy implication from the findings is that the central bank's monetary policy decisions would continue to produce large distributional effects on the reserves of banks with large-sized banks better equipped to cope with tight monetary policy stance. Therefore, the central bank should explore the set of tools in its purview to ensure that its policy actions do not disproportionately disadvantage the relatively smaller banks within the Rwandan banking sector.

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Appendix

Interbank as an indicator of monetary policy (full sample)

	Model1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Dloan(-1)	-0.268***	-0.245**	-0.442***	-0.500***	-0.274***	-0.465***	-0.500***	-0.117***
	(0.097)	(0.108)	(0.060)	(0.080)	(0.095)	(0.091)	(0.080)	(0.029)
ibr(-1)	-0.002	0.027	0.033	-0.010	0.040***	0.043	-0.010	0.014
	(0.026)	(0.030)	(0.031)	(0.027)	(0.015)	(0.033)	(0.027)	(0.022)
Dlsize	0.647***							0.430
	(0.101)							(0.347)
Dliqr	-0.010***							-0.041
	(0.003)							(0.027)
Dcapr	-0.020*							-0.107*
	(0.010)							(0.060)
Rgdp	0.001	-0.004	-0.019**					0.004
	(0.004)	(0.004)	(0.009)					(0.004)
Infl	0.013**	0.016*	0.022**					0.007
	(0.006)	(0.009)	(0.010)					(0.005)
Dnpl	0.001	0.001	-0.000	0.005	0.003	-0.001	0.005	0.001
	(0.009)	(0.010)	(0.010)	(0.009)	(0.010)	(0.012)	(0.009)	(0.013)
ibr×size		0.133***			0.128***			0.056
		(0.020)			(0.012)			(0.059)
ibr×liqr		-0.001			-0.002***			0.006
		(0.001)			(0.001)			(0.004)
ibr×capr		-0.001			-0.003*			0.016*
		(0.002)			(0.001)			(0.009)
rgdp×size		0.004	0.062***			0.059***		0.004
		(0.011)	(0.008)			(0.009)		(0.008)
rgdp×liqr		-0.000	-0.001			-0.000		-0.000
		(0.000)	(0.000)			(0.000)		(0.001)
rgdp×capr		-0.002	-0.002			-0.002		0.000
		(0.001)	(0.001)			(0.002)		(0.001)
infl×size		-0.016		0.054***			0.054***	0.005
		(0.012)		(0.009)			(0.009)	(0.007)
infl×liqr		-0.000		-0.001***			-0.001***	-0.000
		(0.001)		(0.000)			(0.000)	(0.001)
infl×capr		-0.001		-0.003***			-0.003***	0.000
		(0.001)		(0.001)			(0.001)	(0.001)
N	325	325	325	434	434	325	434	335
N_g	14.000	14.000	14.000	14.000	14.000	14.000	14.000	14.000

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

DETERMINANTS OF NON-PERFORMING LOANS AND ITS FEEDBACK EFFECTS ON MACROECONOMIC PERFORMANCE: THE CASE OF RWANDA

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Abstract

This paper investigates the determinants of non-performing loans (NPLs) in the Rwandan banking sector for the period 2012Q1 to 2022Q1. The study uses the bias-corrected fixed effects (BCFE) for the dynamic panel data. The findings reveal that the level of NPLs is explained by macroeconomic conditions such as credit growth, Real Gross Domestic Product (RGDP) growth, and real effective exchange rate. However, inflation is not significant for BCFE, but it is for fixed effect (FE) used as a benchmark. Banks' specific characteristics, namely real interest rate, growth of loans, size, capital adequacy ratio, operating efficiency, and income diversification, were found to be important determinants of NPLs in Rwanda. The study also affirms the robust feedback mechanisms originating from the banking sector via non-performing loans, exerting a tangible influence on the real economy. The main implication from the findings is that the National Bank of Rwanda should continue ensuring macroeconomic stability while reinforcing banking sector supervision, putting in place policies to ensure that the banks avoid excessive lending by maintaining solid credit standards so as to prevent a sharp buildup of NPLs.

***Key Words**: Non-performing loans, Bias-corrected fixed effects, Panel VAR*

***JEL Classification Numbers**: G21, G32, E44, C23*

1. Introduction

Banks are generally exposed to a diversity of risks, such as credit, financial, operational and strategic, and macroeconomic risks. The main activity of banks is to finance the economy by giving out loans to different economic agents. These loans constitute the largest share of banks' total assets, and consequently, credit risk becomes the key risk for banks (Marcucci & Quagliariello, 2009). In Rwanda, the ratio of bank loans to total assets of the banking sector averaged 56.9 percent in the last decade. While the level of NPLs signals the degree of crystallization of key risks, elevated NPLs can be dangerous for macro-financial stability. It is widely believed that rising NPLs are often precursors to financial crises and bank failures. For example, the financial crisis of 2007/2008 was attributed to the rapid default of the United States subprime mortgage. Therefore, assessing the determinants of NPLs becomes an important empirical enterprise worldwide, particularly in Rwanda, where credit risk is more prevalent than other risks that the banking sector faces.

Elevated NPLs impedes not only the growth of the banking sector but also economic growth. As Klein (2013) observes, an increase in NPLs diminishes liquidity, reduces banks' profitability, limits credit growth to viable economic entities, and restrains economies to low growth as the real sector slows down, causing an increase in unemployment. Although the classification of NPLs differs across countries, IMF (2019) and regulation No 12/2017 of 23rd November 2017 of the National Bank of Rwanda on credit classification and provisioning, classify a loan as non-performing if payments (principal and/or interest) due have not been paid for at least 90 days.

Since financial liberalization began in 1995, the Rwandan financial sector has undergone pro- found changes characterized by the deregulation of interest rates, abolition of credit ceilings, market determination of interest and exchange rates, and the adoption of indirect monetary policy instruments. There has been the enhancement of regulatory framework and financial sector supervision aimed at developing the financial market and increasing competition between banks in a bid to achieve efficient financial intermediation. Consequently, the number of banks grew from seven (7) in 1995 to fifteen (15) by the end of 2022. Among these banks, subsidiaries of foreign banks constitute the majority. In this regard, lending activities grew at a higher pace after the liberalization and increased risk-taking as evidenced by Tonell et al. (2004) who stipulate that though financial liberalization is positively linked to growth, it also ignites a lending boom.

Given the importance of NPLs as far as their determinants and macroeconomic effects are concerned, many researchers around the world continue to focus attention on them. Part of the literature has concentrated on the determinants of NPLs using macroeconomic factors and bank-level data Glogowski (2008), while the remaining part of the literature explored the feedback effect of NPLs on the macroeconomic performance after assessing the determinants of NPLs Klein (2013); Espinoza & Prasad (2010)). It is in this last strand of the literature that this study is classified.

However, the existing literature is scanty, especially in Rwanda, where NPLs had trended upward over time before converging to the 5 percent target recently in 2018. To the best of our knowledge, only one paper by Karuhanga K. et al. (2018) attempted to examine the determinants of NPLs in Rwanda with much emphasis on macroeconomic variables and limited focus on bank-specific data over the period 2012Q1 to 2017Q2 by using dynamic panel data techniques.

The objective of this paper, therefore, is to assess the determinants of NPLs in the Rwandan banking sector and their feedback on the real economy spanning the period 2012Q1 to 2022Q1. The latter sample period does not include all quarters of 2022 because of two banks which merged in April 2022, and the study was seeking to include them separately before they became one. The contribution of this paper to the existing literature is the assessment of the determinants of NPLs and their macroeconomic effects by exploring other key variables not considered by previous works, especially bank-specific variables, as well as using a novel estimation technique. In this regard, the paper aims to correct the fixed effect (FE)[12] used by Karuhanga K. et al. (2018) with the use of a bias-corrected alternative. Another contribution of this paper to the existing literature is the assessment of the feedback effect from the NPLs on the selected macroeconomic variables by using a panel VAR. The empirical literature review suggests that no previous paper has attempted to assess NPLs via this angle.

The findings reveal that both macroeconomic and bank-level variables exert a significant im- pact on NPLs. Specifically, economic growth represented by RGDP improves NPLs. Conversely, increases in inflation (INFL) and the depreciation of the real effective exchange (REER) deteriorate the asset quality of banks. In the case of bank-level data, a

[12] The FE estimators are biased for small panels, specifically when the number of cross sections is small.

rise in real lending rate (RIR) increases the burden of borrowers in terms of servicing their debt and, therefore, raises the NPLs ratio. Another important finding is that NPLs are positively related to bank size, implying that the higher the bank size, the higher the NPLs ratio. This finding is consistent with the literature, which suggests a possible moral hazard problem emanating from the "too big to failure" argument whereby big banks usually think that they will be covered by the government in case of financial failures, leading them to take higher risks in their lending activities. We also found a negative relationship between Capital Adequacy Ratio (CAR), Income Diversification (ID), and Bank Operating Efficiency (BOE) with NPLs, as expected.

The evaluation of the feedback effects places significant emphasis on the potent interplay between macroeconomics and finance. This analysis, which leverages on the panel Vector Autoregression (VAR) model and impulse response functions, unequivocally validates the existence of this feed- back mechanism. Specifically, when a shock to the NPLs occurs, it triggers a notable reduction in credit expansion, and real GDP growth, while inflation has an expected direction but is not statistically significant. These findings underscore macro-financial linkages in the Rwandan economy and the need for policies to forestall financial instability and its potential spillover to the macroeconomy.

The rest of this study is organized as follows. Section 2 describes the dynamics of non-performing loans in the Rwandan banking sector. Section 3 presents the literature review. Section 4 outlines the analytical procedure and model specifications and data, while Section 5 reports the empirical results and Section 6 captures the conclusion.

2. Dynamics of Non-Performing Loans in the Rwandan Banking Sector

2.1 Structure of the banking sector

Since financial liberalization began in 1995, the Rwandan financial sector has undergone significant changes, such as the use of indirect monetary policy instruments following the abolition of credit ceilings and other direct control measures, and the market determination of interest rates and exchange rates. The regulatory framework and financial sector supervision have witnessed improvements aimed at developing the financial market and increasing competition between banks in a bid to achieve efficient financial intermediation. The number of banks operating in the Rwandan financial sector has since increased to 15 banks after Banque Populaire du Rwanda PLC and Kenya Commercial Bank Rwanda PLC merged in April 2022, compared to 13 banks by the end

of 2012 and 7 banks by the end of 1995. The latter period coincided with the resumption of economic activities after the end of the genocide against the Tutsi and moderate Hutus in July 1994. Among the 15 banks currently operating in Rwanda, 10 are commercial banks, 3 microfinance banks, 1 development bank, and 1 cooperative bank. 10 banks out of the 15 banks are subsidiaries of foreign banks, equivalent to 53.9 percent of the banking sector's market share in terms of total assets. The banking sector plays an important role in the Rwandan economy since it constitutes a major source of financing for the private sector.

2.2 The performance of the banking sector

The balance sheet of the banks has increased substantially in recent times despite the challenging economic conditions. Indeed, the total assets of the banking sector grew by 123.2 percent to FRW 5,993 billion as of the end of December 2022, from the end-2017 position. The high growth in banks' assets mostly emanated from the rise in loans as banks' deposits and capital base in- creased over the past five years. Lending to the private sector remains the main risk faced by Rwandan banks. By the end of December 2022, net loans accounted for 52.2 percent of the total assets of banks, whereas Government securities constituted 21.1 percent of the total assets of banks.

During the same period, the reserves at the NBR amounted to 8.6 percent, placements in domes- tic banks (8.5 percent), placements in foreign banks (2.9 percent), fixed assets (2.9 percent), other assets (2.3 percent), and cash (1.6 percent). With this balance sheet structure, interest income on loans and advances is the primary source of income for banks, accounting for approximately 59.2 percent of the total revenues of banks. The balance sheet of banks is funded mainly by short-term customer deposits. As of the end of December 2022, customer deposits represented 72.2 percent of the total liabilities of banks versus 78.6 percent recorded during the last 8 years.

The financing of the economy by banks remains good, with the increase of outstanding loans by 21.0 percent to FRW 4,160.3 billion by the end of December 2022 compared to the growth of 15.9 percent on average in the last five years. In terms of sectoral lending, banks continue to carry out credit diversification strategies to mitigate credit risks that could arise from sectoral loan concentration. Nonetheless, loans have been historically concentrated in mortgage industries, trade and hotels. The share of loans in those sectors to total loans has been declining at the expense of an increased share of transport warehousing and communication, manufacturing activities, service sector, and water and energy.

Table 1: Sectoral distribution of credit (in % Share)

	Dec-12	Dec-17	Dec-18	Dec-19	Dec-20	Dec-21	Dec-22
% share							
Personal loan	24.9	8.9	8.8	8.1	8.6	8.3	8.8
Agricultural, fisheries& live-stock	2.8	0.9	0.9	0.7	0.7	0.7	0.5
Mining activities	0.0	0.2	0.2	0.2	0.2	0.0	0.0
Manufacturing activities	3.2	8.6	8.8	12.1	12.2	10.4	11.2
Water & energy activities	1.1	2.5	2.8	4.5	3.8	3.4	4.2
Mortgage industries	31.1	39.4	37.8	37.9	34.6	33.6	30.7
Commercial & hotel	27.4	26.3	24.2	21.2	24.0	26.1	23.4
Transport; warehousing & communication	6.8	9.5	12.8	11.8	11.0	11.5	11.5
OFI & insurance	0.7	1.3	1.0	0.9	0.8	0.3	0.7
Service sector	2.0	2.5	2.7	2.6	4.2	5.7	9.0
% change							
Total credit growth	38.6	12.3	12.4	5.4	33.9	15.6	21.0

Source: National Bank of Rwanda

2.3 Soundness of the banking sector

The banking sector remains sufficiently capitalized, reflecting banks' increased ability to absorb losses. The capital adequacy ratio (CAR) stood at 23.0 percent on average in the last decade, higher than the minimum requirement of 15 percent. Liquidity risks remain marginal as bank funding conditions remain steady while key measures of core liquidity such as Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR) remained above the minimum prudential requirement from June 2018 to December 2022. By complying with these two indicators, banks ensure they are resilient to funding shocks over the short- and longer-term horizons while continuing to support lending activities. The LCR ensures that banks hold a sufficient reserve of High-Quality Liquid Assets (HQLA) to allow them to resist a period of significant liquidity stress for a period of 30 calendar days. The consolidated LCR of banks, by considering all currencies, reached 263.8 percent on average between June 2018 and December 2022 versus the minimum requirement of 100 percent, indicating the resilience of banks to short-term outflow of funds. However, the NSFR ensures funding resilience over a longer time horizon than the LCR, requiring banks to fund long-term assets with long-term liabilities and hence limit the degree of maturity mismatch. Precisely, the NSFR gauges the availability of stable funding of the banks over a one-year horizon. This ratio averaged 162.9 percent between June 2018 and December 2022 against the 100 percent minimum regulatory requirement.

Banks remain profitable, and their excess reserves continue to increase their capital buffers. The aggregate net profits of banks grew by 134.1 percent to FRW 1,198.2 billion between 2018 and 2022 compared with 199.1 percent recorded between 2013 and 2017. The Return on Assets (ROA) averaged 2.1 percent between 2018 and 2022, which is the same level reached in the preceding five years, while the Return on Equity (ROE) stood at 12.3 percent on average, higher than the 10.6 percent recorded during the same period. Within the context of stability, enhanced profitability increases the resilience of banks against shocks through internally generated capital buffers, thus playing a role in capital and liquidity funding role. Foreign exchange loans to gross loan ratio have been increasing from an average of 3.8 percent between 2012 and 2016 to 10.5 percent between 2017 and 2022. This reflects the impact of the exchange rate on loan repayment, especially for borrowers who do not earn foreign currency.

Table 2: Key financial soundness indicators for banks (percent)

	Dec-12	Dec-17	Dec-18	Dec-19	Dec-20	Dec-21	Dec-22
Capital Adequacy Ratio	21.4	21.4	25.5	24.1	21.5	21.6	21.7
LCR (min 100%)	-	-	637.0	191.8	254.7	268.9	215.9
NSFR (min 100%)	-	-	222.0	129.3	161.4	147.1	136.8
FX loans/Gross loans	0.9	11.8	10.7	11.4	9.7	8.3	9.0
NPLs/Gross loans	7.1	7.6	5.0	4.5	4.5	4.6	3.1
Provision/NPLs	45.3	46.7	68.2	83.6	106.3	119.8	141.9
Return on Assets (RoA)	2.2	1.1	1.9	2.2	2.0	2.5	3.0
Return on Equity (RoE)	10.4	6.2	11.2	12.5	11.8	15.0	17.8
Growth of loans	38.6	12.3	12.4	5.4	33.9	15.6	21.0

Source: National Bank of Rwanda

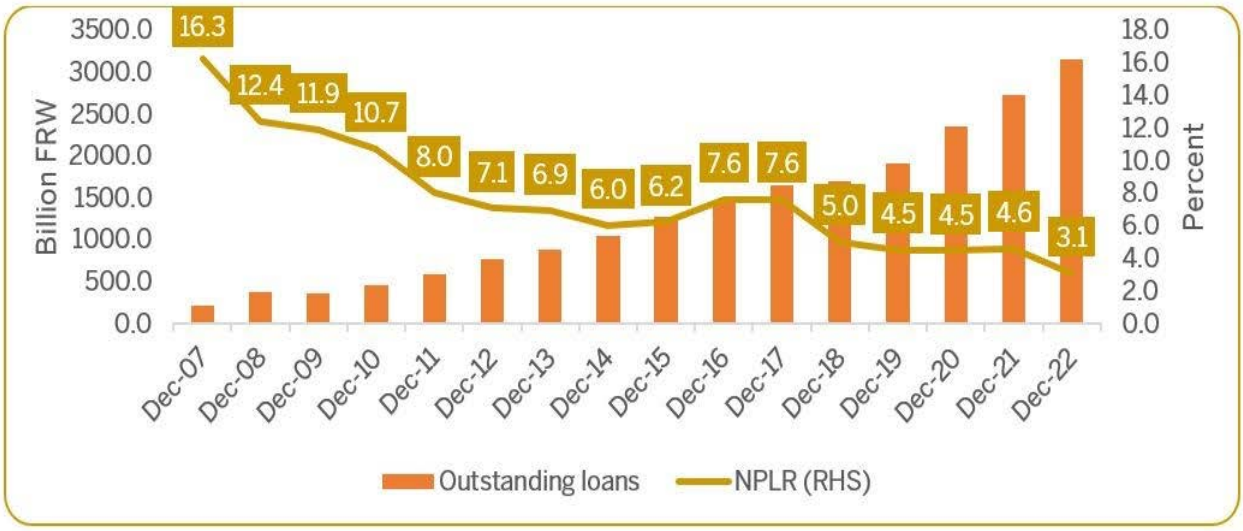
2.3.1 Development in Non-Performing Loans (NPLs)

NPLs declined steadily to converge to the benchmark of 5 percent in 2018. The outstanding NPLs in the banking sector recently reduced by 0.5 percent on average between the end of December 2018 and the end of December 2022. This reflects a decline in the NPLs ratio during that period (4.3 percent) compared to the rise of 15.7 percent in outstanding NPLs on average between the end of December 2011 and the end of December 2017, which corresponds with NPLs of 7.1 percent during the same period. Though the increase in NPLs during the 2011-2017 period was still above the minimum requirement of 5 percent, it was moderate compared to the period prior to 2011 when NPLs were in double digits, averaging 12.8 percent between 2007 and 2010.

In order to achieve the above-mentioned decline in NPLs from double-digit to single-digit, NBR introduced measures to reinforce the prudential and regulatory frameworks and put in place banks' internal credit policies as follows. The NBR enhanced its supervisory role and obliged banks to write off bad loans that were overdue for a long time. Moreover, NBR introduced a credit reference bureau in July 2010 in a bid to reduce the information asymmetry that existed between creditors and borrowers in Rwanda. Several regulations were enacted in different periods to improve the asset quality of banks. Among others, the regulation in 2011 on credit classification and provisioning with the objective of ensuring that banks promptly identify their NPLs and undertake adequate correction measures.

Briefly, NPLs were above the regulatory minimum requirement from 2006 up to 2017 before converging to the minimum requirement of 5 percent in 2018. This reduction in the NPLs ratio was due to several measures undertaken by the National Bank of Rwanda and idiosyncratic reforms by the banks mentioned above, the robust economic performance, which enables banks' clients to service their loans, and increased write-offs of legacy bad loans.

Figure 1: Outstanding Non-Performing Loans Developments in Rwanda



Source: Author's computation with data from NBR

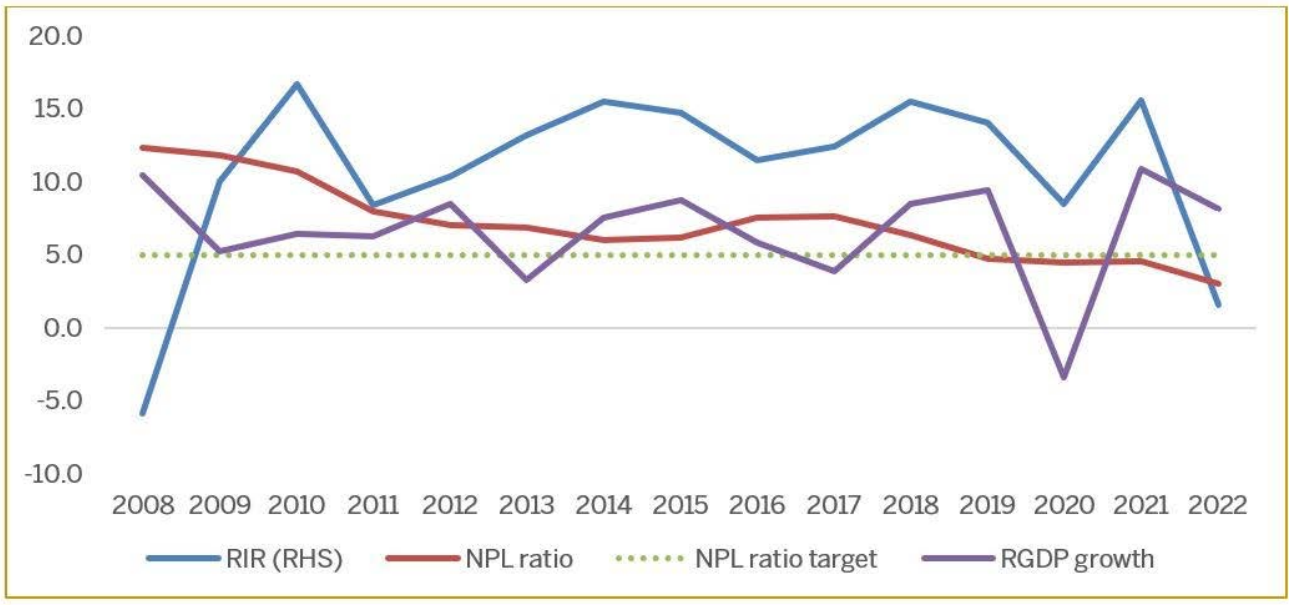
2.3.2 Macro-financial linkages in Rwanda

The figure below shows the trend in the NPL ratio associated with the trend in real interest rate and economic activities. Globally, the trends in RGDP growth and real

interest rate are negatively and positively linked to NPL ratio, respectively. For instance, between 2009 and 2015, the NPL ratio was declining though it was still above the target of 5 percent, while the real GDP growth and real interest rate in many episodes were expanding and decreasing, respectively. From 2018 up to 2022, the NPL ratio continued reducing until it converged to the target of 5 percent due to improvements in economic conditions and a decline in real interest rates, especially in 2018, 2019, and 2021.

