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Foreword

The BNR Economic Review intends to provide information to the public on economic matters, focusing on features and challenges of the Rwandan economy. This 19th volume of BNR Economic Review consists of two issues published in May and December 2022, respectively, with eight research articles touching on topical issues related to macro-financial linkages, price, economic and financial stability as well as external sector sustainability. The papers aim to provide concrete evidence-based analyses and policy recommendations that can help in economic management.

In many countries, studies conducted after the 2007-2008 financial crisis revealed that shocks from the real sector can easily be propagated to the financial sector and vice-versa. Thus, the two first articles of this volume explore macro-financial linkages in Rwanda. The first article contributes to the empirical literature by assessing the linkages between Rwanda's business and financial cycles. The results indicate that the financial cycle is closely related to the business cycle, especially in the medium-term, implying the potential risks of transmitting a shock from one sector to another. While the evidence on the effect of financial systems development on macroeconomic stability is mixed in the literature, the results from the second study, to a larger extent, support the view that financial systems development has contributed to macroeconomic stability in Rwanda, by notably promoting real GDP growth via the investment channel.

The third paper contributes to the literature on monetary policy transmission mechanisms by bringing into the debate the perspective of an underdeveloped interbank market. The main contribution of the article is to provide new insights from the interbank structure, by examining the effect of the interbank network on monetary policy transmission in Rwanda. The results point out that the network structure influences the spread between the interbank and central bank rates and, therefore, monetary policy transmission. The study recommends the central bank to support initiatives that create more hub- banks or encourage banks to actively participate in the interbank market and increase the dynamism that supports the transmission.

The successful conduct of monetary policy requires a thorough assessment of how changes in policy actions are propagated to the real economy. Specifically, such an assessment should unpack how monetary policy actions affect, credit, inflation, and growth in national output. To fulfill its primary objective of maintaining price stability, the national bank of Rwanda conducted its monetary policy by targeting the quantity of money for two decades until December 2018 before switching to an interest rate-based monetary policy in January 2019. By altering the quantity of money or interest rates, the central bank manages the amount of money in the economy and ultimately impacts lending and borrowing, investment and consumption, inflation, and output growth. Each quarter, the Monetary Policy Committee (MPC) of the National Bank of Rwanda convenes to take decisions on the level of the Central Bank Rate (CBR), after assessing both domestic and global macroeconomic conditions and their implications on the primary mandate of maintaining price stability. Changes in the CBR are then expected to affect other short-term interest rates in the economy. In line with the current interest rate-based monetary policy framework, the fourth paper analyzes how an increase in interest rates affects credit, inflation, and output. Findings show that a one percent increase in the interbank rate causes inflation to fall by about five percentage points over eight quarters, and credit to fall by about four percentage points in the first four quarters. Consequently, economic growth falls by about one percentage point.

For the MPC members to make informed decisions, they need to better understand current and future macroeconomic conditions, which itself requires the availability of real-time data on key indicators such as real Gross Domestic Product (GDP). For example, when real GDP data comes out with a time lag, it constrains evidence-based policymaking. While the National Bank of Rwanda already has some benchmark models, to help get current and near-term GDP numbers, the fifth paper contributed to the literature by developing a new set of methods to carry out the same exercise and also tests them against the benchmark models. The paper finds that the new models outperform their benchmark counterparts and thus recommends the integration of the former into a set of the National Bank of Rwanda's forecasting tools.

In addition to price stability, the National Bank of Rwanda has a mandate of fostering financial stability. A financial system is considered stable if it can efficiently mobilize resources and allocate them to productive investments. Given their dominance in Rwanda's financial system, commercial banks are important for financial stability. One way of ensuring the stability of commercial banks is via minimization of the costs they incur while carrying out their intermediation role. The sixth study investigated the drivers of cost efficiency of 10 Rwandan commercial banks for the 2012Q1-2021Q3 period. The paper finds that Rwandan commercial banks are efficient at the level of 81.3 percent, and recommends that efficient management of credit risk and scaling up of the bank funding structure, intermediation ratio, and capital ratio can help to reduce cost inefficiency.

Another important aspect of macroeconomic stability that is of interest to the NBR is external sector stability. The external sector of a country records all those economic transactions conducted between the residents of that country and those of the rest of the world. One way of measuring external sector competitiveness is by looking at the trade performance of a country, particularly focusing on export growth, market share, and the gap between imports and exports (i.e. trade balance). For example, countries that do well are those that export more goods and services than they import and thus enjoy trade surpluses. The performance in trade can be influenced by many factors, such as exchange rate competitiveness. When the exchange rate is overvalued, in real effective terms, then it is not competitive since it discourages exports in favor of imports. Conversely, when the exchange rate is undervalued, in real effective terms, then it is competitive since it encourages exports and not imports. In view of this, the seventh paper focused on analyzing Rwanda's exchange rate and external sector competitiveness. Results show that the Rwandan currency is overvalued in real effective terms by 13.4 percent, compared to the 19.4 percent estimated by the IMF in 2019. To further increase competitiveness, the paper recommends maintaining the exchange rate flexibility to cushion adverse external shocks. Finally, there is a need for effective monitoring of exchange rate developments to avoid higher levels of volatility which could lead to poor performance of the country's tradable sector.

External sector stability also includes a sustainable flow of financial resources to support economic growth. Financial flows in Sub-Saharan African (SSA) countries have for long been largely dominated by foreign aid and grants from advanced countries, and these are largely viewed by policymakers and development partners as an important investment vessel for addressing the continent's growth challenges. The last but not least paper empirically assesses the effect of financial flows' volatility on economic growth in a panel of 23 SSA countries, and extended the analysis to the specific case of Rwanda. The results revealed that financial flows accelerate economic growth in both SSA and Rwanda, while financial flows volatility depress economic growth in Rwanda only, suggesting that there is a need to pursue capital flows management policies to limit potential financial flows volatility, hence avoiding their adverse effect on economic growth.

RWANGOMBWA John
Governor

Comments and questions can be sent to the Acting Director of Research on mkarangwa@bnr.rw, KN 6 Avenue 4, P.O Box 531 Kigali-Rwanda.

CONTENTS

BUSINESS AND FINANCIAL CYCLES IN RWANDA

Callixte Kamanzi[a], Alfred Hakuzwimana[b], Delphine Uwimpundu[c]

[a] *Senior Economist, Research Department, National Bank of Rwanda*

[b] *Senior Economist, Financial Stability Monitoring Department, National Bank of Rwanda*

[c] *Senior Economist, Monetary Policy Department, National Bank of Rwanda*

Abstract

The global financial crisis has made it apparent that the financial cycle plays a more prominent role in macroeconomic dynamics. Cross-country studies have revealed significant links between business and financial cycles and have suggested policymakers to closely monitor the likely impact of shocks from the financial sector on the real economy. Against this background, this paper explores the linkages between Rwanda's business and financial cycles. The empirical results from Wavelet analysis and Structural Vector Autoregressive (SVAR) model indicate that the financial cycle (proxied by overall credit to GDP gap) is closely related to the business cycle (proxied by the output gap), especially in the medium-term, with credit responding more to output. The results point out the presence of macro-financial linkages in Rwanda and highlight the potential risks of a shock from one sector to another.

Key Words: *Business cycle, Financial cycle, Rwanda*

JEL Classification Numbers: *E30, E44, G10, G20*

1. Introduction

The post 2007-2009 financial crisis has renewed interest in the linkages between macroeconomics and finance and put studies of interactions between business and financial cycles to the forefront of research (Caballero, 2010; Woodford, 2010; Claessens et al., 2012; Yan & Huang, 2020), with a specific assessment of the effects of shocks originating from one sector to another. The Global Financial Crisis was characterized by sharp fluctuations in asset prices, credit, and capital flows, which dramatically affected the financial position of households, corporations, and sovereign nations. These disruptions were amplified by macro-financial linkages, almost bringing the global financial system to collapse, fueling the deepest contraction in the world's output in more than half a century, and resulting in unprecedented defies for fiscal, monetary, and financial regulatory policies.

Macro-financial linkages are diverse. On the one hand, shocks from the real sector can be transmitted through financial markets, thereby amplifying business cycles. On the other hand, shocks can be originated from the financial sector, which, in turn, can lead to macroeconomic fluctuations. Overall, the abundance of theoretical as well as empirical studies has strongly argued for the linkages and interactions between financial cycles and business cycles, which led to the consensus among economists that the financial cycle plays an essential role in business cycle fluctuations (Caldara et al., 2016; Christiano et al., 2016) and vice versa.

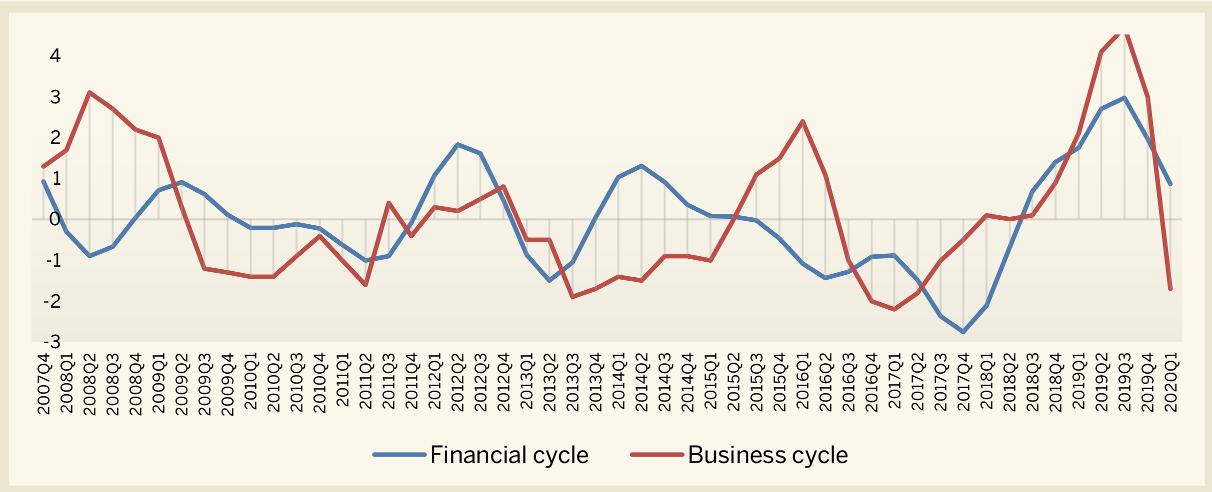
Rwanda has experienced rapid economic expansion and relatively easy financial conditions over the last two decades. Except for a short and shallow recession caused by covid-19 in 2020, annual GDP growth averaged 7.2 percent from 2000 to 2020. However, there have been some episodes where the growth was volatile; hence worth studying the business cycles.

The financial system has also evolved from being almost purely financial intermediary-based to having a growing and active financial market. The banking sector is the largest, accounting for 67 percent of the total financial sector assets. The financial sector has deepened over time, with the credit to private sector ratio to GDP steadily increasing from 4.0% in 1980 to 33.8 percent in 2010 and 56.6 percent in 2019. The total credit to the economy expanded very rapidly, more than doubling as a share of GDP, increasing from 10.3% in 2000 to 21.3 % in 2020. Similar to economic growth, some periods were characterized by volatility in certain financial sector components; hence, the fluctuations in both sectors may be linked.

Cross-country evidences suggest that co-movements between financial and business cycles can occur during economic and financial growth periods, with financial booms enhancing and lengthening output growth (Yong & Zhang, 2016). Again, some empirical evidence revealed that periods of easy financial conditions could amplify economic fluctuations and possibly lead to adverse economic outcomes. For example, Jord#et al. (2013) show that periods of strong credit growth are typically followed by periods of sluggish economic activity.

The illustration below of business and financial cycles for Rwanda indicates that they are positively correlated with some lags, with the business cycle leading in some periods and the financial cycle taking the lead in other periods. This co-movement supports the need for this study, bringing some instincts of the changes in the interaction between the two sectors over time.

Figure 1: Output gap and credit to GDP ratio gap in Rwanda



Source: Authors' computation

No previous studies have attempted the same subject in the case of Rwanda, to the best of the authors' knowledge. Thus, it is critical to assess whether and how financial cycles are linked to the business cycle in Rwanda. Understanding these linkages would help predict and manage downturns and upturns in credit growth and the real sector and formulate appropriate macro-prudential policies.

Empirical results from Wavelet analysis and the SVAR model show the existence of a relationship between the business cycle and the financial cycle in Rwanda. Wavelet analysis indicates a co-movement, with the business cycle leading the financial cycle in the medium term, while impulse responses from SVAR suggest that credit responds more to output than output responds to credit. Contrary to some of the previous studies in other countries, the key insight for Rwanda is that influence of the business cycle on the financial cycle is relatively more important than the other way round; thus, policymakers have to take that into consideration to mitigate the possible effect on future credit growth and financial system stability.

The rest of this study is structured as follows: the next section reviews the literature. Section three explains the methodology used. Section four discusses the empirical results and section 5 concludes.

2. Literature review

The fluctuations of real economic activity and aggregate credit are closely linked mostly through the wealth effects and financial accelerator mechanism (see, among others, Bernanke & Gertler, 1989; Nobuhiro, 1997; Gilchrist & Zakrajsek, 2009). In favorable economic conditions, optimistic growth prospects improve borrower creditworthiness and collateral values. As lenders usually respond with an increased credit supply, more abundant credit allows for more significant investment and consumption and further increases collateral values. In a downturn, the process is reversed.

Extensive practical experience and much formal research highlight the crucial supporting role that financial factors play in an economy's economic growth and prosperity. Just as a robust financial system promotes growth, adverse financial conditions may prevent an economy from reaching its potential. A weak banking system characterized by non-performing assets and inadequate capital or firms whose creditworthiness has eroded due to high leverage or declining asset values are examples of financial conditions that could undermine growth. The financial conditions may affect shorter-term economic conditions as well as the longer-term performance of the economy. Hence, it is logical that the financial and credit conditions changes are important in propagating the business cycle.

Prior to and during the global financial crisis, the linkages between credit growth and GDP growth became more pronounced. In particular, the financial sector plays a significant role during the early stages of the crisis, while the real sector quickly takes over as the dominant source of spillovers.

There are three main channels by which disruptions in financial markets can influence real activity: a pullback in spending owing to reductions in wealth; balance sheet mechanisms that lead to a widening of credit spreads, which curtail the ability of households and businesses to obtain credit; and the direct effect of impairments in the capacity of financial institutions to intermediate credit.

It is commonly assumed that financial cycles are pro-cyclical and accelerate business cycle fluctuations (see, e.g., Borio, 2014). Recent research using cross-country data has revealed important links between business and financial cycles. However, the more likely tendency of the close relationship between real and financial sectors in developing countries, most available studies focused on developed and emerging economies, with SVAR as a dominant methodology applied and few adopting wavelet analysis. Since the macro-financial linkages primarily depend on economic structures, it is worth discussing the empirical literature based on countries' specific and group studies.

Studying the interaction of business and financial cycles in 21 advanced OECD countries and 23 emerging market countries from 1978Q1 to 2009Q4 for the latter and 1960Q1 to 2009Q4 for the former; Claessens et al. (2010) pointed to a strong interaction. They used the index developed by Harding and Pagan 2002 and tracked credit, house prices, equity prices, and exchange rates to measure the financial cycles, while the output was a measure of business cycles. The results show that financial cycles tend to be larger and sharper than business cycles and the business cycles are more synchronized with cycles in credit and house prices than in equity prices and exchange rates. Their results stress the importance of developments in credit and house markets for the real economy as a policy implication.

In another study, Claessens et al. (2012) used a comprehensive database for a large sample of advanced economies and emerging economies to provide a broad empirical characterization of macro-financial linkages. They report three main results. First, business cycles are more closely synchronized with credit and house price cycles than equity price cycles. Second, financial cycles appear to play an essential role in determining recessions and recoveries and influencing the features of business cycles. In particular, recessions are more likely to overlap with financial disruptions, while recoveries are prospective to be linked with booms. Third, recessions associated with financial turmoil, notably house price busts, are often longer and more profound than other recessions.

Antonakakis et al. (2015) examined the business cycle and financial cycle spillovers in the G7 countries, using VAR- based spillover index approach introduced by Diebold and Yilmaz (2009) with data spanned from 1957Q1–2012Q4. By assessing the time-varying relationship between real credit growth and real GDP growth at business cycle frequencies for each of the G7 countries, their results showed spillovers between credit growth and GDP growth, which evolve heterogeneously over time across countries and increase during extreme economic events. Moreover, they found the bidirectional spillovers of shocks between the financial and the real sector.

Krznar and Matheson (2017) explored the link between Brazil's financial and business cycles from 1999Q1 to 2015Q3. They estimated cycles using various commonly used statistical methods with a small, semi-structural model of the Brazilian economy. Two approaches have been used to measure the financial cycle: the medium-term credit cycle and the Financial Conditions Index (FCI). The business cycle was measured by the output gap, calculated by the band-pass filter developed by (Christiano & Fitzgerald, 2003). Both model-based and statistical-based estimates of financial and business cycles conclude that the financial cycle has a longer duration and is larger than the business cycle. The results show that for every 1 percent rise in the output, credit increases by around 3 to 5 percent, on average. In addition, real GDP growth lags the financial conditions. Both facts suggest that financial sector developments are important for economic fluctuations in Brazil. The impulse responses indicate that credit responds more to output than output responds to credit. Private credit is more responsive to output shocks than public credit. Output responds strongly to shocks to financial conditions. The historical decomposition of the output gap suggests that short-term financial conditions and medium-term credit shocks are important in explaining fluctuations in economic activity.

Young and Zhang (2016) studied the linkages and interactions between the financial cycle, business cycle, and monetary policy in the USA, UK, Japan, and China over the period 1987Q1-2015Q4, 1989Q1-2015Q4, 1989Q1-2015Q4, and 1998Q1-2015Q4, respectively. They estimated the equation using the GMM method, and their results showed that the financial cycle has an imperative impact on the business cycle in each country. Their study further investigated the role of financial cycle shock in macroeconomic fluctuations using a small macroeconomic model. The variance decomposition results for major endogenous variables of the model system in the four countries mentioned above showed that financial cycle shock plays a vital role in determining macroeconomic fluctuations.

Oman (2019) analyzed the synchronicity between business and financial cycles in the euro area, both within and across countries, for the period spanning from 1971 to 2015. He used the band-pass filter Christiano and Fitzgerald (2003) proposed for GDP growth, credit growth, credit-to-GDP, and residential property price growth. The results showed that Germany's financial cycle has been remarkably flat throughout the sample period. At the same time, Spain, Ireland, and Greece, which are "high-amplitude" countries, experienced significantly ample financial cycles after the introduction of the euro. The author found that average business cycle synchronization increased gradually over time, albeit with the similarity of the composite business cycle of high-amplitude countries falling in the boom period. He pointed out that the synchronization of financial cycles may influence resource allocation and generate asset price bubbles, hindering cross-country economic convergence and making a systemic financial crisis more likely.

A recent study by Yan and Huang (2020) studied the association between the financial cycle and the business cycle using Wavelet analysis and explored their interactions and dynamic mechanisms by the VAR model. The empirical results showed that the financial cycle is closely related to the business cycle; the business cycle leads the financial cycle with a high positive correlation. More importantly, the financial cycle was a key source of business cycle fluctuations.

In summary, various studies on the linkages between financial and business cycles adopted the structural vector autoregressive models, wavelet analysis, and General Methods of Moment (GMM). We observe the key differences in the proxies of cycles across the studies, whereby financial cycles were measured by credit to GDP ratio gap, growth in the credit to the private sector, or the index of financial conditions, while the business cycles were mainly proxied by the output gap or the real growth of the economy. Despite some prevailing differences in magnitude and direction, the studies revealed evidences of macro-financial linkages. The main contribution of the present study is to analyze the linkages between real and financial sectors in Rwanda as one of the developing economies that lack empirical evidence in this area and have witnessed good progress, but with fluctuations in both sectors.

3. Methodology

This section presents the data source, transformation, and different analytical methods applied in this study.

3.1 Data source and transformation

We collect quarterly data with the sample period running from 2006:1 to 2020:1. The choice of the sample is motivated by the availability of quarterly data for some important series such as Gross Domestic Product (GDP), etc. All data were obtained from the National Bank of Rwanda database. To gauge how financial cycles co-move with business cycles, we compute concordance indices measuring the share of time over which two given cyclical series are in the same phase (expansion or contraction) over the observed period. We employ the band-pass filter developed by Christiano and Fitzgerald (2003) to isolate a quarterly seasonally adjusted series cycle, defined as a deviation of the series from their trends. In addition, variables such as the real monetary condition index and the United States' real gross domestic product (US-GDP gap) are used in this study.

3.2. Analytical methods

We adopt two different methods to analyze the relationship between the business and financial cycles: Wavelet analysis and structural vector autoregressive models (SVAR).

3.2.1. Wavelet analysis

This approach has a huge potential in our analysis, as it allows one to unveil relationships between economic variables in the time-frequency space. Among the various analytical methods of wavelet analysis, we choose the cross-wavelet transform (CWT) that allows one to quantify the co-movement in the time-frequency space. That is, to analyze the interaction between two-time series x and y in the time-frequency domain and assess over which periods and frequencies are the co-movements higher (Rua, 2010).

In the spirit of Torrence & Compo (1998), the wavelet coherence of two-time series x and y can be defined as:

$$R_t^2 = \frac{|s(w_t^{xy})(s)x|^2}{S(s^{-1}|(w_t^x(s|^2).S(s^{-1}|w_t^y(s)|^2} \qquad (1)$$

Where S(.) denotes smoothing in both time and scale, wavelet coherence close to one shows a higher similarity between time series. In contrast, near-zero coherence depicts no relationship (Boako & Alagidede, 2016). Hence, from the wavelet squared coherency output, one can distinguish where and where the link is stronger and identify both time and frequency-varying features.

We simultaneously computed the wavelet phase, which provides information about correlations and lead-lag relationships (causality) with different data series. According to Madaleno and Pinho (2010) and Torrence and Compo (1998), the phase for wavelet depicts any lead/lag linkages between two-time series and can be defined as:

$$\theta_{xy} = tan^{-1}\frac{I\{W_t^{xy}\}}{R\{W_t^{xy}\}}, \theta_{xy} \ \epsilon \ [-\pi, \pi] \qquad (2)$$

An absolute value of θxy less (larger) than $\pi/2$ indicates that the two series move in-phase (antiphase, respectively), referring to the instantaneous time as time origin and at the frequency under consideration. At the same time, the sign of the phase shows which series is the leading one in the relationship. The phase vectors are indicated by arrows (Boako & Alagidede, 2017; Owusu et al., 2017).

If the phase difference becomes zero, it is an indication that the time series move together at the specified frequency. If $\theta x,y \in (0, \pi/2)$, then the time series are in phase (or positive) relation, and x leads y; if $\theta x,y \in (-\pi/2, 0)$, then y leads x. If $\theta x,y \in (\pi/2, \pi)$, the series are in antiphase (negative relationship), then y leads x; if $\theta x,y \in (-\pi, -\pi/2)$, then x leads y.

3.2.2 Structural Vector Autoregressive model

Sims (1980) introduced SVAR models as an alternative to the large-scale macro-econometric models used during that time. Since then, the SVAR methodology has gained widespread use in applied time-series research due to various advantages, such as allowing for the incorporation of contemporaneous variables, an investigation into the impact of individual shocks, and identification of specific independent shocks that are not affected by covariance terms. Thus, the SVAR models have become an appropriate tool for studying relationships and the effects of shocks in macroeconomics, considering the issue of endogeneity and the limited availability of proper instruments.

The empirical analysis is based on the following structural VAR model:

$$AY_t = C(L)Y_t + Bu_t \qquad (3)$$

Where Yt is a vector of endogenous variables (business cycles, financial cycles, and real monetary conditions index), L is the lag operator, A, B, and C are matrices, and ut is a vector of normally distributed errors (ut~N (0, I)).

A 4-variable benchmark model includes the output gap as a measure of the business cycle, the credit to GDP ratio gap as a measure of the financial cycle, based on an increasing amount of literature suggesting the effectiveness of the credit to GDP gap to spot the buildup of financial vulnerabilities (Drehmann & Tsatsaronis, 2014). Basel III recommends the credit-to-GDP ratio as the best-fitted measure of the financial cycle. In addition, the model includes the real monetary conditions (RMCI) measured as a weighted average of the real short-term interest rate and real effective exchange rate and the US GDP gap for consideration of external influence.

Regarding the identification strategy, we use recursive zero restrictions on coefficients (Cholesky decomposition).

Our estimation considers the ordering of variables as follows: Variable representing the business cycle is ordered first; the real monetary condition index is ordered second, and the financial cycle variable is ordered last. This ordering of the variables has the following implications: Monetary authorities consider the business cycle when making decisions. The business cycle and real monetary conditions affect the financial cycle contemporaneously. The main reason for ordering the financial cycle at the last place is to assess the impact of shocks from credit to the economy, which is purely exogenous, i.e., eliminates the effect of output and monetary conditions.

4. Empirical results

4.1 Unit root test

Before estimating models, the stationarity properties of each series are investigated using the Augmented Dickey-Fuller (ADF) test. All series stationary at the level at level, i.e.: I (0).

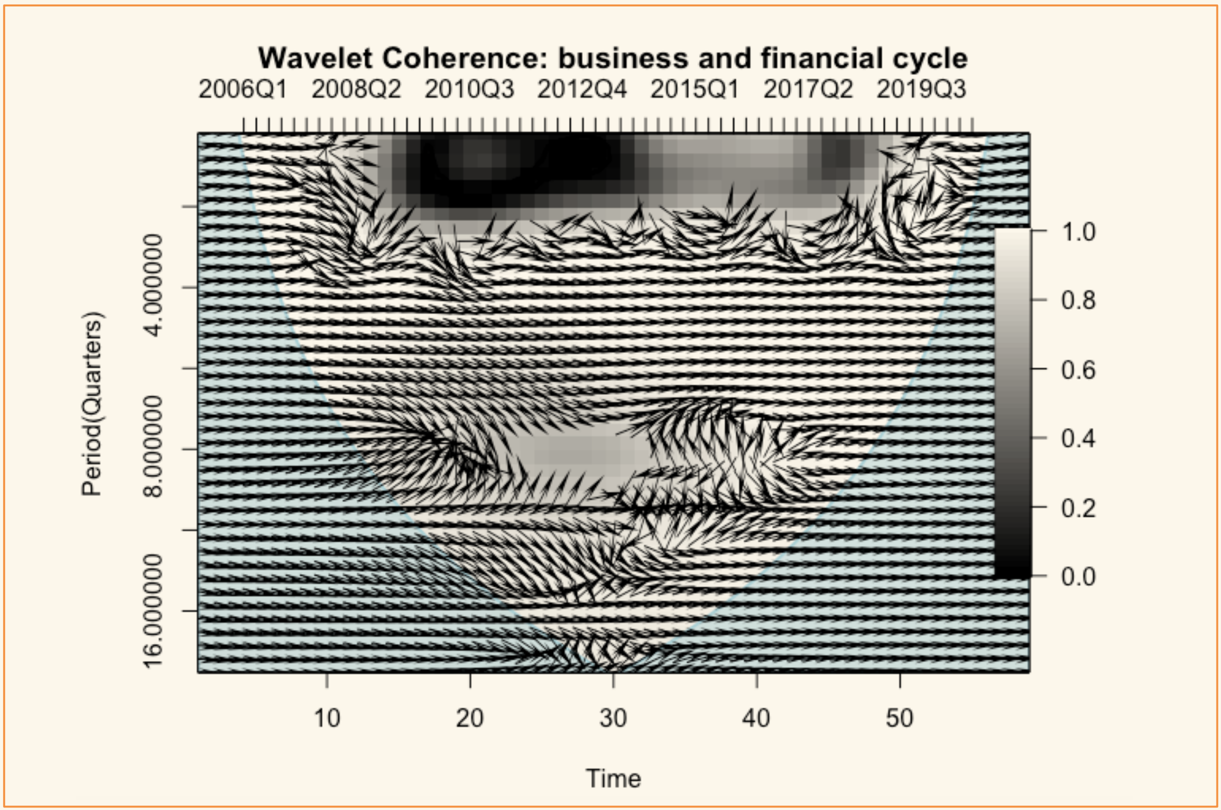
4.2 Results from wavelet analysis

According to Aguiar-Conraria et al. (2013), the interpretation of wavelet coherence can be summarized as follows. On the right-hand side, there is a bandwidth spectrum, which highlights the level of correlation oscillating from the lowest amount of correlation, 0, which is shown in the plot as deep black color, to the highest amount of correlation, 1, which is shown as a light grey color. We are looking for areas with this light grey color for high synchronization, indicating the co-movement of the business and financial cycles.

On the x-axis is the time - period shown, ranging from the beginning of the sample in 2006Q1 to the end of the sample in 2020Q1. The thick white contour in the coherence plot shows areas where the wavelet coherence is significant at the 5% level against red noise estimated from 1500 Monte Carlo simulations. The inverse bell-shaped cone is called the cone of influence (COI). It shows the region in the plot which is of substantial power, where the lighter shade is the significant region (Grinsted, et al., 2004). Furthermore, the direction of the phase-difference arrows inside the plots shows whether the two time - series are in - phase or leading/lagging each other. If the arrows are pointed to the right, it indicates that both time series are in phase with each other, and if it is pointed to the left, it indicates anti-phasing. If the arrow is pointed up, the first time -

series is leading the second, and if the arrow is pointed down, the first time - series is lagging the other.

Figure 2 below highlights the results of wavelet analysis.



Source: Authors' estimation using wavelet

The results point out a strong positive correlation between the business cycle and financial cycles in Rwanda in the time and frequency dimensions, as the dominant color of the cone of influence is the light grey color. Limited correlation is only observed between 2010 and 2012 and the end of 2017, at a small scale of less than two quarters.