However, in 2020 RGDP contracted by 3.4 percent, mainly due to the outbreak of Covid-19. In 2022, RGDP growth decelerated to 8.2 percent from 10.9 percent in 2021 owing to climate changes that affected agriculture production, while industry sector production also contracted mainly due to bad performance of the construction subsector resulting from the completion of large infrastructure projects that supported the economic recovery in 2021. Despite this declining trend in RGDP in 2020 and 2022, the NPL ratio kept decreasing as the real interest rate was reducing.

Figure 2: Macro-financial linkages in Rwanda



2.3.3 NPLs by Economic Sector

From a sectoral viewpoint, compared to the end of December 2016, the NPLs ratio declined in most sectors from the end of December 2017 up to the end of December 2022. The diminution in the NPLs ratio was mainly attributed to the growth of outstanding loans, write-offs, and recoveries for loan loss in some sectors.

All these factors that eased NPLs, have been enabled by different credit policies undertaken by NBR, as mentioned above. However, the NPLs for personal loans and the agriculture sector, on average, stood at 6.4 percent and 7.3 percent, respectively, between the end of December 2016 and the end of December 2022, which is above the minimum requirement of 5 percent.

Regarding the agriculture sector, the surge in NPLs may reflect the poor performance of the sector on account of unfavorable weather conditions and changes in the prices of fertilizers. However, the impact of credit defaults in agriculture on the stability of banks is low due to the low financing of that sector by banks (on average 1 percent of total outstanding loans of banks). On the other side, the high NPLs in personal loans are associated with the fact that those loans are highly risky as they are mainly unsecured, and the recovery rate is low.

Table 3: Non-Performing Loans ratio by economic sector (percent)

Economic sectors	Dec-16	Dec-17	Dec-18	Dec-19	Dec-20	Dec-21	Dec-22
Personal loan	6.6	5.8	6.3	6.9	5.9	8.0	5.4
Agricultural, fisheries& livestock	16.0	8.8	8.6	6.3	4.1	4.1	3.3
Mining activities	0.0	0.0	0.0	0.0	0.0	0.6	0.1
Manufacturing activities	0.4	0.1	0.1	0.1	0.1	0.1	0.1
Water & energy activities	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Mortgage industries	3.6	2.8	3.4	2.2	1.5	2.9	1.7
Trade	4.2	4.4	4.5	4.3	2.5	3.3	1.1
Restaurant & hotel	3.4	1.8	1.9	0.7	0.2	0.8	0.2
Transport; warehousing & communication	1.3	0.8	0.7	0.6	0.8	0.5	0.4
OFI &Insurance	0.1	0.0	0.6	0.4	0.2	0.4	0.0
Service sector	0.2	0. 3	0.4	0.1	0.0	0.0	0.0

Source: National Bank of Rwanda

3. Literature Review

NPLs constitute one of the major risks that banks face, which can lead to financial and macroeconomic instability in the country. NPLs have been the origin of financial crises in different countries. The recent global financial crisis of 2007 /2008 was, for instance, attributed to the rapid default in the subprime mortgage market of the United States. Since then, the determinants of NPLs and their feedback on macroeconomic performance at both cross-country and specific-country levels have become topics of interest in the literature.

According to IMF (2019) and regulation No. 12/2017 of 23rd November 2017 of the National Bank of Rwanda on credit classification and provisioning, a loan is classified as

non-performing if payments (principal and/or interest) due have not been paid for at least 90 days. With the outbreak of the recent global financial crisis, many researchers have analyzed the determinants of NPLs to better understand the dynamic behaviour of NPLs. Results from such empirical works have broadly identified domestic macroeconomic factors, global factors such as fluctuations in external financing and economic conditions, and, more recently, bank-level factors. The first strand of the empirical literature relates macroeconomic factors and bank-level data to NPLs and covers all regions, such as advanced, emerging, and developing countries. Key macroeconomic variables explored in the investigation of the causal factors of NPLs include economic growth, unemployment rate, inflation, interest rate, credit growth, exchange rate depreciation, housing prices and stock exchange indices (Marcucci & Quagliariello,2009; Glogowski, 2008).

Using Italian data, Marcucci & Quagliariello (2009) evaluated the cyclical behaviour of default rate in the banks of Italy. By using a panel data model with a single threshold variable and multiple regimes, their findings reveal that the level of NPLs reduces in good macroeconomic conditions and rises during downturns. Another study on the determinants of NPLs in Italian banks was under- taken by Quagliariello (2006) for the period spanning 1985 to 2002. By using panel data, NPLs and loan loss provision (LLP) [both expressed as a percentage of loan portfolio] are considered as dependent variables in different models. Both static and dynamic models reveal that an increase in NPLs is caused by a decline in GDP growth, an increase in long-term interest rates and a rise in the spread between deposit and lending rates, while loan growth at the bank level negatively affects NPLs with a one-year lag, as loan growth reflects good business conditions. With regards to new LLP increases, they are explained by a slowdown in GDP growth, a rise in long-term interest rates, a reduction in the stock market index (a proxy for the business cycle and probably the value of corporations' assets which could serve as collateral), an increase in interest rate spread, a rise in new NPLs and bank profitability measured by ROA.

Glogowski (2008) analyzed the determinants of Polish banks' loan losses. He examined the links between business cycle variables and loan losses of Polish commercial banks by using a panel approach in order to make maximum use of available supervisory data and to capture the impact of bank profiles on loan losses. Loan loss provisions were used as a proxy for loan losses in Poland. The findings reveal that a reduction in real GDP growth, a rise in real interest rate and an increase in the unemployment rate have a

significant influence on loan losses. However, the influence of the exchange rate was inconclusive despite the high share of FX loans to households.

Fofack (2005) explored the leading causes of non-performing loans in Sub-Saharan Africa in the 1990s, using causality and pseudo-panel models. The results show that at the macroeconomic level, inflation, real interest rate, and growth rate of GDP per capita, are Granger-causal to nonperforming loans across most countries. Considering the bank-level variables, the estimation results show that a higher equity-to-assets ratio leads to lower NPLs, thus confirming the "moral hazard" effect, and higher profitability measured by return on equity (ROE) contributes to lower NPLs and suggests that better-managed banks have on average better quality of assets. Increased risk-taking, as measured by the loans-to-assets ratio, raises NPLs in both fixed effects and difference GMM. The effect of past excess lending captured by the lagged lending growth implies higher NPLs as well. Net interest margins, interbank loans, the real interest rate and real exchange rate appreciation also Granger cause NPLs. However, bank size and expense-to-income ratio were found to be insignificant.

Turk & Love (2013) examined macro-financial linkages in Egypt for the 1993-2010 period. They analyzed the link between several macroeconomic aggregates and loan portfolio quality in a multi- variate framework and used a Panel VAR method which controls for bank-level characteristics. The results demonstrate that a positive shock to real GDP growth and capital inflows improves banks' loan portfolio quality. On the contrary, higher lending rates lead to adverse selection problems and, therefore, to a drop in portfolio quality. The paper also suggests that a big market share of foreign banks in the industry leads to improvement in loan quality.

Sunday et al. (2020) examined the determinants of NPLs in the Ugandan banking sector using the ARDL model for the 2002Q1-2017Q2 period and found that NPLs grow with the rise in lending rates, real effective exchange rate depreciation and high unemployment rate while an increase in returns on assets and real GDP growth rate decrease NPLs. The authors advise commercial banks to diversify their asset portfolio by holding other income-earning assets such as government bonds and equity in order to lower credit risk exposure. Furthermore, policies that boost economic growth and reduce unemployment and lending rate would improve the asset quality of Ugandan banks.

Some papers also focused on bank characteristics such as income diversification, profitability measured by return on assets (ROA), capitalization, and operating efficiency as possible determinants of NPLs. Their findings in terms of signs of coefficients diverge a lot Asif Khan et al. (2020). For instance, Glogowski (2008), Boudriga et al. (2010), Makri

et al. (2014), Berger & De young (1997), Rachman et al. (2018), Asif Khan et al. (2020) found that R0A and income exert a negative impact on NPLs. They suggest that banks begin to invest in high-risk projects when they observe declines in ROA, resulting in high NPLs. Regarding bank operating efficiency (BOE), Fiordelisi et al. (2011), Berger & De young (1997), and Asif Khan et al. (2020) confirm that an improved efficiency of banks improves their future risk levels, implying that BOE and NPLs are negatively related. However, Ekanayake & Azeer (2015), Benthen (2017) find a positive link between BOE and NPLs, indicating that the management conduct of the bank affects its asset quality. Conversely, Louzis & Vouldis (2012), and Rachman et al. (2018) find that BOE does not influence NPLs. It is important to highlight that different measures of operating efficiency used by several above mentioned authors largely impacted on the direction effect of BOE on NPLs.

In the case of bank capital, Makri et al. (2014), Kumar & Kishore (2019), and Keeton (1999) re- veal that low capitalized banks (measured by low capital adequacy ratio) are inclined to get involved in high-risk investments and give loans which may not follow proper credit rating and monitoring procedures. This reflects a negative relationship between bank capital and NPLs. On the other hand, Rajan (1994), Constant & Ngomsi (2012), and Amakwa & Boakye (2015) found a positive relationship between bank capital and NPLs. They argue that banks with high capital levels tend to lower their credit stance and give out loans quite easily since they do not fear bankruptcy. Consequently, those banks engage in highly risky credit activities. Rachman et al. (2018) find income diversification (ID) to be negatively related to NPLs, suggesting that banks with a more diversified income base are more likely to lower their risks as some of the investments are likely to be in less risky ventures. However, Louzis & Vouldis (2012) reveal that non-interest income has a positive association with NPLs, while ROA has a negative impact on them.

The second strand of the literature explores the feedback from the financial sector to the real economy. Indeed, the impact of the real economy on NPLs is mainly reflected in a weakening of borrowers' capacity to pay back their loans, whereas the feedback from NPLs to the real economy is often shown through the credit supply channel. The objective of this study falls in this category of the literature.

Beaton et al. (2016) examined the determinants of NPLs in the Eastern Caribbean Currency Union (ECCU), specifically in Dominica, Grenada, St. Kitts and Nervis, St. Lucia, St. Vincent and the Grenadines for the period spanned 1996Q1-2015Q4. This study also explored the feedback effects of the banking system on economic activity. The results

show that low asset quality can be caused by both macroeconomic and bank-specific variables. Banks with lower exposure to the construction sector and household loans and banks with higher profitability tend to have lower NPLs. In addition, foreign-owned banks have lower NPLs than domestic banks, indicating important differences across bank practices that impact asset quality. In fact, domestic banks function on a very small scale in their country of origin, whereas foreign banks constitute mainly branches and subsidiaries of large international banks with global operations. This larger scale of foreign banks' operations may offer economies of scale for banks to implement great risk management activities that lead to lower NPLs. Regarding the feedback from the banking sector to the real economy, and by using a Panel VAR, the findings suggest that worsening asset quality decreases credit with sharp sectoral differences. Specifically, a deterioration in asset quality causes significant and persistent reduction in credit growth in tourism, agriculture, manufacturing, and construction industries. The results also demonstrate that a decrease in NPLs boosts the real GDP growth in the ECCU, principally through the agricultural and construction industries. In turn, real GDP growth, through the associated reduction in unemployment and a rise in disposable income, largely decreases NPLs mainly in personal and tourism sectors.

In the same context, Klein (2013) conducted a study on determinants of NPLs for sixteen Central Eastern Southern Eastern European (CESEE) countries in the period of 1998-2011 and its feedback effect on the real economy. Using the difference GMM method of Arllelano & Bond (1991), he finds that the level of NPLs can be explained by both macroeconomic conditions and banks' specific factors; however, the impact of the latter set of factors is relatively low. The results suggest that the level of NPLs rises when unemployment increases, the exchange rate depreciates, and inflation is high but declines when economic activity, measured by real GDP growth, picks up. Considering the impact of bank-level data, the results suggest that higher quality of banks' management, as measured by the previous period's profitability, reduces NPLs. However, moral hazard incentives, such as low equity, deteriorate NPLs. Amplified risk-taking (as measured by the loans-to-assets ratio and the growth rate of the Bank's loans) raises NPLs in the subsequent periods. These bank-level factors were significant during both the pre-crisis and post-crisis periods. Regarding the feedback effect from the banking sector to the real economy, the paper uses a Panel VAR model. The findings reveal that a rise in NPLs has a negative effect on credit as a share of GDP and real GDP growth, but a positive impact on unemployment while reducing inflation in the periods ahead.

Espinoza & Prasad (2010) also examined macroeconomic and bank-level determinants of NPLs in the GCC (Gulf Cooperation Council) comprising Baharain, Kuwait, Oman, Qatar, Saudi Arabia, UAE banking sector utilizing a bank-wise panel dataset and fixed effect, difference GMM, and System GMM models. They also explored the feedback effect from the banking sector on the real economy by using a Panel VAR model for the period 1995–2008 on around 80 banks in the GCC. The results confirm a strong negative relationship between real non-oil GDP and NPLs. Global financial market conditions also affect the NPLs of banks. Considering bank-level data, efficiency and past expansion of the balance sheet were significant. The paper also estimated the feedback from increasing NPLs to the real economy using a Panel VAR. Generally, the increase in NPLs has a negative effect on non-oil growth GDP in the GCC. As a policy implication, the study suggests that policymakers in the GCC should monitor carefully the evolution of default in the loan book of banks. In addition, in the context of exchange rate pegs in these countries, a stronger focus on macro-prudential regulation, mostly through capital and liquidity buffers, and countercyclical provisioning, could help alleviate the impact of macroeconomic risks on the banking system and the feedback effects of credit risks on the economy.

From the discussed literature concerning the expected signs of different variables, real economic growth measured by RGDP growth is negatively linked with NPLs. Indeed, good economic conditions improve the capacity of borrowers to service their debts, thus resulting in improved asset quality (Glogowski , 2008; Fofack, 2005; Turk & Love ,2013). Regarding the impact of inflation (INFL) on the NPL ratio, it can either be negative or positive. On the one hand, a reasonable level of inflation can prompt the growth of the economy, thus recovering the debtors' capacity to pay back their loans, thereby reducing NPLs within the banking sector. On the other hand, high inflation on the side of the borrowers (especially whose loans are inflation-indexed) lessens the real value of income and deteriorates their ability to service the loan; thus, NPLs increase (Klein ,2013 ; Fofack, 2005). The impact of exchange rate depreciation [measured by real effective exchange rate (REER)] on NPLs can either be positive or negative. In fact, exchange rate depreciation in a flexible exchange rate regime with large amounts of lending in foreign currency may increase NPL accumulation for borrowers who do not earn foreign currency. With regard to countries with a high level of exports, exchange rate depreciation may improve the debts servicing possibilities of export-oriented firms if the loans are denominated in local currency and therefore reduce NPLs (Sunday et al., 2020 ; Fofack ,2005).

Considering bank characteristics, real interest rate (RIR), is positively associated with NPLs different authors posited that a high real interest rate implies an extra debt burden conveyed to borrowers, and therefore, NPLs are expected to rise, (Glogowski, 2008; Quagliariello,2006). How- ever, the existing evidence on the effect of the size of banks on NPLs is mixed. For instance Tarron & Sukrishnalall (2009) found that there is no relationship between the size of bank and NPLs ratio, Ekanayake & Azeer (2015) found a negative relationship between the two variables while Louzis & Vouldis (2012) and Haq & Heaney (2012) found a positive association between the same variables supported by "Too Big To Fail" theory stated in Stern & Feldman (2004).

In this paper, the size of a bank is measured by the assets of that bank to the total assets of the banking sector. The coefficient on Capital Adequacy Ratio (CAR) (measured by total qualifying capital to total risk-weighted assets) is expected to either be negative or positive. For instance, Makri et al. (2014), Kumar & Kishore (2019), and Keeton (1999) argue that low-capitalized banks tend to be involved in high-risk investments and give loans that do not follow proper credit rating and monitoring systems; thus, NPLs go up. Other researchers, such as Rajan (1994), Constant & Ngomsi (2012), and Amakwa & Boakye (2015), on the other hand, contend that banks that have a high level of capital tend to lower their credit stance more easily since they do not fear bankruptcy. As a result, they engage in highly risky credit activities. Income diversification (ID), measured as non-interest income/ total income, can be negatively or positively related to NPL ratio. Rachman et al. (2018) postulate that banks with diversified income other than interest income are more cautious in taking risks which reduces NPLs.

Conversely, Louzis & Vouldis (2012) found that ID has a positive association with NPLR. The coefficient on the growth of loans (GrL) is expected to either be positive or negative (Klein (2013); Karuhanga K. et al. (2018)) while operating efficiency (BOE), measured by non-interest expenses/non-interest income, can either has a negative or a positive relationship with asset quality; (Fiordelisi et al. (2011); Asif Khan et al. (2020)) suggest a negative relationship, while Ekanayake & Azeer (2015), and Benthen (2017) find a positive link between BOE and NPLs, concluding that the management conduct of a bank affects its asset quality. On the other hand, Louzis & Vouldis (2012), Rachman et al. (2018) find that BOE does not affect NPLR. In addition, NPLs, measured by the total NPLs of a bank over its total gross loans, tend to persist over time, so the lagged NPL ratio (L. NPLR) is added as an explanatory variable. The results given by the literature reveal that previous NPLs contribute to the amount of the current NPLs, so we expect to have a positive sign in our estimation results.

With regard to the feedback effect from NPLs ratio to the selected macroeconomic variables, we expect that an increase in NPLs reduces credit growth, contracts real GDP and definitely decreases inflation due to a reduction in aggregate demand (Klein, 2013; Espinoza & Prasad ,2010).

With regard to different methodologies, many authors examined the determinants of NPLs in specific countries or in a panel of countries in the same region. Such studies mostly used panel data models with fixed effects, random effects, difference GMM or system GMM. Endogeneity encountered in these types of studies is normally addressed using IV-GMM estimators. However, these estimators are biased for small panels, specifically when the number of cross sections (banks) is low, which is the case in this study. Consequently, this paper makes a new contribution to the literature by using a bias-corrected fixed estimator for the dynamic panel data model that works for the autoregressive coefficient estimator and has proven to outperform GMM estimators in dynamic panel models with small cross-sections. However, the feedback of NPLs on macroeconomic performance has been analyzed by many authors via the use of Panel VAR models, as done in this study.

4. Analytical procedure and model specifications and data

4.1 Methodology

The linear panel model takes the following dynamic specification:

$$NPLR_{it} = \alpha NPLR_{it-1} + \beta X'_{it} + \eta_i + \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (1)$$

where $NPLR_{it}$ is the nonperforming loan ratio and $NPLR_{it-1}$ is the lag non-performing loan ratio.

X_{it} represents a vector of regressors namely: Real GDP, Inflation rate, Real effective exchange rate, Real interest rate, loan growth, Bank size, Capital adequacy ratio, Bank operating efficiency, and Income diversification. Where i and t denote Bank and time respectively,

η_i is the unobserved time-invariant specific effects.

Finally, ε_{it} is the two-way error component term of the model assumed to be normal, independent, and identically distributed (IID) with £(ε_{it}.)=0; Var (ε_{it}) = $\sigma^2 > 0$. Due to the fixed effects and the lagged dependent variable among the regressors, equation (1) cannot be estimated using the conventional ordinary least squares (OLS) technique. As a standard practice in panel data analysis, unobserved heterogeneities can be dealt with

using fixed effect (FE) or random effect (RE) estimators. However, these estimators are inconsistent or biased for dynamic panel models, and their standard errors are not robust in terms of cross-sectional dependence. Besides heterogeneity and cross-sectional dependence, the estimation of equation (1) is also subject to endogeneity[13]. One source of endogeneity and simultaneity bias may come from omitted variable bias since some relevant determinants of NPLs might not be included in the model measurement error, which arises from poor variable proxies.

However, the addition of the lag-dependent variable causes a correlation between the lag-dependent variable and the error term, resulting in biased estimates of parameters (Hsiao, 2003; Judson & Owen, 1999). Endogeneity is commonly addressed using IV-GMM estimators. However, these estimators are biased for small panels specifically when the number of cross sections (banks) is low and requires a bias-corrected alternative. This study therefore uses the bias-corrected FE (BCFE) estimator for the dynamic panel data model that works for the autoregressive coefficient estimator, and has proven to outperform GMM estimators in dynamic panel models with small cross-sections (Kao et al., 2021).

The study also explores the feedback effects of the banking sector behaviour, through NPLs, on macroeconomic performance. In particular, we are interested in the linkages between NPLs of banks, growth of loans, GDP growth, and inflation. The assessment of these relations, causality, magnitude, and duration using the most recent Panel VAR (Abrigo & Love, 2016) is expected to reveal potential macro-financial vulnerabilities. The model is specified as follows:

$$Y_{it} = Y_{it-1} + \mathrm{f}_i + \varepsilon_{it} \quad \text{.....(2)}$$

Y_{it} is a set of variables namely NPLs ratio, loan growth, real GDP growth and inflation rate while fi is individual characteristics.

This technique is advantageous since it combines the traditional VAR approach, which treats all the variables in the system as endogenous, with a panel data approach which allows for unobserved individual heterogeneity. The dynamic behavior of the model is analyzed within the context of impulse response functions. The shocks in the VAR are ordered in way that the variables appearing earlier in the ordering are considered more exogenous, while those appearing later in the ordering are considered more endogenous. The following table shows expected signs of key variables from the literature.

[13] Endogeneity refers to the correlation between explanatory variables and the disturbances in a model

Table 4: Summary on expected signs from literature

Authors	Variable	Expected signs
Glogowski (2008) Fofack (2005) Turk & Love (2013)	RGDP growth	-
Klein (2013) Fofack (2005)	Inflation	+/-
Sunday et al, (2020) Fofack (2005)	REER	+/-
Glogowski (2008) Quagliariello (2006)	RIR	+
Louzis & Vouldis (2012) Ekanayake & Azeer (2015) Tarron & Sukrishnalall (2009)	Size	+/- or no effect,
Makri et al. (2014) Amakwa & Boakey (2015)	CAR	+/-
Rachman et al. (2018) Louzis & Vouldis (2012)	ID	+/-
Klein (2013) Karuhanga et al. (2018)	GrL	+/-
Benthen (2017) Asif Khan et al. (2020) Rachman et al. (2018)	BOE	+/- or no effect
Fofack (2015) Karuhanga et al. (2018)	L. NPLR	+

4.2. Data description

In our empirical investigation, we use quarterly data for the 2012Q1–2022Q1 period for a sample of fourteen banks. One bank licensed in 2017 was excluded due to short period of data. The choice of the number of banks, the variables, and the time are determined by the need to consider the possible big number of banks referring to the starting period of their activities in Rwanda for a long sample period. The choice of variables is guided by the theory, the past literature and the realities of the Rwandan banking sector. The main source of bank-level data is the balance sheet of each bank in the dataset of the National Bank of Rwanda (NBR) while data on the macroeconomic variables are obtained from the NBR and the National Institute of Statistics of Rwanda (NISR).

5. Empirical findings

5.1 Descriptive statistics

Some preliminary empirical analysis, namely descriptive statistics and correlation were undertaken before embarking on the panel estimations. Table 4 reports the descriptive statistics of the Rwandan banking sector variables and some macroeconomic indicators. During the period between 2012Q1 and 2022Q1, NPLs were on average 6.2 percent, higher than the minimum requirement of 5 percent. There has also been significant

volatility in a change of different variables. In fact, this volatility in data is a good indicator that our panel model is appropriate for our estimation because it captures heterogeneity arising from different cross section unities. The correlation between NPLR and their determinants has also been done. The results reveal that capital adequacy ratio, income diversification and bank operating efficiency are negatively linked to NPLR. However, REER and bank size are positively associated with NPLR, though not statistically significant, while RGDP is negatively linked to NPLR but not statistically significant (see appendix table 1)

Table 4: Summary statistics

VARIABLES	N	mean	sd	min	max	skewness	kurtosis
NPLR	574	0.0622	0.0416	0	0.295	1.675	7.186
RGDP	574	0.0641	0.0518	-0.187	0.206	-1.110	7.378
INFL	574	0.0381	0.0262	-0.0415	0.0898	0.246	2.114
REER	574	0.0247	0.0422	-0.0637	0.115	0.120	2.662
GrL	574	0.253	1.687	-0.432	39.96	22.81	536.9
RIR	574	0.136	0.0387	0.0103	0.273	0.486	4.066
SIZE	574	0.0704	0.0659	0.00299	0.316	2.070	7.423
CAR	574	0.257	0.135	0.112	2.116	6.454	73.52
ID	574	0.293	0.109	-0.00199	0.701	0.509	3.657
BOE	574	1.413	13.24	-314.6	6.292	-23.73	566.8

Source: Author's own computation (2023)

5.2 Empirical results

The results of the estimation are presented in Table 5 for both FE taken as benchmark model while BCFE is alternative model largely confirm that all bank-specific and macroeconomic factors play a role in influencing the banks' asset quality. However, the contribution of bank-level factors is relatively low compared to macroeconomic factors specifically RGDP growth, inflation and real effective exchange rate. These results are similar to the ones found by Klein (2013). The significance level can be either in FE, BCFE or both as shown in the table 5. From model one to model 4 for each estimator, we assess the contribution of each bank characteristics to NPLs.

An increase of 1 percentage point in real GDP growth leads to a decline in NPLR for all considered models in both FE and BCFE. The coefficient ranges between – 0.068 and – 0. 079. These results are consistent with the findings of Marcucci and Quagliariello (2009); Quagliariello (2006), and Fofack (2005). An increase of 1 percentage point in inflation raises the NPLR in all fixed effects models. The coefficient stands between 0.355 and 0.389. These results are consistent with those of Klein (2013) and Fofack (2005). A depreciation of 1 percentage point in REER reflects an increase in NPLR in all FE and BCFE

models, with a coefficient standing between 0.098 and 0.114. These results coincide with those of Fofack (2005) and Sunday et al. (2020).

Considering the impact of bank-specific factors on NPLR, a rise in RIR deteriorates the NPLs ratio. We found a positive sign for all models in both FE and BCFE, with a coefficient ranging between 0.298 and 0.324. The results are in line with Turk and Love (2013) and Fofack (2005). A rise of 1 percentage point in banks' size increases NPL ratio by 0.252 percentage point in the FE2 and 0.262 percentage points in BCFE 1. These results are in line with Louzis and Vouldis (2012).

The low-capitalized banks tend to be involved in high-risk investments and give loans that do not follow a proper credit rating and monitoring; thus, NPLR goes up. We found a negative relationship between CAR and NPLR with a coefficient of -0.025 in the FE3. These results are similar to Makri et al. (2014), Kumar and Kishore (2019), and Keeton (1999). The ID coefficient is found to be negative and significant, with a coefficient standing at -0.045 for FE1 and -0.048 for FE4 but not significant in BCFE. These results are in line with the ones of Rachman et al. (2018), and Asif Khan et al. (2020). The BOE coefficient has been found to be negative and significant but very low in both FE 1 and BCFE 4. This result is similar to those of Berger et al. (1997) and Asif Khan et al. (2020). The Lagged NPL ratio has been added as an explanatory variable to capture the persistence of NPLs. Its coefficient is positive and significant in all BCFE1, BCFE2, BCFE3 and BCFE4 models, with a coefficient standing at 0.076, 0.073, 0.073 and 0.076, respectively. Hence signifying that a shock to NPLs is likely to have a prolonged effect on the banking system.

Table 5: Estimation of determinants of Non-Performing Loans

	FE1	FE2	FE3	FE4	BCFE1	BCFE2	BCFE3	BCFE4
RGDP	-0.068**	-0.079**	-0.071**	-0.068**	-0.072**	-0.064**	-0.062**	-0.062**
	(0.034)	(0.034)	(0.035)	(0.034)	(0.030)	(0.030)	(0.030)	(0.030)
INFL	0.387***	0.355***	0.379***	0.389***	0.366	0.390	0.398	0.396
	(0.103)	(0.103)	(0.104)	(0.104)	(0.254)	(0.240)	(0.246)	(0.246)
REER	0.100**	0.109***	0.106***	0.098**	0.114***	0.112***	0.104**	0.106***
	(0.040)	(0.041)	(0.041)	(0.041)	(0.041)	(0.042)	(0.041)	(0.041)
GrL	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
RIR	0.318***	0.304***	0.308***	0.324***	0.298*	0.301*	0.315*	0.308*
	(0.085)	(0.086)	(0.085)	(0.085)	(0.173)	(0.169)	(0.174)	(0.178)
SIZE	0.113	0.252**	0.187	0.110	0.262**	0.201	0.132	0.135
	(0.129)	(0.121)	(0.126)	(0.129)	(0.127)	(0.140)	(0.171)	(0.169)

CAR	-0.018		-0.025*	-0.019		-0.023	-0.017	-0.017
	(0.013)		(0.013)	(0.013)		(0.028)	(0.025)	(0.025)
ID	-0.045**			-0.048**			-0.043	-0.041
	(0.019)			(0.019)			(0.041)	(0.040)
BOE	-0.000*							-0.000***
	(0.000)							(0.000)
L.NPLR					0.076**	0.073*	0.073*	0.076**
					(0.038)	(0.038)	(0.038)	(0.037)
N	574	574	574	574	560	560	560	560
R^2	0.075	0.053	0.059	0.070				
AIC	-2.2e+03	-2.2e+03	-2.2e+03	-2.2e+03	.	.	.	.
N_g	14.000	14.000	14.000	14.000	14.000	14.000	14.000	14.000
Log-likelihood	1131.132	1124.490	1126.367	1129.590				

Standard errors in parentheses
*p< 0.1, **p< 0.05, ***p< 0.01

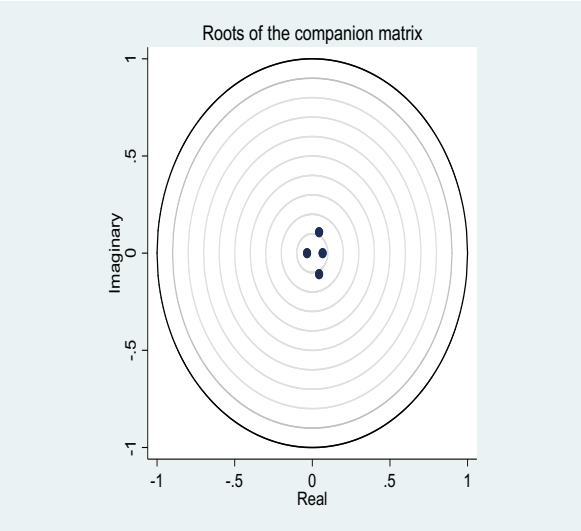
Source: Author's own computation (2023)

5.3 Feedback effect

In furtherance of the comprehensive analysis of the factors influencing NPL ratio, this segment undertakes an evaluation of the reciprocal interactions between the banking sector, as mediated by NPLs, and the broader economic landscape. This is accomplished through the utilization of a panel Vector Autoregression (VAR) framework aimed at scrutinizing the repercussions of NPLs on credit expansion, real GDP growth, and inflation rates. The outcomes derived from our estimations generally align with theoretical premises and practical applications. The impulse response functions presented in figure 4 can be summarized as: an exogenous shock to NPL ratio instigates a contraction in the availability of credit, which subsequently triggers a downturn in real GDP growth and a reduction in inflation levels owing to diminished pressures on aggregate demand.

Before conducting empirical exercise, we first check for stability. As shown in the following figure, all eigenvalues are within inner cycle. This implies that PVAR satisfies stability condition:

Figure 4: Stability conditions



Eigenvalue stability condition

Eigenvalue		
Real	Imaginary	Modulus
.2242414	0	.2242414
-.0118705	-.0429812	.0445903
-.0118705	.0429812	.0445903
.0265343	0	.0265343

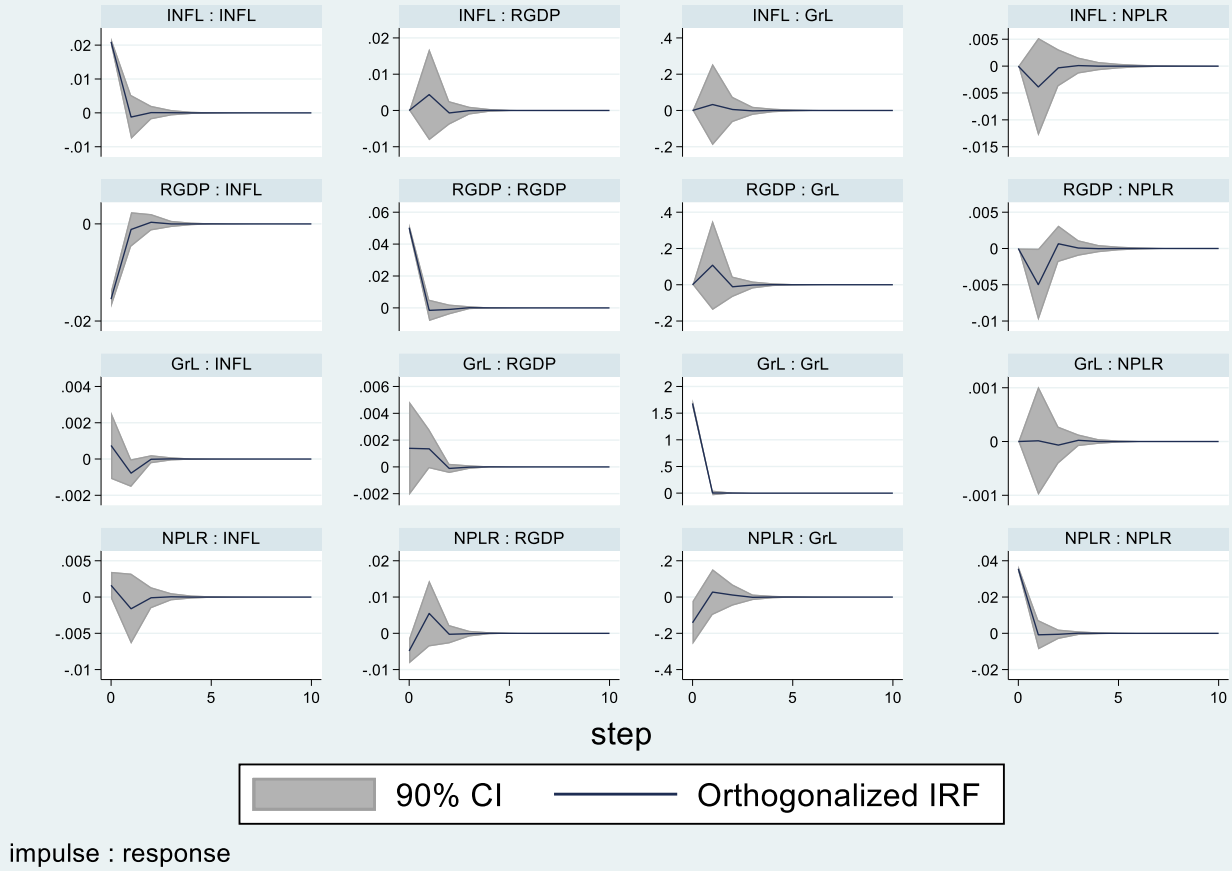
Source: Author's own computation (2023)

Figure 5 which illustrates the impulse responses stemming from a Panel Vector Autoregression (PVAR) model, indicates that 1 percentage point shock to the NPLR yields several noteworthy effects. Firstly, this shock led to a minor decrease in credit availability by approximately 0.0001 percentage points in the initial quarter. Banks, in response to this shock, tend to curtail their loan supply to borrowers as a preventative measure to mitigate further deterioration in asset quality. Secondly, the impact of one - percentage point NPLR shock reduces RGDP growth by 0.05 percentage points within a one-quarter timeframe. It is worth noting that RGDP eventually reverts to its normal trend after three quarters. Lastly, evidence suggest that the effect of one-percentage-point NPLR on inflation has the expected direction but is not statistically different from zero. It is worth mentioning that these empirical findings are consistent with the research conducted by Klein in 2013 and the work of Espinoza and Prasad in 2010.

As mentioned above the effect on RGDP growth and bank lending is in the expected direction, though short lived. This may be associated with the realities of Rwandan economy where financial deepening is not that strong and banks have the room to increase lending in other sectors which are not strongly affected by NPLs in case the latter is not generalized. Besides, the relatively lower effect on RGDP growth can also be associated with the fact that the influence of financial sector on real economy in Rwanda is not that strong as in the case of developed countries. Lastly, the absence of effect on inflation can also be associated with these realities explained above, but also with the fact that there are many episodes of inflation in Rwanda, which were supply driven mostly from agricultural production shock, unrelated with the performance in the financial sector.

The gray space represents the 90 percent confidence interval derived by using the technique of Kilian (1988). In the impulse–response graph, each row shows an impulse, and each column represents a response variable. Each graph's horizontal axis identifies the time units in which the VAR is evaluated, in this paper, quarters. So, the impulse–response graph depicts the effect of a shock over 10 quarters. The vertical axis represents the variables in the VAR in their respective units; in this case, everything is measured in percentage points. Thus, the vertical units in all panels are percentage point changes.

Figure 5: Panel VAR impulse response functions



Source: Staff estimates and calculations (2023)

6. Conclusions and policy implications

The objective of this study was to assess the determinants of NPLs in Rwanda's banking sector and the feedback of NPLs to the broader macroeconomy.

Building on the work of previous authors, we used bias-corrected fixed effects estimators to identify macroeconomic factors and bank-level variables that are capable of affecting the behaviour of NPLs. The results regarding the impact of macroeconomic variables suggest that the increase in the real GDP growth and inflation reduces and raises the non-performing loans ratio, respectively, while the depreciation of REER leads to an increase in NPLs. In fact, the descriptive analysis part showed that the loans in foreign currency have been rising over time in Rwanda, given that Rwanda is a net importer, so depreciation of REER increases the burden of the borrower in terms of paying back their loans in foreign currencies. The insignificance of inflation in our main estimator (BCFE) can be associated with many episodes of inflation in Rwanda, which were supply driven mostly from agricultural production shock, unrelated with the performance in the financial sector.

With regards to the effect of bank-specific variables on NPLs, the rise in real interest rate, bank size, and lagged NPLs raises NPLs while the increase of capital adequacy ratio, income diversification, and bank operating efficiency reduces NPLs.

Examining the feedback effects highlights the strength of macro-financial feedback. By using the panel VAR model, the impulse response functions indicate the feedback effect where shocks to NPLs reduce credit growth, GDP, while inflation has consistent direction but not statistically significant.

Several policy implications arise out of these findings and discussions. Given the adverse effect of NPLs on the economy and because of the contribution of bank-level variables to NPLs, it is imperative for regulators and the National Bank of Rwanda to be concerned about rising NPLs during periods of low growth and tight financing conditions. Thus, it is vital that policymakers put in place policies that ensure sustainable macroeconomic stability. In addition, there is a need to reinforce the supervision of banks to ensure that banks avoid excessive lending, maintain high credit standards and be prudent in lending in foreign currency in order to avoid a sharp buildup of NPLs in the future. In simple terms, a healthy and sustainable growth cannot be reached without a sound and resilient banking system. Since this paper was limited only on determinants of entire NPLs and their feedback on some macroeconomic variables, we recommend for future analysis to also check the effect of domestic banks, subsidiaries of foreign banks and foreign inflows on NPLs.

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Appendix table 1: Correlation matrix

	NPLR	RGDP	INFL	REER	GrL	RIR	SIZE	CAR	ID	BOE
NPLR	1.00									
RGDP	-0.06 (0.12)	1.00								
INFL	0.04	-0.54***	1.00							
	(0.39)	(0.00)								
REER	0.06	0.38***	-0.52***	1.00						
	(0.18)	(0.00)	(0.00)							
GrL	-0.12** (0.00)	0.02 (0.64)	0.03 (0.48)	0.01 (0.85)	1.00					
RIR	-0.04	0.41***	-0.65***	0.34***	-0.03	1.00				
	(0.29)	(0.00)	(0.00)	(0.00)	(0.41)					
SIZE	0.00	0.01	0.01	0.01	-0.03	-0.19***	1.00			
	(0.98)	(0.85)	(0.84)	(0.87)	(0.52)	(0.00)				
CAR	-0.15***	0.03	0.11**	-0.08	0.06	-0.04	-0.20***	1.00		
	(0.00)	(0.51)	(0.01)	(0.05)	(0.14)	(0.32)	(0.00)			
ID	-0.18***	0.05	0.01	-0.05	0.12**	0.04	-0.15***	0.14***	1.00	
	(0.00)	(0.26)	(0.72)	(0.21)	(0.00)	(0.34)	(0.00)	(0.00)		
BOE	-0.08 (0.05)	-0.01 (0.81)	0.04 (0.38)	0.00 (0.98)	0.01 (0.81)	-0.05 (0.28)	0.01 (0.78)	0.02 (0.56)	0.09* (0.03)	1.00

p-values in parentheses
*$p< 0.05$, **$p< 0.01$, ***$p< 0.001$

A WEEKLY INDEX OF ECONOMIC ACTIVITY TO MONITOR THE IMPACT OF COVID-19 IN RWANDA

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Abstract

This paper discusses a weekly index of economic activity developed to track the economic impact of COVID-19 in Rwanda. The index is computed as a common component extracted using the principal component analysis from a number of high frequency indicators representing various economic sectors. The paper describes how these indicators were used to track the economic impact of COVID-19 in Rwanda, assisting policymakers in making appropriate decisions aimed at protecting the population and slowing the spread of the pandemic while minimizing the potential negative economic impact. The study demonstrates the extent to which the COVID-19 pandemic had a detrimental effect on Rwanda's economic activity and the speed at which it recovered once the pandemic was contained and temporary restrictions were lifted.

***Key Words**: High frequency indicators, Weekly economic index of economic activity, Principal component analysis, COVID-19, Rwanda.*

***JEL Classification**: JEL Classification Numbers: C63, C65, E32, E66.*

1. Introduction

The global health crisis caused by the COVID-19 pandemic has taken a toll on human lives and brought major disruptions to economic activity across the world. Faced with the pandemic, countries around the world quickly reacted by imposing measures to prevent the spread of infection, such as lockdowns, social distancing, and quarantines, among other measures. Though these measures were necessary to limit infections and the death toll, they had a negative impact on the economic performance of many economies around the world.

On the global scale, the world economy contracted by 3.1 percent in 2020 compared to a growth of 2.8 percent in 2019, the worst recession since the Second World War. In Rwanda, the Covid-19 pandemic has also substantially weakened economic performance through demand and supply shocks. This resulted in a real GDP growth contraction of 3.4 percent in 2020, the first recession since 1994, after a long-term average growth of 7.8 percent between 2000 and 2019. In 2021, however, the economy started recovering, recording real GDP growth of 10.9 percent, supported by the easing of containment measures thanks to a massive vaccine rollout and continued Government support to hard-hit businesses and vulnerable households.

Throughout the evolution of the pandemic, timely economic data and analysis were needed to assess the impact of the pandemic as well as the policy response. Indeed, prompt and appropriate monitoring of economic performance is a fundamental aspect of economic analysis and a key requirement for policymakers. However, assessments based on usual economic indicators, including Gross Domestic Product (GDP) and monthly frequency indicators, such as total business turnovers, purchasing manager index (PMI), index of industrial production, consumer confidence indicator ,business confidence indicator, etc; were of little use during the crisis when decisions had to be taken on a weekly or even daily basis. In addition, due to the uncertainty, any economic assessment had to be revised much more often during the pandemic. To monitor the economic impacts of the pandemic and provide a well-informed policy response, new types of economic indicators were thus needed.

Regarding the usually available data, the Gross Domestic Product (GDP) is the most widely used and most important and appropriate indicator capturing economic activities (OECD, 2015) since it measures economic activity from an aggregated,

homogeneous, and relatively comparable perspective among countries. However, it is usually compiled every quarter and is available after a considerable time delay after the reference period. In Rwanda for instance, the quarterly GDP figures are released at least 75 days after the end of the quarter, to which they refer. This poses a challenge for real-time assessment of economic conditions that are needed for policymakers, especially in times of crisis.