Regarding which variable is leading or lagging through phasing, the arrows are mainly oriented to the right (they are in phase). Generally, the evidence shows that the business cycle leads the financial cycle at a scale of 2 to 4 quarters, indicating that the booms (recessions) in the economic activities lead to booms (downturns) in credits to the economy after six to twelve months. As the arrows are mainly oriented to the right on a scale of four to eight quarters, both cycles are in phase, with none leading the other. We observe a two-directional correlation between the variables at a scale greater than eight quarters.

Keeping in mind that the wavelet analysis is robust in showing the correlation between series, it is essential to go further with structural VAR, which is more appropriate for judging the response of one sector to a shock from another.

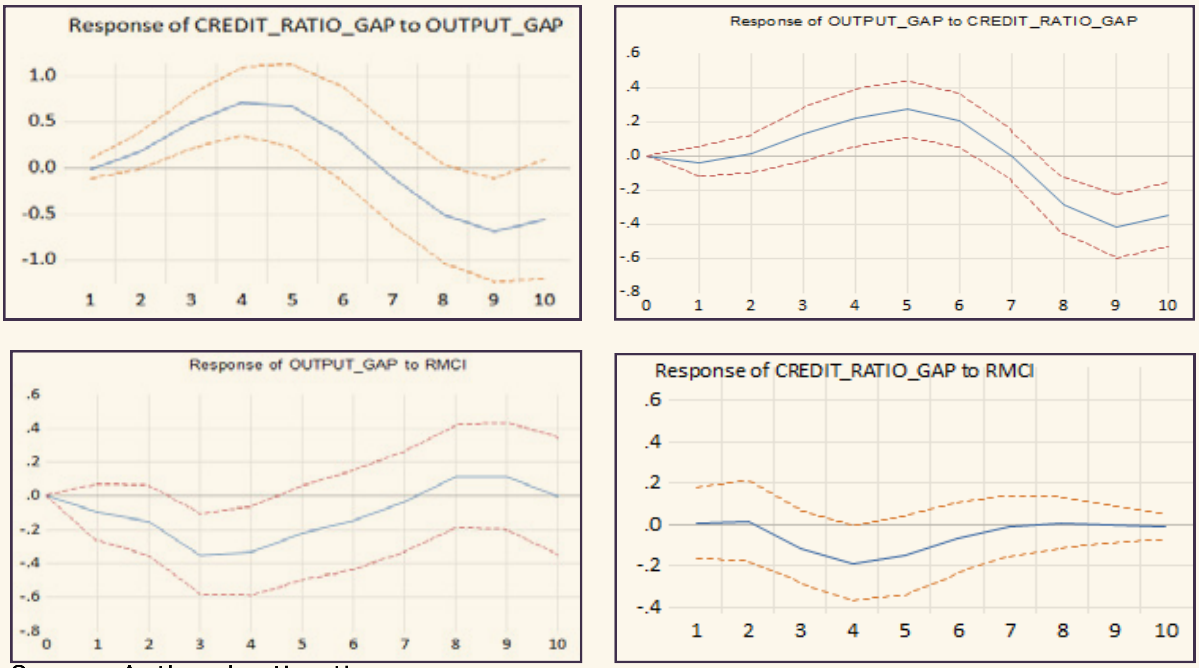
4.3 Results of structural VAR

We estimate an SVAR model which has the advantage of providing evidence on the business cycle response to the financial cycle shocks, reactions in the financial cycle to the business cycle shocks and clarifies the causal relationship between the financial cycle and the business cycle.

We use the Akaike information criterion (AIC) and the Schwarz information criterion (SIC) to determine the lag in the VAR model and find that the optimal lag period is 2 and diagnostics tests indicate that errors are normally distributed, absence of autocorrelation, and the VAR satisfies the stability condition. Figure 3 shows the impulse response functions by using the Cholesky decomposition.

The impulse responses underline the importance of shocks from the real sector to the financial industry. The response of the financial cycle to a shock from the business cycle is quick in the 1st quarter and lasts about six quarters, implying that the boom in economic activities leads to a boom in loans.

Figure 3: Response to Cholesky One S.D. Innovations 95.0% marginal confidence bands



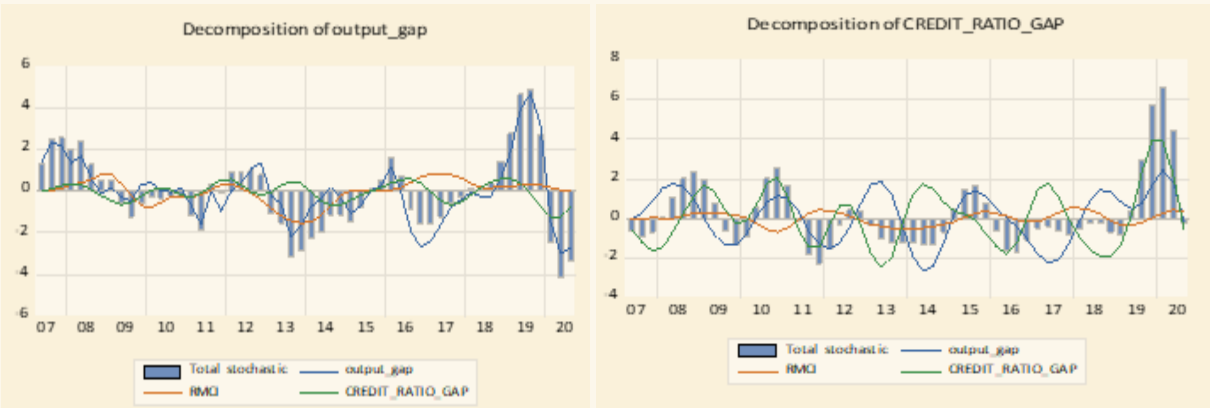
Source: Authors' estimation

However, the abundance in credits to the economy may result in the non-performing assets of lending institutions and later discourage and reduce the financing role, reflected in the negative and harsh impact on the business cycle realized after nine quarters. Our findings are in line with cross-country evidence suggesting that periods of strong credit growth are followed by periods of sluggish growth (Krznar & Matheson, 2017).

The business cycle responds to the financial cycle at the third quarter and lasts for three quarters before it turns negative at the eighth quarter, and the negative becomes stronger than the positive response. This indicates that the shock from the financial system leads to business cycle fluctuations.

The findings reveal that tight monetary conditions reduce the output gap, and the effect materializes in the second quarter but lasts for almost three quarters, in line with our policy horizon. Regarding the response of the financial cycle to monetary conditions, the effect is small and short, realized in the fourth quarter.

Figure 4: Historical decomposition (HD) using Cholesky (d.f adjusted) weights



Source: Authors' estimation

Figure 4 above presents the historical decomposition of the business and financial cycles through the lens of the identified structural shocks from the VAR model. On the left side of the figure, the historical decomposition of the output gap suggests that credit shocks have been important in explaining fluctuations in economic activity, especially during the global financial crisis (GFC) 2008-2009, and a relatively less significant role in other periods. On the right side, the results reveal that the business cycles have played an essential role in the fluctuations in financial cycles, particularly in post-GFC and in recent years of 2019-2020.

4.4 Discussion of the results

Empirical results suggest some similarities with previous studies on developed and emerging economies, but some differences also prevail, noting that the interaction between financial and real sectors depends on the structure of the two sectors and the economy in general.

Recent literature generally presented evidence of the relationship between the two sectors, with financial cycle shock playing a significant role in determining macroeconomic fluctuations. Similarly, for the case of Rwanda, the findings show the existence of the relationship between the business cycle and the financial cycle, with the former leading in the medium term. This implies that it takes a half to a full year for a good performance of the real sector to reflect into the financial sector, justifying that the periods of favorable economic conditions lead to optimistic growth prospects, followed by abundant credit.

Contrary to some of the previous studies in other countries, Rwanda's key insight is that the influence of the business cycle on the financial cycle is relatively more important than the other way round. The results are supported by the fact that the financial sector in Rwanda is dominated by banks, as previously discussed, which also rely on loans as the primary source of income; hence, the performance of the real sector observed through the demand for loans is likely to affect much the financial sector. It is also critical to note that Rwanda's big projects that drove economic growth have much relied on external finance, including grants and loans. Nevertheless, as many firms and, to a large extent, households depend on bank loans for capital projects and large investments, the shock from the financial sector also affects the real sector, as supported by the results.

The results from historical decomposition revealed that the linkages between business and financial cycles in Rwanda became more pronounced during and after the crisis (e.g., in 2008-2009), as found in a study by Krznar and Matheson (2017). This calls for prudent macro-prudential policies to mitigate the likely impact of the current situation of the Covid-19 pandemic, which is affecting both sectors.

5. Conclusion and policy implications

Based on Rwanda's quarterly data, from 2006:1 to 2020:1, this paper analyzes the interaction between business and financial cycles in Rwanda. We adopt the band-pass filter developed by Christiano and Fitzgerald (2003) to estimate cycles from seasonally adjusted series.

To bring more insights into the relationship between business and financial cycles in Rwanda, we adopt two different methods; (1) Wavelet analysis, which is an essential tool to assess simultaneously how two cycles are related at different frequencies and how such a relationship has evolved or which variable has been leading. (2) Structural vector autoregressive models (SVAR) as the appropriate tool for studying relationships and the effects of shocks in macroeconomics.

The results from wavelets analysis point out a strong positive correlation between the business cycle and financial cycles in Rwanda, especially at medium-term frequencies (2–4 quarters), with the business cycle largely leading the financial cycle. This indicates that the booms (recessions) in the real sector lead to booms (downturns) in credit to the economy. At a scale greater than one year, two cycles tend to move in phase, and for a few episodes, the financial cycle leads the business cycle.

The findings from SVAR confirm that business and financial cycles are closely linked in Rwanda. On the one hand, there is a significant and quick reaction of credit to shocks from the output at the first quarter, implying the importance of shocks from the real sector to the financial industry. On the other hand, the business cycle responds to the financial cycle at the third quarter, indicating that the shock from the financial system leads to business cycle fluctuations. In addition, the evidence reveals that tight monetary conditions affect more the business cycle than it does on the financial cycle.

Overall, the empirical analysis in this paper confirms the close relationship between the financial cycle and the business cycle in Rwanda and the critical impact of the business cycle shock on the financial sector. Policymakers should closely monitor the upturns and downturns in each sector and mitigate the likely propagation of shocks from one sector to another with appropriate macro-prudential policies.

Although the results came out with a significant contribution in explaining the dynamics between financial and financial cycles in Rwanda, with related policy implications, the study could not consider the financial condition index to measure financial cycles, which future studies may look at. Future studies may also consider a model-based approach that is advantageous in the sense that financial and business cycles can be jointly estimated, allowing information from all key economic relationships to be used consistently.

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IMPACT OF FINANCIAL SYSTEMS DEVELOPMENT ON MACROECONOMIC STABILITY IN RWANDA

Christian Nyalihama*, Callixte Kamanzi+

Senior Principal Economist, Research Department, National Bank of Rwanda

+ Senior Economist, Research Department, National Bank of Rwanda

Abstract

Despite the dominant consensus of the positive influence of financial systems development on macroeconomic stability, this link has come under increasing scrutiny in recent years, particularly following the 2007-09 global financial crisis. This study examines this issue in Rwanda to contribute to policymaking in devising appropriate policies for sustaining macroeconomic stability and promoting financial systems development. While the evidence on the effect of financial systems development on macroeconomic stability is mixed in the literature, the results from this study, to a larger extent, support the view that financial systems development has contributed to macroeconomic stability in Rwanda. Results from local projection methods generally suggest that financial system development has contributed to macroeconomic stability, notably on real GDP growth via investment, while the effect on consumption is quasi absent.

Key Words: *Macroeconomic stability, financial systems development, Rwanda.*

JEL Classification Numbers: *E30, G00, O40.*

1. Introduction

There is a robust theoretical presumption among policymakers and scholars that financial systems development, defined broadly in terms of the expansion of financial institutions, markets, and infrastructures in the economy, is a catalyst for macroeconomic stability and sustained economic development (Levine, 1997; Demirguc-Kunt, 2006; Demirgüç-Kunt & Levine, 2011; Beck, 2013; Zhang et al., 2012). The standard explanation is that a well-developed financial system smoothens macroeconomic volatility by relaxing credit constraints on firms and households and providing them with various instruments to withstand adverse shocks (Caballero & Krishnamurty, 2001) and promoting diversification and management of risks (Acemoglu & Zilibotti, 1997).

Despite the consensus on the positive influence of financial systems development on macroeconomic stability, this link has attracted more attention from researchers in recent years, particularly following the 2007-09 global financial crisis. It is argued that the impact of financial systems development on macroeconomic stability is nonlinear; that is, as the financial sector deepens, its contribution to reducing volatility declines, hence increasing the propagation and amplification of shocks (Cecchetti & Kharroubi, 2012; Sahay et al., 2015). In the same scope, some studies suggest that the level of financial system development is positive only up to a certain point, after which it becomes a hindrance to macroeconomic stability (Aghion et al., 2005; Arcand et al., 2015; Dabla-Norris & Srivisal, 2013).

Against this backdrop, there are reasons that justify the need for sufficient studies on this matter globally for at least three reasons. First, the issue of macroeconomic stability is profoundly important for policy-makers mandated to mitigate the severity of macroeconomic instability in their respective economies (Ramey & Ramey, 1995). Second, the global financial crisis has re-ignited the policy debate on the role of finance in propagating and dampening macroeconomic fluctuations. Third, the theory of a possible linkage between financial systems development and macroeconomic stability is still controversial (Aghion et al., 1999).

Since the 1990s, many developing countries, including sub-Saharan African countries, have undertaken significant development reforms geared towards financial systems, typically through financial institutions and financial markets. However, the region still lags behind the stages observed in developed and emerging economies. Given that most Sub-Sahara African countries are still below the financial systems development index benchmark level (Mlachila et al., 2016), it's effect on dampening the growth volatility tends to be stronger through reducing borrowing constraints, participation costs, and increased intermediation efficiency.

Similarly, Rwanda recorded noticeable development in the financial system in the last two decades in many aspects, including depth, institutions, markets, and access. Successively, the financial sector in Rwanda has been expanding, consisting of a broad and growing array of institutions and products, and established capital markets. Alongside, Rwanda's economic performance has been outstanding, with annual growth of around 8% on average since 2010, while inflation has generally been contained at moderate levels.

Nevertheless, episodes of macroeconomic instability in terms of economic growth and inflation have been recurrent. This is a big concern for policymaking as it can derail the long-term development path. Notwithstanding the noticeable progress in Rwanda's financial system, some challenges remain, including financial depth, financial access for some sectors, and limited alternatives beyond the banking sector. In such a context, one would wonder whether the level of development in the financial system has helped to improve macroeconomic stability in Rwanda. In addition to this, the divergent views on the effect of financial development on macroeconomic stability give enough reasons to investigate this matter for each economy like Rwanda, which enjoys significant positive changes in both aspects.

Previous studies (Kigabo et al., 2015; Karangwa & Gichondo, 2016; Nyalihama & Kamanzi, 2019) assessed the relationship between Rwanda's financial development and economic performance. Their findings suggest a positive effect of credit to the private sector on economic growth and suggest bi-directional causality between financial development and economic growth in the long run, thereby confirming that financial development is important for economic growth in Rwanda and vice versa. All these studies looked at economic growth and not macroeconomic stability, and so far, empirical evidence on the latter is still lacking in Rwanda. Thus, our main contribution is to address the link between financial system development and macroeconomic stability in Rwanda. Another contribution of this study is using a new financial development index developed by the International Monetary Fund (IMF) that captures this aspect in various dimensions: depth, access, and efficiency of the financial system (i.e., both financial institutions and financial markets).

Moreover, the study captures not only economic growth volatility as a measure of macroeconomic (in)stability but also considers other macroeconomic variables such as inflation and exchange rate that are important indicators of macroeconomic stability in the Rwanda context, as they can be subject to acute shocks with implications to the real sector.

This study sheds light on the impact of financial systems development on macroeconomic stability in Rwanda and aims to contribute to policymaking going forward in devising appropriate policies to sustain strong macroeconomic stability and promote financial systems development. It aims to assess whether financial system development contributed to Rwanda's macroeconomic stability and identify potential channels through which this may have happened.

Empirical results are largely in line with the literature. In the case of Rwanda, evidence from the local projection method suggests that financial system development in Rwanda has generally contributed to macroeconomic stability in Rwanda. The stabilizing effect is relatively more evident in GDP growth and per capita GDP. The effect on GDP growth is mostly via stabilizing effect on investment.

The paper is structured as follows: the next section reviews the main developments observed in the Rwandan financial sector. Section 3 reviews the literature. Section 4 explains the methodology used. Section 5 presents the empirical results, and section 6 concludes.

2. Financial system development in Rwanda

The Rwandan financial system has tremendously grown over the past two decades, thanks to various factors, including political stability, a conducive macroeconomic environment, and the entry of new market players. More notably, the National Bank of Rwanda (henceforth, NBR) has put in place important reforms to ensure that the financial system remains sound. These reforms include the establishment of appropriate market infrastructure, especially the efficient legal and regulatory framework, supervisory tools, modern payment systems, and the private credit reference bureau.

The Rwandan financial sector comprises a range of institutions, markets, and financial infrastructure. As of June 2020, the NBR regulates 603 institutions, including 16 banks, 14 insurance companies; 459 microfinance institutions; 13 pension schemes, 97 foreign currency dealers and remittance companies, and four registered lending-only institutions. Total assets of these institutions amounted to FRW 5,747 billion at the end of June 2020 (equivalent to 63 percent of GDP). Total assets of mainstream financial institutions (Banks; MFIs; Insurance; and Pension) stood at FRW 5,718 billion (62 percent of GDP). The capital market, regulated by the Capital Market Authority (CMA), is also an integral component of the Rwandan financial system.

The financial sector remains dominated by the banking sector, accounting for 67.0 percent of the total financial sector assets as of the end of June 2020. The banking sector is not only the largest but also a systemically important sector based on its interconnectedness with the rest of the sub-sectors; combined deposits of microfinance, insurance, and pension funds accounted for 23 percent of banking sector deposits at the end of June 2020. The pension sector comes in second place with a 17.2 percent share of the financial sector assets. The pension sector is dominated by the mandatory public-defined benefit pension scheme (RSSB), with 95 percent of the pension sector assets (the 12 private pension schemes account for 5 percent of pension sector assets). The insurance and microfinance sectors account for 9.5 percent and 5.7 percent, respectively, of the financial sector assets, while the rest (foreign currency dealers, remittance companies, and lending-only institutions) account for the remaining 0.5 percent.

The financial sector is becoming more inclusive, as revealed by the recent FinScope survey (2020). This survey done every 4 years indicates that the percentage of the adult population in Rwanda served by the formal financial sector (i.e., regulated sector) increased from 69 percent in 2016 to 77 percent (5.5 million adults) in 2020. These are adults that have or use formal financial products and services, including the banking sector and other formal (non-bank) financial products/services from insurance firms, Mobile Network Operators (MNOs). The Government of Rwanda targets to increase the proportion of formally served adults to 100 percent by 2024, as elaborated in the National Strategy for Transformation (NST 1). The formal inclusion gains in the last four years (2016-2020) were driven by the increase of bank account holders (from 1.1 million in 2016 to 2.6 million in 2020), increased uptake of mobile money (4.4 million in 2020, against 2.3 million in 2016), U-SACCOs (2.4 million account holders in 2020, against 2 million in 2016), more insured adults (1.2 million in 2020, from 0.5 million in 2016), and increased account holders in other MFIs (0.7 million in 2020, from 0.3 million in 2016).

Table 1: The Structure of the Financial System

Regulated Financial Institutions	June 2020		
(Assets in FRW Billion)	Number	Assets	% of Total Assets
Banks	16	3,854	67.0
Commercial Banks	11	3,142	54.7
Microfinance Banks	3	66	1.15
Development Banks	1	265	4.6
Cooperative Banks	1	381	6.6
Pension Schemes	13	990	17.2
Public	1	941	16.4
Private	12	49	0.8
Insurers	14	544	9.5
Life	3	52	0.9
Non-Life	11	492	8.6
Microfinances	459	330	5.7
U-SACCOs	416	139	2.4
Other SACCOs	24	97	1.7

Limited Companies	19	94	1.6
Foreign Currency Dealers & Remittances	97	9	0.2
Forex Bureau	83	9	0.2
Remittance Companies	8	-	0.0
Money Transfer Agencies	6	-	0.0
Lending only Institutions	4	20	0.3
Grand Total	603	5,747	100

Source: National Bank of Rwanda, 2020

The level of financial sector development and deepening has also been increasing though it remains low, just like in other developing countries. Credit to the private sector as a percentage of GDP has almost doubled, rising from 10.3% in 2000 to 20.1% in 2019. The monetization of the economy accelerated as the ratio of M3 to GDP increased from 16.5% to 26.3%, and the deposit to GDP ratio increased from 13.4% to 23.9%.

The financial sector has played an essential role in financing the economy, witnessed by the increased share of new authorized loans (NALs) to various sectors, despite the minimal share of loans to risky sectors such as agriculture.

Table 2: Distribution of NAL by economic sector in % share

Economic Sector	2015	2016	2017	2018	2019
Commerce	33.8	34.1	35.2	32.9	27.2
Public works and building	32.0	24.7	28.0	26.2	25.6
Personal loans	9.0	9.9	11.0	11.0	12.7
Manufacturing activities	6.9	8.1	7.3	7.3	12.4
Transport & warehousing & communication	7.3	4.8	8.9	14.6	7.7
Water & energy activities	0.2	3.1	2.4	1.6	5.2
Services provided to the community	3.0	2.8	2.4	3.1	4.5
Restaurants and hotels	3.9	10.1	2.5	1.6	2.2
Agricultural, fisheries& livestock	1.9	1.5	1.1	1.2	1.5
OFI & Insurance and other non-financial services	2.0	0.7	1.1	0.5	1.1
Mining activities	0.0	0.2	0.1	0.0	0.0
TOTAL	100	100	100	100	100

Source: National Bank of Rwanda, 2019

2.1. Banking sector development in Rwanda

The size of the banking industry has consistently been expanding since 1995 on the back of the financial sector development programs adopted by the Government of Rwanda, a strong legal and regulatory environment enforced by the NBR to comply with international standards and best practices, financial liberalization, and entry of new banks in the market.

The number of banks in Rwanda has been increasing over time, reaching 16 as of June 2020, of which 11 commercial banks, three microfinance banks, one development bank, and one cooperative bank, from one commercial bank in 1964. The number of bank branches increased from 99 in 2010, and now the sector serves its clients through a network of 200 branches, 150 sub-branches and outlets, and 4,706 agents and digital platforms like internet banking and mobile banking. The banking sector is predominantly private and subsidiaries of foreign banks. Currently. 14 out of 16 banks are private banks based on majority shareholdings, while 11 out of 16 banks are subsidiaries of foreign banks and holding companies. Deposits increased from FRW 90.3 billion in 2000 to FRW 2,184 billion in 2019, while credit to the private sector increased from FRW 70.9 billion to FRW 2,084 billion, and total assets increased from FRW 879 billion to FRW 3,476 billion in the same period.

Table 3: Evolution of total assets, loans, and deposits of banks (in FRW billion)

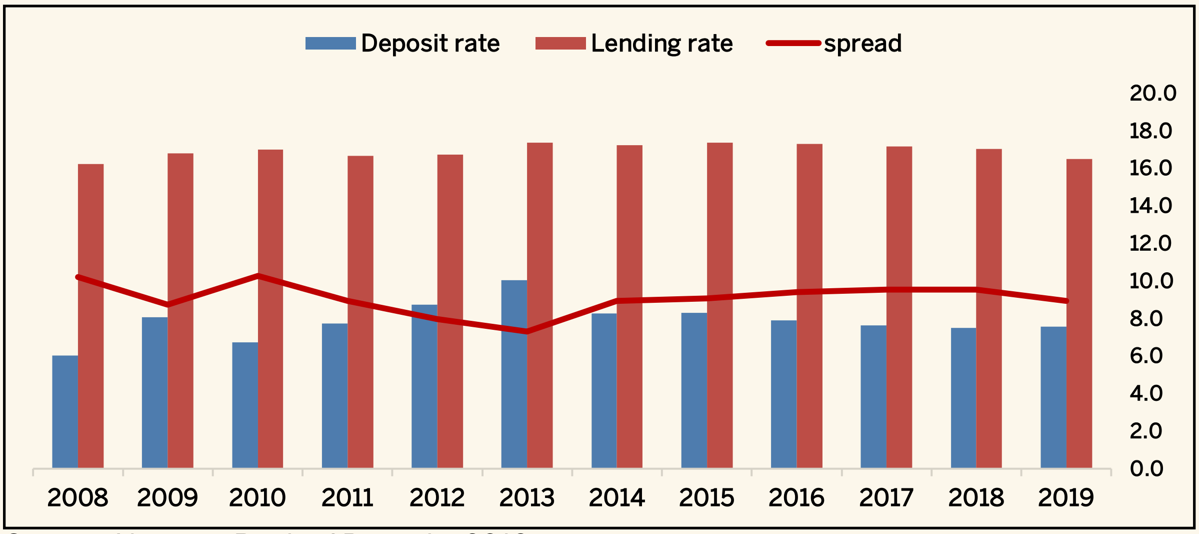
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Total Assets	879	1,084	1,248	1,511	1,803	2,133	2,380	2,685	3,091	3,476
Total loans	456	583	775	881	1,051	1,269	1,457	1,646	1,871	2,084
Total Deposits	536	651	741	866	1,042	1,418	1,530	1,723	1,965	2,184

Source: National Bank of Rwanda, 2019

Financial intermediation remains the core business of banks, with 56.7 percent of their assets being loaned at the end of June 2020. The other two key earning assets for banks are Government securities- treasury bills and bonds (18 percent of total assets) and; placements in foreign financial institutions (4.7 percent). Other assets include cash and reserves at the central bank (7.1 percent of total assets), due from other financial institutions in Rwanda (6.7 percent); fixed assets (4.2 percent); and other assets (2.4 percent). Bank lending is primarily to the private sector with around 95 percent of the stock of loans to private entities- Public Enterprises account for 5 percent of the total stock of banking loans. Banks maintain a stable funding profile, with 76.8 percent of their liabilities being deposits. Interbank and foreign borrowings, the two secondary sources of funds for banks, account for 18.1 percent and 0.7 percent, respectively. Other liabilities account for the remaining 4.3 percent of total liabilities.

The wedge between the average lending and deposit rate, which generally indicates the efficiency of banks, has remained relatively sticky over time, suggesting that there is still room for improvement with regard to banks' efficiency. The main reason attributed to lending rates that have been rigid and quite high over the past compared to the fluctuating and less elevated deposit rates. However, the most recent developments indicate improved efficiency in the banking sector, whereby the spread between the lending rate and deposit rate dropped by 63 basis points to reach 8.85 percent on average in 2019.

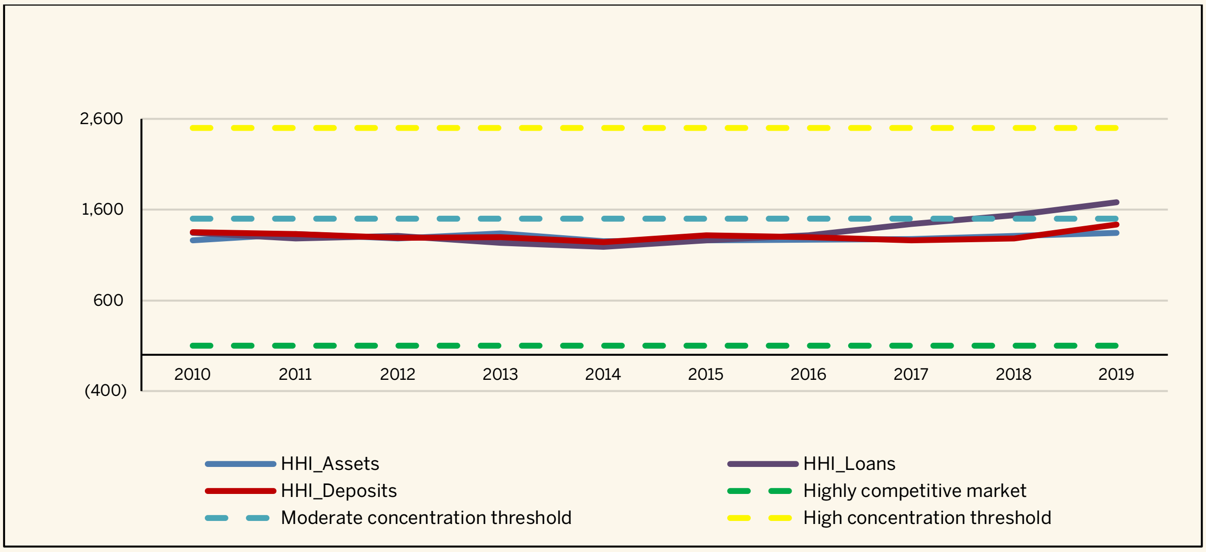
Figure 1: Annual average interest rate spread in Rwanda (2008-2019)



Source: National Bank of Rwanda, 2019

Another important aspect is the concentration of the banking sector in Rwanda. The computed Herfindahl-Hirschman Index (HHI) on banks' assets, loans, and deposits indicates that the banking sector in Rwanda has been unconcentrated. However, since 2016, the sector has become less competitive, and the loan market has become concentrated since 2018, indicating the increase in the loan market power of some banks.