Nevertheless, some economic indicators are available at a higher frequency (monthly, weekly and daily) and can be used to assess economic performance. These high-frequency indicators (HFIs) became particularly popular in the wake of the COVID-19 outbreak. For the case of Rwanda, reliable high-frequency indicators available include turnover data of Value Added Tax (VAT)-registered companies operating in the industry and services sector (using real-time information from Electronic Billing Machines (EBM), exports, imports, electricity production, cement (imported and domestically produced) as well as credit to the private sector. It is also possible to combine them into a composite index of economic activities. However, some of these indicators were available only on a monthly basis and often with a lag, therefore not useful in times when health and economic conditions evolve rapidly, and policy decisions need to be taken with a sense of urgency. In times like this, there is need for data availability on a weekly or daily basis.

This paper intends to describe the constitution of a novel dataset of weekly indicators of economic activities as well the computation of a weekly composite index used in Rwanda to monitor the economic impact of COVID-19. A team of Rwandan Economists searched through all sources of data and found reliable and available data on a weekly basis for variables including EBM sales or turnover data, exports and imports, new authorized loans, and VAT. These indicators were accessible with a lag of one to two weeks and combined into a weekly index of economic activities (WIEA). Other indicators were people's movement trends, produced by Google, indicating mobility across different categories of places such as retail and recreation, groceries and pharmacies, parks, transit stations, workplaces, and residential.

Using the aforementioned indicators, the country started producing a weekly report on economic activities. This analysis complemented regular reports on the health situation (number of cases, hospitalizations, deaths) and helped policymakers to take appropriate decisions aiming at protecting the population and limiting the progress of the pandemic while at the same time trying to minimize the potential negative

economic impact. Some of the decisions taken included whether or not to start a total or partial lockdown, the length of a curfew, restrictions on public gatherings, working from home as well as the use of personal protective equipment.

The paper aims to contribute to the literature on the economic effects of COVID-19 and containment measures (Mascagni and Lees, 2022; Aragie et al., 2021; Bizoza and Sibomana, 2020)as well as the literature on the use of high daily and weekly frequency indicators to monitor economic activities. The contribution is through the demonstration of how HFIs can be used in the context of Low-Income Developing Countries (LIDCs) in Africa and elsewhere with limited data availability, using simple and well-known statistical techniques. Similar papers have been done only on advanced economies, mainly using advanced techniques such as principal component analysis and state space dynamic factor model (Lewis et al., 2020), expectation maximization algorithm (Eraslan and G tz, 2021), and wavelet transformation approach (Qureshi, 2022).

From a policy-making point of view, this paper is relevant for other countries as it documents how policymakers in Rwanda used high-frequency data to make important decisions during the pandemic and how they could evaluate the effectiveness of policies such as "working from home" or total or partial lockdowns, using satellite data made published by Google. Additionally, by enhancing tax compliance, nations can improve real-data sources that can be useful proxies of economic activity.

Looking at the analysis of these HFIs, this paper shows the extent to which the Covid-19 pandemic had a negative impact on Rwanda's economic activity, but also how quick economic recovery occurred as soon as the pandemic was under control and temporary restriction measures were relaxed.

The rest of this article is organized as follows, section 2 discusses the literature on covid-19 impact briefly and section three presents the methodology. Section four is about empirical findings while section five concludes.

2. Literature Review

Timely information is a prerequisite for good economic analysis and policy decision-making. Especially, during periods of shocks such as COVID-19, which have severely

affected human health across the world and also had a negative impact on economies around the globe.

COVID-19 has had a significant effect on economic activity, by reducing economic growth, workforce, and human capital, thereby causing job losses, disrupting supply chains, increasing income inequalities, and worsening poverty traps, hitting investment and savings but positively impacting innovation and knowledge. However, the impact was mixed across countries depending on heterogeneity in the policy responses (Deb et al., 2022; Callegari and Feder, 2022; Calderon and Kubota, 2021). For instance, according to Deb et al. (2022), fiscal and monetary policies implemented during the COVID-19 crisis were crucial in reducing the negative effects of containment measures on economies, with the effects being more severe in countries where less fiscal stimulus was implemented and monetary policy easing was more restricted.

Calderon and Kubota (2021) indicate that certain economic conditions contributed to a larger decline in economic growth during the COVID-19 pandemic crisis. These conditions include increased exposure to global markets, vulnerabilities to commodity price volatility, increased dependence on external financing, primarily Foreign Direct Investment (FDI); greater reliance on global value chains and increased public debt exposure to private creditors. Contrary, they note that sufficient fiscal space and foreign savings served to buffer the steeper losses in economic growth.

COVID-19 affects the economy through three transmission channels (Carlsson-Szlezak et al., 2020). The first, which is direct, is related to the reduced consumption of goods and services. Prolonged lengths of the pandemic and the social distancing measures might reduce consumer confidence by keeping consumers at home, wary of discretionary spending and pessimistic about the long-term economic prospects. The second, pass through financial market shocks and their effects on the real economy. Household wealth will likely fall, savings will increase, and consumer spending will decrease further. The third channel is about supply-side disruptions. As COVID-19 keeps production halted, it will negatively impact supply chains, labor demand, and employment, leading to prolonged periods of layoffs and rising unemployment.

To assess the impact, different economic indicators have been used. Some papers used macroeconomic indicators such as Real GDP growth, inflation, unemployment rate, fiscal deficit, tax revenues, central bank rate, exports, imports, and FDI (UNDP-

Rwanda, 2020; for Latin America and the Caribbean (ECLAC), 2020; Calderon and Kubota, 2021; UNCTAD, 2022; Bank, 2021; Cho et al., 2021) while authors like (Lewis et al., 2020; Blonz and Williams, 2020; Eraslan and G tz, 2021; Chen et al., 2020) prioritized the use of high-frequency indicators to fast track deteriorating economic conditions during the COVID-19 pandemic period and make timely and well-informed economic decisions to support COVID-19 economic policy response.

3. Methodology

To monitor the impact of COVID-19 in Rwanda, we followed the methodology used by Lewis et al. (2020), Wrynn and Bedogni (2020), Chen et al. (2020). They employed high-frequency indicators and created a composite index on weekly frequency for quick identification of the magnitude of the shock.

3.1 The High-Frequency Indicators

A survey of high-frequency economic indicators was conducted to choose readily available indicators on a weekly and daily basis. Table 1 provides an overview of the selected indicators.

Table 1: Indicators used in the WIEA.

Indicator	Description	Frequency	Availability (t=week)
EBM sales	The total value of sales recorded by all businesses that use the EBM machines. They are compiled on a weekly basis as a sum of the sales between Monday and Sunday and are classified by economic sectors according to ISIC 2017.	Daily	t+2
VAT	Value Added Tax. This variable takes the total amount of VAT that is supposed to be levied on taxable sales recorded through the EBM system. It is compiled weekly, taking a total of Monday to Sunday.	Daily	t+2
NAL	New Authorized loans. This indicator is the total sum of the value of new authorized loans by the banking system every week.	weekly	t+1
Traditional exports	The sum of coffee, tea, minerals (Cassiterite, Coltan, and Wolfram), and pyrethrum exports.	weekly	t+1

-Non-traditional exports	The sum of all other formal goods exports mainly Horticulture, Other minerals, and manufacture product.	weekly	t+1
Imports	This indicator is the sum of the formal import of goods. In addition to the total import of goods, the index comprises the capita Good imports, Good consumer imports, Intermediary goods imports, and Fuel Imports.	weekly	t+1

To correctly assess the impact of the COVID-19 pandemic, we have to compare indicators of a particular week with their average value during the pre-COVID period. The latter span from the first week of 2019 (starting period of available data) to the eleventh week of 2020, as the countrywide lockdown was imposed from week 12 of 2020. In addition, we consider a four-week moving average trend to reduce the volatility of the series.

In addition to the high-frequency data, we use the google community Mobility data. Daily Google mobility has been used across the world to monitor the trend of Covid-19 and the responsiveness of different policies put in place to curb the effect of the pandemic (Yilmazkuday, 2021; Bravo and Jooste, 2020; Spelta and Pagnottoni, 2021)

Google published a new source of mobility data from late March 2020, based on the same location data used to indicate busy hours for restaurants and museums (Aktay et al., 2020). As data is only collected from users who have enabled 'location history' on their Android devices, it raises no new privacy concerns. To protect the privacy of the individuals whose data is used, the data is aggregated and anonymized. All metrics with a differential private count of contributing users (after noise addition) of less than 100 or a geographic region of less than 3 km^2 are discarded (Aktay et al., 2020).

The Google data indicate how the movements of people to different places, such as retail and recreation, groceries and pharmacies, parks, transit stations, workplaces, and residential, vary in comparison to the baseline days. The latter represents normal values for that day of the week, computed as the median value over the period spanning from January 3*rd* to February 6*th* 2020. The categorized places are retail & recreation (including restaurants, cafes, shopping centers, theme parks, museums, libraries, and cinemas); grocery & pharmacy (including grocery markets, food warehouses, farmers markets, specialty food shops, drug stores, and pharmacies); parks (including national parks, public beaches, marinas, dog parks, plazas and public

gardens); transit stations (public transport hubs such as subway, bus and train stations); workplaces and residential (Aktay et al., 2020).

3.2 The Weekly Index of Economic Activity (WIEA)

To capture all information available on a weekly basis, we compute a more comprehensive, representative, and reliable indicator called the weekly index of economic activity.

To compute the Weekly Index of Economic Activities (WIEA), We use the same methodology that the Federal Reserve Bank of New York, as well as the Irish Parliamentary Budget Office, employed to produce the weekly tracker for the economic activities (Lewis, et al., 2020; Wrynn & Bedogni, 2020) using the principal component analysis (PCA) method. The PCA is a statistical procedure that reduces the dimensionality of large datasets by transforming a large set of variables into a smaller one that still contains most of the information in the large set (Joliffe &Cadima, 2016; Karamizadeh, et al., 2013).

In PCA, an original dataset of n correlated variables to various degrees is transformed to n numbers of uncorrelated principal components (PCs) which have equal sums of the variances with the original variables. Though the number of PCs is the same as the original variables, the transformation is made in such a way that the first few PCs explain the majority of the variance in the data set, hence reducing the dimensionality of the original data set. The PCs are sequenced from the highest to the lowest variance, i.e., the first PC describes the data's highest variance proportion. The next highest variance is explained by the second PC and so on. Let us denote by X the matrix of $x_1, x_2, ..., x_n$ original variables, $X_a = \sum_{i=1}^{n} a_i x_i$ a linear combination of these variables, a is a vector of constants $a_1, a_2, ..., a_n$, S_a the sample covariance matrix associated with the dataset, and $a^{'}$ the transpose of a.

The variance of X_a is : $Var(X_a) = a^{'} S_a$ (1)

The objective is to determine the linear combination X_a that maximizes the variance $V(X_a)$. It is shown that the solution to that maximization problem is the one

defined by a, which maximizes the quadratic form $a^{'}S_{a}$ (Jolliffe and Cadima, 2016). To allow that problem to have a well-defined solution, a is imposed to be a unit norm vector: $a^{'}a=1$.

Thus, the maximization problem is equivalent to

Max $\left[Z(a)=a^{'}Sa-\lambda(a^{'}a-1)\right]$ (2)

A First condition gives: $\frac{\partial Z(a)}{\partial(a)}=0 \Leftrightarrow Sa-\lambda a=0$ (3)

$\Leftrightarrow Sa=\lambda a$ (4)

Therefore, a must be a unit norm eigenvector and λ the corresponding eigenvalue of the covariance matrix Sa.

It is important to note that λ are variances of Xa $Var(Xa)=a^{'}Sa=\lambda a^{'}a=\lambda$ (5)

S is a n x n real symmetric matrix with exactly n real eigenvalues $\lambda_{k}(k=1,...,n)$.

Their corresponding eigenvectors can be defined to form an orthonormal set of vectors,

i.e. $a^{'}_{k}a_{k^{'}}=0,\forall k\neq k^{'}$; (k=1 if k=k').

With that restriction of orthogonality of coefficient vectors, the full set of eigenvectors of S are the solutions to the problem of obtaining up to n new linear combinations $X_{ak}=\sum_{j=1}^{n}a_{jk}x_{j}$,

which successively maximize variance, subject to uncorrelatedness with previous linear combinations as $Cov(X_{ak},X_{ak'})=a^{'}_{k}S_{a_{k}}=\lambda_{k}a^{'}_{k}a_{k}=0,\forall k\neq k^{'}$.

Xa_{k} are called the principal components of the dataset.

a_{k} are called the principal component loadings, and elements of Xa_{k} are called the principal component scores, values that each individual would score on a given principal component.

The principal component loadings will be associated with selected high-frequency indicators to form the weekly economic activities index and this relationship is expressed by equation 6.

$$\boldsymbol{WIEA_t = W_{11}X_{1t} + W_{12}X_{2t} + W_{13}X_{3t} + \cdots + W_{1N}X_{Nt}}; \text{ .....(6).}$$

Where $W_{1i}$are the principal component loading from the principal components that capture the majority of information from the high-frequency indicators and X_{it} are the variables.

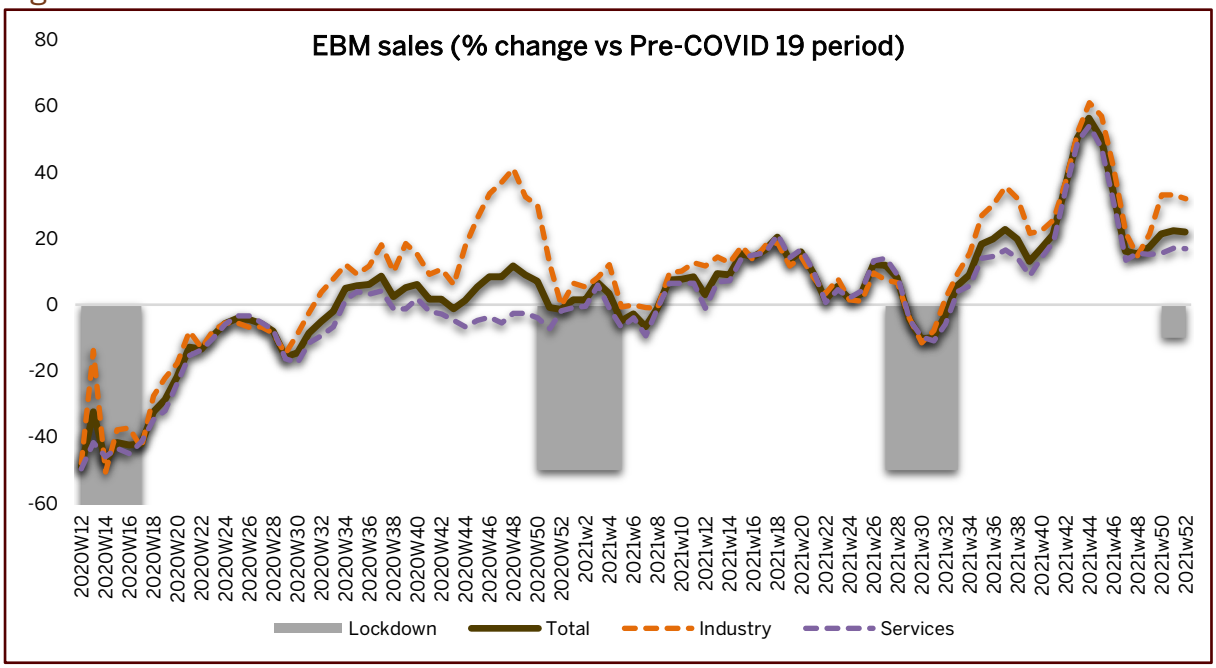
4. Empirical results

4.1 High-Frequency Indicators Trends

Rwanda has faced four main COVID pick periods in terms of COVID-19 contamination, hospitalizations, and deaths. During these periods, economic activities were affected negatively, given the measures to save people's lives and limit the COVID-19 virus spread. The first happened in 2020; following the first case of COVID-19, a country-wide total lockdown was imposed to limit the spread of the virus. This lockdown spanned the second week of March 2020 to the end of April 2020. During this period, all unnecessary movements outside the home have been banned except for essential services such as health care and shopping for groceries. Both public and private workers were ordered to work from home to help prevent the spread of the COVID-19 virus, and Rwanda's borders were completely closed, except for goods and cargo and returning citizens. Other pick periods were in January 2021 and July 2021, when the hike in pandemic infections caused the tightening of virus containment measures, including regional lockdowns. The latest period happened from the second week of December 2021 and January 2022; there was no lockdown but a tightening of other restrictions measures such as increasing curfew time, lowering staff working from the office as well the capacity of bus passengers, and limiting access to all business areas to no vaccinated people.

The selected economic indicators showed that during the period of tighter restrictions measures, there was a weakening economic performance. For instance, EBM sales fell by 42.5 percent on average during the first lockdown and improved gradually as restriction measures were eased, allowing the resumption of economic activities.

Figure 1. EBM sales

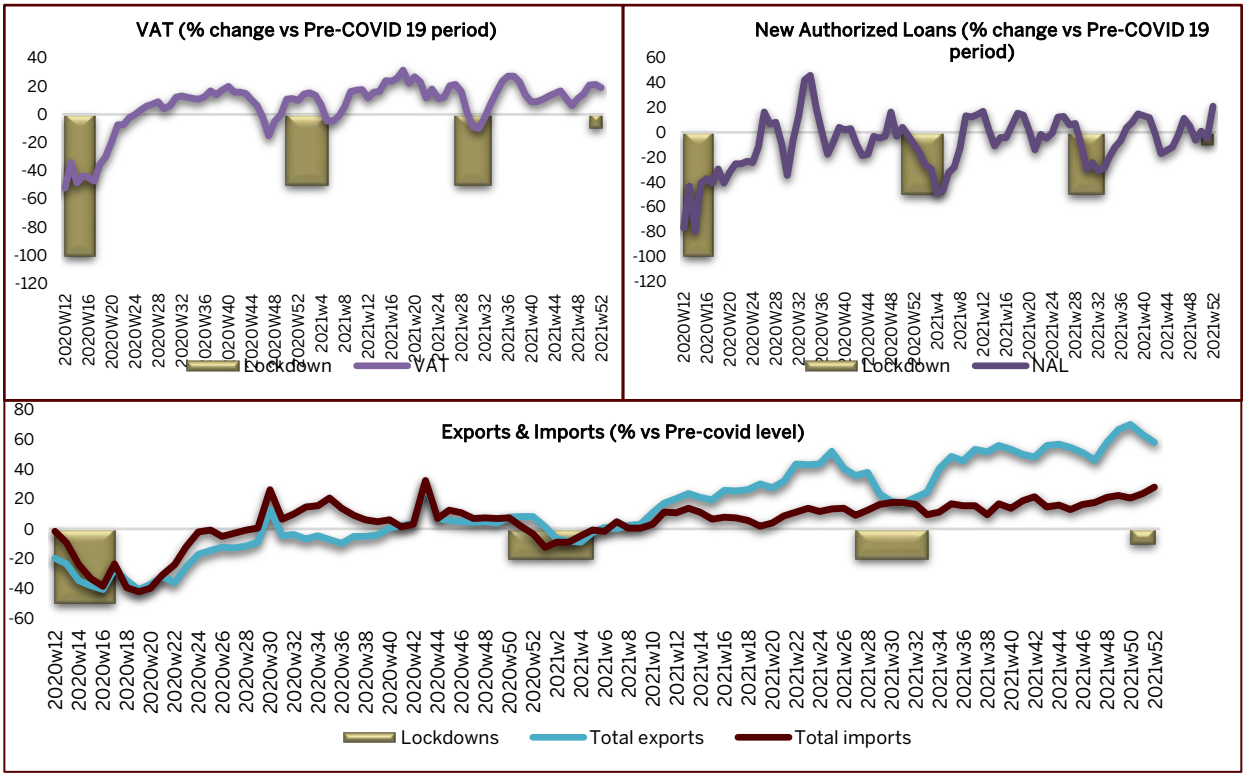


Source: RRA, 2022

In this regard, they evolved from -30.9 percent recorded in the last week of the lockdown to a growth of 23.9 percent in the first week of December 2020. Turnovers further increased by 10.0 percent on average between February and June 2021 after dropping by 4.8 percent during the partial lockdown of January 2021. In July 2021, EBM sales fell by an average of 10.4 percent during the second lockdown, this time partially. Then, following the easing of containment measures that led to the resumption of all economic activities and the vaccination campaign, EBM sales recorded an average growth of 24.5 percent between August and December 2021. In the last two weeks of December 2021 saw, COVID-19 restrictions were put in place following the surge in cases, but there was not much impact on economic activities. In December, the EBM sales' growth decelerated compared to their level in November (around 50 percent per week on average), but they kept growing by around 20 percent, which is close to the average of August-December.

The same economic conditions revealed by the EBM sales series are reflected by the evolution of the weekly VAT, New authorized loans, exports, and imports. These indicators declined in the period of crisis, and they picked up in the period of eased containment measures, evidencing severe economic conditions when COVID-19 cases were rising and economic recovery after the crisis period.

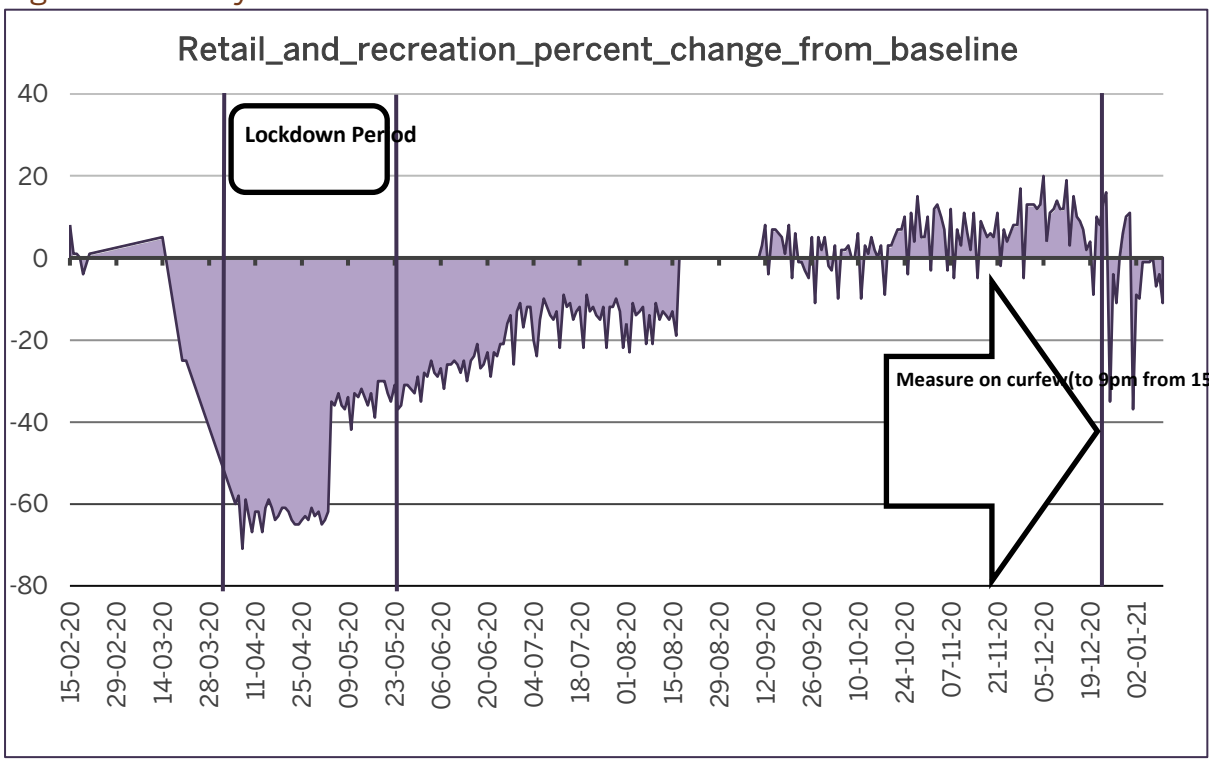
Figure 2: VAT, New Authorized Loans, Exports, and Imports



Regarding google community Mobility reports; we observe that the lockdown was strictly respected by the Rwandan population as mobility dropped drastically during the lockdown for recreation and retail. Since May, mobility is gradually increasing. In the period from Sept 10 to November 15, mobility for retail and recreation is higher than pre-COVID levels reflecting the relaxation of the curfew measures from 7 PM to 9 PM and efforts to promote domestic tourism. The surge of cases that made the government of Rwanda tighten measures is reflected in figure 3 where we see a negative trend due to the reduction of the curfew hours from 9 PM to 8 PM introduced on the 22nd of December and the close of all business at 6 PM later from 5 January 2021.

The graphs below show how effective some of the measures taken by the government.

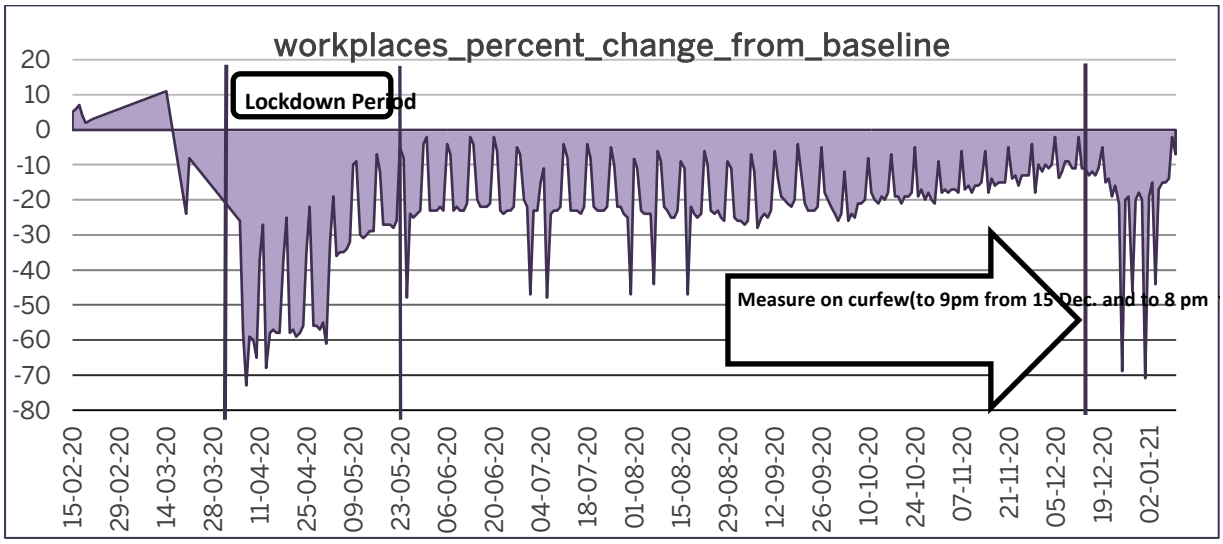
Figure 3. Mobility for Retail and Recreation



Source: Google COVID-19 community reports

Mobility to workplaces was very low during the lockdown as every worker was asked to work from home. It is still limited due to the "50% work-from-home policy". Between the end of August and the end of October, there was a change in Government guidelines from 50% to 30% and back to 50% in November regarding the share of workers allowed to work at their workplaces. The government took more stringent measures due to the surge in new cases and rising rate of mortality, where the share of workers allowed working at their workplace went from 30% from December 15th to 15% from 5th January, this was strictly respected by Government institutions, and mobility levels remained relatively low. The fluctuations can be explained by the weekends when mobility is at almost similar levels compared to the pre-covid situation.

Figure 4. Mobility for Workplaces



Source: Google COVID-19 community reports

4.2 Weekly Index of Economic Activity

The starting point for computing the index is the assessment of the appropriateness of the aforementioned HFIs. These indicators accurately represent the GDP's expenditure side. Table 2 shows that they have a strong relationship with both the GDP and the Composite Index of Economic Activities (CIEA). The latter is a monthly composite index that has a strong track of Rwandan Real GDP, evidenced by a correlation rate of 90 percent on average in the last ten years.

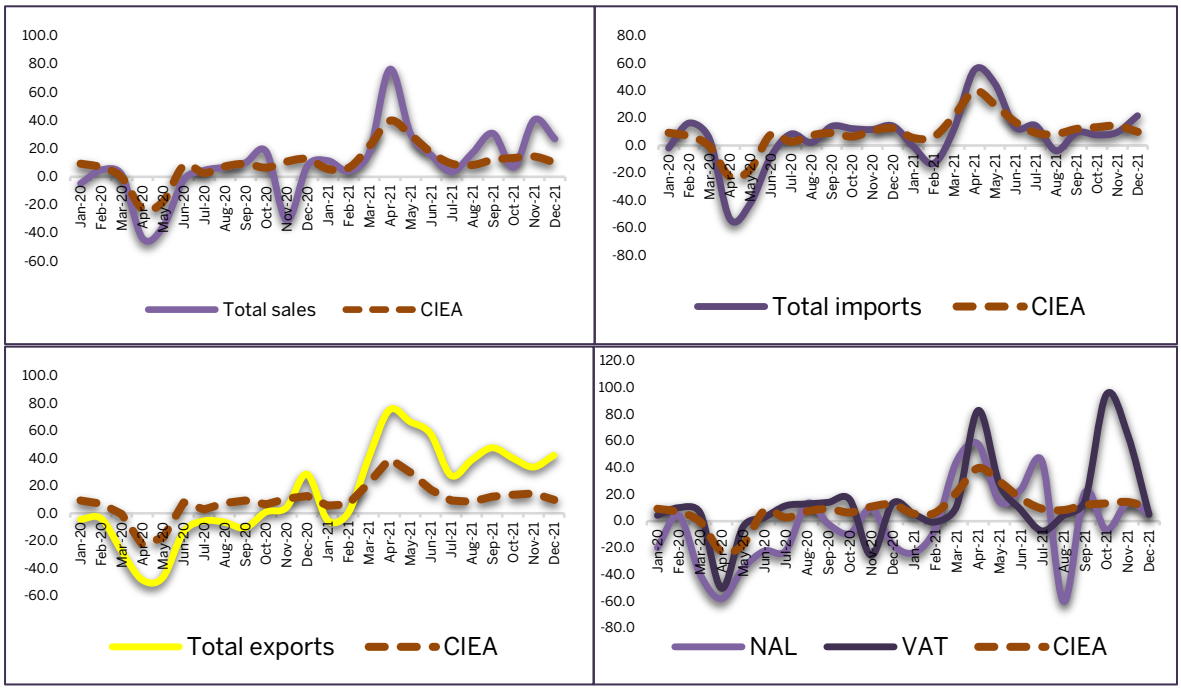
Table 2: Variables used to compute the WIEA

Type		Correlation with GDP	Correlation with CIEA
Industry and services turnovers	Total sales	83.9	90.0
Export	Total exports	75.0	94.1
Imports	Total imports	76.5	92.6
Credit to the private sector	New Authorized Loans	70.6	86.0
Tax	Value Added Tax	73.5	80.5

Source: Author's computation, 2022

To have a much clearer picture of the fit between the selected indicators and the reference variable, we plot the series of the chosen variables. Their monthly version is compared to the CIEA.

Figure 5: Selected variables and the CIEA evolution (Percent year-on-year)

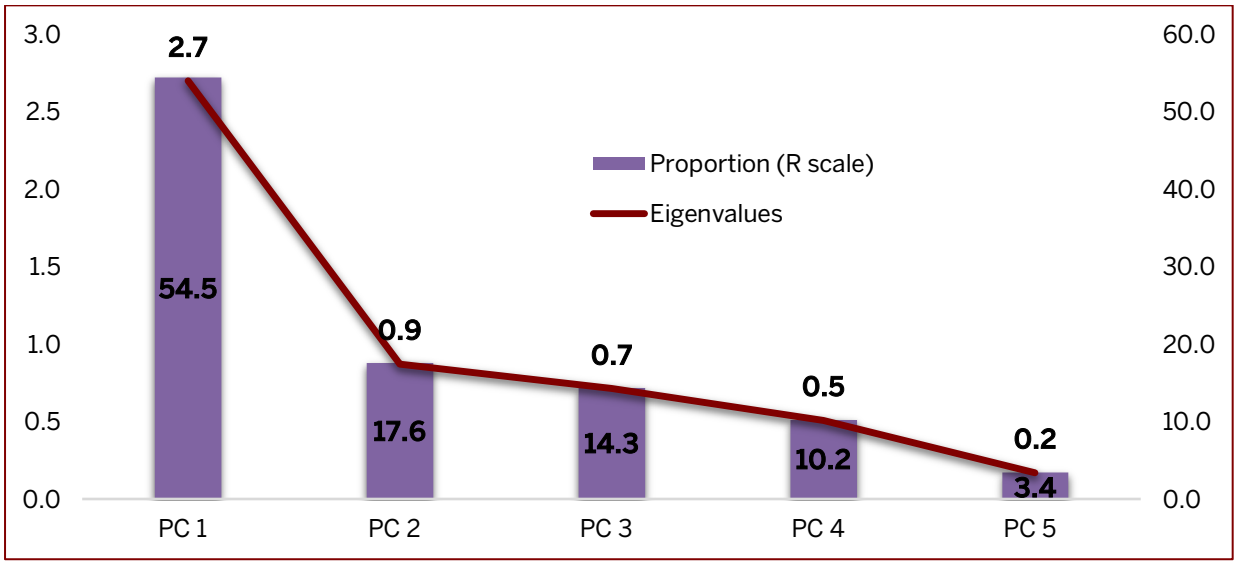


Source: Author's computation, 2022

Figure 5 presents the evolution of the selected variables, and the observed trends confirm the strong correlation between the chosen variables and the CIEA. Furthermore, they all reveal the economic fallout during the lockdown periods as well as the subsequent gradual recovery of economic activities after the resumption of economic activities.

After assessing the suitability of the variables, we combine these indicators in one index constructed using the principal component analysis (PCA). The computation of PCA shows that the first principal component contains rich information with a proportion of 54.5 percent, while the rest is shared between four principal components representing less information individually, as illustrated by figure 6.

Figure 6. Scree plot and percentage variance for each principal component



Source: Author's computation, 2022

Therefore, we proceed by computing the WIEA, following equation 6, using the first principal component. The associated weights for the chosen variable are presented in table 2.

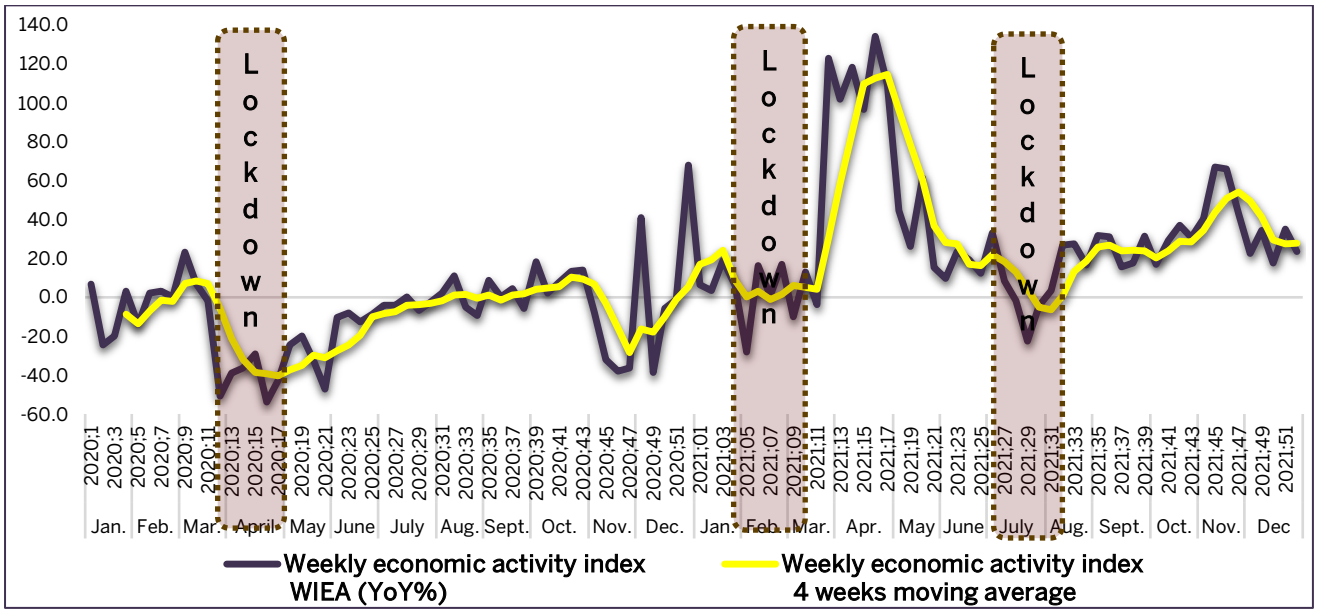
Table 3: Weights derived from the first principal component

Variable	eigenvector loading
Total EBM sales	0.53
Total exports	0.42
Total imports	0.45
NAL	0.26
VAT	0.52

Source: Author's computation, 2022

The computed index, which year-on-year growth is presented in figure 2, provides timely information on economic conditions, mostly during this period of the COVID-19 pandemic. The index indicates the extent of economic activities fallout in each period of lockdown and evidence also the recovery amid the easing of restrictions measures.

Figure 7: Weekly Index of Economic Activities

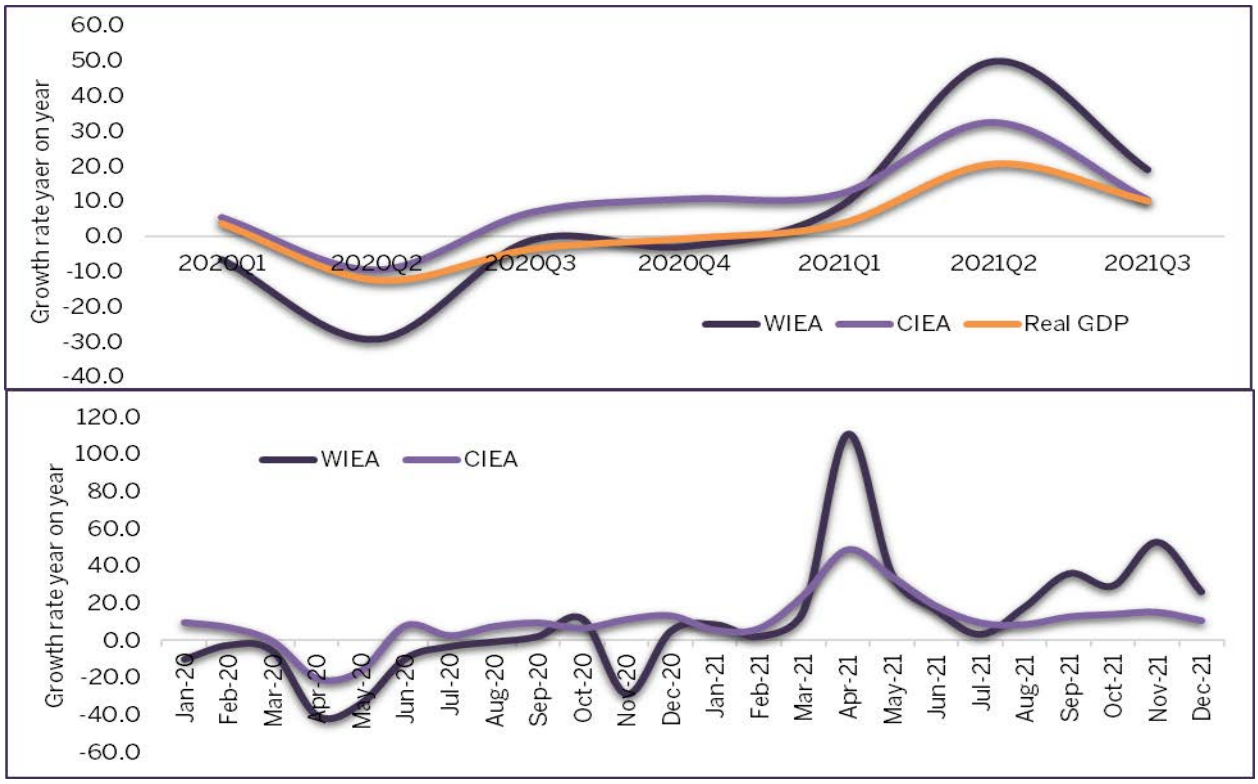


Source: NBR using RRA and BNR raw data , 2022

The comparison of the WIEA with the real GDP as well as the CIEA, reveals that the index conveys the same message about the recent evolution of the Rwandan economy. Therefore, the index is a powerful early warning indicator. It has a correlation of 87.0 percent and 85.1% percent vis- -vis the CIEA and Real GDP, respectively.

Given its overall performance, it can be used to inform the monetary policy process about the current and near-future trends of overall economic activity.

Figure 8: Relationship between WIEA, Real GDP, and CIEA



Source: Authors' estimation

5. Conclusion

Comprehensive economic indicators that provide accurate descriptions of economic conditions are normally accessible with a modest delay. This can complicate the process of economic decision-making, specifically when conditions evolve rapidly from day to day and week to week, as is the case of the COVID-19 period where governments around the world have to take quick measures to fight the health and negative economic consequences of COVID-19 pandemic.

This paper presents high-frequency indicators and a simple approach to generate an index of economic activities on a weekly basis which can help to track economic conditions and the economic impact of COVID-19 in Rwanda. The constructed weekly index of economic activities demonstrates a strong correlation with real GDP and the Composite Index of Economic Activities, making a valuable measure of economic activities and an early warning index that facilitates policy decision-making. The economic analysis based on these indicators has complemented other health reports and assisted policymakers in taking appropriate measures and decisions to safeguard populations and stop the spread of the pandemic while minimizing the potential negative economic impact.

This paper contributes to the literature and the policy-making environment by showing how HFIs can be used in the context of Low-Income Developing Countries (LIDCs) in Africa and elsewhere with limited data availability. This paper is particularly relevant for other developing economies because it shows that with some indicators usually available on a more regular basis, a reliable index can be computed in a relatively simple way. However, it is important for Rwanda and for other countries to keep investing in the automation of various processes such as tax payment and declarations, economic transactions to avail more HFIs for economic analysis. The Google mobility data also offers a good opportunity to measure the impact of mobility restriction measures put in place during the pandemic.

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THE DRIVERS OF INFLATION DYNAMICS DURING THE PANDEMIC IN RWANDA: EVIDENCE FROM DISAGGREGATED CONSUMPTION DATA

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Abstract

This research seeks to examine the behavior and/or dynamics of inflation during the pandemic, using monthly disaggregated consumption data for Rwanda covering the period 2005 to 2021. This article specifically examines the dynamics of inflation during the pandemic and the effect of consumption on these patterns. The study used the Sum of Autoregressive Coefficients (SARC), estimated using the ADF method as in Andrews and Chen (1994) as well as the Grid bootstrap method as in Hansen (1999), to measure inflation persistence. Inflation persistence helps to show how the pandemic shock affects different components of CPI and overall inflation and how long it takes for this shock to dissipate. The results show that inflation persistence before the pandemic is generally high compared to inflation persistence during the COVID-19 pandemic. However, the persistence of headline inflation is higher compared to other groups of inflation, mainly driven by the persistence of inflation for volatile CPI components. Thus, the Central Bank should always monitor movements in the inflation of these volatile components, especially during shocks similar to the pandemic.

Keywords: COVID-19 Pandemic, Inflation, Consumption, Inflation Persistence

***JEL Classification Numbers**: E32, E31, E21*

1. Introduction

The COVID-19 pandemic had far-reaching effects on human life and economic development in general. By 2022, globally, more than 480.9 million cases and 6.06 million deaths had been recorded (Ritchie et al., 2022). Though the pandemic has generally stopped, the world is still grappling with its effects, compounded by the recent emergence of new COVID-19 variants in China. The pandemic not only devastated the health sector but also led to economic recessions across the world. An estimated 31 million people were pushed into poverty around the world, of which more than 26 million are from sub-Saharan Africa, including Rwanda, and this number could even be as high as 62 million people (Lakner et al., 2021).

The pandemic and its collateral impacts negatively affected a majority of economies as supply chain disruptions from the pandemic resulted into a rise in consumer demand, and higher commodity costs, which altogether pushed inflation upwards in several countries (World Economic Forum, 2022). Inflation, which had been consistently low for a while prior to the pandemic, fluctuated drastically, having a significant impact on the economies and momentarily lowering prices. Not only that, but also in 2021, as the economic recovery accelerated, inflation increased above levels seen prior to the pandemic. The supply shocks have been propagating within the other sectors of the value chain, which also created a decline in aggregate demand of the households due to a rise in precautionary savings resulting from uncertainty. Moreover, households and firms were forced to reduce private spending and employment, respectively, due to a shortage in money balances (IMF, 2021).