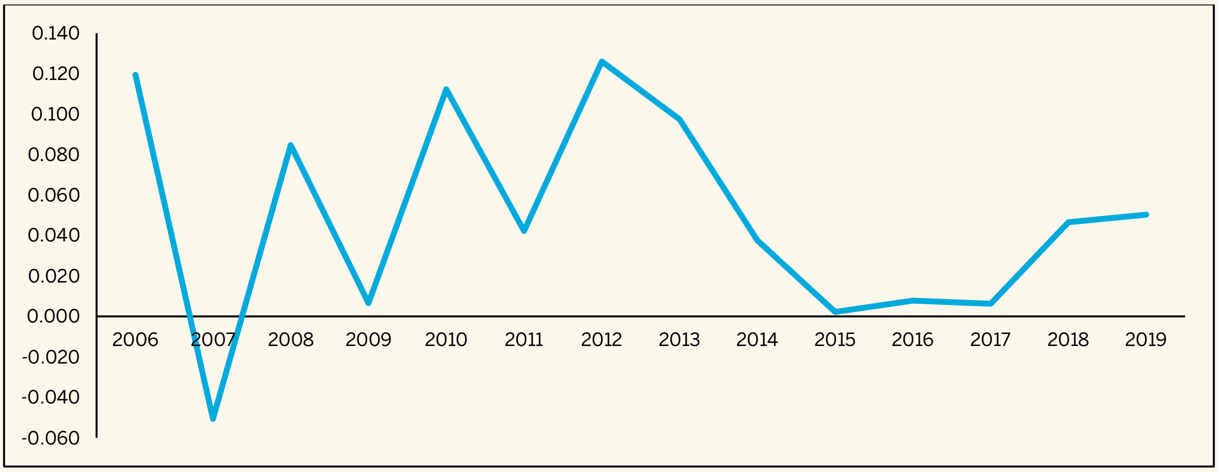
Figure 2: Evolution of HHI on banks assets, loans, and deposits



Source: Authors' computation

The most used indicator of competition is the Lerner index (or price-cost margin). The figure below displays the evolution of the average Lerner index in the banking sector in Rwanda. A lower Lerner index implies less market power to price above the marginal cost, hence more competition. The index shows that the competition in the banking sector in Rwanda has been increasing since 2012, although in the last two years (2018 and 2019), that trend has reversed, and the market has become relatively less competitive.

Figure 3: Evolution of Lerner index



Source: Authors' computation

2.2. Microfinance institutions highlights

Microfinance initiatives burgeoned from 2002, primarily as a response to the weak involvement of the traditional banks in small and micro enterprises and rural areas. The microfinance sub-sector, which consists of microfinance institutions with limited liability status as well as saving and credit cooperatives (SACCOs), remains an important component of the financial sector, especially through its role in driving financial inclusion. The presence of microfinance institutions in all administrative sectors (Imirenge) of the country reduces the distance to a formal financial institution, thereby eliminating the access barrier to financial inclusion. According to the financial inclusion survey (AFR, 2020), there is a slight increase in the uptake of Umurenge SACCOs, whereby 2.4 million adults have Umurenge SACCOs accounts for saving or borrowing from 2.0 million in 2016.

Because the microfinance sector largely serves the rural population, more than 70 percent of which is involved in agriculture, the growth of deposits and loans reflects the 'farmers' access to financial services. This has partially solved the structural problem of insufficient financial capital by farmers, as they can now trade their produce, save generated revenues, and borrow from the nearest microfinance institution.

The size of microfinance institutions (MFIs) extended significantly between 2015 and 2019. Total assets of the sector increased by 53.5%, from FRW 208.9 billion to 320,7 billion. Deposits in MFIs from their clients also increased by 45.1% in the period under review to FRW 170.2 million from FRW 117.3 million. MFIs investment in government securities tremendously increased by 1081.4% to FRW 5.5 billion in 2019 from FRW 461.91million in 2015. Deposits of MFIs in commercial banks also increased by 36.5%, amounting to FRW 101. 5 billion from FRW 744 billion.

Table 4: MFIs Performance Indicators

Indicators	Dec-15	Dec-16	Dec-17	Dec-18	Dec-19
Assets (FRW billion)	209	223	244	280	321
Loans (FRW billion)	117	134	138	164	184
Deposits (FRW billion)	117	115	124	144	170
Equity (FRW billion)	65	79	87	98	114
Net profit/Loss (FRW billion)	7	10	2	7	12
Capital Adequacy Ratio (%)	31.1	35.2	35.8	35.1	35.7
NPLs Ratio (%)	7.9	9.0	8.2	6.5	5.7
ROA (%)	3.4	4.4	1.0	2.6	3.8
ROE (%)	11.4	13.7	2.9	7.7	10.7
Liquidity Ratio (%)	89.6	88.8	102.0	100.3	100.4

Source: National Bank of Rwanda, 2019

2.3. Capital market developments

With an ambition to develop a more resilient, reliable, and diversified financial sector, the Government of Rwanda considers the capital market as an alternative source of finance for big investments that will drive the economy on its path to growth and development and a channel for long-term savings and investment. ' 'Rwanda's capital market was established in 2011 under the Capital Market Act of 2011 to lead the development of capital markets.

In 2007, the Rwanda capital market advisory council was established before establishing the Capital Market Authority (henceforth, CMA). The council's mission was to develop the capital market in Rwanda, facilitate the trading of debt and equity securities, enable securities transactions, and perform regulatory functions over the Rwanda Stock Exchange (henceforth, RSE). From then to now, a solid foundation has been put in place through a robust legal and regulatory framework and important milestones.

As of October 2010, ten (10) companies were listed on RSE, and by December 2019, the market capitalization stood at US$ 3.31 billion, representing 41% of Rwanda's Gross Domestic Product. Despite the good performance, RSE is still nascent with limited transactions, which favors the banking sector to remain the primary source of funds for the corporate sector.

The Treasury bond is one instrument widely used to develop the capital market due to the high level of trust in the Government, hence lower risks of investing in T-bonds. The terms on which a government can sell bonds depend on how creditworthy is rated by the market. In Rwanda, bonds are issued on a quarterly basis for maturity periods of 2, 3, 5, 7, 10, 15, and 20 years. In a bid to develop the Rwandan bond market, the Government of Rwanda, in collaboration with NBR, published its quarterly bond issuance program in February 2014. Subsequently, the total outstanding bond significantly increased, with a better diversification of investors.

All T-bonds issuances have been oversubscribed, showing the appetite of economic agents to invest in Government securities and that the bourse presents an immense opportunity to mobilize funds. The capital market in Rwanda is providing saving opportunities to more economic agents. The investor base broadened since 2014 due to the collective effort of public awareness campaigns across the country and within the region.

The increased participation of institutional investors and retailers also contributed to the development of the secondary market of government securities in recent years. The number of deals on the secondary market increased from 99 to 274, and the value of issued bills on that market increased from FRW 1,634 million to FRW 19,874 million between 2016 and 2019.

Table 5: Development in the secondary market of T-bonds

	2016	2017	2018	2019
Number of deals	99	179	187	274
Value of the bonds on primary market(in FRW million)	1,634	5,121	9,740	19,874
Value of the bonds on secondary market(in FRW million)	1,680	5,195	10,034	20,713
Turnovers (in FRW billion)	1.7	5.3	10.0	20.7

Source: National Bank of Rwanda, 2019

3. Literature review

Theoretical and empirical studies on the relationship between financial systems development and macroeconomic stability have been relatively scanty. The theoretical literature outlines various ways for financial development to affect macroeconomic stability.

On the one hand, there is a solid theoretical presumption that financial deepening promotes stability by mitigating economic growth volatility. A well-functioning financial sector provides a closer match between savers and investors and helps absorb exogenous shocks in the real sector. It can also promote diversification, which in turn reduces risk and dampens cyclical fluctuations (Acemoglu & Zilibotti, 1997). In addition, efficient financial markets mitigate information asymmetries and enable economic agents to process information more effectively, resulting in lower growth volatility (Greenwald & Stiglitz, 1991).

On the other hand, it is debated that the recent financial crisis and the following recession were caused by financial innovation and the preceding liberalization of financial sectors. The financial depth and the complexity of the financial system may increase the probability of a financial crisis and thereby increase the risk of sharp fluctuations in macroeconomic activity (Bernanke et al., 1999). Furthermore, larger financial systems may also indicate higher leverage on the part of economic agents, which implies more risk and lower stability. Certainly, there is strong evidence that the excessive size of financial systems in some advanced economies was a causal factor behind the global crisis (Smaghi, 2010).

Moreover, financial frictions and the underlying agency and informational asymmetries can be important in transmitting real sector shocks via the credit channel. Particularly, shocks to the net worth of non-financial borrowers in the presence of credit market imperfections limit the country's ability to reallocate resources, amplifying macroeconomic fluctuations and contributing to their persistence (Bernanke & Gertler, 1990; Kiyotaki & Moore, 1997; Greenwald & Stiglitz, 1991).

Various empirical studies have attempted to examine whether financial depth reduces macroeconomic volatility using a variety of approaches. The results, however, appear to be sensitive to the measures of financial development considered, the sets of controls, aggregation periods, country samples, and the estimation techniques employed. Important to note here that across the literature, the role of financial development in macroeconomic stability is often assessed via its impact on reducing instability or volatility in key macroeconomic variables, notably economic growth or per capita growth.

In most cases, empirical pieces of evidence s that financial development leads to macroeconomic stability in most cases. Using panel data for 110 advanced and developing countries, Dabla-Norris & Srivisal (2013) assessed the effect of financial depth on macroeconomic volatility. They found that financial depth plays an important role in dampening the volatility of output, consumption, and investment growth, but only up to a certain point. They further found robust evidence that deeper financial systems serve as shock absorbers, moderating the negative effects of real external shocks on macroeconomic volatility. However, financial depth amplifies consumption and investment volatility at very high levels, such as those observed in many advanced economies. Fidrmuc & Scharler (2013) investigated how the development of financial systems influences the magnitude of output growth fluctuations in a sample of OECD countries between 1995 and 2005. Their findings indicate that while the development of banking sectors is not significantly related to the magnitude of macroeconomic fluctuations, countries characterized by developed stock markets experience less pronounced fluctuations.

Using panel data from 22 OECD countries from 1970 to 2000, Hahn (2003) found a robust relationship between stock market development and the severity of the macroeconomic cycle and evidence that well-developed financial systems magnify monetary shocks and dampen real ones. Their results also indicate that the stock market size matters when interaction with stock market volatility is controlled for.

Using panel data for 60 developed and developing countries, Easterly et al. (2000) find that deeper financial systems development is associated with lower volatility. Besides, they suggest that this relationship is nonlinear. Their point estimates indicate that output volatility starts rising when credit to the private sector reaches 100 percent of GDP. With a similar methodology but different controls and aggregation periods, Denizer et al. (2000) supported a negative correlation between financial depth and growth, consumption, and investment volatility. Nevertheless, they did not find private sector credit as a fraction of GDP as a significant determinant of macroeconomic volatility.

A study by Ibrahim & Alagidede (2018) on 29 sub-Saharan African countries from the system generalized method of moments (GMM) reveals that rapid and unbridled credit growth comes at a huge cost to economic growth with consequences stemming from the financing of risky and unsustainable investments coupled with excessive consumption fueling inflation. However, the pass-through excess finance-economic growth effect through the investment channel is more substantial. A similar study on sub-Saharan African countries by Mlachilaet al. (2016) suggests that financial development has supported growth and reduced its volatility by facilitating other economic policies to enhance and stabilize the economy. They pointed out that further financial development could yield additional gains for the region and confirm the salutary impact of financial development on reducing the volatility of growth and other macroeconomic variables. Nevertheless, they suggested that countries need to be vigilant about emerging macro-financial risks to effectively manage the risks in financial development.

In summary, looking at results from empirical studies, the consensus on financial development and macroeconomic stability is yet to be reached. The fact that studies (Dabla-Norris & Srivisal, 2013; Ibrahim & Alagidede, 2017; Easterly et al., 2000; Denizer et al., 2000; Fidrmuc & Scharler, 2013) used different methods and different measures of financial development and different sample period can be one of the reasons behind the diverging conclusion. Our study aims at contributing to the assessment of this issue using different methods and a set of variables.

4. Methodology

4.1. Justification

Empirical analysis with macroeconomic variables always faces challenges related to the problem of endogeneity and reverse causality. For this study, in particular, there is a possibility that in Rwanda, as a developing market with rapid economic growth and structural reforms, macroeconomic stability may bolster financial system development, and other unobserved common factors may influence both. The literature suggests different approaches to overcome this issue. One of the most used is the structural VAR (SVAR) framework.

While the SVAR has proven to be a valuable tool, especially in the analysis of dynamics of macroeconomic variables after a shock, some concerns were raised with regard to the reliability of impulse response functions at distant time horizons when the estimated VAR does not necessarily represent the true data generating process (Ramey, 2016), and when the sample period is relatively short.

One of the alternative methods, especially in recent studies on credit cycles, has been the local projection methods pioneered by (Jord[illegible], 2005). The advantages of local projections methods are that they are robust to model misspecifications, especially when their alternative, VAR, may not capture the data generating process well. For the Rwanda case, this study adopts the local projection method for mostly two reasons. First, it addresses the recurrent issue of a short sample period, which may limit degrees of freedom, especially in a multivariate model. Second, our empirical strategy gives us other advantages if the VAR would not fully capture the data generating process and offers the flexibility to identify shocks within the VAR framework and compare impulse response functions from local projection and VAR.

Even though Plagborg-Møller & Wolf (2020) argued that the local projection method and VARs are not conceptually different, and their impulse responses are similar at short-term horizons. They also highlighted that at finite lag lengths, the two approaches could yield different dynamics in impulse response at long horizons. Besides, the local projection method offers the advantage due to its flexibility and possibility of comparison with VAR impulse responses.

Several studies on macro-financial linkages, especially on credit and housing cycles, and their macroeconomic implications, have also used the local projection methods with additional features. (e.g. Mian, Sufi, & Verner, 2017; Jorda, Schularick, & Taylor, 2013).

According to Ramey (2016), the impulse response from Jorda's local projection methods can be estimated from the following regression:

$$Y_{i,t+h} = \theta_{i,h}\varepsilon_{1t} + X + \epsilon_{t+h} \qquad (1)$$

Where $\theta_{i,h}$ is the estimate of the impulse response of Y_i at horizon h to a shockε_{1t}. X is the vector of control variables, which include lags of Y_i and lags of other variables. As in this method, a separate regression for each horizon is estimated; the control variables do not necessarily need to be the same for each regression.

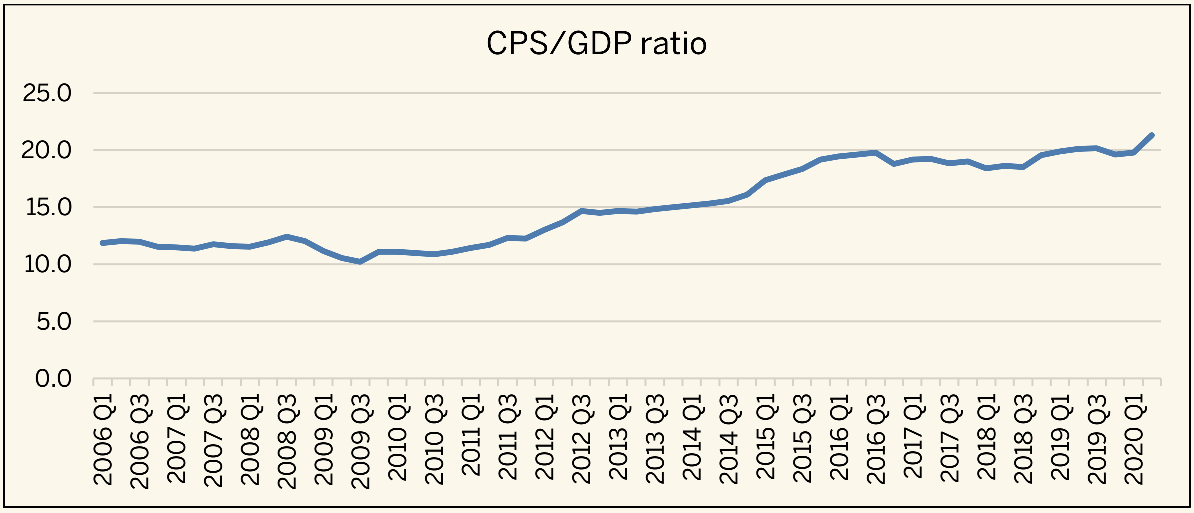
4.2. Data justification and description

This section describes the variables used for the Rwanda case. The main variables of interest are indicators of financial system development and macroeconomic stability. Starting with financial system development, this is a broad concept involving many aspects, including how the financial system channels funds to the economy, mobilizes resources, manages risks, and issues of efficient and inclusive intermediation. Many previous studies have opted for traditional measures of financial system development, such as the ratio of credit to the private sector to GDP, or its alternative, such as the ratio of broad money to GDP, banking sector assets to GDP, stock market to GDP ratio (Dabla-Norris & Srivisal, 2013; Levine et al., 2000). Despite its shortcomings in measuring some of the aspects of financial system development, we opt for the ratio of credit to the private sector from the banking system to GDP, as it is the best proxy available in quarterly observations.

Alternatively, we use the financial development index recently developed by the IMF. This index considers various aspects of financial development, including financial institutions' access, depth, and efficiency, and financial market access, depth, and efficiency. The country index is derived using the principal component analysis. This indicator provides more insights into Rwanda's financial development journey as it considers more aspects of financial system development. It is only available on an annual basis, and the quarterly values are derived using linear interpolation.

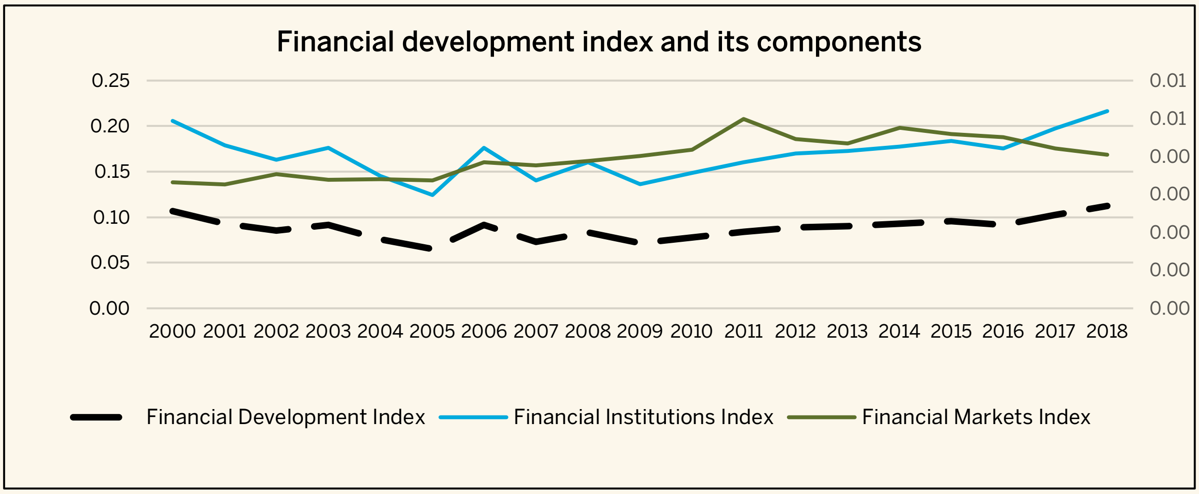
Figures 4 and 5 below depict the two main indicators of financial development, especially improvements made since 2006 in both institutions and markets. The ratio of credit to the private sector to GDP also indicates improvement in financial deepening over time.

Figure 4: Evolution of credit to GDP ratio



Source: Authors' estimation

Figure 5: Financial development index



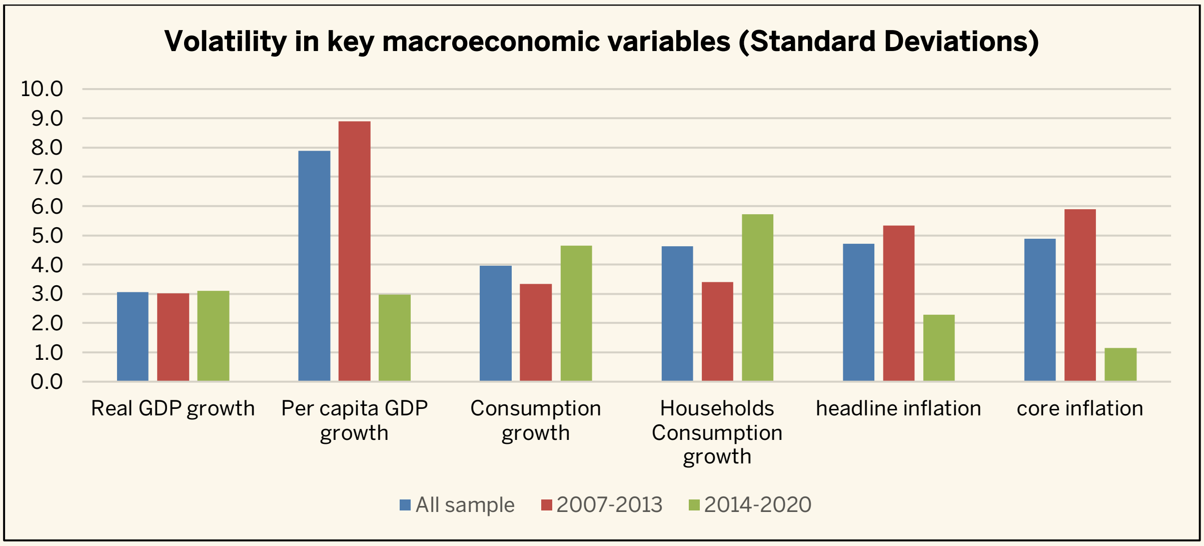
Source: Authors' estimation

Regarding indicators of macroeconomic stability. This study considers the standard deviation in real GDP growth, real GDP per capita growth, and inflation rate, which capture the internal and exchange rates, indicating the external balance. A number of studies reviewed considered only GDP or GDP per capita (Dabra-Norris and Srivisal, 2013). Nevertheless, in Rwanda, inflation and exchange rate are important indicators of macroeconomic stability, especially as they can be subject to acute shocks with implications for the real sector.

An important point to highlight here is the measurement of stability. Most of the studies reviewed have used standard deviations or gaps, which usually measure instability. For instance, Dabra-Norris and Srivisal, 2013 derived the deviation from the trend, especially on real GDP growth and inflation, while other studies (e.g., Denizer et al., 2002, Islam, 2016) considered the standard deviation in the rate of GDP growth, per capita GDP growth and inflation. Nevertheless, for the case of Rwanda, we opted for standard deviation in variables highlighted in the previous section as a proxy for macroeconomic stability.

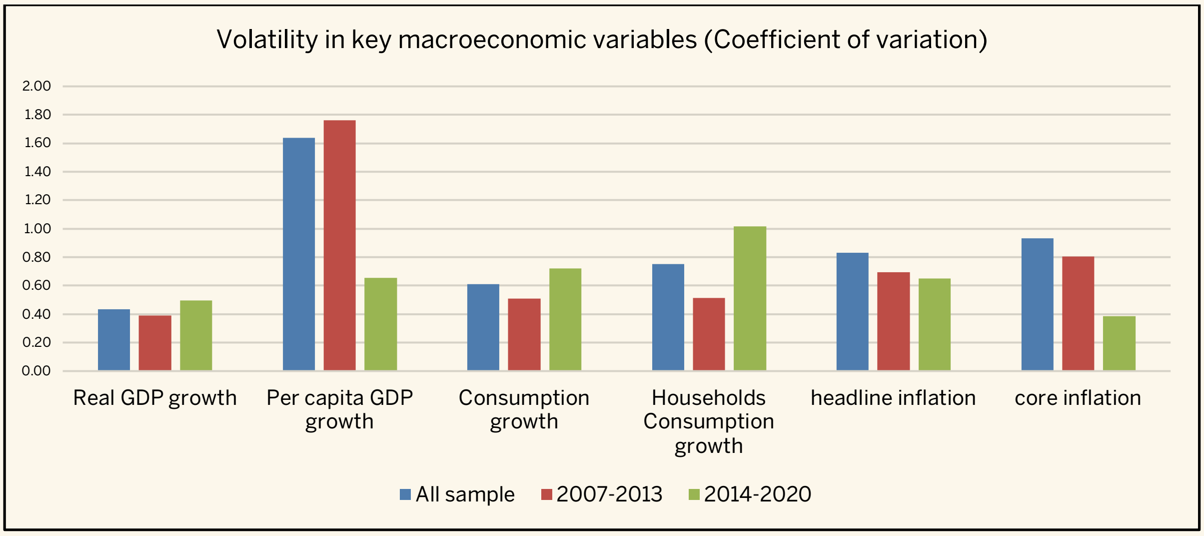
As illustrated in figures 6 and 7 below, volatility in real GDP has not changed much over time, despite sustained good economic performance. This is primarily due to recurrent episodes of adverse shocks in the agriculture sector, notably from weather conditions. On inflation, noticeable improvements are evident in line with the modernization of monetary policy, which contributed to inflation stabilization over time.

Figure 6: Evolution of volatility (standard deviation) in key macroeconomic variables



Source: National Bank of Rwanda, 2019

Figure 7: Evolution of volatility (coefficient of variation) in key macroeconomic variables



Source: National Bank of Rwanda, 2019

Control variables include investment (in levels), inflation rate (in percentage), the real monetary conditions index, and global oil prices. Investment is included in all models estimated as a proxy of capital, which is one of the main factors of production and is in the logarithm. Inflation is the annual percentage change in the monthly consumer price index, averaged per quarterly. It is included as another indicator of business cycles and helped identify the shock to our variable of interest, namely the indicator of financial system development. The real monetary conditions index is included as an indicator of monetary policy stance, which usually can affect macroeconomic stability. It is the weighted average of the real effective exchange rate and real interest rate.

4.3. Identification strategy

Local projections are performed within the VAR framework, and we opted for the recursive method to identify the shock on financial system development. The financial development indicator was ordered last in various models estimated in order to fully exogeneize the shock from other variables included. For the remaining variables, we followed the usual ordering in VAR for a monetary policy where output and inflation are ordered ahead of the monetary policy indicator.

5. Empirical results

5.1. Unit root tests

Table 5 below summarizes results from stationarity tests; for variables integrated of order one, we used their difference to ensure the stability of the systems.

Table 6: Stationarity tests

	ADF test level	ADF test 1st differences	Results
CPI inflation	0.00		I(0)
Log of financial development index	0.35	0.27	I(2)
Log of credit ratio to GDP	0.38	0.00	I(1)
Log of investment	0.00		I(0)
Log of oil prices	0.25	0.00	I(1)
Real monetary condition index	0.01		I(0)
Consumption (std deviation)	0.62	0.00	I(1)
Real GDP growth (std deviation)	0.91	0.00	I(1)
Exchange rate (std deviation)	0.03		I(0)
Inflation (std deviation)	0.87	0.00	I(1)
Investment (std deviation)	0.91	0.00	I(1)
Per capita GDP (std deviation)	0.92		I(1)
GDP gap	0.07		I(0)

Source: Authors' estimation

5.2. Estimation results

As previously explained, we use standard deviation to measure macroeconomic instability; hence the increase would imply more macroeconomic instability while their decline would imply increasing stability. Secondly, we alternatively use two proxies of financial system development, namely the financial development index developed by IMF (for left-hand side charts) and the ratio of credit to the private sector to GDP (for right-hand side charts). The responses from local projections are in green, while the ones of VAR are in blue. The confidence bands are for VAR impulse responses.

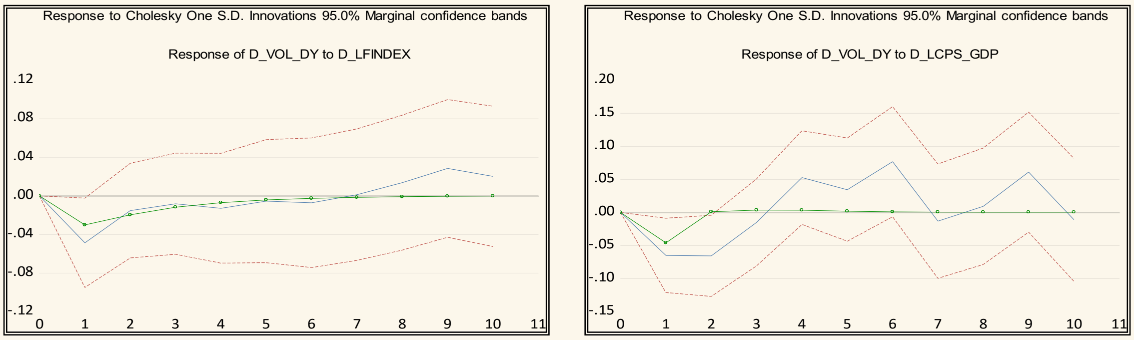
5.2.1. Effect on output stability

As explained in the methodology, we use standard deviation in selected macroeconomic variables as a proxy of macroeconomic stability. However, it is well known that these instead capture variables' volatility. Nevertheless, consistent with other studies, the decline in standard deviation would subsequently indicate an improvement in stability.

Regarding output, evidence suggests that financial development has contributed to dampening the output volatility in Rwanda when we use the financial development index as an indicator. Impulse responses in figure 8 are on the negative side, indicating that financial development leads to lower output growth volatility. However, using the credit to the private sector to GDP, evidence rather suggests that dampening effects are only short-lived and do not last beyond the first quarter.

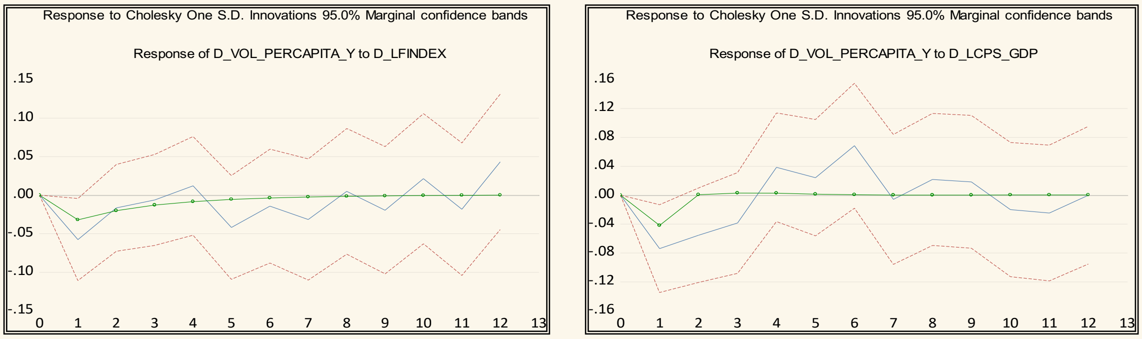
Considering per capita GDP as an alternative indicator of macro stability, the results are almost similar, as shown in figure 9, as financial development is associated with lower volatility in per capita GDP.

Figure 8: Effect on growth volatility (measured by standard deviation)



Source: Authors' estimation

Figure 9: Effect on per capita GDP volatility (measured by standard deviation)



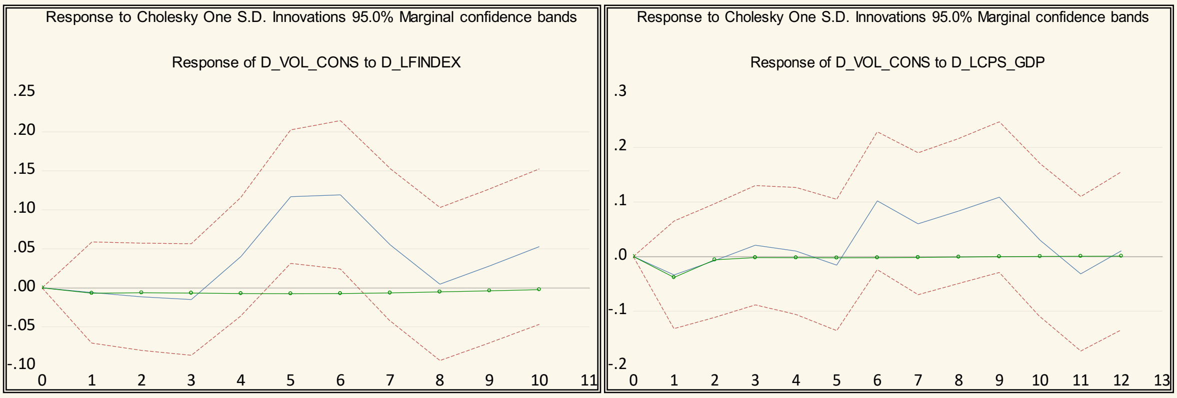
Source: Authors' estimation

5.2.2. Effect on consumption stability

To understand the channels via which financial development influences output stability, we analyze the relationship of the former with consumption and investment as the main component of aggregate demand. Regarding consumption, evidence suggests that the influence of financial development on consumption stability is rather absent, contrary to the view that financial development would usually help to smooth out consumption.

Important to note that this may be due to some imperfections in how consumption is measured in Rwanda's national account compilation. Actually, consumption is measured as residual after subtracting Government expenditures and net exports from the total GDP compiled from the production side.

Figure 10: Effect on consumption growth volatility (measured by standard deviation)

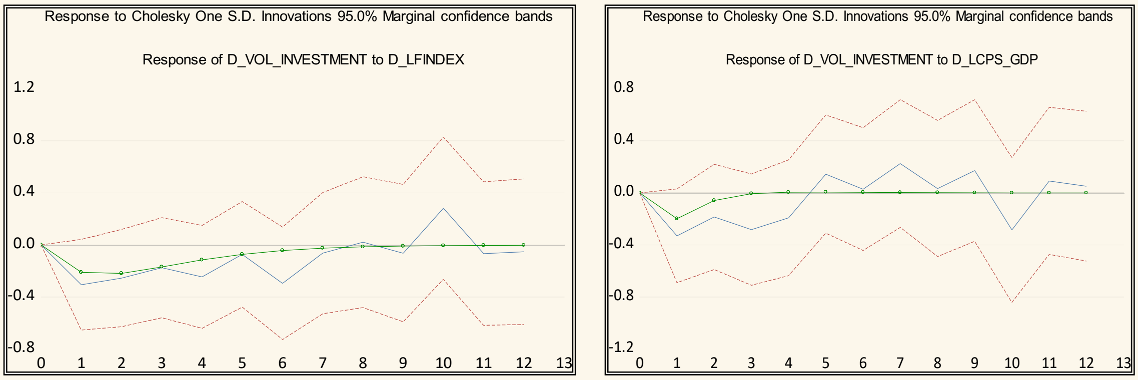


Source: Authors' estimation

5.2.3. Effect on investment growth stability

Regarding investment, the impulse responses in figure 11 suggest that financial development has contributed to stability in investment, which is in line with the literature. The effect is more significant when financial development is proxied by the financial development index. Obviously, investment is the main channel via which financial development has contributed to output stability in Rwanda.

Figure 11: Effect on investment growth volatility (measured by standard deviation)

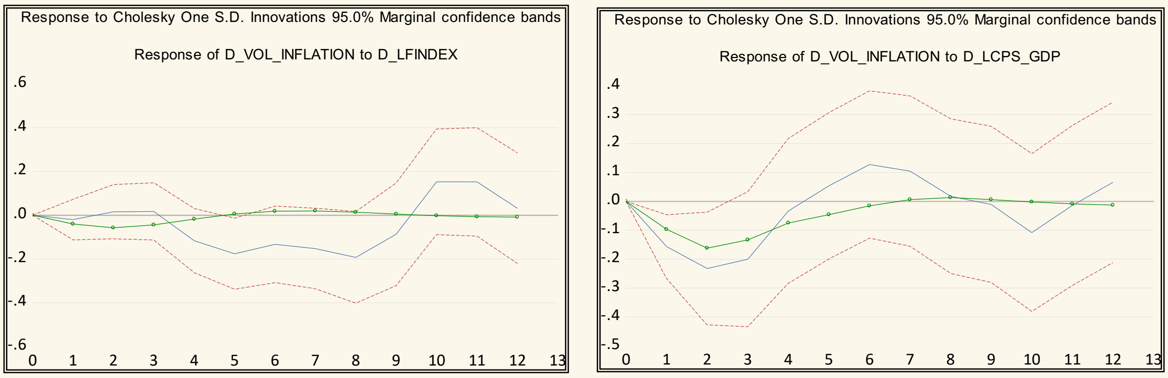


Source: Authors' estimation

5.2.4. Effect on inflation stability

About inflation. Evidence is rather mixed. On one side, using the index, the effect of financial development is quasi absent. Nevertheless, using the credit to GDP ratio, Impulse responses indicate that financial system development has had a stabilizing effect on inflation.

Figure 12: Effect on inflation volatility (measured by standard deviation)

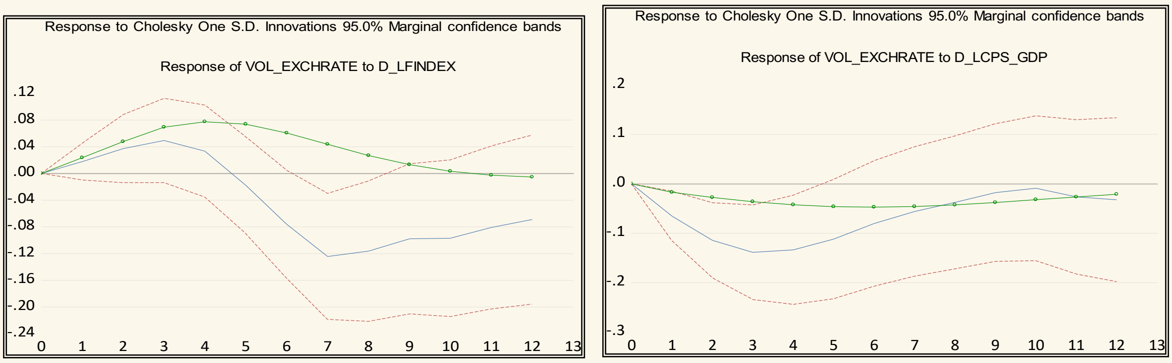


Source: Authors' estimation

5.2.5. Effect on exchange rate stability

We use the standard deviation in the year-on-year percentage change in the FRW exchange rate against the US dollar. Contrary to the case of GDP growth and inflation, evidence suggests that financial system development has led to more exchange rate volatility, notably when financial development is proxied by the index. Nevertheless, when the credit measures financial development to GDP ratio, impulse responses rather depict some stabilizing effect, as shown in figure 13. Thus, similar to inflation, the evidences are also mixed.

Figure 13: Effect on the volatility of exchange rate depreciation (measured by standard deviation)



Source: Authors' estimation

In summary, despite some contradictions due to different measures used to proxy on one side, financial development and on the other side macroeconomic stability, we can conclude that the positive effect of financial development is obvious on macroeconomic stability via its dampening effect on volatility in economic growth, especially via its effect on smoothing out investment volatility. This is noteworthy evidence considering the importance of investment in promoting sustainable economic growth.

The positive effect is not that evident for the remaining macroeconomic variables considered in this study. This may be due to many factors. For instance, both inflation and exchange rate are prone to exogenous shocks such as food supply and foreign inflows shocks. Lastly, as explained in previous sections, the issue with consumption is mostly with its measurement in national account compilation.

6. Conclusion

This study aims to assess the impact of financial system development on macroeconomic stability in Rwanda and identify potential channels through which the effect is propagated. This was motivated by the recent concerns raised by the literature, demonstrating that the expansion in financial services, such as rapid credit growth due to financial sector development, may introduce potential macroeconomic volatility, an issue of profound importance for policy-makers mandated to mitigate the severity of macroeconomic instability. The divergent views on the effect of financial development on macroeconomic stability give enough reasons to investigate this matter for each economy like Rwanda, which enjoys significant positive changes in both aspects.

Our analysis purposefully uses the local projection method with quarterly data. We opt for the ratio of credit to the private sector from the banking system to GDP as the dominant and best proxy available for financial development and alternatively use the recent financial development index developed by the IMF. As generally recognized as indicators for macroeconomic stability, we use the real GDP growth, real GDP per capita growth, and inflation rate, which depict the internal balance, and the exchange rate, which indicates the external balance. The stability of macroeconomic variables was proxied by the standard deviation in those variables listed above.

The results generally indicate that financial development had contributed to stabilizing output in Rwanda using the financial development index as a proxy, but the stabilizing effect is short-lived and mild when the financial development is captured by the ratio of credit to the private sector to GDP.

The same analysis reveals no evidence that financial development has a stabilizing effect on consumption. The results on consumption may result from some imperfections in how consumption is measured as residual in Rwanda's national account compilation. The evidence on investment is somehow encouraging as they indicate a stabilizing effect of financial development on investment in line with the literature. The effect is more significant when financial development is proxied by the financial development index.

Regarding inflation and exchange rate depreciation, evidences are rather mixed. There are some insights of stabilizing effects from financial development on inflation contrary to exchange rate. As previously explained, this may be due to the fact that inflation and exchange rate are prone to exogenous shocks such as food supply and foreign inflows shocks.

In summary, despite some mixed results due to different measures used to proxy financial development and macroeconomic stability, we can conclude that the positive effect of financial development is evident in dampening instability in economic growth, especially via its effect on smoothing out investment volatility in Rwanda. This is noteworthy evidence considering the importance of investment in promoting sustainable economic growth.

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INTERBANK MARKET AND MONETARY POLICY IN RWANDA

Bruno Mwenese[a], Patrick Mugenzi[b], Patrick Hitayezu[c]

[a] *Principal Economist, Research Department, National Bank of Rwanda*

[b] *Economist, Monetary Policy Department, National Bank of Rwanda*

[c] *Director, Research Department, National Bank of Rwanda*

Abstract

The paper explores the influence of the banks' network characteristics on the spread between the interbank market rate and the central bank rate and, therefore, on the monetary policy transmission. The paper models daily spread at the bank level as a function of bank positions in the interbank network and other bank features in a panel setup. The findings suggest that high centrality in the network market seems to back the monetary policy transmission by narrowing the spread. However, some contradiction in the direction of this influence can emerge as the findings also indicate that the relationship-borrowing and diversification of lenders push up the spread and do not support the transmission of monetary policy. To improve the latter, the central bank should support initiatives that create more hub-banks or encourage banks to actively participate in the interbank market and increase the dynamism that supports the transmission.

***Key Words**: Network formation, Interbank market, Monetary policy, Transmission mechanism.*

***JEL Classification Numbers**: E52, L14.*

1. Introduction

The 2008 global financial crisis (GFC) altered market-based interbank liquidity distribution and distressed usual banks' business models, especially in developed economies. At the same time, the GFC that centered on dry-ups in wholesale funding liquidity exposed the importance of the interbank market in the financial system across economies. The Interbank market has then attracted the attention of researchers and policymakers for the last decade, partly to remedy disruptions in market-based liquidity distribution that have impaired the conditions of monetary policy transmission.

Monetary policy transmission refers to the influence of monetary policy actions on real economic activity and inflation. The interbank market is vital in the first stage of the transmission linking the central bank and commercial banks (Maehle, 2020). Since central banks do not directly control the supply of credit to the private sector or its pricing, they use reserve balances to exert some influence. The Commercial banks keep reserves at the central bank that they use in settling payments due to other banks from operations between them or on behalf of their customers. They also transact with the central bank and the government in treasury bills, bonds, and foreign exchange.

During these operations, some commercial banks end up in a shortage of reserves. Indeed, commercial banks face unforeseen or late-in-day demands for payment that require them to look for funds to meet those obligations. Challenged with these liquidity shocks, banks borrow money from peers that end in excess at a given interest rate; this is the essence of the interbank market. Commercial banks can also resort to central bank money in the Standing Lending Facility or the Discount Window. Since the central bank determines the interest rate on these facilities, it provides a basis for pricing on the interbank market. Borrower banks look at it as the cost of funds, and lender banks take it as the opportunity cost of not lending before they both engage in interbank transactions. Therefore, when the central bank changes the interest rate on its funds, commercial banks adjust the pricing or the volume of the interbank market since central bank money is an alternative source of funds. By doing so, the interbank market plays a vital role in the conduct of monetary policy through liquidity management. Then, commercial banks pass this adjustment either into retail rates, which will affect loan demand as posited in the interest rate channel, or pass it into loan supply consistent with the bank lending channel. The literature provides supporting evidence on the role of the interbank market in the transmission of monetary policy. Notable studies include Kashyap and Stein (1997), Freixas and Skeie (2009), Freixas and Jorge (2008) and Bucher& Neyer, (2014).

The outlined traditional views have been completed by recent literature on interbank network structure, on the premise that interconnectedness determines the extent of the adjustment in the interbank market. The network structure represents banks' linkages via their bilateral trades. It brings together essential information such as the number of active banks, the number of bank counterparties of each bank, or the value of each bilateral position, de facto revealing the actual interbank market forces. Network analysis contributes to understanding the transmission by synthesizing this vast amount of information in easily usable indicators, taking into account the peculiarities of each banking system.

The debate on network analysis surged in the aftermath of the GFC, which has exposed how network linkages and interactions between banks are critical to systemic risk and monetary policy transmission. A network structure comprises key elements characteristic of its nature, such as centrality, cohesion, and distance, determining how substantial a monetary policy change will be. For example, banks with high network centrality and low centrality pay different prices for interbank borrowings. Consequently, depending on the volume transacted, the network positions of the banks have a direct impact on the interbank rate spread and the effectiveness of the transmission. Studies have shown that banks with strong local network positions are less affected by monetary policy actions since they can get liquidity from different sources. On the other hand, monetary policy actions can alter the interbank network structure. Empirical research found that by changing the width of the interest rate corridor, central banks can affect the mean network density; that is, the number of trading relationships and transactions among banks (Blasques, Bräuning, & Lelyveld, 2015).

Evidence suggests that banks are keen on building relationships because they help hedge against liquidity needs. Interbank relationships are dynamic and can be short-term or long-term. Analysis of the length of the interbank relationships is vital since where long-term relationships exist, they may lead to what Chiu, and Monnet (2016) call relationship premium. The latter explains why some banks borrow above the interest rate corridor set by the central bank. Lelyveld & in 't Veld (2012) indicate that policymakers should monitor the network structure because it provides insights into the market discipline and relationship lending. It can also inform about the stability of the system and contagion risk.

Most of the research on interbank networks focused on Eurozone economies with developed interbank markets. In recent years, many central banks in developing countries have made several improvements for effective monetary policy to respond to changes that continue to take place in those economies. The recorded progress features notable projects, including setting an appropriate monetary framework, developing market infrastructure, and introducing new market instruments, among others. Some scholars explored these aspects in developing countries (Kireyev, 2015, and Primus, 2016). However, the literature on the interbank network in an underdeveloped interbank market is scanty, specifically examining the influence of the network in the context of the conduct of monetary policy. Few studies that explored the role of network analysis in developing countries include Oduor, et al, (2014), who assess to what extent market segmentation impacts the efficiency of the interbank market and the effectiveness of monetary policy in Kenya. Others include Murinde et al., (2015), who investigate whether the interbank market in Kenya is an effective peer-monitoring and market discipline device.

Since 2017, the interbank network in Rwanda has experienced several changes. The interbank market includes both unsecured and secured transactions among 16 commercial banks and one cooperative bank. The securitizing or not of interbank market transactions is a distinctive aspect characterizing the relationships between banks. The interest rate setting on the interbank market follows a corridor system around the policy rate. The National Bank of Rwanda started the accommodation cycle from the fourth quarter of 2017 to the third quarter of 2020; however, the interbank rate reaction showed some persistence and rigidity close to the upper limit of the corridor. This persistency is another anecdotal evidence of the existence of relationship lending. The latter had shown resistance to the monetary policy actions while it helps to understand some intricacies in interbank trade.

Nonetheless, the volume and the number of interbank transactions overshot recently, and banks that were not active in the market started trading. At the same time, the monetary policy framework changed from monetary targeting to a price-based framework while targeting an optimal level of liquidity during implementation changed to targeting an interest rate corridor. The money market in Rwanda operates in a liquidity surplus setting, but within the past two years, episodes of shortages intensified. These developments indicate likely changes in the interbank network and banks' trading, leading to a different reaction to policy actions.

Against this backdrop, the paper's objective is to examine the effect of the interbank network on monetary policy transmission in Rwanda. It explores the influence of the banks' network characteristics on the spread between the interbank market rate and the central bank rate.

This paper is different from other studies that analyze the interbank market or transmission channels of monetary policy in Rwanda. The existing studies, such as that Mwenese and Kigabo (2016), look at the direct reaction of the interbank rate to the policy rate controlling for some macroeconomic variables. Others include Kamanzi, et al, 2019), who examine the role of bank-specific characteristics in transmitting monetary policy impulses. The main contribution of this paper is to provide new insights from within the interbank structure that impact the quality of the monetary policy transmission in Rwanda. The study also contributes to the literature on monetary policy transmission mechanisms by bringing into the debate the perspective of an underdeveloped interbank market. It explains how network analysis can help understand areas that need much focus to improve monetary policy transmission in developing economies.

2. Literature

2.1 Theoretical literature on interbank network formation

The most commonly used interbank network models are the Erdos-Renyi and scale-free networks. Erdős Renyi (1959) the network consists of a given number of nodes, and each link between nodes forms independently with a given probability P. It is a binomial model of link formation with short average paths and low clustering that assumes low heterogeneity; that is, most nodes have the same number of connections. The other commonly used network model is the scale-free network (Barabasi & Albert, 1999). They model the algorithm for generating a random scale-free network using a preferential attachment mechanism. Analysis observes a scale-free network in natural and human-made systems. The degree distribution resulting from the Barabasi-Albert model is a power-law distribution.

The scale-free graph has a few but significant nodes with many connections and a trailing tail of nodes with very few links at each level of magnification. A scale-free network is instrumental in modeling financial hubs in the interbank system.

In the past two decades, the theory of network formation has been an active area of research. One strand of literature on network formation considers only linkages and disregards other features of the nodes that make up the network. As a result, this literature models network formation as a random process, using methods from statistical mechanics (Newman, Barabási, & Watts, 2006). Another branch of study on network formation focuses on incentives that push for building relationships. In the model developed by Goyal and Vega-Redondo (2007), individuals form links based on a trade-off between the benefits and the costs involved in creating connections. The idea is that linking with another player gives access to the links of the latter. Some earlier works assumed that the benefits all these players enjoy from the connections are non-rival. By contrast, Goyal and Vega-Redondo (2007), study a setting where the benefits are rival. A critical issue is how different players share the benefits in such a context.

The early network theory assumes random link formation that results in homogenous nodes. In contemporary work, a scale-free model predominantly emerging from real-world networks postulates heterogeneous nodes. The latter describes the shape of the interbank network given that banks have different liquidity positions daily where banks with liquidity deficits borrow from those in surplus. One limitation of the aforementioned statistical models is that they do not provide an account of link formation; that is, they do not model the dynamic process by which financial institutions enter into obligations to one another in the first place. This challenge has been taken up recently in the financial networks literature.

This section concentrates on the interbank network literature and identifies three main ways to model network formation. One strand of the literature builds on random link formation, for example, using network growth models. Typically, these are random network models where new nodes are born over time and form attachments to existing nodes when they are born. The literature on financial networks identifies an empty network and mechanically connects nodes. One option is to generate links according to a stochastic process (Anand, Gai, Kapadia, Brennan, & Willison, 2013). Another option is to condition random link formation on the characteristics of the nodes, making it more likely to create links with banks that have higher profits (Lenzu & Tedeschi, 2012) or a higher willingness to extend an interbank loan (Lux, 2015). This process of network formation is called preferential attachment. Trust is a critical element in this regard. Banks trust other banks based on their performance or their reliability in lending. Another feature of preferential attachment is that it provides a mechanism to generate scale-free distributions Barabasi and Albert (1999), another feature of the interbank network.

A second area uses strategic network formation, where banks assess the costs and benefits of forming a link with another bank. A prominent theme in strategic network formation is rollover decisions by banks, often modeled using global games techniques. Creditors strategically decide to roll over a loan after receiving a signal about the solvency or performance of the borrower (Allen and Carletti, 2012; Fique and Page 2013; Anand, et al, 2013). Also, using strategic network formation Farboodi (2014) and In 't Veld and Lelyveld (2014) analyze how bank heterogeneity leads to the formation of a core-periphery network. Further, Acemoglu, and Tahbaz-Salehi (2015) show how banks may over connect and diversify in equilibrium, potentially creating excessively prone networks to contagious defaults.

The third area builds network formation based on portfolio optimization by financial institutions. In this line, two approaches stand out. The first is where banks choose the amount of interbank lending or borrowing by optimizing their (heterogeneous) balance sheets (Aldasoro and Alves, 2015; Bluhm and Krahnen, 2014). This optimal amount then gets allocated among the banks. A second option is to fix the overall amount of borrowing and lending (Bräuning and Fech, 2012; Halaj and Kok, 2015). Banks then have the choice of their counterparty.

2.2 Role of the interbank market in monetary policy transmission

The interbank market is among the critical money markets and constitutes the cornerstone of the central banks' implementation of monetary policy. The interbank markets emerge from heterogeneity in banks' liquidity position, which arises when banks engage in their usual lending and deposit activities, where some banks fall short of funds and resort to the peer banks that end up in surplus (Allen & Babus, 2009).

Banks may also solicit central bank money. In this case, banks can adjust their interbank lending in terms of price or loan supply when the central bank changes monetary policy (Kashyap & Stein, 1997). In this adjustment process, the interbank market becomes a conduit of monetary policy to the real economy. Allen and Babus (2009) Posit that in normal times the interbank market should work well without asymmetric information, a view put forward by (Chiu, Eisenschmidt, & Monnet, 2016) that theoretically, the interbank market rate should stay within the corridor band defined for monetary policy implementation.

Freixas and Jorge (2008), Freixas and Skeie, (2009) and Bucher & Neyer (2014) complete this view by allowing the imperfections of the interbank market in their analysis. They establish that under asymmetric information, the interbank market is unable to intermediate liquidity effectively. Concerning monetary transmission mechanism, when liquidity shortage characterized by the positive spread between interbank market rate and policy rate prevails, asymmetric information renders the effect of monetary policy stronger.

2.3 Interplay between interbank network and monetary policy

The literature asserts that network analysis describes well the functioning of the interbank market. This literature includes Kobayashi and Takaguchi, (2018); Chiu and Monnet (2016), Gabrieli and Georg (2016), Blasques and Lelyveld, (2015), and Afonso and Schoar, (2014). They argue that network arises endogenously from the fact that banks tend to build relationships with peers to reduce information asymmetry for the lender bank or hedge against liquidity shortage for the borrower bank. This reasoning is consistent with arguments in earlier literature such as (Ehrmann & Worms, 2002). They posit that the distribution of liquidity among banks moves in a network style. However, they suggested that networks are mechanisms that can counteract monetary policy transmission, especially in monetary tightening situations, since banks can react by redistributing liquidity among them.

The analysis of network characteristics revealed essential points on the interbank market vis a vis monetary policy. For example, Chiu& Monnet (2016) showed how a network structure disappears in an accommodative policy stance in which banks lose incentives to build relationships. In the same line, implementing new central bank instruments can alter the network structure. Barucca and Lillo (2015) found that net borrowing banks became net lending banks while the latter became inactive following the introduction of long-term refinancing operations in the Eurozone. It is important to note that this effect depends on the banking sector structure, as argued by (M.Ehrmann & Worms, 2001).

On the other hand, however, the bank's position in the network has been proven necessary in responding to monetary policy. In the network literature, several features describe a bank's position in a network. The degree distribution is one key measure of the centrality of a bank that captures the bank's borrowing diversification. Empirical evidence showed that banks recording a high degree are less sensitive to policy rate variation. On the contrary, Ardekani and Tarazi (2019) found that considering the authority centrality, which measures a bank’s lender strength based on outgoing links, stronger banks have a more pronounced reaction to monetary policy.

2.4 Countries’ experiences

Most studies on the linkages between network structure and monetary policy explored developed interbank markets in advanced economies. Some key findings are noteworthy. Network characteristics explain changes in interest rates and their impact on policy transmission. It is the case for the US federal funds market as ascertained by (Bech & Atalay, 2008), (Akram & Christophersen, 2010) for the Norwegian interbank market, or (Gabrieli & Georg, 2016) for the case of the Eurozone. The research established an essential element about computing the network measure, claiming that daily networks are relevant.

The evidence in these economies shows that the interbank structure evolves with time, and its effects vary accordingly. The case studies refer to the 2007/8 GFC and relate the pre-crisis time, the crisis, and the post-crisis times. Some examples include (Br[illegible]uning & Fech, 2012) for the German interbank market and Kobayashi and

Takaguchi(2018), who explored the Italian interbank market. (Bräuning & Fech, 2012) bring out the importance of capturing the composition of the banks, pointing out the role that cooperative banks play in the German bank network. Oduor et. al, (2014) provide another supporting evidence on the effect of bank composition by giving the experience from an underdeveloped interbank market. They indicate that banks trade primarily with peers in Kenya and not small banks with large banks. This segmentation impedes monetary policy transmission in the short run.

In summary, this literature outlines the fundamental reasons for banks to form interbank networks. It is either a random process or a strategic move by banks. In the latter case, banks can optimize the income from interbank transactions or choose the counterparties with a fixed amount intermediated on the interbank market. One inference from the literature is that interbank network formation is a dynamic process arising from the heterogeneous liquidity positions of banks. Another key takeaway is that the network analysis describes well the functioning of the interbank market and its role in transmitting monetary impulses. Some differences stem from economies' development levels and the composition of the banking sector.

3. Methodology

In this paper, we follow the approach of Akram and Christophersen (2010), Bech and Atalay (2008), and Gabrieli (2011) in estimating the spread between interbank and central bank rates. We model the spread between the interbank market rate and the central bank rate at the bank level as a function of the bank's positions in the interbank network and other bank characteristics such as size (Bank's total assets). We investigate whether banks considered systemically important can borrow at lower rates than banks deemed comparatively small.

Furthermore, we assess and compare the interbank rate of borrowers with credit relationships in the period before and after adopting a price-based framework in January 2019. Following the adoption of this framework, the number of interbank transactions doubled in 2019 compared to the previous year, evidencing structural changes in the development of network structure, particularly the level of interconnectedness. As a result, it is necessary to explore these two periods separately to capture the aforementioned changes in the network. Trust comes out as a standing pillar in the formation of interbank relations (Lenzu & Tedeschi, 2012); thus, we wish to explore if there is a significant influence of relationship in the network formation of the Rwandan interbank market.

3.1 The model and variables of interest

The study uses an econometric model estimated using panel data of interest rates paid by borrowing banks in the sample period. Particularly, we estimate a random effect model with 16 different commercial banks and consider them as lenders or borrowers depending on specific transactions. The dataset displays an unbalanced panel as every bank does not participate in the market every day.

Bank characteristics in the interbank network are the main determinants of borrowing rates. The connections of banks in the system network explain the interbank market and more often take the form of an adjacent matrix, a square matrix of dimensions NxM with n as the number of nodes (banks in the network) and M_{ij} as edges(links or connections) or amount bank i lends to bank j. A bank cannot arrange an interbank transaction with itself; thus, $M_{ij} = 0\ if\ i = j$. Therefore, the connectivity matrix of n=3 can be simplified into:

$$\begin{pmatrix} 0 & M_{12} & M_{13} \\ M_{21} & 0 & M_{23} \\ M_{31} & M_{32} & 0 \end{pmatrix}$$

This network is characterized by incoming connections (borrowing) and outgoing connections (lending), and the common terms in the network analysis are in–degree and out-degree, respectively. This study hypothesizes that as banks diversify more their lenders, the more they get reduced rates. The econometric model considers in-degree k_i^{in} (number of banks that lends to bank i), measured daily for each transaction that happened for a given bank

$$k_i^{in} = \sum_{j=1}^{n} A_{ji}$$

To better capture the significance of any interbank connection relative to others in the network, we normalize the matrix by taking M_{ij} divided by the total amount borrowed in the given quarter. Therefore, this becomes a weighted network. Our interbank network considers 11 quarters starting from 2017Q4 to 2020Q2. In this network, we are more interested in two significant statistics for our research: betweenness centrality and authority, and these serve as measures of centrality and systemic importance.