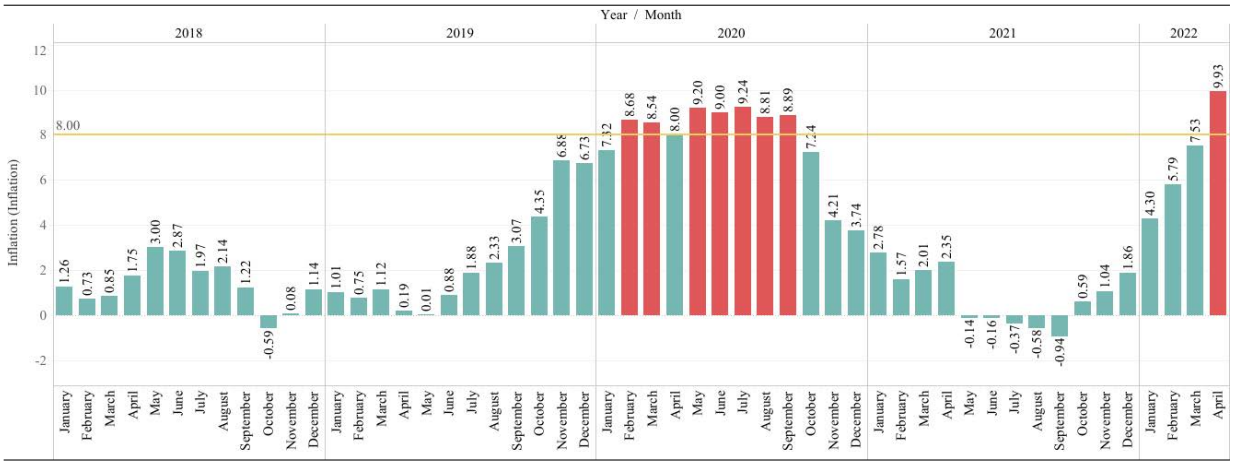
From a transmission point of view, households' increased consumption stimulates demand. That increased demand often leads to businesses raising their prices. Hence, increased consumption can push prices upward. Cavallo (2023) shows that during COVID-19 changes in expenditure patterns (demand behaviors of households) distorted the inflation dynamics because some consumer goods became more important than others. In this case, the underlying patterns of inflation can become complex to be measured from the general indices, which can pose serious risks to monetary authorities and policymakers. Consequently, there is a need for empirical research that bases on disaggregated consumption data in order to understand the clear dynamics of inflation levels because it improves the clarity in the drivers of inflation dynamics (Lunnemann & Math , 2004).

In 2020, Rwanda had a negative Gross Domestic Product (GDP) growth rate of 3.4% below zero (i.e., -3.4%) from a 9.5% growth rate in 2019. Additionally, there was a

decline in households' consumption expenditure from 9% in 2019 to 3% in 2020, however, the consumption rebounded instantly in 2021 to 10% due to recovery in economic activities. Despite the lower levels of output that caused stagnation in economic activities, the average inflation rate of was 7.72% compared to 2.43% from 2019 (NISR, 2020). The negative effects of COVID-19 twisted the behaviors of both consumers and producers, causing inflation to exhibit unusual trends. Existing literature indicates that if inflation increases because aggregate demand keeps rising, stabilization policies can still reach their goals without putting constant recovery measures at risk. On the other hand, when inflation is caused by inadequate aggregate supply, stabilization policies might face possibly costly contradicting choices and diversion within consumption patterns due to excess demand be- cause supply shocks are small contributors and reduce the overall variance of real GDP growth and inflation, respectively, compared to demand shocks (Bekaert et al., 2020).

Figure 1 shows the inflation trend in Rwanda on a monthly basis from January 2018 to April 2022. The yellow line shows the upper bound of the inflation target for the National Bank of Rwanda. The year-on- year (y-o-y) inflation was highest in 2020, reaching levels above the upper bound, notably in the months of February (8.68%), March (8.54%), May (9.20%), June (9.00%), August (8.81%), and September (8.89%), with a peak recorded in July (9.24%).

Figure 1: Rwandan headline inflation (y-o-y)



Source: BNR (2022)

Inflationary pressures recorded in 2020 are deemed to be a combination of the effects of increased demand and supply chain disruptions due to the COVID-19 pandemic (BNR, 2022). During the pandemic, lockdowns led to the closure of several businesses, thus hampering production, which resulted into demand-supply mis- matches. The restrictions on movements as well as other containment measures, also negatively impacted production and supply chains and led to an increase in public transport fares. Even though the first case of coronavirus in Rwanda was recorded on March 14th, 2020, by the Rwanda Biomedical Center (RBC), Ndishimye et al (2020), the global supply chain was already under pressure following the rapid spread of COVID-19 after the first case was reported in Wuhan, China, in late 2019. As depicted in figure 1, the year 2021 was characterized by declining inflation. In fact, deflation was recorded throughout the months of May to September. However, inflation picked up again in 2022, with April 2022 recording the highest inflation (9.98%) since 2009. The rapid increase in inflation in 2022 was attributed to the effects of the emergence of the Omicron variant Anghelache et al. (2022). Later, the war between Russia and Ukraine amplified these inflationary pressures Diop and Asongu (2022).

Inflation dynamics were generated from various sources, and there was a growing need to collect data from different sectors to understand what may have had a major influence on inflation dynamics during this period. Thus, this paper uses disaggregated consumption data to study the inflation dynamics and to assess inflation persistence due to the COVID-19 shock. This study will only examine the effect of the COVID pandemic on inflation, where the effect of the Russian-Ukraine war will be controlled for by using a sample excluding the Russia-Ukraine war. The objectives of this study are to examine the drivers of inflation dynamics during the pandemic and analyze the effect of consumption on the dynamics of inflation. The stated research objectives will be achieved by using the Sum of Autoregressive Coefficients (SARC) and the Grid Bootstrap methodologies, which will be applied to data for the Rwandan economy covering the period January 2005 to December 2021. To the best of our knowledge, this is the first study to have used the SARC and Grid Bootstrap methods in the scope of the Rwandan economy to try to examine the dynamics of inflation during the pandemic using disaggregated consumption data.

Apart from the general background given in section 1, the rest of the paper is organized as follows: section 2 discusses the relevant literature on the inflation dynamics and debates throughout the time; section 3 presents the methodological approach, and

estimation techniques; section 4 presents the empirical estimations, analysis and findings; while Section 5 provides the conclusion and policy implications.

2. Literature review

There is scanty literature on the analysis of inflation dynamics for Rwanda using disaggregated consumption data and the underlying shocks that may arise in the economy. For the rest of the World, many economists have studied the behavior of inflation dynamics in the context of shocks as well as the dynamics of different components of inflation. For example, Duca et al. (2021) used the ordered logit and VAR models to reveal that when consumers expect higher inflation in the future, they increase their current spending patterns. This observation is consistent with Acunto et al. (2016),

Manasseh et al. (2018) and Sheremirov et al. (2021), However, according to some studies, the effect of inflation expectations on current expenditure varies between durable and non-durable goods (Weber, 1975; Coibion et al., 2019). This explains why inflation projections and inflation expectations are important inputs into monetary policy decisions and why it is important to analyze inflation dynamics using different components of the CPI basket.

Additionally, Cavallo (2023) shows that the effect of inflation may also differ depending on the income of households, whereby during a crisis like COVID-19, low-income households are more likely to suffer from high inflation compared to high-income households. Using Carlson and Parkin (CP), and VAR methods, Soric (2013) found that consumers plan to lower future spending when they experience a shock in both actual and perceived inflation because they feel that inflationary pressures erode away their real income and wealth, which makes them spending averse. The study also reveals that a change in inflationary expectations motivates consumers to increase their expenditures before the period of inflation takeoff happens.

Ha, Kose and Ohnsorge (2021) applied the Factor-Augmented Vector-Autoregressive (FAVAR) model on monthly data for the 2001-2021 period for a sample of 30 advanced economies and 55 emerging market and developing economies (EMDEs) as well as on quarterly data for the 1970-20 period for up to 35 advanced economies and 52 EMDEs to examine the drivers of the observed inflation dynamics during the pandemic and the

likely trajectory in the near-term. They found that expectations play a crucial role in determining inflation during the pandemic where the inflation expectations of the current year would increase the expectations by more than one percent for the following year. Their take is that if inflation expectations are well anchored, it may not warrant any monetary policy response, otherwise tight monetary policy may be necessary. These findings are similar the one by Tenreyro (2020) that it is a crucial to anchor inflation expectations to ensure price stability. Indeed, inflation expectations have been cited to be an important driver of inflation persistence (Vijlder, 2022).

Regarding the measurement of the inflation persistence on disaggregated data, Clark(2006), used the Sum of Autoregressive Coefficients (SARC) of the consumer price indices from 1984 to 2002. His findings indicated that, unlike other similar studies, the differences in inflation persistence between durable goods, nondurable goods, and services seem to not be substantially changing just like in the case of non-housing inflation, compared to overall inflation.

Phiri (2012) investigated how the threshold levels of inflation can affect its persistence in South Africa on monthly data from February 2000 to December 2010. Using threshold autoregressive roots (TAR) models and SARC, they found that inflation in headline CPI exhibits the highest persistence in regimes of higher inflation rates, and this is similar for the core inflation which can be persistent to more than a unity when it is between 4.7 and 8.5 percent, whereas it has the lowest SARC if the rate is below 4.7 percent. Phiri (2016) also used monthly inflation from 2003 up to 2016 for the Reserve Bank of South Africa (SARB) to study the effect of financial crisis on inflation. He used the univariate autoregressive model and estimated the persistence level of inflation using SARC[14]. Disaggregating inflation into 5 main sub-components (total CPI of memorandum item, administrative prices, total, goods and services), he found that the persistence was higher before the crisis but significantly lower in periods subsequent to the financial crisis. However, Phiri (2016) does not mention the persistence during the financial crisis itself[15].

Anguyo et al. (2020) investigated the inflation persistence in both headline and core inflation in the Ugandan consumer prices using monthly and quarterly data from 1993

[14] He disaggregated the series of the inflation into five (5) main categories

[15] He did not construct any sample that exclusively takes into account the period of financial crisis.

to 2015 for headline inflation and 1998 to 2015 for core inflation. The research uses quantile regression approach[16]. Results reveal that the inflation rate is not characterized by a unit root, which implies that the effect of the shocks dies out over time and the inflation returns to its long-run value.

Table 1: Literature Summary on Dynamics of Inflation

Author	Period	Underpinning Theories	Methodology/Estimation Techniques	Variables of interest	Key Findings
Knotek II, E. S., Za-man, S. (2017)	1999 - 2017	Phillips Curve	Time-Varying Parameter -VAR with Stochastic Volatility	Inflation, Unemployment	Reduction in inflation persistence level
Paya, I. Duarte, A., Holden, K. (2007)	1947 - 2005	Temporal Aggrega-tion	Cumulative Impulse Re-sponse (CIR)	Inflation (CPI, PCE)	Lower frequency time-series im-plies higher inflation persistence.
De Soyres, F., Franco, S. (2019)	1970 - 2017	Market Size, Trade, and Productivity	Correlation regressions with Fixed Effects	Inflation (CPI), GDP De- flator, Global Value Chains (Trade Flows)	High level of correlation between production linkages and inflation.
Coleman, S. (2010)	1989 - 2002	Optimum Currency Area, Aggregation	Fractional Integration	Food and non-food Infla-tion prices	Some evidence of long memory (persistence) in food and non-food inflation
Nguyen, A. D. M., Dridi, J., Unsal, F. D., Williams, O. H. (2017)	1988 - 2013	Inflation Persistence	Global Vector Autoregres-sions (GVARs)	CPI, nominal effective ex- change rate, broad money, nominal interest rates, real GDP	Domestic demand pressures, global shocks, and shocks to output have played a larger role in driving inflation recently.

[16] This research uses full sample and subsamples for both the headline and core inflation based on structural breaks from the series

3 Methodology and Data

3.1. Models for inflation persistence

The reason behind the sum of AR coefficients is that more persistent inflation has a higher sum of autoregressive coefficients (ρ_i). This shows that shocks to the inflation process do not go away quickly and that prices keep more of the initial shock (i.e., persistence). For example, this parameter would show how much of an immediate pandemic shock keeps influencing inflation for a particular sub-component of the CPI basket or of the overall CPI basket, and for how long before the effect of this shock dissipates. This research uses disaggregated consumption data to assess whether, during the pandemic, inflation for some CPI sub-components was more persistent compared to others, relative to the pre-pandemic periods and hence, to indicate which components may have influenced the general inflation persistence.

The generic model for inflation persistence can be written as follows:

$$\Delta\pi_t = \alpha + \sum_{i=1}^{q-1} \phi_i \pi_{t-i} + (\rho - 1)\pi_{t-1} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

In equation (3.1), the change in the inflation rate between two periods is expressed as $\Delta\pi_t = \pi_t - \pi_{t-1}$. This equation corresponds to the well-known Augmented Dickey Fuller (ADF) regression suggested by Dickey and Fuller (1979; 1981), which can be used to determine whether a time-series process is stationary.[17]

This methodology was justified by Andrews and Chen (1994) as accurate and robust to measure the persistence of inflation. The method was used by various authors to investigate the persistence of headline inflation and of its sub-components, for example, Sheremirov (2021) for the U.S. and Figueiredo and Machado (2017) for Brazil.

Due to the concern of biasness that may arise from OLS estimators in finite/small samples, this research has extended the estimation methodology by using the mean unbiased estimator method proposed by Hansen (1999). This method obtains a mean

[17] See also Paya et al. (2007)

unbiased estimator of the sum of autoregressive coefficients (SARC), where the lag order is chosen based on AIC information criterion. The SARC model (equation 3.1) includes the intercept and trend components:

$$\pi_t = \alpha + \beta t + \rho_i \pi_{t-1} + \sum_{i=1}^{q-1} \phi_i \Delta\pi_{t-i} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.1)$$

The full sample (January 2005-December 2021) accounts for all the shocks that happened, such as the 2008 global financial crisis, the increase in international commodity prices (2008 and 2011/12), the decrease in international commodity prices (2015/16), the aid shock (2012/13), the various domestic agricultural shocks, and COVID-19 but excludes the Russian-Ukraine war (2022). We also define sub-samples to try and capture particular shocks: (1) the first sub-sample covers the January 2005 – December 2007 period, and this corresponds to the period before the global financial crisis; (2) the second sub-sample covers the January 2008 – December 2012 period, and this captures the global financial crisis, the fluctuations in international commodity prices, and the aid shock but excludes COVID-19; (3) the third subsample covers the January 2020 – December 2021 period and this caters for the COVID-19 shock but excludes the Russia-Ukraine war shock. Nevertheless, there is a downside in shock identification because the shocks outlined above are not the only ones present in the samples defined in this study, which means that all the shocks that occurred within the time frame of the samples are not fully known even though they may be captured in the empirical estimations.

3.2. Data

To measure and/or assess inflation persistence using the SARC model, we use disaggregated consumption data. The analysis discussed in this chapter relies on month-over-month and year-over-year changes in the twelve (12) major groups of the Consumer Price Index (CPI) and combines these groups to form a headline CPI and a core CPI. This paper was also interested in looking at food inflation and energy inflation as separate groups. The core CPI is the part of the headline CPI that does not include prices of fresh food and energy. The time span is from January 2004 to December 2021, for the inflation groups (216 observations). The year-on-year inflation rates are approximated by multiplying by 100 the difference between the natural logarithm of the CPI for a given month and that of the corresponding month

of last year (100*[log difference of the same month of 2 consecutive years]). We use monthly Central Bank Rate (CBR) and CPI data, sourced from the NBR and NISR, respectively. The monthly time-series data is obtained from the BNR (CBR) and NISR (CPI) website. Though CPI data starts in 2004, y-o-y computations imply that we lose the first 12 observations, reducing the sample number of observations from 216 to 204.

4. Findings

4.1 Descriptive Analysis

Before estimation, it is necessary to review the reliability of the sample size. The mean of the headline inflation shows that the mean inflation rate (5.6%) for the whole sample is below the upper bound of the NBR inflation target band (8%). This implies that the NBR managed to keep inflation below the upper bound, at least on average, for the period ranging from January 2005 to December 2021. However, this average value masks a lot of realities since it is affected by outliers. Note that if inflation is persistently high, the NBR can face challenges while trying to stabilize prices. Though average inflation does not show the degree of inflation persistence, it is an indication that shocks to inflation were generally short-lived and theNBR managed to stabilize prices in general, despite the occurrence of such shocks. However, an empirical investigation of inflation persistence is needed.

Table 2: Descriptive Statistics

Sample	2005m01 - 2021m12					
Variable	Mean	Std. Dev	Skewness	Kurtosis	Jarque-Bera	Obs
Headline	0.056	0.043	1.175	4.795	74.296** (0.000)	204
Core	0.048	0.040	2.023	7.339	299.229** (0.000)	204
Food	0.068	0.072	0.470	2.886	7.630** (0.022)	204
Energy	0.060	0.064	1.117	2.756	42.935** (0.000)	204
Transport	0.050	0.064	0.366	5.289	49.099** (0.000)	204

Source: Author's calculations. Std. Dev is the abbreviation of Standard Deviation, Obs. stands for the number of observations, JB stands for Jarque-Bera x^2 statistic. ** Denotes the significance at 5% level. The letter M denotes months.

4.2 Monthly inflation persistence

Using the SARC, we analyze the persistence of inflation for the various CPI components before and after thepandemic. Thereafter, we identify those components that had the

biggest influence on the overall inflation persistence during the periods under review. The SARC results are compared to those from a benchmark model, notably the autoregressive (AR) of order 1 (AR(1)).

Table 7 gives the results of the AR(1) model. Note that the SARC model is presented as an AR (p) model and the sum of autoregressive coefficients shows the level of inflation persistence. The variables of interest are: (1) Headline inflation; (2) Core inflation; (3) Food and non-alcoholic beverages inflation, and; (4) Housing, energy, water, and fuel inflation. The results show relatively slight differences between AR(1) and SARC coefficient estimates. The comparison of the AR(1) and the SARC models has been frequently utilized in the literature for the U.S and Euro area, Pakistan and Asia-Pacific, to name a few (Marques, 2004; Tillmann, 2011; Muhamad et al., 2012). As expected, the AR(1) shows higher inflation persistence compared to that obtained using the AR(p) model. However, the results from the two models are not fundamentally divergent.

The SARC (i.e. AR(p)) estimations show that the year-on-year headline inflation has the highest level of inflation persistence, standing at 90.8 percent., This means that, ceteris paribus, the weight of headline inflation for the previous 4 months in the current level of headline inflation is 90.8%, after a shock. Alternatively stated, the shock induced inflation dynamics for the past 4 months explain 90.8% of the current level of inflation. In addition, 88.8% of the current core inflation is explained by the inflation dynamics of the previous two months. For the other categories, the persistence of inflation for food and non-alcoholic beverages stands at 90.9%, whereas the inflation for housing, water, electricity, gas, and other fuels is persistent at 91.5%, each with a lag of months. Transport inflation exhibits the least persistence, standing at 84.9%. Thehigh level of inflation persistence for headline inflation, relative to core inflation, confirms the importance of the persistence for food and non-alcoholic beverages and for housing, water, electricity, gas, and other fuelsin driving overall inflation persistence/dynamics.

Table 3: Sum of Autoregressive Coefficients (SARC)

Variable	AR(1)	Lag	AR(p)
	2005m01 - 2021m12		
Headline	0.964543	4	0.908
Core	0.934699	2	0.888
Food	0.946615	2	0.909
Energy	0.919833	2	0.915
Transport	0.902702	2	0.849
SS1	2005m01 - 2007m12		
Headline	0.838505	1	0.834
Core	0.906844	2	0.830
Food	0.915792	2	0.829
Energy	0.961104	1	0.500
Transport	0.603317	1	0.522
SS2	2008m01 - 2019m12		
Headline	0.970240	2	0.933
Core	0.962990	3	0.912
Food	0.950864	2	0.910
Energy	0.906334	1	0.889
Transport	0.953137	3	0.901
SS3	2020m01 - 2021m12		
Headline	0.960139	1	0.750
Core	0.85235	1	0.690
Food	0.959103	1	0.521
Energy	0.841754	1	0.621
Transport	0.834434	1	0.691

Source: Author's calculations. "p" denotes the lag length order obtained using Schwartz Information Criterion (SIC)

The persistence of headline inflation can be relatively higher compared to core inflation due to the continuous persistence of energy and food inflation as can be seen from Table 3. The sub-groups of volatile components may exhibit high persistence after the shocks and this may cause what Cevik (2022) calls the aggregation effect, given that headline CPI is a weighted sum of the components. This is an indication that high inflation persistence in non-core components has an effect in the dynamics of headline inflation and must therefore be monitored by monetary authorities. Walsh (2011) argued that the

importance of non-core CPI components in influencing inflation dynamics is more pronounced in developing economies where food prices are more volatile and persistent from shocks. Hence, the monetary policy decisions in developing countries should be tailored to such challenges, especially by mitigating second-round effects.

The AR(p) model estimations discussed were obtained using the Augmented Dickey Fuller (ADF) Method, which has been criticized on grounds that its OLS estimations tend to be biased, especially in finite samples (O'Reilly & Whelan, 2005; Capistr n & Ramos-Francia, 2009; Tillmann, 2011). For robustness check, we do the re-estimations using the Hansen Bootstrap method developed by Hansen (1999). This method obtains bootstrapped confidence intervals for an estimator of the sum of autoregressive coefficients (SARC) where the lag order (p) is chosen based on the SIC information criterion. Table 4 displays the SARC estimates based on Hansen (1999)'s grid bootstrap method.

Table 4: Hansen's Grid Bootstrap

Variable	SARC($\hat{\rho}$)	S. Err.	Confidence Interval
	2005m01 - 2021m12		
Headline	0.911513	0.021045	[0.887355, 0.965449]
Core	0.960514	0.015895	[0.949244, 1.011454]
Food	0.912941	0.022683	[0.888747, 0.974762]
Energy	0.911755	0.034888	[0.885870, 1.024283]
Transport	0.867485	0.030824	[0.835303, 0.943243]
SS1	2005m01 - 2007m12		
Headline	0.837207	0.094951	[0.807752, 1.126338]
Core	0.875963	0.071358	[0.865584, 1.117279]
Food	0.851445	0.066609	[0.806250, 1.064616]
Energy	0.500845	0.213428	[0.346369, 1.197065]
Transport	0.599216	0.139564	[0.478852, 1.087589]
SS2	2008m01 - 2019m12		
Headline	0.943861	0.023627	[0.926858, 1.018050]
Core	0.951952	0.016028	[0.937443, 1.007668]
Food	0.912089	0.027968	[0.884986, 1.011696]
Energy	0.898310	0.035930	[0.868064, 1.020376]

Transport	0.904344	0.023973	[0.878529, 0.968176]
SS3	**2020m01 - 2021m12**		
Headline	0.803864	0.145190	[0.760280, 1.214711]
Core	0.764000	0.147817	[0.717903, 1.204679]
Food	0.657341	0.182609	[0.542835, 1.203493]
Energy	0.521053	0.146436	[0.369634, 1.091886]
Transport	0.739492	0.148096	[0.674396, 1.198139]

Source: Author's calculations. [ ] denotes confidence interval brackets.