Betweenness centrality, a concept borrowed from sociology, is the probability that a node (bank in our model) lies on the shortest path between any two unconnected nodes Freeman (1979) or the number of these shortest paths that go through the node. This measure takes into account the borrowing and lending activity of each of the banks and its counterparties. The authority variable also portrays the bank's position or centrality in the interbank. This variable measures the importance of each bank's total number of interbank lenders (incoming links) relative to the other banks in the network and considers its lenders' strength based on their outgoing links. Therefore, banks with solid authority connect to strong Hubs (dominant lenders) in the network (Ardekani, Distinguin, & Tarazi, 2019). Authority is calculated based on the HITS algorithm (Kleinberg, 1999). Both betweenness centrality and authority statistics have been calculated quarterly from 2007Q1 to 2020Q2 using Gephi software developed by (Bastian, Heymann, & Jacomy, 2009).

Moreover, the study includes a relationship variable to capture the possible effects of banks' credit relationships on the interbank market. We measure relationship as the share of funds obtained from a bank's two primary lenders in the sample period (Akram & Christophersen, 2010). After identifying two primary lenders of a given bank, we create a dummy variable of relationship that equals one if a transaction is a trade with any of those two primary lenders and 0 otherwise.

The position of a bank in borrowing activities at the market also matters in influencing the interbank rate; we assume that large banks borrow relatively high amounts than small banks. As a result, we control for the bank's borrowing share in the total daily borrowing. The previous studies found that larger banks borrow at a lower cost than small banks (Furfine, 2001; Cocco, Gomes, & Martins, 2009; Akram & Christophersen, 2010).

The study also considers other bank characteristics, such as the effect of the bank's total assets on the interest rate spread, assuming that larger banks (systemically important banks) borrow at lower rates and small banks relatively trade at higher rates.

Finally, the study adds another control dummy variable size that takes 0 if a bank has a microfinance background and one otherwise.

Therefore, the study estimates the following model in panel random effects setup:

$$spread_{it} = \alpha_i + \beta_1 in\_degree_{i,t} + \beta_2 betweenness_{i,t} + \beta_3 authority_{i,t} + \beta_4 relationship_{i,t} + \beta_5 dayshare_{i,t} + \beta_6 l\_size_t + \beta_7 dum\_size_i + \varepsilon_t$$

$Day - share$ stands for the bank’s share in the total daily borrowing.

size represents the importance of the bank, computed as the log of the bank's total assets.

dum_size is the dummy variable that equals zero for having a microfinance background and one otherwise.

Empirical evidence asserts that microfinance banks are more inclined to build a relationship than other commercial banks in a bid to have a liquidity hub. Other categories such as saving banks and cooperative banks, rarely intervene in the interbank market since they can get liquidity from their union or head institutions (Affinito & Pozzolo, 2017). This dummy variable allows us to consider these aspects in the model.

4. Results

4.1 Descriptive statistics

The degree statistic shows that from 2017 to 2020, a bank borrowed from 1.4 banks on average, where a bank with the highest counterparties totals 5. Around 72 percent of transactions banks borrow from one bank. Few banks borrow from many counterparties.

Table 1: Summary statistics 1

	(1)	(2)	(3)	(4)	(5)
VARIABLES	N	mean	sd	min	max
degree	1,071	1.385	0.701	1	5
betweenness	1,072	5.798	9.347	0	33.57
day-share	2,354	0.221	0.319	0	1
rel	1,071	0.508	0.500	0	1
spread	1,071	0.289	0.339	-2.500	1.017

Source: Authors' Estimation

The betweenness centrality reveals that around 55 percent of the interbank borrowing transactions are small and do not influence the system's flow, while just one percent of borrowing from 2 banks can influence the flow. This is related to the fact that 2 banks that cover around 30 percent of the borrowing transactions are generally small and are not the bridges of the interbank system. The bank with the lowest betweenness is the same bank with the highest degree. That is, the bank that has the most diversified lenders does not influence the market. Regarding authority centrality, banks connected to strong hubs in the network, meaning that they transact with dominant lenders, represent less than 20 percent of the transactions.

Table 2: Summary statistics

	(1)	(2)	(3)	(4)	(5)	(6)
	degree 1	degree 2	degree 3	degree 4	degree 5	degree.
	Freq	Freq	Freq	Freq	Freq	Freq
rel	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)
0	356***	126**	32	12	1	
	(46.35)	(57.53)	(52.46)	(57.14)	(50)	
1	412***	93**	29	9	1	
	(53.65)	(42.47)	(47.54)	(42.86)	(50)	
Total	768	219	61	21	2	0

Source: Authors' computations

Around 51 percent of the borrowing transactions go through the same lenders, indicating a strong relationship with lending in the Rwandan interbank market. About 8 percent of the time, the interbank market recorded one transaction.

4.2 Regression analysis

To decide the fitting model, the Hausman test and the Breusch-Pagan Lagrangian multiplier test assert that the random-effects model is appropriate, and there are significant differences across banks (Table 4 & 5).

Table 3: Hausman test results

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
      degree |    .0481569     .0478147        .0003422        .0007082
 betweenness |   -.003623     -.0036708        .0000478        .0001858
   authority |    .1074356     .1237637       -.0163281        .0152498
         rel |    .0839159      .084517       -.0006012        .0009153
    dayshare |   -.2836281    -.2841008        .0004727        .0018555
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        2.64
                Prob>chi2 =      0.7548
```

Table 4: LM test results

```
spread[bank_id,t] = Xb + u[bank_id] + e[bank_id,t]

Estimated results:
                   |       Var     sd = sqrt(Var)
          ---------+-----------------------------
            spread |   .1145887       .3385095
                 e |   .0830325       .2881536
                 u |   .0214682       .1465204

Test:   Var(u) = 0
                          chibar2(01) =   398.19
                       Prob > chibar2 =   0.0000
```

Source: Authors' computations

Table 6 presents the results of the model. Columns 1 and 2 solely look at the network features, and the results assert that degree and relationship have a positive and significant effect on the spread while betweenness centrality has a negative effect. The authority variable is not significant. A bank with a high degree position, meaning that it can get interbank loans from a different bank, increases the spread, which means it borrows at higher rates. These results contrast with other findings in the literature, such as those (Ardekani, Distinguin, & Tarazi, 2019).

On the contrary, the betweenness centrality shows that banks that constitute the bridges among banks in a network borrow at lower rates. This result is in line with Brüning and Fech (2012) findings that the more the bank moves towards the center, the more it gets better rates, as other banks assume that they can get liquidity quickly.

Similarly, in column 2, our findings indicate that a bank that tends to build a relationship with its peers by regularly borrowing from the same lender cannot negotiate a lower rate and increase the spread. This contradicts the findings of Temizsoy & Montes-Rojas (2015) that relationship lending delivers better rates for both traders.

The findings reported in column 3 of table (6) indicate that banks that borrow higher amounts on the interbank market are likely to negotiate for a reduction in rates. Column 4 presents parameter estimates of the model, including bank-specific characteristic variables as bank size and a dummy variable representing if the bank comes from a microfinance background or not. The coefficients are significant but respectively positive and negative. The findings suggest that when a bank grows in assets, it borrows at increasing rates on the interbank market; however, this situation reverses when the bank is in the category of commercial banks, contrary to former microfinance banks.

Table 5: Regression results

	(1) Spread	(2) Spread	(3) spread	(4) spread
degree	0.0232	0.0271*	0.0476***	0.0427**
	(1.69)	(1.98)	(3.57)	(3.23)
betweenness	-0.00401**	-0.00414**	-0.00383**	-0.00267*
	(-3.01)	(-3.14)	(-3.02)	(-2.16)
authority	0.0576	0.0582	0.123	-0.0760
	(0.66)	(0.67)	(1.49)	(-0.92)
rel		0.0936***	0.0852***	0.0814***
		(4.99)	(4.72)	(4.53)
day-share			-0.285***	-0.234***
			(-9.39)	(-7.87)
l_size				0.282***
				(7.78)
size_3				-0.592***
				(-5.45)
_cons	0.207***	0.155**	0.241***	-4.607***
	(3.64)	(2.65)	(4.72)	(-7.25)
N	1071	1071	1071	940

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: Authors' computations

The network features change as the network evolves based on the interbank transactions; the study examines whether the effect of the network on the spread changes over time. The analysis refers to February 2019, the first monetary policy committee date in the price-based framework. There is a significant difference in the estimated coefficients in the period before and after the new framework. In the pre-period, the authority is the sole network feature that is significant and negative, suggesting that building a strong hub of counterparts helps banks to negotiate a reduction in the borrowing rates (see table 7). However, the coefficient of the relationship variable is significant and positive, indicating that borrowing from the same bank puts a bank in a weak negotiating position and borrows at increased rates. In the post-period, all the variables are significant except the network variable degree. Other network variables are significant and negative, indicating that the changes in the network structure narrow the spread in this period. The coefficient of the relationship variable remains the same in both periods. Another noteworthy difference is that larger borrower banks pay lower rates in the post-period while this variable was insignificant in the pre-period.

Table 6: Regression results

	(1)	(2)
	Spread	Spread
degree	0.0204	0.0195
	(0.84)	(1.50)
betweenness	0.00146	-0.00580***
	(0.71)	(-4.90)
authority	-0.319**	-0.244*
	(-2.62)	(-2.50)
rel	0.0647*	0.0464**
	(2.13)	(2.59)
day-share	-0.0680	-0.117***
	(-1.49)	(-3.35)
l_size	0.0987	0.182***
	(1.25)	(5.92)
size_3	-0.239	-0.311***
	(-1.16)	(-5.44)
_cons	-1.629	-2.712***
	(-1.20)	(-5.14)
N	351	591

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

4.3 Discussion

The results show a significant influence of the network structure on the spread between the interbank and central bank rates and, therefore, on monetary policy transmission. For the whole sample, the results show some contradiction in the direction of this influence. Diversification of lenders is still low and seems not to support the transmission as more diversified banks push up the spread. However, more pivotal banks in the market seem to back the monetary policy transmission by narrowing the spread. Relationship borrowing is present in the Rwandan interbank market and takes a substantial weight in transactions. Banks seem to prefer this mechanism though the latter widens the spread. It is important to note that both relationship and diversification affect the spread upwardly. The latter likely stems from the fact that small banks initiate both actions; while they do not have enough power to negotiate a reduction in rates.

As the network structure evolves, changes in the effect of the network appear in the way that facilitates the transmission of the monetary policy. In the period after adopting the price-based framework, the dynamism in the network resulted in banks surrounding themselves with strong hubs and improving their interbank businesses at both ends of the network. One can deduct this from the changes in the coefficients of betweenness and authority variables. At the same time, the degree coefficient representing diversification becomes insignificant while that of the relationship eases though it remains significant. Another critical point to note is that as a bank borrows more considerable amount on the interbank market, it gains some power to negotiate for a better rate. Nevertheless, this is not always the case looking at the period before the new framework. The coefficient of the variable of interest (bday-share) is not significant. It may imply that the increase of the amount intermediated on the interbank market does not always support monetary policy transmission. These findings align with the literature, especially Chiu & Monnet (2016) and Barucca & Lillo (2015) , who demonstrate that network structure can disappear or banks change positions constantly where a borrower bank becomes a lender and vice versa.

5. Conclusion and recommendation

The objective of the paper is to study the effect of the interbank network on monetary policy transmission in Rwanda. It explores the influence of the banks' network characteristics on the spread between the interbank market rate and the central bank rate. The motivation stems from the evidence that interbank network structure and relationship lending determine how much monetary policy change affects the economy. At the same time, the Rwandan interbank market continues to record the progress that alters its structure and, therefore, the monetary policy transmission. The empirical literature demonstrates that the position of a bank in the network, expressed in terms of degree and centrality measures, has been proven essential in responding to monetary policy. The study applies a random-effects model to a panel of 12 banks active in the interbank market.

The main finding is that the network structure influences the spread between the interbank and central bank rates and, therefore, monetary policy transmission. Specifically, the finding is that building relationship borrowing and diversification of lenders do not support the transmission of monetary policy. On the contrary, the dynamism in the interbank structure leads to active business at both ends of the network back the transmission. These findings have some policy implications. The central bank should support initiatives that create more hub- banks or encourage banks to actively participate in the interbank market and increase the dynamism that supports the transmission.

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MONETARY POLICY, CREDIT GROWTH, AND ECONOMIC ACTIVITY IN RWANDA

Augustin Ndarihoranye[a], Delphine Uwimpundu[a], Placide A. Kwizera[b]

[a] *Senior Economist, Monetary Policy Department, National Bank of Rwanda*

[b] *Economist, Research Department, National Bank of Rwanda*

Abstract

The successful conduct of monetary policy requires a thorough assessment of how changes in policy actions are propagated to the real economy. We employ the Vector Autoregression (VAR) type of models to examine the effect of monetary policy on goal variables, namely, credit, output, and inflation in Rwanda. The empirical findings from standard VAR models show that the effect of the interbank rate on goal variables is consistent with theoretical propositions and empirical applications. A positive shock to the interbank rate causes inflation to fall by about five percentage points over eight quarters, and credit to fall by about four percentage points in the first four quarters. Consequently, economic growth falls by about one percentage point. The Vector Error Correction (VEC) model shows that the previous quarter's deviation from long-run equilibrium is corrected for in the current quarter at an adjustment speed of 0.1%. These findings remain robust when we apply a Structural Vector Autogressive (SVAR) model, and these models capture the essential macroeconomic relations between a monetary policy indicator and goal variables, following the recent improvement in financial markets.

***Key Words**: Interest rate pass-through, Monetary Policy, VAR Model, Impulse response.*

***JEL Classification Numbers**: C32, E51, E52, E58, E60.*

1. Introduction

The main mandate of monetary policy is to ensure price stability and the soundness of the financial system, and its ability to influence credit and the real economy remains the central concern for both monetary policymakers and academics (Bernanke et al., 1988). The conventional wisdom in monetary economics considers credit as a very important engine of a transmission channel of monetary policy in modern economies from small-scale credit to big credit that allows a firm to invest (Bernanke et al., 1988). However, credit may have an inflationary impact on the economy, which might hamper the attainment of the Central Banks' main objective of price stability (Saiki and Frost, 2014).

The voluminous literature on the relationship between monetary policy and credit (Berkelmans, 2005; Bernanke et al., 1988) highlights theoretical assumptions and empirical findings such as those of Aiyar et al. (2016), Bowman et al. (2015), Giannone et al. (2012) , Kuttner (2018) that expansionary monetary policy leads to an increase in credit supply or a monetary policy tightening lowers credit.

The bulk of the literature and the mass of empirical findings have focused on the traditional interest rate channel of the monetary policy, and the majority of these studies cover the most advanced economies with well-functioning financial systems (Mishra et al., 2010). Even though the empirical studies established that changes in monetary policy decisions are eventually followed by changes in the real economy, they are largely silent about what happens in between, and thus the studies on the effects of monetary policy have treated the monetary policy transmission mechanism itself as a" black box."

For developing economies, the channels of monetary policy are impeded by financial underdevelopment and weak institutions (Beck and Levine, 2002). This is in line with views indicating that the interbank markets are still underdeveloped, and, even though some central banks use policy rates, changes to these policy rates have only limited effect on other interest rates and on the economy more generally (Fischer, 2015). These findings emphasize the role of financial development in shaping the impact of monetary policy on the economy, supporting the source of finance as a crucial input to capital accumulation, economic growth and price stabilization (Beck et al., 2009).

The empirical fronts, particularly in the specific case of Rwanda, like studies of Kigabo and Kamanzi (2018), have provided optimistic evidence about the performance of the monetary policy transmission mechanism, but the interest rate pass-through generally is not very active in Rwanda, and the lending rate remains very weak, which limits the impact of monetary policy actions on the cost of bank loans. Generally, the empirical findings for the case of Rwanda, as given by Irankunda (2014) and Dempere (2022), show that the changes in the interest rate do not significantly affect the banks' lending behavior. These findings are consistent with those for other developing economies which cite the underdevelopment of the financial sector and the presence of weak institutions as the key impediments to the efficient monetary policy transmission mechanism (Beck et al., 2009).

The limited number of studies that have investigated Rwanda's monetary policy transmission mechanism typically found evidence of a relatively weak transmission process, and the extended analysis of monetary policy, credit growth, and economic activity has not been subjected to profound analysis, and very few studies rely upon the classic VAR models with mixed findings. Furthermore, since the shift of the National Bank of Rwanda to the Price Based Monetary Policy framework, there is a greater need for critical analysis to uncover clarity on the potential effects of policy decisions on the real economy, including specific information on magnitudes, time lags, and the relevant monetary policy transmission channel.

Unlike several other studies in this area, this study seeks to conduct a deeper analysis of the effect of monetary policy on target variables, notably credit, output, and inflation in Rwanda. A prime result of our paper is that the transmission of a positive interest rate shock to credit conditions and to the real economy depends on financial sector development.

The paper adds to the body of empirical works by providing a critical review of the existing stock of knowledge by identifying the important gaps and providing explicit analysis that might be useful for the National Bank of Rwanda to contribute to the current policy in central banking. First, it adds to the scarce literature that examines the effect of monetary policy on credit, output, and inflation in Rwanda.

Secondly, we believe that monetary policy cannot be a static and stable function in time. This implies that the conduct of monetary policy cannot be the repetition of strategies deemed useful in the past. The present investigation becomes essential to accommodate for the effect of structural changes, such as technological, institutional, or policy-related changes, specifically following the recent move from quantity-based to price-based monetary policy.

Lastly, from an econometric perspective, the standard VAR applied by Kigabo (2018) in the specific case of Rwanda is not exhaustive; even though the VAR model has good properties when applied to covariance-stationary time series, most of the economic variables exhibit unit roots and such non-stationary variables may create the so-called problem of spurious relationships. To avoid this problem, the VEC model is used to specify both short-run and long-run relationships among variables of interest. We also check whether the pre-observed relationships are imprecise in the so-called ''price puzzle'' that is commonly observed in the current body of literature that is not previously investigated, especially in the case of Rwanda. As a robustness check, we depart from the previously specified models, given that they arbitrarily select lags but do not tolerate contemporaneous relationships among variables, which is particularly important when the frequency of the data is relatively long (i.e., quarterly). Furthermore, the deficiency in the standard VAR is that its error terms will, in general, be correlated, and the model does not also allow for one to impose several highly specific restrictions on the coefficient and residual covariance matrices. Thus, we apply the SVAR approach, which derives identifying restrictions for the structural shocks and imposes them on the reduced form of the model. To the best of our knowledge, there is no existing work assessing monetary policy, credit growth, and economic activity using those two improved techniques in Rwanda.

The rest of the paper is organized as follows: Section 2 describes the literature review; Section 3 describes the institutional and macroeconomic context; Section 4 summarizes the methodology and data; Section 5 discusses the empirical analysis, while Section 6 concludes.

2. Literature review

The central objective of monetary policy is to ensure price stability and the soundness of the financial system, and its ability to influence credit and the real economy remains the central concern of both monetary policymakers and academics (Bernanke et al., 1988). Every Central Bank around the world selects the monetary policy framework allowing it to anchor inflation expectations. So far, three main monetary policy frameworks are used by the central banks, namely, monetary targeting, inflation targeting, and exchange rate targeting (Mishkin, 1998).

The channels through which the monetary policy can influence output and, ultimately, prices are the interest rate channel, the exchange rate channel, the asset prices channel, and the bank-lending channel (Mishkin, 1995). The majority of the literature and the mass of empirical findings have focused on the traditional interest rate channel of the monetary policy, and a big number of these studies analyzed the interest rate pass-through in the most advanced economies with well-functioning financial systems (Mishra et al., 2010).

The bank-lending channel, which is the topic of interest in this paper, is a better way to understand the link between monetary policy, credit growth, economic activity, and eventually inflation. The bank-lending channel gives a wider view of the role of credit in economics, namely the credit channel of monetary policy. According to theory, the credit view of monetary policy works through the balance sheet channel and the bank-lending channel. The balance sheet channel mainly focuses on how monetary policy affects the value of assets of borrowers and, finally, their net worth by ultimately affecting their eligibility to obtain new loans given the changes in their collateral. The bank-lending channel concerns the impact of monetary policy on the supply of loans provided by banks (Bedikanli, 2020).

Some macroeconomists use the IS/LM model to organize their thinking about how various events affect aggregate demand. However, this model is too simple. An example is the IS/LM model's asymmetric treatment of money and credit. This approach makes bank liabilities essential to the monetary transmission mechanism while ignoring the role of bank assets despite much theoretical literature which shows the importance of intermediaries in the provision of credit. According to this theory, if financial intermediation is reduced, either by regulating credit granted to different economic sectors or by increasing or decreasing the interest rate, aggregate supply and demand may be affected (Bernanke and Blinder, 1988; Angeloni et al., 2009). This view states that some borrowers whose non-bank finances are not substituted for bank loans, meaning that those borrowers heavily rely on financing from the banking sector, will be affected by the monetary policy implemented by the central bank. For example, a tight monetary policy contracts the size of the banking sector and decreases the overall supply of loans to these dependent borrowers. Consequently, investment and aggregate demand reduce by more than they could have reduced under the conventional money channel (Kashyap et al., 1992; Bernanke et al., 1988).

Empirically, numerous authors worked on the nexus between monetary policy, credit market, and economic activities around the world using different methodologies in different periods. Generally, the studies on developed countries focused on the non-linearity between credit markets and economic activities, estimating the models with the Threshold Auto-Regression (TVAR), while a few of them used VAR (Holtemöller, 2002; Angeloni et al., 2009; Avdjiev and Zeng, 2014). However, most of the studies in emerging and developing countries focused on linear models (i.e., VAR, SVAR, or VEC models) to test the link between monetary policy, credit, and economic activity. The variables of interest in different papers are largely the ones that well signal the stance of monetary policy, either the policy rate, short-term interest rates, or monetary aggregates; the proxies of credit market developments and economic activity, mainly credit to the private sector and real GDP respectively; and, inflation.

For instance, a study done in the US by Avdjiev and Zeng (2014) examined the nonlinear nature of the interactions among credit market conditions, monetary policy, and economic activity using the Threshold Vector Auto-regression (TVAR). The selected variables were real GDP growth, inflation, the federal funds rate, real credit growth, and the spread between Baa-rated corporate bonds and 10-year Treasury bonds. Their findings showed that the interactions among credit market conditions, monetary policy, and economic activity change significantly as the economy moves from one stage of the business cycle to another. The shocks to output growth and credit growth have the biggest impact when economic growth is in a recession. However, real output growth is most sensitive to credit shocks when the economy is booming. Li and St-Amant (2010), conducted the same study and used the same method on Canadian data, namely Canadian real output growth, inflation, the real overnight rate, and a financial stress index. In addition to the above findings, these authors found that monetary policy contraction appears to have more powerful effects, in general, than monetary policy easing. Moreover, the effects of tight monetary policy are particularly large in regimes of high financial stress. Other papers on developed economies that used TVAR include Calza and Sousa (2005), Atanasova (2003), and Balke (2000), among others.

The studies on monetary policy and credit in Australia and ASEAN-5 economies (Indonesia, Malaysia, Philippines, Singapore, and Thailand) were done by Berkelmans (2005) and Tnga et al. (2015), respectively, and used SVAR models. Berkelmans (2005) used real Australian GDP, quarterly inflation, real credit (nominal credit deflated by the CPI), the cash rate, and the real trade-weighted exchange rate index for the 1983Q4-2003Q4 period. In addition to these domestic variables, he added foreign variables such as commodity prices in US dollars deflated by the US CPI and real US GDP to capture the openness of Australia's economy. His findings showed that shocks to the exchange rate, interest rate, and past shocks to credit are found to be significant for credit growth in the short run, whereas shocks to inflation, output, and commodity prices play a greater role in the long- run. The response of credit to changes in monetary policy is relatively slow, similar to that of inflation and slower than that of output.

Tnga et al. (2015) introduced the financial stress variable in the domestic variables, excluding the real trade-weighted exchange rate index, to show the impact of monetary policy. Their results suggested that an increase in financial stress leads to tighter credit conditions and lower economic activity in all five countries. The estimated impact on the real economy showed an initial rapid decline followed by a gradual dissipation. In Malaysia, the Philippines, and Thailand, the central banks tend to decrease policy interest rates when financial stress increases, though there is substantial cross-country variation in the magnitude and time dynamics. The accommodative monetary policy is found to have a little significant effect in reducing financial stress but is still important in stimulating economic activity through other channels.

A study done by Dempere (2022) on Sub-Saharan Africa (SSA) using the dynamic system-generalized method of moments (GMM) and the one carried out by Allybokus et al. (2010) in Mauritius using a vector autoregressive (VAR) model revealed the presence of the lending channel in the studied SSA countries. Employing quarterly data on Gross Domestic Product (GDP), price level, money supply, and credit to the private sector from 1985Q1 to 2006Q4, a study for Mauritius revealed the effectiveness and relevance of a credit channel and monetary policy in the short-run. Changes in the monetary policy variable (M2) affected the credit variable (CPS) in the short run. GDP rose temporarily, while the increase in monetary variables increased prices. However, a study done by Mugume (2011), which used SVAR for Uganda data, showed a weak bank-lending channel. The weakness in the bank-lending channel in Uganda resulted from the credit market frictions, which made the deposits at the central bank, government bonds, and foreign securities much closer substitutes among themselves than these alternative assets are with private sector credit. Furthermore, a high amount of remittances and trade credit constituted the non-negligible alternative sources of finance for many Ugandan economic agents.

Concerning the studies on Rwanda, numerous papers on monetary policy transmission mechanisms worked on the interest rate channel (Kamanzi and Kimenyi, 2020; Kigabo and Kamanzi, 2018; Rutayisire, 2020; Bernanke et al., 1988; Balke, 2000; Mwenese et al., 2016). Their findings revealed a weak interest rate channel. A study done by Hitayezu and Nyalihama (2019) showed a weak exchange rate channel with some noticeable improvement arising from the introduction of a more flexible exchange rate regime. To the best of our knowledge, only the Kamanzi et al. (2019) study covered the bank-lending channel in Rwanda, limiting its analysis to the impact of monetary policy on the supply of loans. Their results revealed the presence of a lending channel in Rwanda, though still very weak. Regarding the effect of bank characteristics, big banks respond less to monetary policy change, while well-capitalized banks and more liquid banks react more to monetary policy changes compared with lower capitalized banks and less liquid banks. In addition to the analysis of how monetary policy affects the supply of loans as covered in Kamanzi et al. (2019), this paper goes beyond to examine the nexus between monetary policy, GDP, and inflation in Rwanda.

3. Institutional and macroeconomic context

A steady macroeconomic environment is good for business and can reduce banks' risk aversion and price mark-up. The macroeconomic environment in Rwanda has been healthy, stable, and sound over the past fifteen years, with high real economic growth of 7.1 percent on average, stable inflation of 5.6 percent, and a stable exchange rate as the country runs a relatively flexible exchange rate regime (depreciation of 3.8 percent against the US dollar for the last fifteen years).

3.1 Monetary policy frameworks in Rwanda

NBR is an independent central bank with the following missions: ensuring and maintaining price stability, enhancing and maintaining a stable and competitive financial system without any exclusion, and supporting the government's general economic policies without prejudicing its other missions (BNR law 48/2017, article 6).

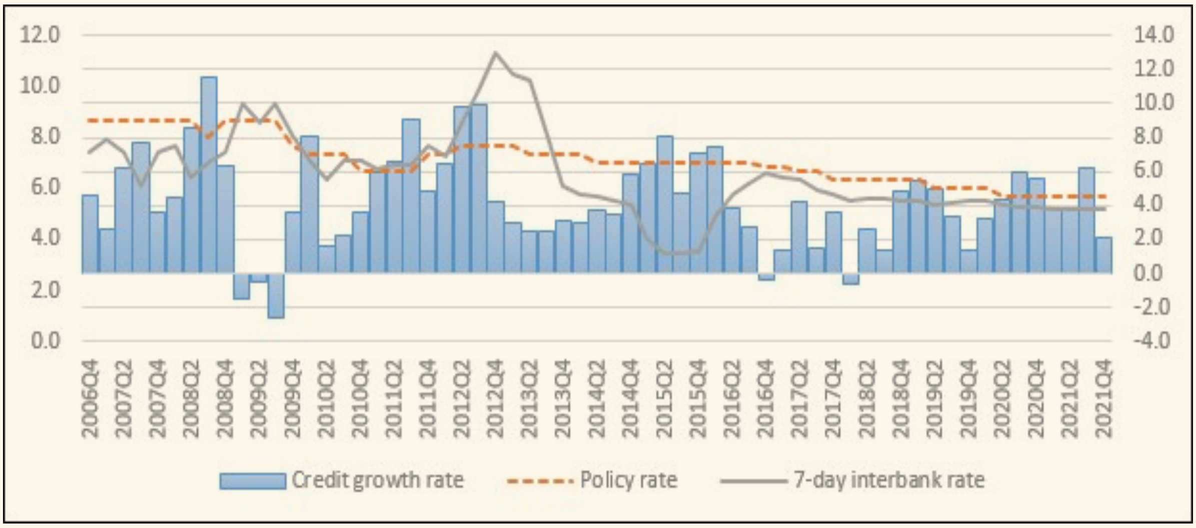
From 1995 to 2018, the National bank of Rwanda conducted its monetary policy under the monetary targeting framework, with the broad monetary aggregate as the intermediate target and reserve money as the operating target. While the macroeconomic and price stability achieved under the monetary targeting regime was estimable, the continuing economic transformation in both financial and real sectors posed new challenges that weakened the relationship between inflation and broad monetary aggregates.

In addition, the NBR observed a tendency among economic agents to gradually focus on interest rates in their saving and consumption decisions as a result of the developments in the domestic financial system, such as the avenue of modern payment systems and new financial products. These trends were revealed by the surge in term deposits and investments as well as in government securities by retail businesses and institutional investors. Under those conditions, a more forward-looking monetary policy that applies the interest rate as an operating target to direct market expectations became the most relevant framework.

The price-based monetary policy presents several benefits over the quantity-based monetary policy. First, a price-based monetary policy has the benefit that a stable link between money and inflation is not necessary for the success of the monetary policy. Second, prices of money (interest rate) and goods and services (as measured by inflation) can be easily observed by the general public and market players, which enables more effective communication, greater transparency, and increased accountability of NBR. In view of this, the National Bank of Rwanda shifted from a quantity-based monetary policy framework to a price-based approach in January 2019.

During the period of analysis, the interbank market remained stable with an upward trend in the amount exchanged. Therefore, the interbank market plays a critical role in the domestic financial system by providing a liquidity price-discovery mechanism in the money market and being a channel of monetary policy transmission.

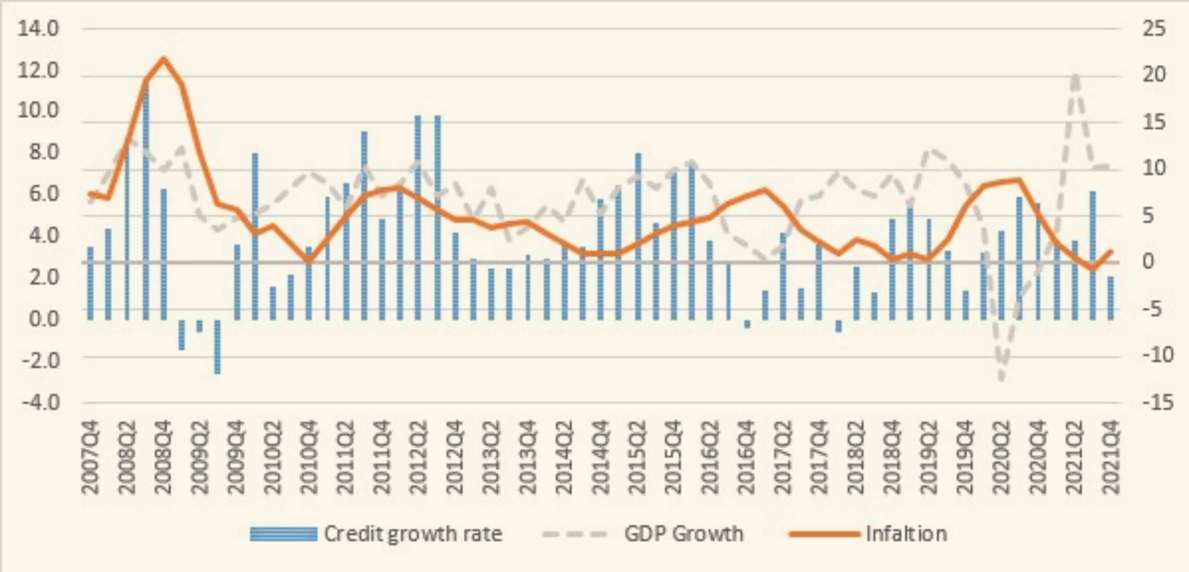