The table 4 above shows Hansen's (1999) median unbiased estimator of the sum of autoregressive coefficients and the bootstrapped 90% confidence bands based on 200 grid points and 1,999 replications to obtain bias- corrected confidence intervals for finite-sample OLS estimators. The interpretation of inflation persistence is based on the definition by Marques (2004) as the duration of shocks in inflation. The results show a higher persistence of inflation within the full sample. Both headline and core inflation have an inflation persistence rate of 91.2% and 96.1%, respectively. The remaining subgroups have 91.3%, 91.2%, and 86.7% inflation for food ((i.e., food an inflations), and transport inflation), respectively.

The first subsample (SS1) is characterized by relatively high persistence in inflation compared to the period of the pandemic. Inflation persistence is especially higher in SSI for core inflation (87.6%) and food inflation (85.1%) compared to persistence during the pandemic which is 76.4% for core inflation and 65.7% for food inflation. The headline is persistent at 83.7% compared to 80.4% during the pandemic period. The energy and transport inflation exhibit the lowest persistence of 50.1% and 59.9%, respectively. However, the persistence in transport during the pandemic is relatively high (73.9%) compared to the period before the subprime crisis mainly due to shortage in transport 7 means during this period. (BNR, 2020)

The second sub-sample (SS2) exhibits more persistent inflation compared to other sub-samples other than the full sample. As stressed by Karangwa and Mwenese (2015), and Karangwa (2017), this period included various shocks, such as the demand shock (2009), the rise international commodity prices (2008 and 2011), and the aid shock (2012 – 13). These cumulative shocks caused delayed readjustment of prices, hence making inflation to be more persistent.

The third sub-sample SS3 captures the COVID-19 pandemic that broke out at the end

of 2019. Estimation results show that SS3 exhibits the lowest persistence in headline and core inflation compared to other sub- samples. However, estimations for SS3 show that headline inflation is relatively more persistence (80.4%) than any other components mainly due to the supply chain disruptions caused by the coronavirus pandemic alongside with poor agricultural performance recorded in 2020 (where food inflation persistence is 65.7%). The core inflation also exhibits the lowest persistence in SS3 unlike in other sub-samples (and also in the full sample), implying that the effect of the pandemic shock to inflation was transitory.

In general, the dynamics of inflation during the pandemic does show characteristics of lower persistence where there is evidence from the results that the coefficients of SARC during the pandemic are lower compared to other samples. Paying special attention to SS3, the results show that persistence for all inflation groups drops relative to that from the other sub-samples. For example, compared to SS2 (2008-2019), inflation persistence for SS3 (2020-2021) drops, where the persistence in headline inflation falls by 10% from 94.4% to 80.4% percent; core inflation persistence drops by 18.8% from 95.2% to 76.4%; food inflation persistence drops by 25.5% from 91.2% to 65.7% percent, energy inflation persistence drops by 37.7% from 89.9 to 52.1 percent, while transport inflation persistence slightly declined from 90.4% to 73.9% which is the least among other subcomponents. Compared to SS1 (2005-2007), inflation persistence for SS3 (2020-2021) drops in the aggregate components (headline and core inflation). The persistence in headline inflation falls by 3.3% from 83.7% to 80.4%; core inflation persistence drops by 11.2% from 87.6% to 76.4%, food inflation persistence drops by 19.4% from 85.1% to 65.7%. Contrary, energy inflation persistence slightly increases by 2.0% from 50.1% to 52.1%, while transport inflation persistence increases from 59.9% to 73.9%.

These results show that the shocks from the pandemic were significantly transitory compared to other periods, implying that the shocks from the pandemic did not last longer, hence faster readjustments in prices during this period. These results also have an implication on how the monetary policy should respond; if the persistence in inflation is not large, monetary policy may not always choose to tighten since the price shocks are transitory and are probably going to remain for a relatively short time and dissipate onwards. However, this research gives evidence that accumulation of shocks in inflation may contribute to the persistence of inflation.

4.3 Robustness Check

This research carried out some robustness checks to understand how inflation persistence estimates would reflect the actual inflation for the whole period. The approach compares fitted values for the sample sizes set for the model using persistence coefficients and compare differences among those samples. The first test looks at the differences between estimation techniques, namely the ADF SARC and the Hansen's Grid Bootstrap to understand the differences between the estimates.

In the perspective of sample differences, the figures 9-13 in the appendix reveals that the divergences be- tween estimates among the sample of 2005 – 2021 and sub-sample 2008 – 2019 are relatively closer compared to the estimates in the remaining sub-samples (i.e., 2005 – 2007 and 2020 – 2021). Maxwell, Kelly and Rausch (2008) emphasized the importance of sample size in the accuracy of the parameter estimates; this is confirmed by the large standard errors in small sizes and wide confidence intervals compared to the larger sample sizes.

From the perspective of inflation components, the estimates of Grid Bootstrap and SARC are closer in aggregate components than in individual components. For example, the components of energy and transport inflation have large differences in estimates for the sample of 2005 – 2007 with a difference of roughly 30% and 20%, respectively. Despite those differences, generally, the Grid Bootstrap and SARC are closer and generate consistent estimates among both aggregate and components of the inflation.

This paper calculated the differences between estimates and actual values using the popular measures of Root Mean Squared Errors (RMSE) and Mean Absolute Errors (MAE) Despite that the sample size playing a big role in error minimization, it is not totally the case for all samples because the estimates of period 2008 – 2019 minimizes the errors compared to other samples and is followed by 2005 – 2021, 2005 – 2007 and finally the Covid-19 sample (2020 – 2021). Moreover, Figure 11 shows that the trends of the absolute values of deviations between estimated values (Grid Bootstrap) show differences among the samples during the pandemic compared to the deviations of other samples of the pre-pandemic period. To wrap up, this study has responded to the research questions as follows: (i) the inflation during the pandemic has shown lower persistence level, (ii) during the pandemic, headline inflation had a relatively high persistence than core inflation and was influenced by mainly the food prices and global supply chain disruptions.

5. Conclusion and Policy Implications

The main objective of this research was to examine the drivers of inflation dynamics during the pandemic based on evidence from disaggregated consumption data for Rwanda. The results of this study adds more clarity in understanding the drivers of inflation dynamics during the pandemic. Results portray the following conclusions. First, the inflation persistence before the pandemic is generally high compared to the inflation persistence during the COVID-19 pandemic. Second, core inflation persistence is high compared to headline inflation in all samples, except during the pandemic period.

Furthermore, all components of inflation show lower persistence during the pandemic period (i.e., SS3) than in other sub-samples, except for transport and energy whose persistence is higher in the 2020m01 - 2021m12 sub-sample compared to the 2005m01 - 2007m12 sub-sample. The persistence in headline inflation for the 2020m01 - 2021m12 sample mainly results from the mixture of supply chain disruptions and persistence in volatile sub-groups of inflation, notably food inflation. Therefore, it is crucial that monetary policy takes decisions by considering both headline and core inflation to avoid biased decisions in case components of food and energy inflation become more persistent as it is evident that headline inflation during the pandemic tends to become relatively more persistent than does the core component due to COVID-19 along with bad agricultural performance.

This research bridges the gap between existing literature by emphasizing the need to use disaggregate data to assess the persistence of inflation for the case of Rwanda and in the context of an economic shock, such as COVID-19. A similar study could be undertaken to capture the Russia-Ukraine war shock and to better identify shocks in each of the sub-samples considered.

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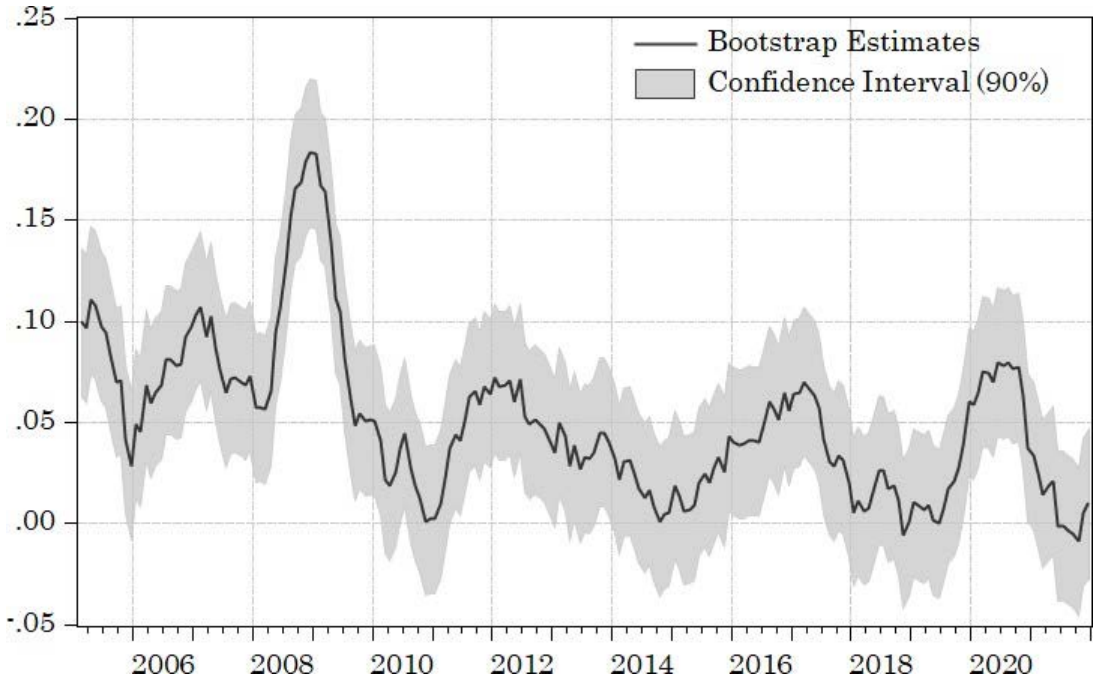
Appendices

Headline Inflation (fitted) from Hansen (1999) Grid Bootstrap. Grey Area is the Bootstrap Confidence Interval (2005 – 2021).



Source: *Author's Calculations*

EXCHANGE RATE MISALIGNMENT IN RWANDA. DOES EXPORT DIVERSIFICATION MATTER?

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Abstract

Export diversification is a key instrument that helps developing economies to hedge against price volatility and external shocks. Export diversification helps to reduce macroeconomic volatility, notably exchange rate misalignment by alleviating and stabilizing export revenue and domestic output. The main objective of this paper is to estimate the equilibrium fundamental exchange rate misalignment and investigate the role of export diversification in reducing real exchange rate misalignment in Rwanda. We employ quarterly data, covering the period 2000Q1-2022Q4. Building on the behavioral equilibrium exchange rate (BEER) Approach, we estimate the relationship between the real effective exchange rate and economic fundamentals using single equation cointegration-based techniques, particularly the dynamic ordinary least squares (DOLS) model. To derive the level of REER misalignment, the estimated equilibrium real exchange rate results are used, along with the Hodrick-Prescott filter to obtain sustainable levels of REER and decompose REER into their permanent and cyclical components. The main results indicate that the real effective exchange rate is in line with the economic fundamentals. Alternating episodes of undervaluation and overvaluation are identified. 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 in the external sector. We also estimated the link between real exchange rate misalignment taken in absolute values and export diversification. The results point to the fact that export diversification reduces exchange rate misalignment in Rwanda. Accordingly, we recommend implementing policies to diversify Rwanda's export base. Greater diversification of exports would make Rwanda less vulnerable to exogenous shocks and more protected against the risks of short-term devaluation.

Key Words: Exchange Rate Misalignment, Dynamic Ordinary Least squares.

JEL Classification Numbers: F41, C22

1. Introduction

Exchange rates are key macroeconomic prices and their variation affect economic activity, prices, interest rates, and trade flows. Over the recent past, the dynamics of the real effective exchange rates in developing and emerging countries have been characterized by large swings, strong volatility, and persistent misalignments (Carrera, et al., 2020). Significant and persistent real exchange rate misalignments, i.e. deviation of actual RER from its equilibrium level indicate the presence of macroeconomic imbalances that may cause macroeconomic crises, especially when it exceeds a certain threshold level, leading to disruptive exchange rate adjustment (Kubota, 2009). For instance, currency overvaluation may have a reducing-effect on 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., 2022). 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). In this context, one of the key policy instruments is export diversification, which is premised on the fact that for developing economies, export expansion has become key in making international integration an efficient tool for development. An important argument is that diversification helps developing economies to hedge against price volatility and external shocks (Tran, et al., 2020).

This paper investigates the role of export diversification in correcting persistent RER misalignment in Rwanda. We begin by estimating the equilibrium real exchange rate, determine the level of real exchange rate misalignment, and generate the export diversification index, which is regressed against the exchange rate misalignment indicator, along with other relevant determinants of RER misalignment. Several studies that examined this topic in Rwanda remains limited and have mainly focused on measuring the level of exchange rate misalignments without attempting to relate it to the export diversification. For instance, (Nuwagira & Kigabo, 2014) estimated the exchange rate misalignment using quarterly data from 2000Q1 to 2012Q1 and derives a long-run Behavioural Equilibrium Exchange Rate (BEER). Similarly, (Nuwagira & Muvunyi, 2016) using quarterly data spanning the period 2000Q1 to 2015Q4, analysed 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 evidences of exchange rates misalignments. Muvunyi, et al., (2022) Using quarterly data, covering the period 2000Q1-2020Q4 and 5-year period medium term projections, re-assessed Rwanda's exchange rate and external sector

competitiveness applying the three complementary approaches proposed by the IMF consultative group on exchange rate issues (CGER). The results pointed to an average exchange rate misalignment of 13.4 percent, suggesting that Rwanda's exchange rate is overvalued in real effective terms. While the relationship between exchange rate misalignment and export diversification is lacking for Rwanda, similar studies have been conducted especially in the context of developing economies. Notable contributions include Cottet & Madariaga (2012) who show heterogeneity among Franc Zone Countries in terms of export diversification due to different modes of diversification used by different countries. Gnimassoun (2017) indicate that the concentration of Franc Zone Countries exacerbates the adverse effect of real exchange rate misalignment.

In view of this, this paper makes a contribution to the ongoing debate on the role of export diversification in correcting Rwanda's real exchange rate misalignment. The novelty of this research lies in the fact that we construct export diversification index, used as a policy instrument to mitigate the size and persistence of RER misalignment.

This link can be explained as follows: First, aggregate productivity gains and the exploitation of economies of scale that result from export diversification can reduce pressure on prices across the economy, allowing countries to maintain external competitiveness. Diversification therefore appears to be a solution to limiting the risks of political instability and export revenue volatility. The objective of this paper is therefore to examine, on the basis of cointegration based estimators, especially DOLS, and FMOLS the role of export diversification on both the size and the persistence of real exchange rate misalignments in Rwanda. To attain this objective, the first step is to identify the economic fundamentals that influence real exchange rate. This study draws on the literature on the determinants of the real exchange rate. The second step, the identified fundamentals are regressed against real exchange rate, which along with Hodrik-Prescott filter are used to obtain sustainable values of RER. The third step is to subtract the generated equilibrium exchange rate from the actual exchange rate to obtain RER misalignment, and finally, relate the established exchange rate misalignment with export diversification. Our main finding indicate that export diversification plays a central role in limiting RER misalignment in Rwanda, a result that is consistent with (Dubas, 2009).

The rest of the paper is the organized as follows. Section 2 reviews the empirical literature on the relationship between RER misalignment and export diversification. Section 3 elaborates both the theoretical model and the empirical models used in study. Section 4 reports the estimation results of equilibrium exchange rate and real exchange rate

misalignment as well as the estimated relationship between RER misalignment and export diversification. Section 5 provides conclusion and policy recommendations.

2. Empirical Literature

In this study, we combine two important strands of literature. The first relates to the estimation of equilibrium real exchange rate, which along with the HP filter is used to obtain RER misalignment indicator. The second strand focuses on the role of export diversification in reducing the magnitude of real exchange rate misalignment.

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.

The first strand of literature has mainly focused on the estimation of the equilibrium exchange rate. (Chinn & 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 for 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, with an addition case of developing countries of which the dependence of foreign financial inflows positively affect the current account. On the other hand, the countries' level of openness tends to negatively affect the current account balance.

Dvornak et al; (2003) applied the MB approach in Australia; to determine the medium-term macroeconomic factors that affect the exchange rate, i.e. its relationship with the current account. They have started with two hypotheses; firstly, is that the internal macroeconomic balance is achieved with the economy is performing at the potential level, secondly, the external balance is achieved when the exchange of flows (current and financial flows) between two countries are on equilibrium, no matter how their individual current accounts are performing. In their empirical analysis, they estimate how elasticities between the current account and the output for Australia, then the estimate the exchange rate adjustment to reduce the gap between the current national saving and optimum level derived from the model. However, they conclude that the model does not explain how to make the exchange rate policy adjustments in order to reduce the gap.

With the fear of large fluctuations of hard currencies in medium-term, (Borowski & Couharde, 2003) tried to determine the macroeconomic balances between major countries vis- -vis to their exchanges rate, since these fluctuations may cause world macroeconomic instability. They went further from the MB model and used panel equilibrium exchange rate model in selected industrial countries, by applying the fundamental equilibrium exchange rate, using the data until 1995 and with the medium-projections up to 2000. They suggested adjustment of the Dollars, Yen and Euro, to be aligned with the fundamentals.

As articulated by the Washington consensus, 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 will hamper internal balance (economic growth) and sustainability of the external balance (current account) (Rodrik, 2008).

Other studies, however, have provided theoretical and empirical evidences 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 improve them, mostly in developing countries. Sekkat, et al., (2011), found evidence supporting the view of (Rodrik, 2008) and showed that under the sample of 52 developing countries and using the REER model, they deliberately choose the policy to keep 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 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.

Cheng & Orden (2005), use 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 the overvaluation was more than 10 percent, however, in the aftermath of 1991 crisis, the RER adjusted towards the equilibrium. B nassy-Qu r , et al., (2008) used a panel data

methodology to estimate the misalignments of bilateral and multilateral real effective exchange rates of G20 currencies. As a result, they find that the currencies of five Asian countries were overly undervalued at the beginning of 2006. These results also indicate that lack of exchange rate adjustment in Asian countries has an impact.

Limited on other misalignments against the US dollar and in addition, the bilateral misalignments between the United States and the other countries depend mainly on misalignments of the exchange rate of all countries. Baffes, et al., (1999) building on the work of Edwards, 1989; Devarajan, et al., 1993 and Elbadawi & Soto, 1994) on the determination of RER by the single-equation model, estimated the RER and the degree of misalignment of countries such as Cote d'Ivoire and Burkina Faso. They 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 conclude that the devaluing the currency depends on the fundamentals, 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 indicate that the long-term variations in the real exchange rate are explained by the real GDP growth rate, the interest rate differential, the real world prices of the exported raw materials. These results also show that when the RER deviates from its equilibrium trajectory, it reverts back to it between 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 converge 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 the panel cointegration techniques, especially the ordinary dynamic-least-squares developed by Kao & Chiang, (2000) and 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.

With regard to country specific studies, Nuwagira & 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 fundamentals factors, and the coefficients highlighted that

some of the factors that influence RER under-valuation. These factors include the increase in government expenditure and the decrease of terms of trade and other factors help to explain RER over-valuation, while the increased in foreign financial inflows and the supply side of output. 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 percent and 2.3 percent.

Muvunyi et al., (2019) used this external sustainability approach to evaluate the Rwandan current account deficit vulnerability to the level of net foreign assets, on a sample drew 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 lower-down with the medium-term projections, suggesting a small RER adjustment in order to close the gap. Muvunyi et al., (2022) using quarterly data, covering the period 2000Q1-2020Q4 and 5-year period medium term projections, re-assessed Rwanda's exchange rate and external sector competitiveness applying the three complementary approaches proposed by the IMF consultative group on exchange rate issues (CGER). The results pointed to an average exchange rate misalignment of 13.4 percent, suggesting that Rwanda's exchange rate is overvalued in real effective terms.

The second strand of literature relates to the limiting the effects of real exchange rate misalignments. Our focus is limited to previous related work conducted on developing countries. Broadly speaking, much of the work has focused on the effects of the exchange rate regime on exchange rate misalignments (Burkart & Coudert, 2002; Calvo & Reinhart, 2002; Coudert & Couharde, 2009; Dubas, 2009 and Bikai & Owoundi, 2016). On the other hand, related work has focused on the effects of institutional quality (Nouira & Sekkat, 2015). Sovereign wealth funds (Raymond, et al., 2017). Financial development (Aghion, et al., 2009), (Allegret, et al., 2014) and currency crises (Dubas, 2009). Up until now, very few studies have attempted to identify export diversification as a variable that can influence real exchange rate misalignment. The first studies that looked at this link showed that real exchange rate stability favors export diversification (Sekkat & Varoudakis, 2000; Melitz, 2003; Rodrik, 2008; Agosin, et al., 2011; Freund & Pierola, 2012 and Wondemu & Potts, 2016).Very few studies have focused on the influence of export diversification on real exchange rate misalignments (Bodart & Carpantier, 2016) and recently (Nvuh, et al., 2021).

3. Methodology

3.1 Theoretical Model

The main aim of this section is to demonstrate through a simple theoretical framework how structural factors such as export diversification can affect the relationship between the RER of a small exporting country and the price of its main export. To do so, we present a model of a small open economy. We build upon the model developed by Bodart, et al., (2012), which extends the model of Gregorio & Wolf (1994). The model is anchored on the following key assumptions of the model. First, the economy produces two goods, a primary product that is not consumed locally (and thus exported entirely), and a non-tradable good that is only available to the domestic consumer. Second, private agents can also consume an imported consumer good. They therefore derive their utility from the consumption of the locally produced non-tradable good and the imported good. Third, domestic agents take the world market price of the exported goods and the imported consumer good as their price. In what follows, exported, non-tradable and imported goods are denoted as X, N and M, respectively. From the production side, it is assumed that the exported primary good Y_x is produced with a technology combining capital K_x and labour L_x. However, the production of non-tradable goods Y_n requires only labour. Perfect mobility of labour is assumed in both sectors, but capital is specific to the exportable sector. The production function of these two goods follows a cobb-Douglas specification.

$$\alpha_x L_x^{\alpha} K_x^{1-\alpha} \quad \text{..... (1)}$$

$$Y_n = \alpha_n L_n \quad \text{..... (2)}$$

Where α_x and α_n are exogenous factors of production with sequence limit $0 \geq \alpha \leq 1$. Moreover, in this model, the domestic price of the exported product is assumed to be determined by the purchasing power parity in the long-run.