Figure 1: Monetary conditions and bank credit



Source: Authors' Estimation

Figure 1 shows that monetary conditions represented by the interbank rate affect the credit growth rate, with the two variables inversely related: hikes in the interbank rate correspond to low credit growth and vice-versa. The introduction of FMOC in 2016 has improved the interbank market and also contributed to the stabilization of the growth of credit to the private sector of 3.4% on an average quarterly basis.

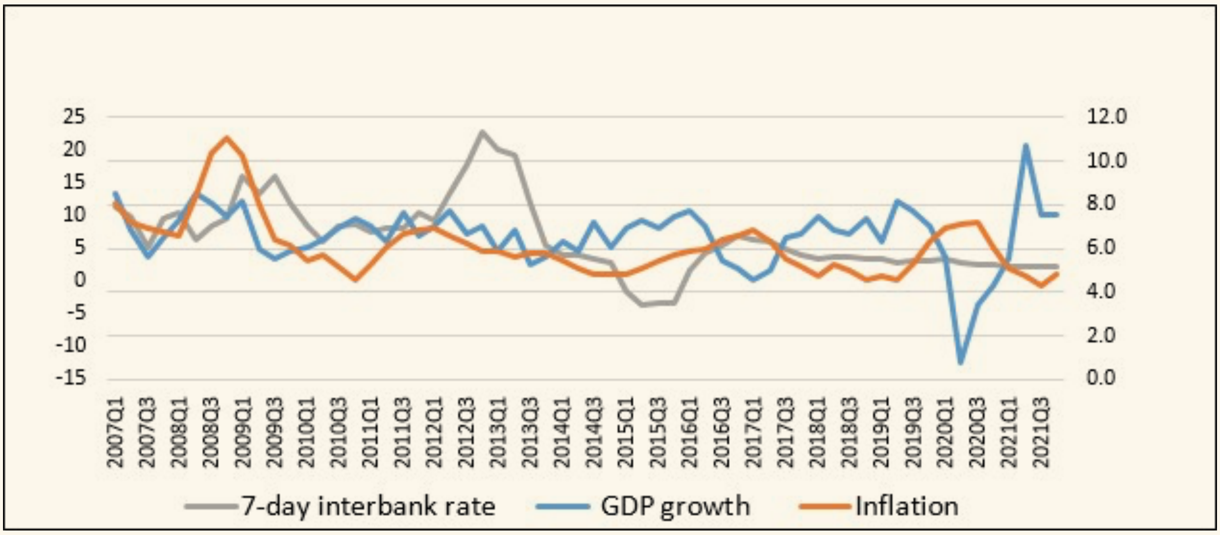
Figure 2: Credit growth, Real GDP growth, and inflation rate



Source: Authors' Estimation

Figure 2 illustrates the development of credit, real GDP growth, and inflation. It reveals that credit growth has a positive effect on real GDP growth despite the shocks of the covid-19 period. Real GDP growth has the same pattern over the sample period. However, the effect of credit growth on inflation depends on the sensitivity of the latter to supply shocks.

Figure 3: Monetary conditions, real GDP growth, and inflation



Source: Authors' Estimation

Figure 3 reveals that monetary policy actions represented here by the interbank rate have limited influence on real GDP growth; however, inflation and real GDP growth have a direct relationship, although this relationship has been hampered by the Covid-19 effects since 2020.

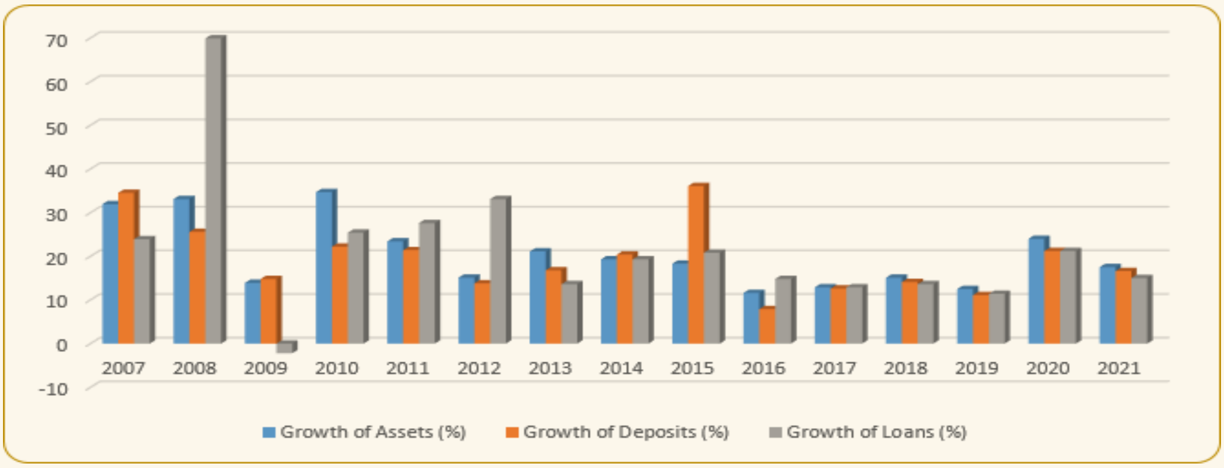
2.3. Financial sector development in Rwanda

The financial sector continued to grow throughout the period under study; by 2021, total assets of the financial sector expanded by 19.0 percent, to FRW 7,531 billion in December 2021, higher than the 14.3 percent average growth registered over the five years prior to the pandemic. In 2021, financial sector assets stood at 68.8 percent of GDP (Dempere, 2022).

The banking sector remains the largest component of the financial sector, accounting for about 67.2 percent of total financial sector assets. Because of its size and interconnectedness with the other subsectors, the health of the banking sector underpins the overall soundness of the financial sector (Dempere, 2022).

The sector is comprised of 16 banks (of which eleven is commercial banks, three microfinance banks, one development bank, and one cooperative bank). A large number of competitors and a range of products and services in the banking sector has tremendously improved over the past fifteen years as a result of the strong economic growth of the country, good and improving conditions for doing business, and an appropriate regulatory environment. The benefit of this competition is expanded outreach through bringing people that were previously excluded into the banking market, enhancement such as accounts with no fee, and product innovation such as the introduction of credit and debit cards. The entry of foreign-owned banking institutions has expanded the new business model, strategy, and capability to the market (Dempere, 2022).

Figure 4: Development in Banking Sector indicators (%)



Source: Authors' Estimation

4. Methodology and data

4.1 Benchmark Models

In line with Sims(1980), most of the empirical studies in monetary economics are based on VAR methods (Br#ggemann & L#tkepohl, 2001). The VAR models often succeed in capturing the dynamic relationships among macroeconomic variables since they can be applied to simulate the dynamic response over a horizon of any indicator to either an 'own' disturbance or a disturbance to any other indicator in the framework (Bernanke and Gertler, 1995). The coefficients of a VAR model are estimated by OLS, and the regressors are the lagged values of all the indicators included in the system. In a general representation, a VAR model of an order ρ has the following form:

$$y_t = A_1 y_{t-1} + ... + A_k y_{t-k} + \varepsilon_t \text{............} \qquad (1)$$

Where y_t is a vector of the dimension of the exogenous variables k that include the stationary variables, A_1,..., A_k are the coefficients' matrices to be estimated, ε is a vector of error terms, and Σ is the covariance matrix of the errors that may be contemporaneously correlated but are uncorrelated with their own lagged indicators and uncorrelated with the exogenous indicators and the lagged stationary variables.

In this VAR modeling procedure, we make two basic model-selection choices. First, we choose which variables to include in the VAR, typically motivated by the research question and guided by theory. Second, we choose the lag length, once the lag length has been determined, we proceed to Estimation, and the parameters of the VAR are estimated, and we can perform post-estimation procedures to assess the model fit.

Hence, the VAR to estimate is $\begin{bmatrix} Inf_t \\ Gdpg_t \\ Credit_t \\ Interb_t \end{bmatrix} = \alpha_0 + A_1 \begin{bmatrix} Inf_{t-1} \\ Gdpg_{t-1} \\ Credit_{t-1} \\ Interb_{t-1} \end{bmatrix} + \ldots + A_k \begin{bmatrix} Inf_{t-k} \\ Gdpg_{t-k} \\ Credit_{t-k} \\ Interb_{t-k} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \end{bmatrix}$

α_0 is a vector of intercept, and each of A_1 to A_k is a 4×4 matrix of coefficients. VARs with these variables, or close analogs to them, are common in monetary policy analysis. We use the above VAR model as a benchmark.

We depart from the previously specified model to implement the VEC model (VECM). Since most economic time series appear to be first difference stationary with their levels exhibiting unit root, the conventional regression estimators, including VARs, have good properties when applied to covariance-stationary time series but encounter difficulties when applied to processes. These difficulties were illustrated by Granger and Newbold (1974) when they introduced the concept of spurious regressions. The VECM is specified as follows:

$$\Delta y_t = \varphi + \prod y_{t-1} + \sum_{i=1}^{\rho-1} \psi_i \Delta y_{t-i} + \varepsilon_t \text{.........(3)}$$

Where $\prod = \sum_{j=1}^{j=\rho} A_j - I_k$ and $\psi_i = -\sum_{j=i+1}^{j=\rho} A_j$

If all variables y_t are $I(1)$, the matrix Π has a rank $0 \le r \prec K$, where r is the number of linearly independent cointegrating vectors. If the identified variables are cointegrated ($r \succ 0$), the VAR in the first differences is misspecified as it excludes the error correction term. If the rank of $\Pi = 0$, there is no cointegration among the non-stationary variables, and a VAR in their first differences is consistent.

If the rank of $\Pi = K$ all of the variables in y_t are $I(0)$ and a VAR in their levels is consistent. If the rank of Π is $r \succ 0$, it may be expressed as $\Pi = \alpha\beta'$ were α and β are $(K \times r)$ matrices of rank r. We must place restrictions on these matrices' elements to identify the system. We will also present suitable models for dynamic forecasts.

4.2 Alternative Model

Although VAR has been the standard tool for empirical macroeconomic analysis, it cannot address some fundamental research questions that might be unsatisfactory for two reasons. First, it allows for arbitrary lags but does not allow for contemporaneous relationships among its variables. The economic theory often links variables contemporaneously, and if we apply VAR to test those theories, it must be modified to allow for contemporaneous relationships among the model variables. A VAR that does allow for contemporaneous relationships among its variables, known as the SVAR model, may be written as:

$$Ay_t = C_t y_{t-1} + \ldots + C_k y_{t-k} + \varepsilon_t \ldots .(4)$$

And we introduce a new notation (the C_i) because when $A \neq I$ the C_i will generally differ from the A_i in the reduced-form VAR. The A matrix describes the contemporaneous relationships among the variables in the VAR system.

The second deficiency of the reduced VAR is that its error terms, in general, are correlated. We want to decompose these error terms into mutually orthogonal shocks to be able to better examine the effect of a particular shock in one equation, holding all other shocks constant. This helps to keep other shocks constant when conducting impulse response analysis. Nevertheless, if the error terms are correlated, then a shock to one equation is linked with shocks to other equations; the assumed experiment of holding all other shocks fixed could not be performed. The solution is to denote the errors as a linear combination of "structural" shocks:

$$\varepsilon_t = \beta\mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Without loss of generality, we can impose $\mathrm{E}(\mu_t \mu_t') = I$, so our duty, then, is to estimate the parameters of a VAR model that has been extended to include correlation among the endogenous variables and exclude correlation among the error terms. Combine (4) and (5) to obtain the structural VAR model,

$$Ay_t = C_t y_{t-1} + \ldots + C_k y_{t-1} + \beta\mu_t \ldots\ldots\ldots\ldots (6)$$

So the goal is to estimate A , β , and C_i . Unfortunately, there is little more we can demonstrate at this stage because, at this level of generality, the model's parameters are not identified. The main method of identification is to set $A = I$ and require β to be a lower-triangular matrix, putting zeros on all entries above the diagonal. This identification scheme places n^2 restrictions on β and places $n(n-1)/2$ restrictions on β the order condition is satisfied. The mapping resulting from structure to reduced form is:

$\beta\beta^{'} = \Sigma$ .... (7)

Along with the requirement that β it be lower triangular. There is a unique lower-triangular matrix β that satisfies (7); hence, we uniquely recover the structure from the reduced form.

For the restrictions on the contemporaneous matrix of structural parameters β, we follow the original paper by Sims (1980), whereby Cholesky decomposition is applied to the contemporaneous parameter matrix. Equation (8) summarizes the nonrecursive ide ntification approach based on equation (7), the ordering of the newly obtained triangular matrix is written as follows:

$$\begin{pmatrix} \mu_{Inf} \\ \mu_{Gdpg} \\ \mu_{Credit} \\ \mu_{Interb} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ a_{21} & 1 & 0 & 0 \\ a_{31} & a_{32} & 1 & 0 \\ a_{41} & a_{42} & a_{43} & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_{Inf} \\ \varepsilon_{Gdpg} \\ \varepsilon_{Credit} \\ \varepsilon_{Interb} \end{pmatrix} \quad (8)$$

Where μ_{Inf}, μ_{Gdpg}, μ_{Credit} and μ_{Interb} are the structural disturbances inflation shocks, output shocks, credit shocks, and monetary policy shocks, respectively. ε_{Inf}, ε_{Gdpg}, ε_{Credit} and ε_{Interb} are reduced-form residuals that describe the unanticipated movements of each regressor, respectively. This identification structure is often called "Cholesky" identification because the matrix β can be recovered by taking a Cholesky decomposition Σ. This method can be thought of as imposing a causal variable ordering in the VAR model: the shocks to one equation contemporaneously affect variables below that equation but only affect variables above that equation with a lag. We follow the VAR identification exercise that is similar to many studies used in the context of VARs in advanced economies, including Christiano, et al., (1996), but we have modified it to take into account the institutional context of the conduct of monetary policy in Rwanda.

As with the benchmark model (i.e., the VAR model), the selection of the lag order for the SVAR model is based on the AIC and SC information criteria, with a maximum of two lags considered.

4.3 Data and sample selection

We estimate the preceding VARs family using quarterly Rwandan data that runs from 2006:Q1 to 2021:Q3. In our benchmark model, we consider four variables: a variable to represent the monetary policy stance, the output and inflation measure, and a credit variable. All these variables are sourced from the National Bank of Rwanda.

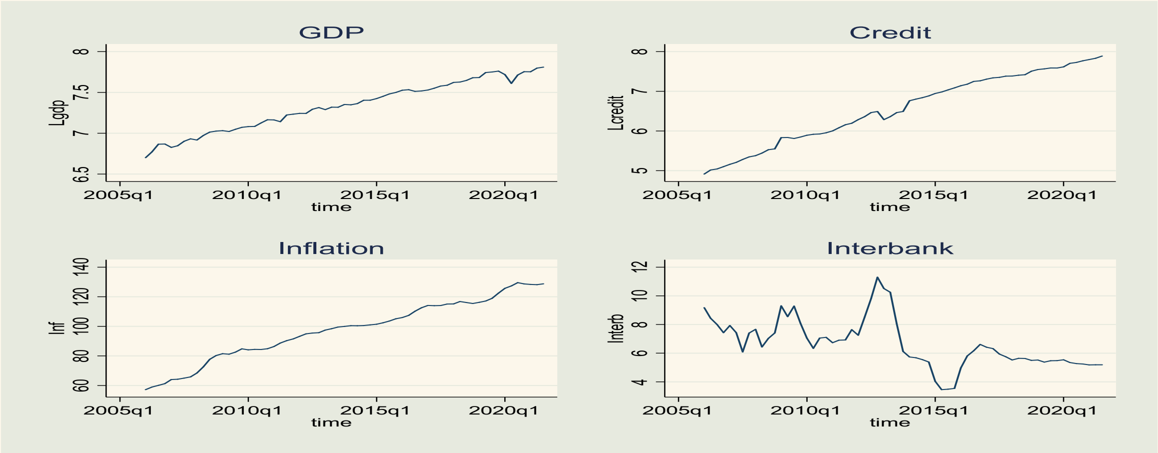
The ordering inflation, output, credit, and interest rate, means that output and price level react to innovation in credit with a lag, or, alternatively, credit growth res ponds contemporaneously to innovations in output and prices. This assumption is reasonable for slow-moving macroeconomic variables such as output and prices. The interest rate is ordered after credit, consistent with the practice that the policy rate or other interest rates (e.g., T-bills rate against which policy rates may be benchmarked) are increasingly being used by the National Bank of Rwanda as an additional instrument to signal changes in the monetary policy stance.

5. Empirical findings and interpretations

5.1 Preliminary tests

Before deeper analysis, let us first visualize the features of the data. We observe patterns variable under study exhibit unit root; then the series is probably not white noise.

Figure 5. Data visualization



Source: Authors' own computation

Table 1. Unit root test

GDP	-3.986 (0.0092***)	I(0)
D.Lcredit	-8.378(0.0000***)	I(1)
D.Inf	-4.472 (0.0017***)	I(1)
D.Interb	-6.182(0.0000***)	I(1)
D.Lm3	-5.210 (0.0001***)	I(1)

Notes: With a constant and a linear trend, Lags are based on the SIC criterion.
P-values are in parentheses and for the ADF tests,
5% critical value in brackets; *Significant at the 5% level.

Source: Authors' own computation

The unit root tests suggest that most, but not all, of the variables included in the model are non-stationary, I (1), processes. The preference for VAR explained by conventional wisdom, at least can be considered as a benchmark. Nevertheless, the possibility of spurious relationships between the I(1) variables remain. Ensuring this is not the case is perhaps to resort with the VEC model that is plausible on economic grounds.

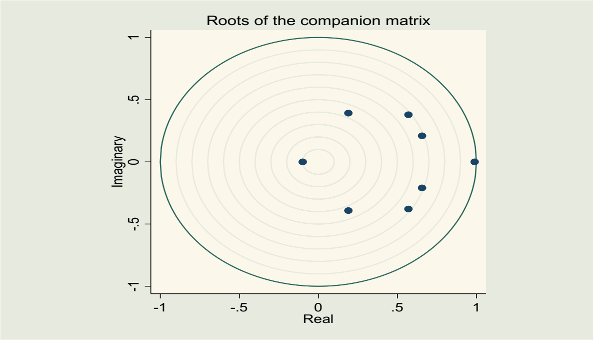
5.2 Benchmark model- VAR Estimation

The stability test (unit root property of the variable) is also performed using the AR root table. The results, as results show that all the roots of the polynomial's characteristic are smaller than one. This observed result specifies that the VAR model is variance and covariance stationary, which satisfies the stationary condition.

Table 3. Stability test

Eigenvalue stability condition	
Eigenvalue	Modulus
0.9885106	0.988511
0.6558632 + 0.2094295i	0.688489
0.6558632 - 0.2094295i	0.688489
0.5697597 + 0.3788096i	0.684195
0.5697597 + 0.3788096i	0.684195
0.1899484 + 0.3916506i	0.435282
0.1899484 + 0.3916506i	0.435282
-0.09904908	0.099049

Figure 6. Roots of Companion matrix



Furthermore, the VAR estimation obtained the following results:

Table 4. VAR estimation results

Sample: 2006q3 - 2021q3	Number of obs = 61				
Log likelihood = 258.815	AIC = -6.68246				
FPE = 8.79e-10	HQIC = -5.93656				
Det(Sigma_ml) = 1.42e-10	SBIC = -4.779213				
	Coeff.	Std.Err.	t	p>|t|	[95% Conf. Interval]
Inf(-1)	0.077601	0.091991	0.84	0.403	-.1071692 .262371
Inf(-2)	-0.03379	0.091283	-0.37	0.713	-.2171426 .1495502
Lgdp(-1)	2.653945	3.634864	0.73	0.469	-4.646894 9.954783
Lgdp(-2)	-2.17309	3.448687	-0.63	0.531	-9.099977 4.753808
Lcredit(-1)	-2.86148	2.069186	-1.38	0.173	-7.017565 1.294601
Lcredit(-2)	1.546576	1.800078	0.86	0.394	-2.068987 5.162139
Interb(-1)	1.035843	0.138775	7.46	0.000	.7571042 1.314581
Interb(-2)	-0.34853	0.144404	-2.41	0.020	-.6385685 .0584827
Lm3(-1)	-6.60152	4.349113	-1.52	0.135	-15.33697 2.133934
Lm3(-2)	6.312371	4.874583	1.29	0.201	-3.478516 16.10326
_cons	5.125712	17.41126	0.29	0.770	-29.84584 40.09727

Source: Authors' own computation

It's often pretty hard to interpret the coefficients of a VAR, as one variable says one thing and another doesn't; there are no clear dynamics between the variables we wish to investigate. However, our analysis focuses mainly on impulse responses. Before going on the impulse response, let us first explore two post-estimation statistics, which are mainly Lagrange-multiplier and normality tests, to assess VAR output.

Table 5. Lagrange-multiplier

lag	chi2	df	prob>chi2
1	22.9104	16	0.11615
2	17.2194	16	0.37154
3	19.6066	16	0.23846
4	17.6754	16	0.34324
5	12.015	16	0.74295
Ho: no autocorrelation at lag order			

Table6. Jarque Bera test

Equation	chi2	Df	prob>chi2
Inf	0.07	2	0.96547
lgdp	2.1221	2	0.24626
lcredit	5.678	2	0.0585
Interb	1.215	2	0.54484
All	9.082	8	0.33533
dfk estimator used in computations			

Source: Authors' own computation

The results show to not reject the null hypothesis that there is no autocorrelation in the residuals for any of the five orders tested and the Jarque-Bera test for normality also indicates the residuals are normally distributed; thus, our model is correctly specified.

Granger causality tests

Granger Causality indicates whether a variable or set of variables is influenced by the other variables in the model. We continue by taking all possible combinations of the four variables included in the VAR model.

Table 7. Granger causality test

Equation	Excluded	F	df	df_r	prob>F
Inf	Lgdp	4.8652	2	52	0.0116
Inf	Lcredit	0.55058	2	52	0.5799
Inf	Interb	0.08722	2	52	0.9166
Inf	All	3.282	6	52	0.0082
Lgdp	Inf	0.11569	2	52	0.891
Lgdp	Lcredit	4.0429	2	52	0.0233
lgdp	Interb	0.88108	2	52	0.4204
Lgdp	All	3.0871	6	52	0.0116
Lcredit	Inf	5.4923	2	52	0.0069
Lcredit	Lgdp	1.5428	2	52	0.2234
Lcredit	Interb	8.9074	2	52	0.0005
Lcredit	All	4.4737	6	52	0.001
Interb	Inf	0.75624	2	52	0.4745
Interb	Lgdp	0.21944	2	52	0.8037
Interb	Lcredit	0.74142	2	52	0.4814
Interb	All	0.87556	6	52	0.5193

Source: Authors' own computation

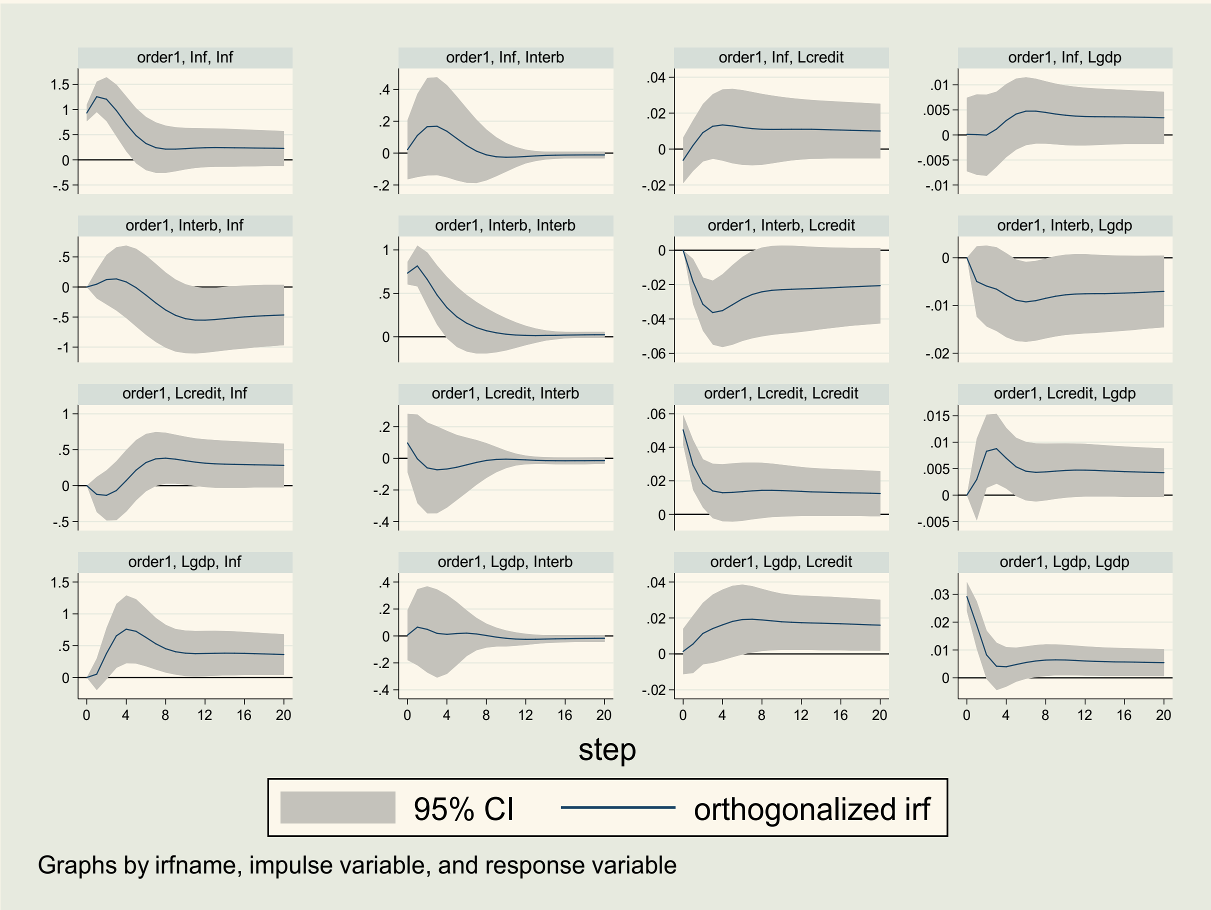
The first panel shows that the inflation granger causes gross domestic product and all variables. The second panel indicates that the gross domestic product granger causes credit and all variables. The third panel points out that credit granger causes inflation, interbank, and all set of variables, while the last panel illustrates that there was no feedback on the interbank to another set of variables.

Impulse Responses

We now turn to the impulse response functions from the model, which are presented in figure 7. These basically trace out the implied dynamic paths of the endogenous variables in the system following one of the innovations from a one-time shock.

Generally, the effect of interest rate on goal variables is consistent with theoretical propositions and empirical applications. Specifically, the interbank rate shock causes inflation to fall about five percentage points over eight quarters; since a higher interbank rate means higher borrowing costs, economic agents eventually start spending less. The demand for goods and services then drops, which causes inflation to fall.

Figure 7. VAR impulse responses



Source: Authors' own computation

The interbank rate shock reduces credit in the first four quarters by about four percentage points. This means that the shock of interbank induces potential investors or borrowers to become more hesitant to borrow money due to the higher cost. Finally, the shock on the interbank rate tends to reduce consumer spending and investment. This will lead to a fall in aggregate demand which subsequently lower economic growth but its effects are dying over time before its normalization. Following the transmission process of variables, the empirical finding is in line with those of (Garcia & Schaller, 2002) (Weise, 1999) (Peersman & Smets, 2001)), who all suggest that credit shock has a greater impact on output in developing economies. Intuitively, a decrease in the interest rate, on the surface, appears to improve liquidity, hence increasing credit supply. Specifically, when economic agents are more likely to be credit and liquidity limited, this effect becomes more pronounced. As a result, when economic growth is below par, monetary policy shock has the greatest impact.

The gray space shows the 95 percent confidence interval derived using the technique of (Kilian, 1998). In the impulse–response graph, each row represents an impulse, and each column represents a response variable. Each graph's horizontal axis represents the time units in which the VAR is evaluated, in this instance, quarters; so, the impulse–response graph depicts the effect of a shock over 20 quarters. The vertical axis represents the variables in the VAR in their respective units; in this case, everything is measured in percentage points. Hence the vertical units in all panels are percentage point changes.

5.3 Benchmark model-VEC Estimation

Table 8. VEC estimation results

Vector error-correction model					
Sample: 2006q3 - 2021q3		Number of obs = 61			
		AIC = -1.637259			
Log likelihood = 76.93639		HQIC = -1.27109			
Det(Sigma_ml) = 9.43e-07		SBIC = -.7029375			
	Coeff.	Std.Err.	t	p>|t|	[95% Conf. Interval]
ECM(-1)	-.0012644	.0012404	-1.02	0.308	-.0036955 .0011666
D.linf	.0595003	.0879877	0.68	0.499	-.1129523 .231953
D.lgdp	1.038519	3.498747	0.30	0.767	-5.818898 7.895937
D.Lcredit	.1337111	1.735483	0.08	0.939	-3.267773 3.535196
D.Interb	.2343204	.1326974	1.77	0.077	-.0257617 .4944025
_cons	-.349595	.2443918	-1.43	0.153	-.8285948 .1294035

Source: Authors' own computation

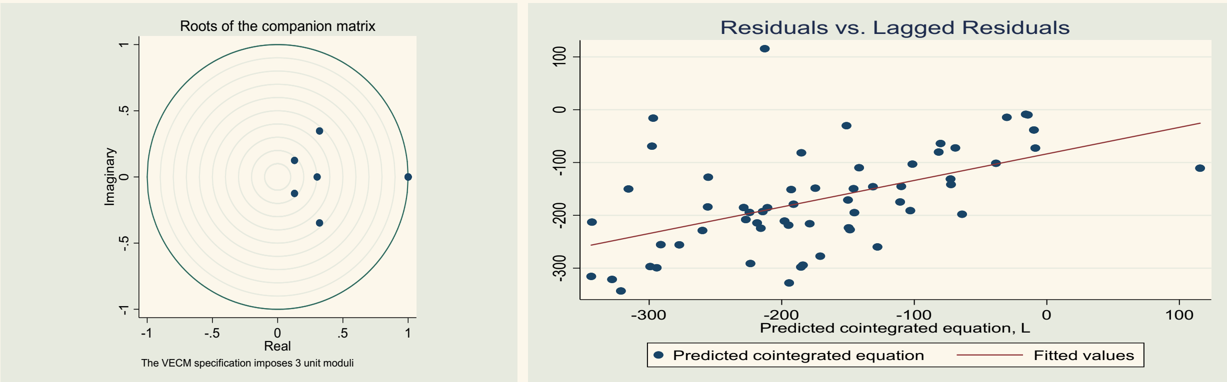
The estimated results of the multivariate VECM with rank two and no constant non-trend configuration are presented. The D_ before the variables denotes that they are modeled as first-difference. The model has a low log-likelihood, about 77% value, which indicates that the VECM is relatively good compared to the estimated VAR model. The interpretation of the VECM is difficult since the model in itself is a system of equations where the variables take turns being the dependent and independent variables. The economic Intuitive of insignificant coefficients can be whether their variables adjust when the first cointegrating equation is out of equilibrium. Thus, we could just decide to use the current results unless we impose restrictions on those parameters and refit the model.

However, the variables affect each other over time, and different lags can provide different information, which makes it hard to interpret the dynamics. That is why we rely on the IRFs in the underlying VECM framework to trace the dynamics. The "speed of adjustment" coefficient of the ECM term has a negative value, which is good since it implies convergence towards the long-run equilibrium. The adjustment term, in this case, the inflation equation, suggests that the previous quarter's deviation from long-run equilibrium is corrected for in the current quarter at an adjustment speed of 0.1%. In the long-run effects, the coefficients would be interpreted in the opposite sign, and this implies that a positive shock on interbank has a negative impact of 0.59%, 1.03%, and 0.13% on credit, GDP, and inflation respectively.

The stability condition of the VECM estimates

We check whether the cointegrating equations are correctly specified and if a VECM has endogenous variables K and r cointegrating vectors, the unit moduli in the companion matrix are $K-r$. The process is stable if all the remaining eigenvalues r are strictly less than one. If any of the remaining moduli are too close to one, either the cointegrating equations are not stationary, or there is a common trend, and the rank specified in the VECM is too high.

Figure 8. Stability condition of the VECM estimates



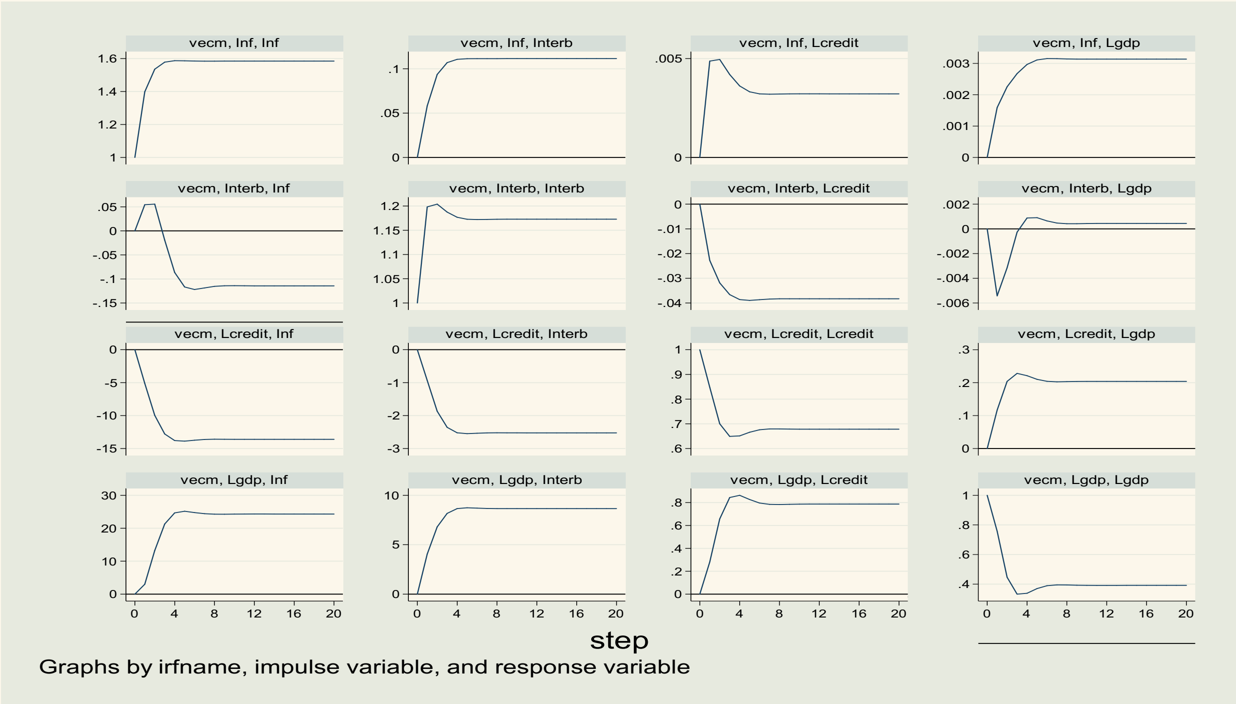
Source: Authors' own computation

The stability condition indicates a well-specified model (stationary variables and correctly specified) with stable results, which is important for the interpretation of the IRFs.

Impulse-response function

The impulse responses show that they are quite consistent across the different models, as is evident by looking at the various dynamism and magnitudes in the impulse response in the context of the variation.

Figure 9. VECM impulse responses



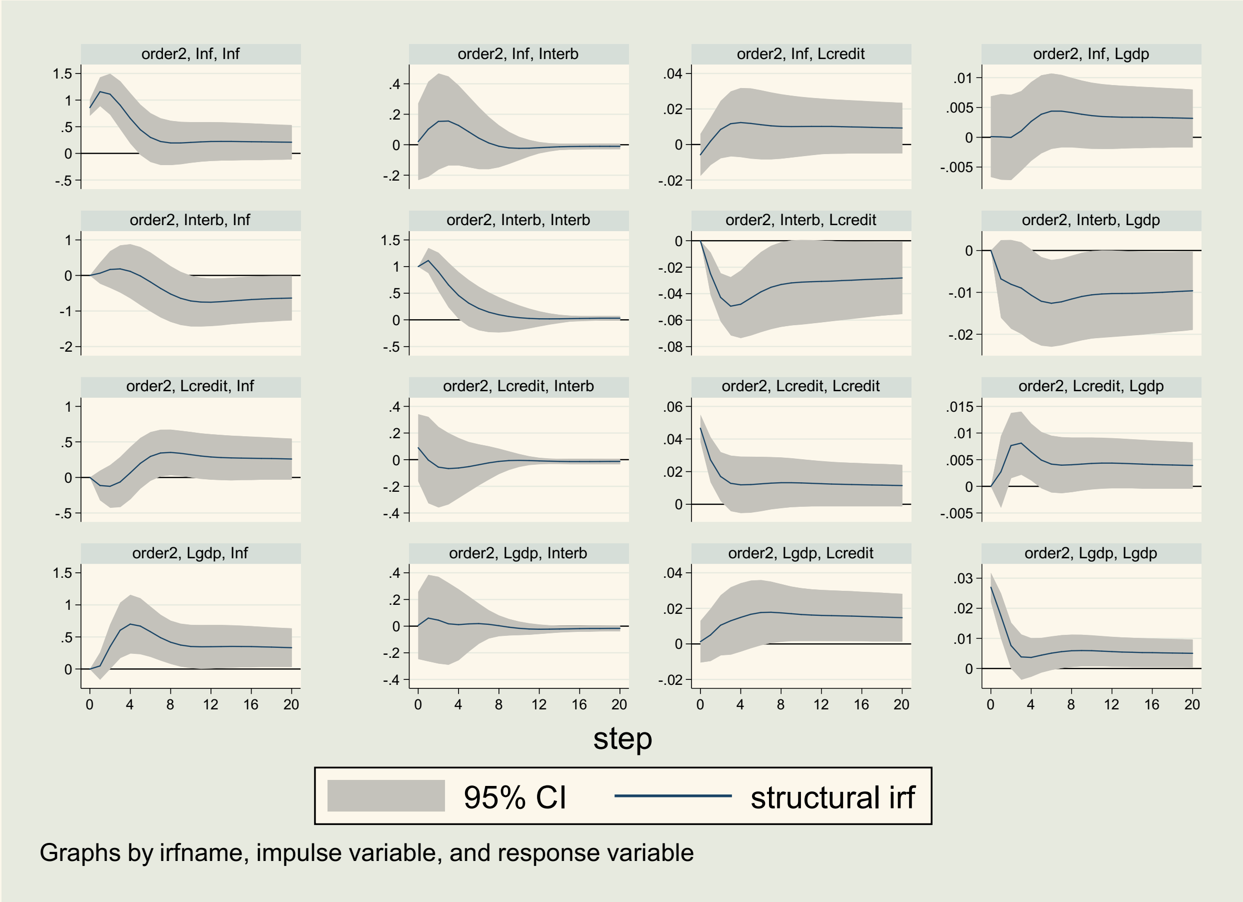
Source: Authors' own computation

From our benchmark models, the interbank rate shock on inflation is quite robust and the models capture the essential macroeconomic relations, primarily the impact of monetary policy on the credit, GDP, and inflation, with no "price puzzle'' observed.

5.4 Alternative model- SVAR estimation

The previous models treated all variables symmetrically, and it did not depend on econometric restrictions in (Sims, 1980) model. Thus, SVAR solves this problem since SVAR introduces enough restrictions to interpret the shocks of the system (Cooley & M. Dwyer, 1998); (Kim & Roubini, 2000).

Figure 11. SVAR impulse responses



Source: Authors' own computation

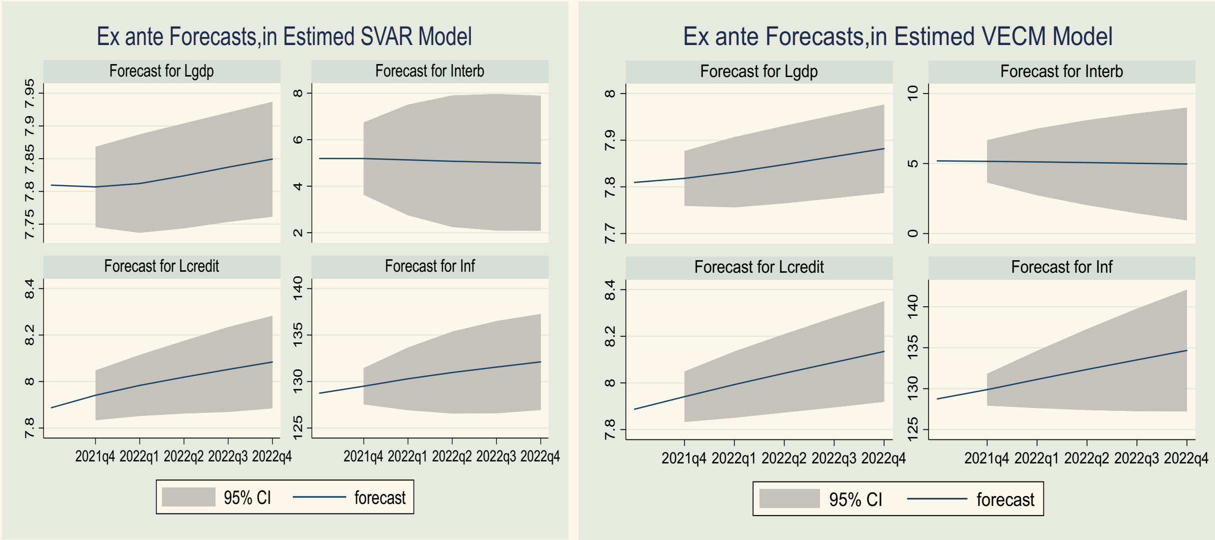
All impulse responses show the expected signs, and the structural impulse responses have generally improved the existing findings, but the stipulated effects are in line with the previous models, and we kept the two lags in our SVAR model for consistency.

The structural interbank rate shock reduces the credit by four percentage points, and the GDP in the first to four quarters and normalizes over the horizon. In addition, the interbank shock is also consistent with our benchmark models, which is consistent with other empirical findings. The SVAR model is particularly quite robust; the impulse responses for all variables have broadly the same shape as baseline findings. Consistently with the baseline models, the structural impulse response also has not shown a "price puzzle."

5.5 Other robustness checks -Dynamic Forecasting

We further extend our SVAR and VEC findings to determine their predictive power by providing sample forecasting. Following the graphical approach of (Harvey, 1989) and (Batten & Thornton, 1983), the estimated SVAR and the VECM offer similar information about future behavior in our data.

Figure 12. Forecasting comparisons



Source: Authors' own computation

6. Conclusion

The aim of this paper was to provide a deeper analysis of the effect of monetary policy on target variables, for example, credit, output, and inflation in Rwanda. The paper adds to the body of empirical works by providing a critical review of the existing stock of knowledge and addressing the important gaps.

The paper adds to the scarce literature that examines the effect of monetary policy on credit and economic activity to shed more light on how the central bank's actions reflect and persist in the real economy. Monetary policy cannot be a static and stable function in time, implying that the conduct of monetary policy cannot be the repetition of strategies deemed useful in the past. The present investigation becomes essential to accommodate the effect of structural changes, such as technological, institutional, or policy-related changes, specifically the current move from quantity base monetary policy to price-based monetary policy.

The VAR applied in the specific case of Rwanda is not exhaustive; even though the VAR model has good properties when applied to covariance-stationary time series, most economic variables exhibit unit root; thus, the VEC model is more appropriate. We also check whether or not the pre-observed relationships are biased in the so-called ''price puzzle" that is common observed in the literature.

The empirical findings show that broadly the effect of interest rate on goal variables is consistent with theoretical propositions and empirical applications. Specifically, the interbank rate shock causes inflation to fall by about five percentage points over eight quarters; since a higher interbank rate means higher borrowing costs, economic agents eventually start spending less. The demand for goods and services then drops, which causes inflation to fall. The interbank rate shock reduces credit in the first four quarters by about four percentage points. This means that the shock to the interbank rate induces potential investors or borrowers to become more hesitant to borrow money due to the higher cost. Finally, the shock on the interbank rate tends to reduce consumer spending and investment. This will lead to a fall in aggregate demand which subsequently lowers economic growth but its effects are dying over time before normalizing.

The results from VECM show that the previous quarter's deviation from long-run equilibrium is corrected for in the current quarter at an adjustment speed of 0.1%. The impulse responses show that they are quite consistent across the different models, as is evident by looking at the various dynamics and magnitudes in the impulse responses. From our benchmark models, the interbank rate shock on inflation is quite robust and the models capture the essential macroeconomic relations, primarily the impact of monetary policy on the credit, GDP growth, and inflation, with no "price puzzle" observed. The findings remain robust when we apply SVAR, and the models capture the essential macroeconomic relations between a monetary policy indicator and goals variables, following the recent improvement in financial markets. In line with the baseline models, the structural impulse responses do not exhibit a "price puzzle." We further extend our SVAR and VEC findings to determine their predictive power by providing the samples with ample forecasting; the estimated SVAR and the VECM offer similar information about the future behavior in our data. We assume the structural factors under our analysis as predetermined, an assumption that can be relaxed in the future studies.

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NOWCASTING THE REAL GDP GROWTH OF RWANDA

Christian Manishimwe[a], Priscille Ziraje Mikebanyi[b]

[a] *Senior Economist, Monetary Policy Department, National Bank of Rwanda*

[b] *Senior Economist, Governor and Board Affairs Office, National Bank of Rwanda*

Abstract

The main contribution of this paper is to develop a new set of real Gross Domestic Product (DGP) nowcasting tools, namely, the Bridge equations, Mixed Frequency Data Sampling (MIDAS) models and the combined forecasting technique, and to compare their performance against the benchmark models currently used at the National Bank of Rwanda (NBR), namely, the Autoregressive Moving Average (ARMA) models and the Dynamic Factors Model (DFM). Our empirical findings indicate that all three new nowcasting models outperform the benchmark models, with the bridge equations taking the lead. We, therefore, recommend the inclusion of MIDAS, Bridge and combined forecasting models as part of the GDP nowcasting system for the NBR, to complement the existing models as this can help to improve the forecast accuracy.