$P_x = EP_x^*$ ..... (3), where E is the nominal exchange rate, defined as the rate of domestic currency per unit of foreign currency and P_x^* is the foreign price. Let w be the wage rate paid to labour and r the domestic interest rate,

From the theoretical foundations of profit-maximization, we can derive the following expressions relating the price of each good to the price of factors of production, constituting capital and labour shares in output received in a perfectly competitive equilibrium:

$$P_x = \left(\frac{\varphi_x}{\alpha_x}\right) w^{\alpha} r^{1-\alpha} \quad \text{..... (4)}$$

$P_n = \frac{w_n}{\alpha_n}$ Or $\vartheta_x = \alpha^{-\alpha}\left(1-\alpha\right)^{-(1-\alpha)}$ ..... (5)

Let us now assume that q is the real exchange rate defined as the ratio between the price of the non-tradable goods and the price of the tradable good (exportable good). Combining equations (4) and (5), we obtain the following expression:

$$q = \frac{P_x}{P_n} = \left(P_x^{(1-\alpha)} \alpha_x \alpha_n^{-\alpha} \vartheta^{-1} r \left(1-\alpha\right)\right)_{\alpha}^{1} \quad \text{..... (6)}$$

So far, we have defined the real exchange rate as the relative price of the non-tradable good in terms of the tradable good. But it can also be defined in different ways. For instance, it is very common to define the real exchange rate as the ratio of the domestic consumer price index P to the foreign consumer price index expressed in the domestic currency EP^*. Since $P = P_n^{\gamma}\left(EP_m^*\right)^{1-\gamma}$ and $P^* = P_m^*$, we obtain:

$$q' = \frac{P}{EP^*} = P_n^{\gamma}\left(EP_m^*\right)^{-\gamma} \quad \text{..... (7)}$$

Where P_m^* is the foreign price of imported consumer good. We can easily illustrate that the two real exchange rates are related as follows:

$$q^{'} = q^{\gamma}\left(P_x^*\right)^{\phi\gamma}\left(w_x^*\right)^{-\phi\gamma}\left(\frac{\varphi_m}{\alpha_m}\right)^{-\gamma} \quad \text{..... (8)}$$

As a result we obtain:

$$\sum\left(q^{'};P_x^*\right) = \gamma\left[\sum\left(q;P_x^*\right)+\phi\right] \quad \text{..... (9)}$$

The relationship in equation (9) indicate the elasticity of the real exchange rate with respect to the foreign price. To examine whether the degree of export diversification affects the magnitude of the real exchange rate response to international commodity price shocks, we extend model (1) to include the production of a second tradable good and make further assumption that this new tradable good is a manufacturing good, produced but not consumed in the domestic market. We also assume that the production of the manufactured good Y_d involves two intermediate inputs, the primary product X_d and an intermediate input produced by the foreign economy $\left(G_d^*\right)$:

$$Y_d = \alpha_d X_d^{\eta} G_d^{*1-\eta} \quad \text{..... (10)}$$

In equilibrium, the price of the manufacturing good is determined as follows:

$$P_d = \frac{\vartheta_d}{\alpha_d} P_x^{\eta} P_f^{1-\eta} \quad \text{..... (11)}$$

Where P_f is the price of the foreign intermediate good in domestic currency when $P_f = EP_f^*$ and $\vartheta_d = \eta^{\eta}\left(1-\eta\right)^{-(1-\eta)}$.

In this new framework, we redefine the real exchange rate $\left(q\right)$ as the ratio between the price of the non-tradable good and a composite price of the two exportable goods and this gives:

$$\tilde{q} = \frac{P_n}{P_t} \text{ or } P_t = P_t^{\tau} P_d^{(1-\tau)}$$

In what follows, the analysis is limited to the case where the exchange rate is fixed and capital is perfectly mobile. Under these assumptions, we obtain through several direct substitutions that the elasticity of $\tilde{q}$ with respect to P_x^* gives us:

$$\sum\left(\tilde{q};P_x^*\right)=\left(\frac{1-\alpha}{\alpha}\right)+(1-\eta)(1-\varepsilon) \quad \text{..... (12)}$$

This elasticity is then greater than the corresponding elasticity obtained in the model with an exportable good (see equation 9). This model indicate that the degree of export diversification can affect the magnitude of the change in the real exchange rate in response to a global commodity price shock. In particular, this model suggest that when commodity prices rise (fall), countries with broadly diversified exports should experience a larger appreciation (depreciation) of their real exchange rate than countries with weakly diversified exports. This result comes from the fact that the variation of P_x leads to a less than proportional variation of P_d. The inclusion of a second good does not affect the expression of q' and thus the elasticity $\sum\left(q';P_x^*\right)$ is independent of the degree of export diversification.

3.2 Empirical Model Specification

To estimate the real exchange rate misalignment, we follow the reduced form equilibrium exchange rate approach, particularly the behavioural equilibrium exchange rate (BEER) model proposed by MacDonald & Clark (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 with a challenge in a sense that the equilibrium real exchange rate is unobservable, thus the starting point to addressing this is to define the concepts of real exchange rate and equilibrium real exchange rate.

The RER is domestic relative price of traded to non-traded goods, expressed as $reer = E * \frac{p_t^*}{p_n}$, where E is the nominal exchange rate, p_t and p_n are prices of tradables and non tradables, respectively. In his pioneering work (Nurkse, 1945) defines ERER as the value of RER that induces both the internal and external equilibrium, given sustainable values of relevant variables 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. In this paper we use fundamentals akin to (Berg & Miao, 2010; MacDonald & Vieira, 2010 and Comunale, 2017). Our empirical model is thus specified as:

$$reer_t = \alpha + +\alpha_1 open_t + \alpha_2 nfa_t + \alpha_3 prod_t + \alpha_4 gov_t + \varepsilon_t \quad \text{..... (13)}$$

Where $t = 1....,T$ denote time period, $reer_t$ is the real effective exchange rate, $open_t$ 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, $\alpha = (1,....,4)$ are parameters to be estimated and ε_t is the error term.

3.2.1 Estimation strategy

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 cointegration based on reduced rank regression approach due to Johansen (1988) to confirm the presence of cointegrating relations to check whether there is existence of a long-run relationship between the real exchange rate and the fundamentals. Thirdly, we estimate the long run parameters of equilibrium RER using single equation cointegration based estimators such as dynamic ordinary least squares (DOLS) model and fully modified ordinary least squares (FMOLS). 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 overvaluation (undervaluation).Finally, we incorporate the RER misalignment indicator in the monetary reaction function to check for the impact of RER misalignment on monetary policy implementation.

The Single equation cointegration estimators such as the fully Modified Ordinary Least Squares (FMOLS) developed by Phillips & Hansen (1990) and Pedroni (2000) and the Dynamic Ordinary Least Squares (DOLS) estimator developed by Saikkonen (1991), Kao & Chiang (2000), Stock & Watson (1993) and Mark & Sul (2003) are advantageous in a sense that these estimation techniques generate consistent parameter estimates and correct for endogeneity.

Despite the fact that (Pedroni, 1996) finds that the DOLS method has higher size distortions than FMOLS, Kao & Chiang (2000) indicate that the FMOLS method can be more biased than DOLS. In this study, we apply the DOLS technique to determine the long-run determinants of the real effective exchange rate. This approach improves OLS by addressing the problem of small sample bias and dynamic sources of bias given that it corrects for endogeneity by adding leads and lags. While DOLS is chosen for this study, we use it, along with complementary estimators such as fully modified ordinary least squares (FMOLS) and canonical cointegration regression (CCR).

3.2.2: 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 $reer_t = \sum_{t=1}^{k} neer_{it} * \frac{p^*}{p}$.

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 $nfa = total\ Assets - total\ liabilities$, this definition follows (Lane & 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 $ngdppc\_gr = ngdppc - ngdppc_{t-1} - 1$.

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 2000Q1-2022Q4 and data is sourced from World Bank's world economic outlook database (WEO) and National Bank of Rwanda database.

3.2.3: Estimating Exchange Rate Misalignment and Export Diversification Nexus

After generating the RER misalignment and export diversification index, we proceed to estimate the link between real exchange rate misalignment and export diversification in terms of size of RER misalignment. Accordingly, we estimate the impact of export diversification on the size of misalignments, this is implemented by regressing export diversification, along with other relevant variables against RER misalignment indicator. Similar to (Dubas, 2009), we take RER misalignment in absolute terms. The model is specified as:

$$|mis| = \beta_0 + \psi divers_t + \gamma divers_{t-1} + \varphi z_t + \varepsilon_t \quad \text{..... (14)}$$

Where $|mis|$ is the misalignment indicator expressed in absolute value, β_0 is the intercept, ψ is the parameter estimate for export diversification index ($divers_t$), γ is the coefficient that captures the persistence in export diversification, z_t is vector of exogenous variables including financial depth measured by the ratio of broad money to GDP $\left(\frac{M_3}{GDP}\right)$, terms of trade and openness. In terms of expected signs, countries with significant financial development have a stable exchange rate. We therefore assume that financial development reduces misalignments. Therefore, the expected sign is negative. We expect terms of trade changes to be associated with a positive sign.

4. Empirical Results

4.1 Results of Behavioural Exchange Rate Model

Our empirical analysis starts with checking the stochastic properties of data. The unit root results indicate that except for real GDP per capita growth, financial depth and export diversification index, all other variables are integrated of order one (see appendix 1). Given that variables used in our estimations are integrated of different orders, we tested for Johansen cointegration and the results point to one cointegrating vector given that the trace statistic is less than the critical value at 5 percent only at rank 3 (see results in appendix).

Turning to the BEER model results, Table 1 presents the results of the reduced form model based on single equation cointegration estimators such as DOLS, FMOLS and CCR, with a particular focus on DOLS. We estimated the long-run relationship between the real effective exchange rate and a set of economic fundamentals. The estimated coefficients are presented in columns (1) - (3).

All variables included in our empirical specification are statistically significant, with correct signs, implying that the real exchange rate is influenced by economic fundamentals. Broadly speaking, improvement in relative productivity, government spending and net foreign assets leads to real exchange rate appreciation, while increased degree of trade openness induces real exchange rate depreciation. The coefficient of openness emerges positive and statistically significant, this implies that trade restrictions in terms of higher tariffs, resulting in higher demand for non-traded goods leads to higher domestic prices that induce real exchange rate appreciation. The coefficient of productivity is positive and statistically significant, indicating that productivity gains relative to trading partners induces real exchange rate appreciation, a phenomenon well known in literature as "Balassa- Samuelson effect". Government expenditure turns out to be positive and statistically significant, this is due to the fact that higher government expenditure translates into higher demand for non-traded goods leading to the rise in prices of non-traded goods, resulting in the real appreciation of exchange rate. The coefficient of net foreign assets is positive and statistically significant, implying that higher net foreign assets induce real exchange rate appreciation given that Rwanda has received substantial amounts of capital inflows, which allows it to afford a more appreciated REER. The coefficient of trade openness is negative and statistically significant, this implies that improvement in trade openness leads to lower tariffs, resulting in higher demand for tradable goods and higher prices for foreign goods that induce real exchange rate depreciation. Despite the ambiguity that surrounds the sign of the coefficient associated with trade openness, several empirical studies support a negative relationship between the real exchange rate and trade openness (Dubas, 2009) (Elbadawi & Soto, 2012).

Table 1: BEER Estimation Results

VARIABLES	(1) DOLS	(2) FMOLS	(3) CCR
Productivity	0.192***	0.210**	0.235*
	(0.069)	(0.106)	(0.123)
openness	-0.129**	-0.117	-0.141
	(0.064)	(0.109)	(0.126)
Net foreign Assets	0.120***	0.051	0.061
	(0.037)	(0.067)	(0.073)
Government spending	0.441***	0.363***	0.360**
	(0.071)	(0.136)	(0.141)

Constant	2.042*** (0.291)	2.350*** (0.542)	2.249*** (0.596)
Observations	89	91	91
R-squared	0.526	0.170	0.290

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

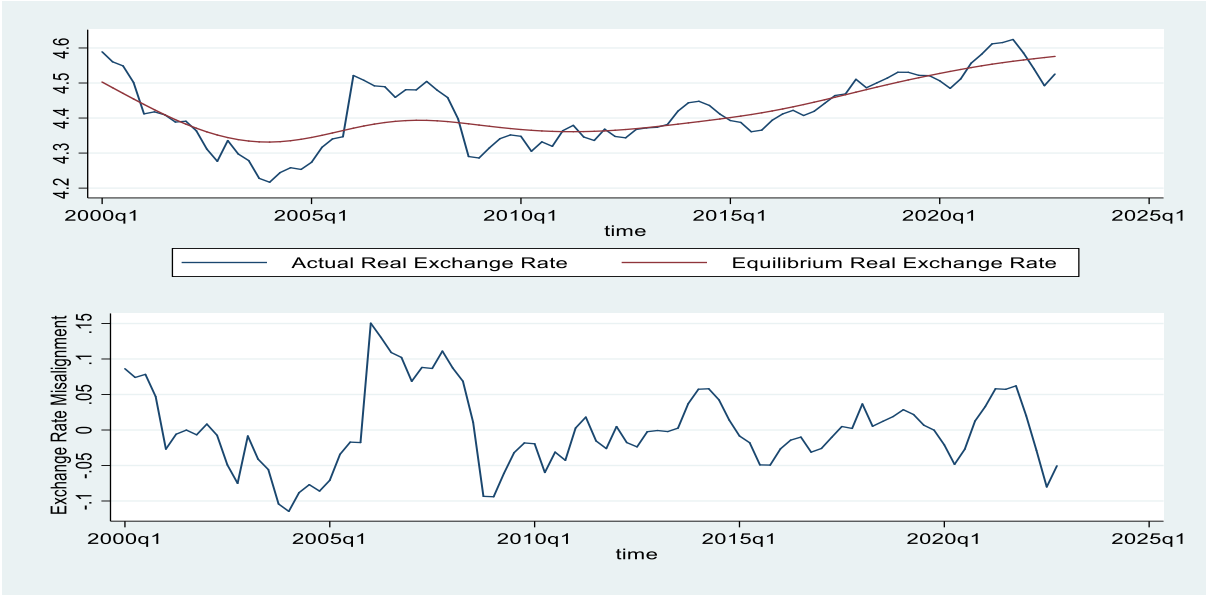
Source: Authors' Estimations

4.2. Exchange Rate Misalignment in Rwanda

The estimated results of the BEER model, coupled with the (Hodrick & Prescott, 1997) HP filter are used to derive the sustainable values of economic fundamentals, whereby HP filter decomposes REER into their permanent and cyclical components[18] and thus the level of misalignment is computed 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 2, we were able to identify different but alternating episodes of overvaluation and undervaluation. While overvaluation and undervaluation are not the desirable outcome for long-run REER stability, the estimated level of RER misalignment is not prolonged and not very high. Considering the last episode, Rwanda's real effective exchange rate is overvalued by 15 percent, suggesting that Rwandan franc should depreciate by 15 percent in real effective terms to restore REER to its sustainable levels.

[18] *Since we use quarterly data , we extract the trend components of RER using the Hodrick-Prescott filter, following a conventional smoothing parameter value =1600*

Figure 1: Evolution of Rwanda's REER Misalignment

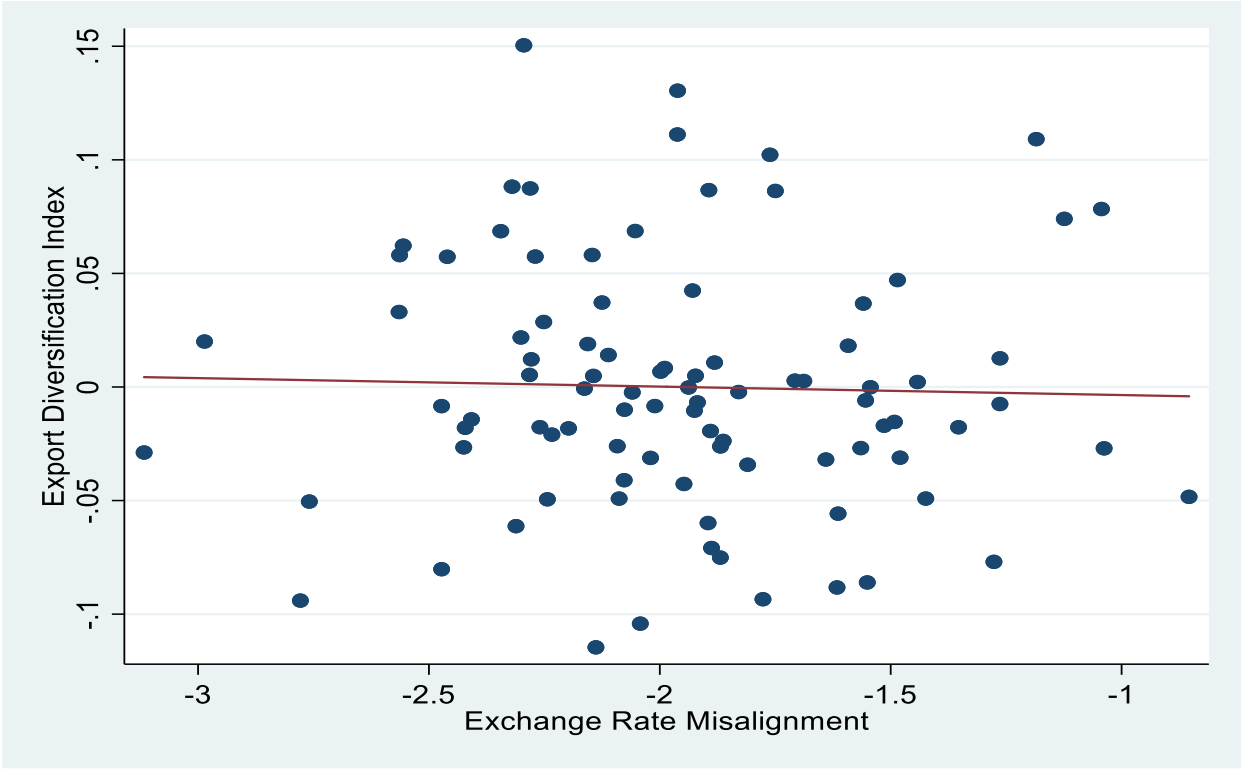


Source: Authors' Estimations

4.3 Size of RER misalignments and Export Diversification

Prior to computing the magnitude of RER misalignment in relation to export diversification, we first checked for the correlation between the two variables. The scatter diagram in figure 2 indicate that exchange rate misalignment is negatively correlated to export diversification, suggesting that export diversification reduces the size of RER misalignment in Rwanda.

Figure 2: Correlation between Exchange Rate Misalignment and Export Diversification



Source: Authors' Estimations

Table 2 reports the results of the size of RER misalignment measure with respect to export diversification. As expected, the coefficient of export diversification is negative and statistically significant, implying that Rwanda could reduce potential real exchange rate misalignments by putting in place strategies to diversify its export base. Greater diversification of exports would make Rwanda less vulnerable to exogenous shocks and more protected against the risks of short-term devaluation. However, policy makers should be cognizant of the fact that diversification strategies are processes that are implemented in the medium to long term. The coefficient of trade openness is negative and statistically significant, indicating that the more Rwanda opens up to the rest of the world, the more it trades and attracts capital from trading partners thereby minimising the level of RER misalignment. The coefficient of terms of trade turns out to be positive and statistically significant, implying that improvement in the terms of trade increases export prices, contributing to high level of RER misalignment. The coefficient of financial depth/development is negative and statistically significant, implying that it is RER misalignment reducing, a result that is in line with (Devereux & Lane, 2003) who indicate that domestic financial development helps in stabilizing exchange rates in developing countries through intertemporal smoothing by households and firms.

(Dubas, 2009) also highlights the role of financial development in reducing the size of RER misalignments. Indeed, the periods of banking crises have been associated with large and significant misalignments.

Table 2: Results on the Size of Absolute Misalignment

VARIABLES	(1) DOLS
Export diversification	-0.035***
	(0.007)
openness	-0.001***
	(0.000)
Terms of trade	0.038**
	(0.015)
Financial depth	-0.051***
	(0.013)
Constant	0.037
	(0.071)
Observations	89
R-squared	0.469

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Source: Authors' Estimation

5. Conclusion and Policy Recommendation

The main objective of this paper is to estimate the equilibrium real exchange rate and misalignment and examine the role of export diversification in reducing real exchange misalignment in Rwanda. We employ quarterly data, covering the period 2000Q1-2022Q4. Building on the behavioural equilibrium exchange rate approach, we estimate 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 our main results, we also use the complementary estimators such as FMOLS and CCR.

To derive the level of REER misalignment, the estimated equilibrium real exchange rate results are used along with Hodrick-prescott filter to obtain sustainable levels of REER and decompose REER into their permanent and cyclical components and thus the level of REER misalignment is 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. Alternating episodes of undervaluation and overvaluation are identified. 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.

We also estimated the link between real exchange rate misalignment taken absolute values and export diversification and the results points to the fact that export diversification reduces exchange rate misalignment in Rwanda. Accordingly, we recommend that policies to diversify Rwanda's export base should be implemented Greater diversification of exports would make Rwanda less vulnerable to exogenous shocks and more protected against the risks of short-term devaluation. However, policy makers should be cognizant of the fact that diversification strategies are processes that are implemented in the medium to long term.

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Appendices

Appendix 1: Unit Root Test Results

Variables		Critical Values			
	ADF	1 %	5%	10%	Conclusions
Lreer	7.81	4.06	3.46	3.15	I(1)
Lrgdppc_gr	8.65	4.06	3.46	3.15	I(0)
Lopen	11.37	4.06	3.46	3.16	I(1)
Ltot	3.15	4.06	2.88	2.58	I(1)
Lnfa	9.88	4.06	3.46	3.15	I(1)
Lfindepth	4.07	4.06	3.45	3.15	I(0)

Gov_gdp	12.39	4.06	3.46	3.15	I(1)
Ldivers_hhi	5.68	4.06	3.45	3.15	I(0)

Source: Authors' Estimation

Appendix 2: Results of Johansen Tests for Cointegration

Maximum Rank	Eigenvalue	Trace Statistic	Critical value at 5 %
0	-	279.1143	192.89
1	0.61998	193.0040	156.00
2	0.49416	132.3474	124.24
3	0.36720	91.6213*	94.15
4	0.29787	60.1479	68.52
5	0.26387	32.8829	47.21
6	0.14439	19.0045	29.68
7	0.12930	6.6818	15.41
8	0.06987	0.2357	3.76
9	0.00264		

Source: Authors' Estimation

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