Key Words: *Gross Domestic Product, Nowcasting, Mixed Frequency Data Sampling, Forecast combination, Bridge equations.*

JEL Classification Numbers: *C22, C52,*

1. Introduction

Public policy making such as in monetary policy or public finance, depends on information on the past, current, and near-future conditions of the economy as a whole. However, data on many macro-economic indicators are published with substantial delays. This is especially true for the Gross Domestic product, a key macro-economic indicator, whose data collection and processing takes a while and is published almost three months after the referenced quarter. This has raised the need to come up with economic and statistical models that use information that has been published earlier to predict GDP for the real-time perception of the economy's state, which is known as nowcasting.

Nowcasting has been defined as the prediction of the very recent, current, and near-future of the concept of interest (Marcellino et al., 2008; Blanco et al., 2017; Habimana et al., 2020). It is basically exploiting all possible available hard and/or soft information1 that are published before the target variable, GDP in our case, and using them to make its early predictions. A challenge in using other indicators to predict GDP, is that they too are published on different dates, such that the last observation is different from one series to another, hence making some indicators have missing numbers. Such a database would then be described as being 'jagged/ragged edge.' Another challenge is that different indicators have different frequencies, e.g., some are released at daily, monthly, or quarterly frequencies. Different models of nowcasting treat these data issues differently.

There are many models used to nowcast. Examples of commonly used approaches are the bridge equations, Dynamic Factor Models (DFM), Mixed-Data Sampling (MIDAS), and Combined Forecasting Approaches. The differences in these approaches stem from how they treat the raggedness of the data, the different frequencies, different data ranges considered useful, and how they model the relationship between the different variables and GDP (Bell et al., 2014). The task of a model analyst is to find out which model(s) make(s) the most accurate prediction of GDP.

Monetary policy decision-making in Rwanda, like other public policies, relies on a timely assessment of past, present, and future economic conditions. Assessments of current economic conditions are often complicated by the delay of the GDP data which is usually published in the third month after the end of the reference quarter. This leads to lack of real time GDP data to be used to produce macroeconomic projections in the forecasting round of the reference quarter to better inform the monetary policy committee (MPC). Habimana et al. (2020), Aiolf et al. (2010) and Vlcek et al. (2020) list a publishing schedule for different indicators of varying frequencies that have been used to forecast the Rwandan GDP.

In this context, the National Bank of Rwanda has been producing the GDP nowcast since the establishment of the price-based monetary policy, and the results are incorporated into the Quarterly Projection Model (QPM) to help provide an accurate macroeconomic forecasts, especially regarding the future path of inflation.

The NBR has uses the DFM model to provide the GDP nowcast (Karangwa and Mwenese, 2015). However, the nowcast experience at NBR has been recently characterized by large forecast errors, and according to Mancuso and Werner (2013), significant deviations of forecasts from actuals can lead to a negative impact on economic performance through misguided policy decisions. Thus, the goal of this study is to improve the accuracy of the Real GDP growth nowcast produced by National Bank of Rwanda (NBR), by exploring other nowcasting models.

Apart from the DFM model, which is one of the most used models for forecasting current GDP, this paper will also examine other commonly used models; the bridge equations (B.E.) and MIDAS models whose accuracy has been different for different countries when compared to each other (Kunovac and Špalat, 2014; Bańbura et al., 2013; Kuzin et al., 2009).

This study also adopts the forecast combination technique which is suggested to improve the forecast accuracy by minimizing forecasting errors of individual nowcasting models (Hibon and Evgeniou, 2005; Kapetanios et al., 2008; Aiolf et al., 2010). These bridge equation, MIDAS and forecast combination techniques are compared to the DFM and ARMA models, with the latter two representing the benchmark models.

This paper contributes to a growing literature on GDP nowcasting in Rwanda by examining the performance of the Bridge equation, mixed-data sampling (MIDAS) and the Dynamic factor model (DFM), as well as the combination forecasts of the models.

This paper is divided into five sections, the first being the introduction. Section two presents a description of the forecasting methods being used while the third section discusses the data and empirical results. Section four concludes.

2. Approaches to Nowcast GDP

2.1. The bridge equations.

This nowcast approach is used to estimate many small forecasts and then aggregate them for the final value of the target variable. It is said to be one of the earlier adopted methods of nowcasting using mixed frequency data. It is said to be iterative since it requires several steps in order to forecast the dependent variable. The first step is to deal with the missing observations of the predictor variables by forecasting them using models such as A.R., VAR, and ARMA to fill in the gaps for the remaining projection period of the dependent variable (Schumacher, 2014; Foroni and Marcellino, 2013; Allan et al., 2019).

The second step is aggregating or interpolating the predicting indicators in order to have the same frequency as the dependent variable. Aggregation is a technique for adjusting the high-frequency indicator to match the low-frequency dependent variable. How to aggregate will depend on whether the variable is a stock or a flow. Typically, an average is used for stock variables and a sum for flow variables. Another option for aggregating both flow and stock variables is by using the latest available value for the high-frequency variable. Interpolation, which is rarely used, is adjusting the low-frequency variable to the high-frequency one (Schumacher, 2014).

After aggregation, the third step is to use the aggregated values as regressors in the bridge equation, which has the structure of a simple OLS equation. The variables used may not be based on causal relation but on the timeliness of the updated information. They can be selected using information criterion, RMSE performance, or Bayesian Model Averaging Performance (Foroni and Marcellino, 2013).

The bridge model can be represented as follows;

$$y_{t_q} = a + \sum_{i=n}^{l} \phi y_{t-1\ldots t-n_q} + \sum_{i=1}^{l} \delta_i(L) x_{it_q} + u_{t_q}$$

Where $\delta_i(L)$ is a lag polynomial, and x_{it_q} are selected monthly indicators at a quarterly level q. The equation also contains an autoregressive term $\phi y_{t-1\ldots t-n}$ whose lag order, l, can be determined by information criteria (Anderson & Reijer, 2015).

Each indicator will have its own bridge equation and, therefore, its own forecast of the dependent variable. The final step is then to either find the mean of all projected values or select the best models by selecting them using RMSE.

2.2. The Mixed-Data Sampling (MIDAS) Model

The main feature of this model is that it forecasts using predictors in their original frequencies, whether different, hence its name, and regardless of whether they are jagged or not. MIDAS approach is a more direct approach where the dependent (forecasted) variable is associated with the indicator variables and their lags without aggregation to match the frequency of all variables. In addition, another key factor that distinguishes the MIDAS model is its attempt to use as few parameters as possible(parsimony) through a polynomial which makes it easier to interpret and understand (Foroni and Marcellino, 2013; Schumacher, 2014; Chikamatsu et al., 2018; Allan et al., 2019; Habimana et al., 2020; Laine and Lindblad, 2021).

Laine and Lindblad (2021) illustrate the structure of a simple MIDAS model, which has one explanatory variable;

$$y_t = \beta_0 + \beta_1 \sum_{h=0}^{l} \phi_h x_{tm-h} + u_t \quad (2)$$

where y_t is the dependent low-frequency variable and $x_{tm\ h}$ the high-frequency variable. m is the number of times the high-frequency variable is published by the time the low-frequency variable is published. β_1 shows the association between the predictor and predicted variables. I is the number of lags of the explanatory variable included in the model.

ϕ_h is the function that helps achieve parsimony in the model. It is a polynomial that enables the model to consider and weigh a large number of lags for the high-frequency explanatory variable and its lags. Some lag polynomials that can be used are the Exponential Almond lag polynomial or the smooth lag polynomial, which allow flexible weighting schemes that can even be hump-shaped or decaying (Laine and Lindblad, 2021; Schumacher, 2014). This beats the weighting done by the bridge equation, which implicitly places equal weight, through aggregation, on recent and past values or on more volatile and less volatile periods on explanatory variable observations, yet these make more sense to be weighted differently so as not to lose important information (Allan et al., 2019).

An unrestricted-MIDAS(U-MIDAS) model would be used in the case that the lags included are not so many, such that every lag would have its own regression parameter. Other forms of the MIDAS equation have been detailed by Foroni and Marcellino (2013).

2.3 Dynamic Factor Model (DFM)

Nowcasts have also been estimated by dynamic factor models. This is a dimension reduction technique that summarizes the sources of variation among variables. The behavior of a large number of variables can thus be accounted for by a few unobserved factors due to the high degree of co-movement among them, which is the case for many macroeconomic variables (Doz and Fuleky, 2019; Blanco et al., 2017; Bańbura et al., 2013). It is also used for mixed frequency and jagged data without aggregation.

Each independent variable x_{it} can be illustrated in two parts as follows Doz and Fuleky (2019);

$$x_{it} = \lambda'_i f_t + \epsilon_{it} \qquad (3)$$

In the first part, f_t is the unobserved common component in the variables, while λ'_i is a r 1 vector. The second part, ε_{it}, is an idiosyncratic component that has variations/features specific to each indicator. $\varepsilon_{it} = e_{it} + u_i$, where u_i=the mean of x_i. (Doz and Fuleky, 2019; Andersson and den Reijer, 2015).

The factors are estimated either by the Kalman filter or the Principal Component Analysis (PCA). In DFM models, missing observations due to jaggedness or mixed frequencies are considered to be missing randomly. The Kalman filter handles the missing values by:

"...either allowing the measurement equation to vary depending on what data are available at a given time or by including proxy value for the missing observation while adjusting the model so that the Kalman filter places no weight on the missing observation" (Doz and Fuleky, 2019).

In order to estimate the factors using the PCA, the missing variables have to be imputed using the Expectation-Maximization (E.M.) algorithm (Kunovac and Špalat, 2014; Doz and Fuleky, 2019). To handle missing observations and for other types of factor models. Thus, these two features of DFM analysis enable forecasting for mixed frequency and jagged edge data.

The factor estimates will then be aggregated, and if small enough, they will be regressed against the key dependent variable using a standard regression. It will be assumed that shocks to these factors would represent a shock to the aggregate variable.

2.4 Combined forecasting model

Analysts are increasingly recommending the use of forecast combinations as they provide more accurate forecasts rather than choosing and using one model. Single models might perform well in some periods and not in some. Structural breaks affect their efficacy (Blanco et al., 2017; Chikamatsu et al., 2018).

In the process of using only one model, a lot of potentially useful information is not used in another model, and since we have complicated markets, it is beneficial to include as much information as possible. A combined forecast will also be able to capture distinct features of different models, which normally use different forecasting techniques (Mancuso and Werner, 2013).

A lot of studies that have used single approaches and combined them have unanimously concluded lower forecast errors when the latter approach is used (Galli et al., 2019; Blanco et al., 2017; Lundberg, 2017).

Linear representation of forecasts combination can be written as follows (Chikamatsu et al., 2018);

$$Y_t = \sum^{N} w_{j,t} XY_{j,t} \quad (4)$$

where $w_{j;t}$ is the weight applied to the j_{th} forecast model in period t.

Different weighting schemes have been suggested by different analysts. For example, the system for averaging models (SAM) by Lundberg (2017), where the current weights of predictions are based on their historical performance in predicting accurately. Hibon and Evgeniou (2005) use simple averages for their forecast combinations, meaning equal weight for all. Mancuso and Werner (2013) also describe subjective decision-making using the Delphi method or selecting the best experts for the intuitive selection of models.

3. Empirical Application

3.1 Data

The data used for nowcasting the real GDP growth consist of domestic and foreign variables. The domestic variables are high frequency indicators that can be related to the expenditure approach of the GDP. These indicators are the total turnovers of industry and services sectors that can proxy the consumption, credit to private sector and domestic demand of cement representing the investment and external trade data (exports and imports) for export and imports GDP components. We include also production data for the industry sector, which are the index of industrial production and the electricity.

For the foreign variables, guided by the QPM Vlcek et al. (2020), we collect data on real GDP growth of US and Eurozone as well as purchasing manager index of those economic regions.

In total all these variables amount to 85 variables. To choose which variables to use in the nowcasting models, we compute their correlation with GDP. But, before that, we have seasonally adjusted the data and log differenced them to ensure their stationarity.

Table 1 in appendix show the indicators we used and table 2 indicates the correlation of each variable with GDP. We chose the variables that have a relatively high correlation with the GDP (above 50 percent) to be used in the nowcasting process. The chosen variables are 59.

3.2 Estimation procedure

An individual Bridge and MIDAS equation is estimated for each indicator following the selection of the variables. The Root Mean Square Error (RMSE) is then calculated in order to compare models to benchmark models and select the top model.

3.3 Evaluation method

To check the forecast accuracy of the nowcasting models, we compare the Root Mean (RMSE) of each model with the RMSE of the benchmark model.

$$RMSE = \sqrt{\frac{\sum_{t=1}^{T}(y_t - \hat{y}_t)^2}{T}}$$

where yt and yt hut are the actual and forecast values of GDP growth and T is the total number of forecasts.

The benchmark models consist of ARMA and the dynamic factor model (DFM). The latter is the first nowcasting model used by NBR (see Karangwa and Mwenese, 2015). For ARMA model, we found we find the ARMA (1, 0) to be the best model (see, in appendix table 2 and 3 for estimation results).

3.4 Empirical Results and Discussion

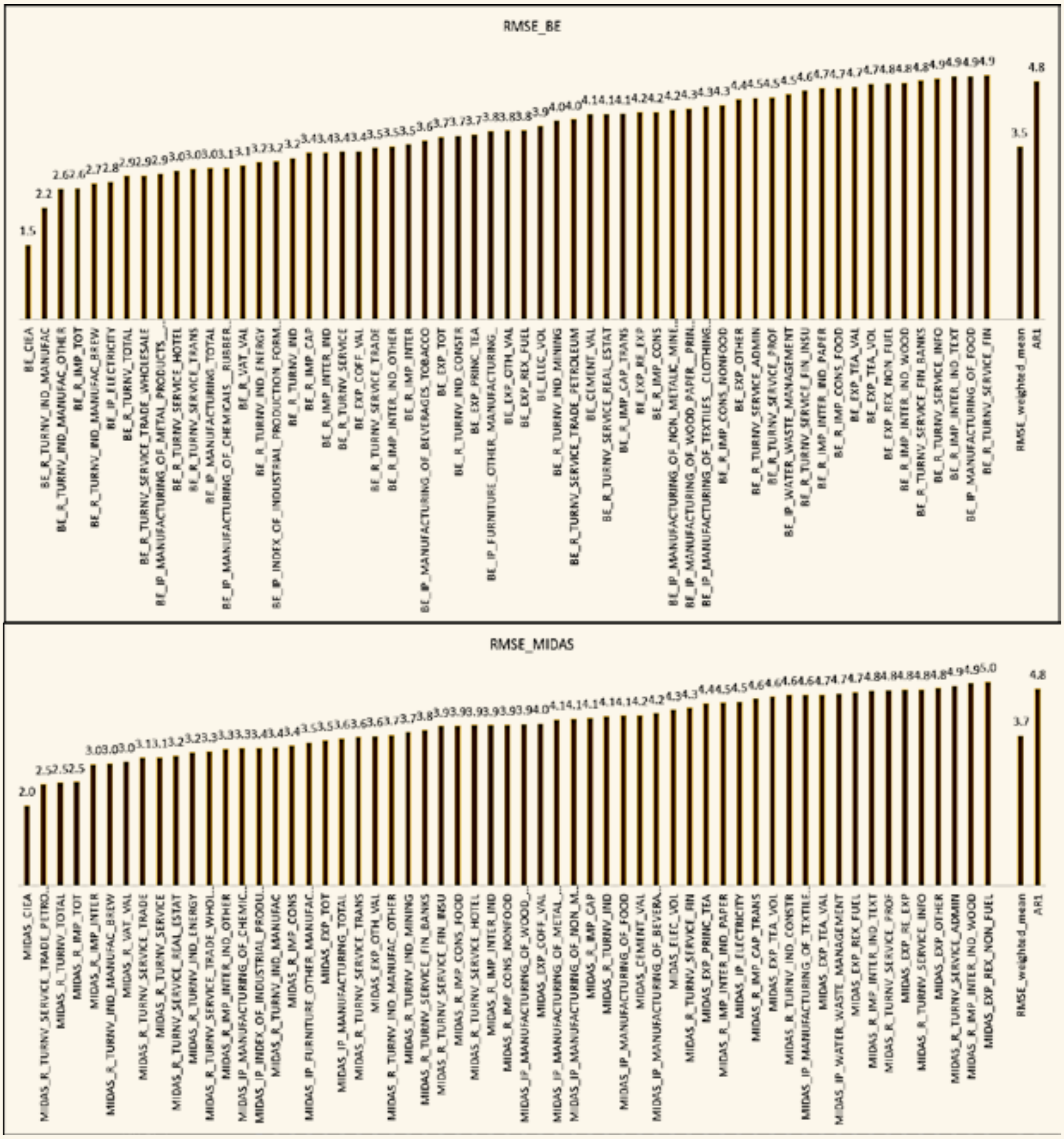
In this section, we evaluate the forecasting performance of each indicator the outcome resulting from univariate autoregressive distributed lag (ARDL) model estimation under both bridge and MIDAS models framework. First, we rank the predictive ability of each model and compare them with the forecast performance of the AR1 model. Afterward, models with lower RMSE relative to the AR1 are combined and the combined forecast is compared to the DFM model predictive ability.

We examine the out-of-sample performance of the nowcasting models during 2019Q1 to 2022Q1. This evaluation is done for the nowcast of GDP as total and the bottom-up approach, where we aggregate the nowcast of agriculture and non-agriculture GDP.

3.4.1 Total GDP

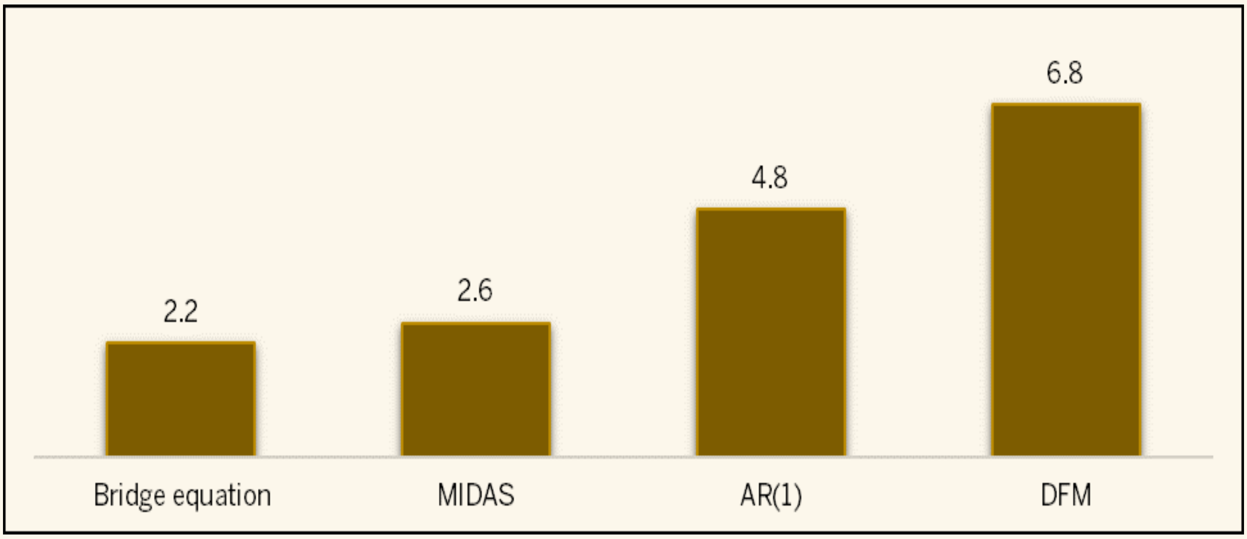
We start by selecting the best set of indicators from both the Bridge equation and MIDAS estimation. We select the all indicators' equation that presents a lower RMSE relative to the main benchmark model. The results shown in figure 1 indicate that both the Bridge and the Midas equations outperform the AR1 model. These findings corroborate with other empirical results indicating the outperformance of Bridge equation and Mixed data et al., 2020; Abdić et al., 2020; Feldkircher et al., 2015). For a more accurate model, we select the indicators whose equation has a smaller RMSE than the RMSE of the weighted average forecast of all indicators.

Figure 1: RMSE of all indicators models from Bridge and MIDAS estimations



Source: Authors' Estimation

Figure 2: Comparison of best indicators bridge equation and MIDAS against the benchmark models



Source: Authors' Estimation

The selected indicators are shown in table 3. This process will always be based on the ranking of the RMSE; hence the indicators in this group are subject to change given their nowcasting performance.

The comparison of the forecast performance of the bridge equation and MIDAS of the final set of indicators indicate that the Bridge equation and MIDAS equations perform well against the benchmark models: AR1 and dynamic factor model (DFM), as indicated in figure 2.

Table 3: Best performing indicators

CIEA	CIEA
Turnovers of manufacturing industries	Petroleum services turnovers
Turnovers of other manufacturing industries	Total turnovers
Total imports	Total imports
Turnovers of brewery industries	Intermediate goods imports
Index of industrial production of electricity	Turnovers of brewery industries
Total turnovers	VAT
Turnovers for wholesale and retail trade	Trade services turnovers
Index of industrial production of metal, machinery and equipment	Services 'sector's turnovers
Turnovers for hotels and restaurants	Real estate turnovers
Transport services turnovers	Energy sector turnovers
Index of industrial production of all manufacturing industries	Turnovers for wholesale and retail trade
Index of industrial production of chemicals, rubber, and plastic	Other industrial products intermediate goods imports
VAT	Index of industrial production of chemicals, rubber, and plastic
Energy sector turnovers	index of industrial production
Index of industrial production	Turnovers of manufacturing industries
Turnovers for industry sector	Consumer goods imports
Capital goods imports	Index of industrial production of furniture and other manufacturing industries
Industrial products intermediate goods imports	Total exports
Services 'sector's turnovers	Index of industrial production of all manufacturing industries
Value of coffee exports	Transport services turnovers
	Other exports

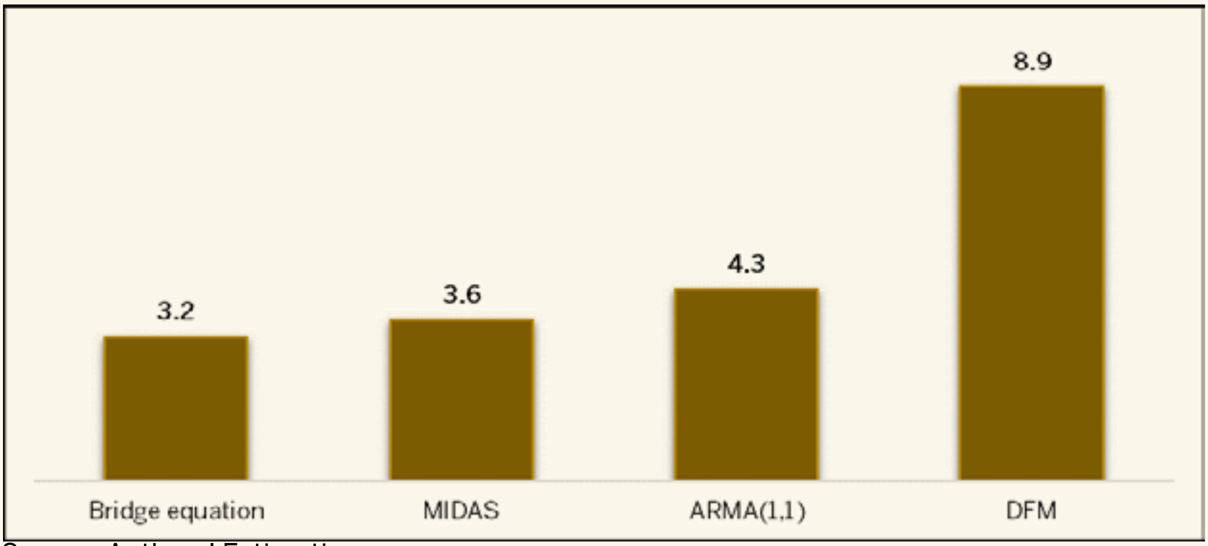
3.4.2 Bottom-up approach

This approach forecasts the agriculture and the rest separately, and GDP would be the sum of these two components. The bridge equation and Midas produce the nowcast for the non-agriculture sector, while the forecast of the agriculture sector is based on ARMA as the existing high-frequency indicators are related to the activities of industry and services sectors.

The agriculture sector was found to follow an autoregressive and moving average of order one after testing ARMA models and observing the Akaike, Swharz, and Hannan-Quin information criteria. We also found that the forecast for agriculture growth is better than the naïve model forecast based on their RMSE, which are 2.1 (ARMA) and 2.3 (Naïve model)

For the non-agriculture sector, we apply the same procedure as on total GDP, where we first select the best indicators (see appendix figure 1 and table 5), and we produce a combined nowcast from the outcome of these indicators' equations, which is compared with the benchmark models.

Figure 3: Comparison of best indicators bridge equation and MIDAS against the benchmark models for the Non-agriculture sector



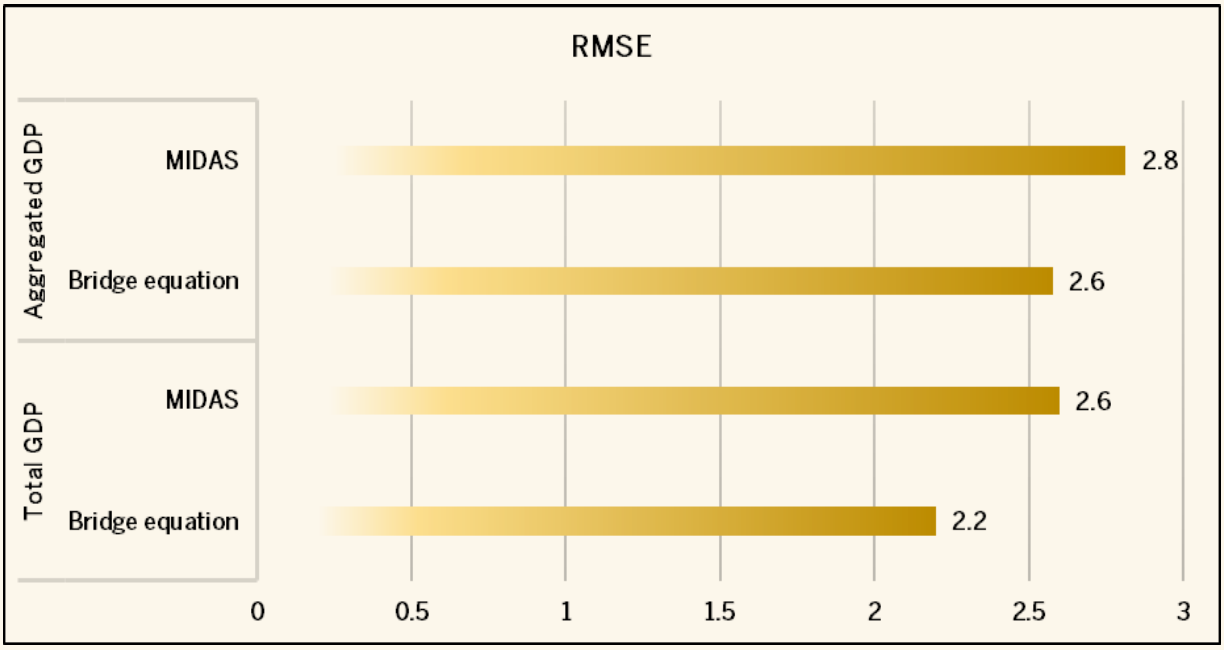
Source: Authors' Estimation

The RMSEs in figure 3 show that the Bridge equation and MIDAS again outperform the Benchmark models and the order of performance is the same as for the nowcast of total GDP.

The aggregation of agriculture and non-agriculture 'sectors' nowcast yield a GDP nowcast that is also better than the results from the benchmark models, as shown in figure 4. However, the performance of the bottom-up approach has a lower performance than the nowcast of total GDP; but this approach has the advantage of providing room to add information or judgment for the agriculture sector, which could improve the overall nowcast performance for the concerned period.

To sum up, these results indicated that the Bridge equation and the MIDAS techniques perform better in nowcasting GDP for Rwanda compared to the ARMA model and the dynamic factor model.

Figure 4: Nowcast performance for bottom-up and total GDP approaches

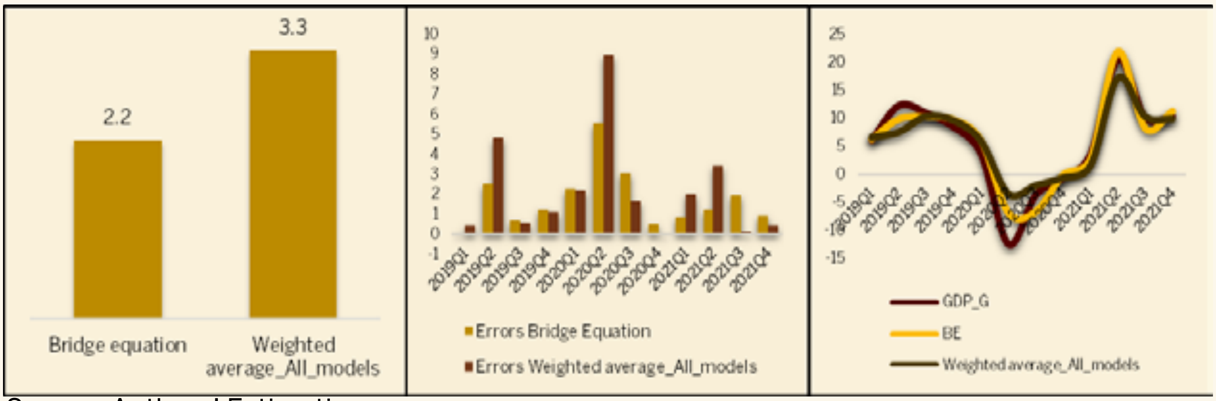


Source: Authors' Estimation

The Bridge equation technique came out as the top performer, but since no single technique can consistently produce best forecast, as observed by Feldkircher et al. (2015), the most efficient technique is to combine the outcome of all the models. This strategy was also used by Kalisa and Uwase (2018) and Habimana et al. (2020) and was found to perform relatively well than considering solely one technique of nowcasting GDP.

Therefore, we tested the performance of a combined forecast of all the models. We observe that the outcome of the combination of all model has a higher RMSE than the Bridge equation. This demonstrates that the Bridge equation outperformed the other models in the evaluation sample.

Figure 5: Bridge equation and combined forecast evaluation



Source: Authors' Estimation

When we look at the evolution of errors for the two forecasting approaches, we note that the combination forecast has a lower absolute error than the Bridge equation in seven out of twelve quarters. This implies that, during the nowcasting exercise, all models and their combinations should be evaluated, and the outcome with the smallest error should be used for the real GDP nowcast for that period.

4. Conclusion

Economic policy decision making, especially monetary policy, depends on the real-time assessment of the current and future macroeconomic conditions. Since the MPC of the NBR convenes every quarter to decide on policy actions aimed at influencing the future path of the economy, especially aimed at fulfilling its main mandate of price stability, such real time assessment of the economy is important. Unfortunately, some key economic indicators such as GDP are often released with a lag of several weeks after the end of the period of interest. Thus, the nowcasting econometric technique offers a remedy to this challenge.

In this paper, we used this technique with the objective of improving the accuracy of the NBR nowcasting system. We evaluated the out of sample nowcasting performance of Bridge equations and mixed data sampling (MIDAS) technique against the dynamic factor and ARMA models. The findings evidenced that these two types of nowcasting technique outperformed the benchmark models and the combination of all the models also was found to improve the accuracy of the GDP nowcast.

Therefore, we recommend upgrading the existing NBR nowcasting system by including the Bridge equations and MIDAS class of models and using the all models combination in the GDP nowcasting exercise. In addition, all models and the combined forecast must be evaluated in order to select the outcome with the smallest error for the relevant period. Furthermore, in pursuit of a more accurate GDP nowcast, we recommend a continuous exploration of new data and indicators, as well as other nowcasting alternatives.

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APPENDIX

Table 1. Series used in the nowcasting models

Indicator	Source	Frequency	Publication lags (months)
Real GDP growth	NISR	Q	3
CIEA	NBR	M	1
Cement	CIMERWA, PRIME CEMENT and RRA	M	1
Electricity	REG	M	1
Coffee exports	NAEB	M	1
Tea exports	NAEB	M	1
Mining exports	RRA	M	1
Other exports	RRA	M	1
Index of Industrial Production (IP)			
IP Mining & quarrying	NISR	M	1
IP Manufacturing of food	NISR	M	1
IP Manufacturing of beverages & tobacco	NISR	M	1
IP Manufacturing of textiles, clothing & leather goods	NISR	M	1
IP Manufacturing of wood & paper; printing	NISR	M	1
IP Manufacturing of chemicals, rubber & plastic products	NISR	M	1
IP Manufacturing of non-metalic mineral products	NISR	M	1
IP Manufacturing of metal products, machinery & equipment	NISR	M	1
IP Furniture & other manufacturing	NISR	M	1
IP Manufacturing Total	NISR	M	1
IP Electricity	NISR	M	1
IP Water & waste management	NISR	M	1
Overall Index (IIP)	NISR	M	1
IMPORTS			
Total Imports	RRA	M	1
Capital imports	RRA	M	1
Capital imports_transport materials	RRA	M	1
Capital imports_Non-transport materials	RRA	M	2
Consumer goods imports_food	RRA	M	1
Consumer goods imports_Non-food	RRA	M	1
Consumer goods imports	RRA	M	1
Energy imports_Non-petroleum	RRA	M	1
Energy imports_Petroleum	RRA	M	1
Energy imports	RRA	M	1
Intermediary goods imports_ construction materials	RRA	M	1
Intermediary goods imports_Fertilizers	RRA	M	1
Intermediary goods imports_Chemicals	RRA	M	1
Intermediary goods imports_food	RRA	M	1

Intermediary goods imports_metals	RRA	M	1
Intermediary goods imports_other industrial products	RRA	M	1
Intermediary goods imports_paper	RRA	M	1
Intermediary goods imports_industrial products	RRA	M	1
Intermediary goods imports_textile	RRA	M	1
Intermediary goods imports_wood	RRA	M	1
Intermediary goods imports_other intermediary goods	RRA	M	1
Intermediary goods imports	RRA	M	1
TURNOVERS (TURNV)			
TURNV_Agriculture	RRA	M	1
TURNV_construction	RRA	M	1
TURNV_energy and water	RRA	M	1
TURNV_breweries	RRA	M	1
TURNV_other manufacturing (other than brewery)	RRA	M	1
TURNV_total manuacturing	RRA	M	1
TURNV_mining	RRA	M	1
TURNV_total industry sector	RRA	M	1
TURNV_total Services sector	RRA	M	1
TURNV_Wholesale and Retail trade; Repair of motor vehicles and motorcycles	RRA	M	1
TURNV_ Wholesale and retail trade	RRA	M	1
TURNV_Petroleum Distributors	RRA	M	1
TURNV_Transport and storage	RRA	M	1
TURNV_Hotels and Restaurants	RRA	M	1
TURNV_Information and Communication	RRA	M	1
TURNV_Financial and insurance	RRA	M	1
TURNV_Banks	RRA	M	1
TURNV_Insurance companies	RRA	M	1
TURNV_Real Estate	RRA	M	1
TURNV_Professional, Scientific and Technical services	RRA	M	1
TURNV_Administrative and Support Services	RRA	M	1
TURNV_Public Sector	RRA	M	1
TURNV_Education	RRA	M	1
TURNV_Human Health and Social Work	RRA	M	1
TURNV_Arts, Entertainment and Recreation	RRA	M	1
TURNV_Other Services	RRA	M	1
TURNV_TOTAL	RRA	M	1
VAT	RRA	M	1
US GDP	Federal Reserve Economic Data	Q	1

EUROZONE GDP	Federal Reserve Economic Data	Q	1
US PMI	Bloomberg	M	1
EUROZONE PMI	Bloomberg	M	1

Table2. Indicators correlation with GDP

Variable	IP_ELECTRICITY	IP_FURNITURE_OTHER_MANUFACTURING_	IP_INDEX_OF_INDUSTRIAL_PRODUCTION_FORMAL_ACTIVITY	IP_MANUFACTURING_OF_BEVERAGES_TOBACCO	IP_MANUFACTURING_OF_CHEMICALS__RUBBER_PLASTIC_PRODUCTS	IP_MANUFACTURING_OF_FOOD	IP_MANUFACTURING_OF_METAL_PRODUCTS__MACHINERY_EQUIPMENT	IP_MANUFACTURING_OF_NON_METALIC_MINERAL_PRODUCTS
Correlation	99.2	94.8	98.0	86.2	93.6	87.9	92.8	93.1
Variable	IP_MANUFACTURING_OF_TEXTILES__CLOTHING_LEATHER_GOODS	IP_MANUFACTURING_OF_WOOD_PAPER__PRINTING	IP_MANUFACTURING_TOTAL	IP_MINING_QUARRYING	IP_WATER_WASTE_MANAGEMENT	CEMENT_VAL	CEMENT_VOL	CIEA
Correlation	90.9	90.8	97.2	15.0	95.4	83.9	30.9	99.2
Variable	ELEC_VAL	ELEC_VOL	R_CPS	R_IMP_CAP	R_IMP_CAP_TRANS	R_IMP_CONS	R_IMP_CONS_FOOD	R_IMP_CONS_NONFOOD
Correlation	97.1	98.3	96.7	58.6	67.0	83.4	79.9	51.0
Variable	R_IMP_ENER_NON_PETROLEUM	R_IMP_ENER_PETROLEUM	R_IMP_ENERG	R_IMP_INTER	R_IMP_INTER_CONSTR	R_IMP_INTER_FERT	R_IMP_INTER_IND	R_IMP_INTER_IND_CHEM
Correlation	48.9	44.7	46.7	79.0	17.4	24.5	86.5	24.0
Variable	R_IMP_INTER_IND_FOOD	R_IMP_INTER_IND_METAL	R_IMP_INTER_IND_OTHER	R_IMP_INTER_IND_PAPER	R_IMP_INTER_IND_TEXT	R_IMP_INTER_IND_WOOD	R_IMP_INTER_OTHER	R_IMP_TOT
Correlation	36.9	-27.7	88.6	86.7	83.9	62.4	30.2	89.5
Variable	R_IMP_TRANS_NON_TRANS	R_TURNV_AGR	R_TURNV_IND	R_TURNV_IND_CONSTR	R_TURNV_IND_ENERGY	R_TURNV_IND_MANUFAC	R_TURNV_IND_MANUFAC_BREW	R_TURNV_IND_MANUFAC_OTHER
Correlation	41.0	37.1	99.0	92.1	97.1	99.0	97.4	98.7
Variable	R_TURNV_IND_MINING	R_TURNV_SERVICE	R_TURNV_SERVICE_ADMIN	R_TURNV_SERVICE_ARTS	R_TURNV_SERVICE_EDUC	R_TURNV_SERVICE_FIN	R_TURNV_SERVICE_FIN_BANKS	R_TURNV_SERVICE_FIN_INSU
Correlation	79.0	98.0	89.4	23.5	28.4	96.7	96.8	93.4
Variable	R_TURNV_SERVICE_HEALTH	R_TURNV_SERVICE_HOTEL	R_TURNV_SERVICE_INFO	R_TURNV_SERVICE_OTH	R_TURNV_SERVICE_PROF	R_TURNV_SERVICE_PUBLIC	R_TURNV_SERVICE_REAL_ESTAT	R_TURNV_SERVICE_TRADE
Correlation	41.9	56.3	84.9	-60.7	91.0	33.1	87.3	97.8
Variable	R_TURNV_SERVICE_TRADE_PETROLEUM	R_TURNV_SERVICE_TRADE_WHOLESALE	R_TURNV_SERVICE_TRANS	R_TURNV_TOTAL	R_VAT_VAL	EXP_COFF_VAL	EXP_COFF_VOL	EXP_MINING_VAL
Correlation	78.3	96.8	92.9	98.7	97.7	67.7	17.9	38.5
Variable	EXP_MINING_VOL	EXP_OTH_VAL	EXP_OTHER	EXP_PRINC	EXP_PRINC_CASSITERITE	EXP_PRINC_COFFEE	EXP_PRINC_COLTAN	EXP_PRINC_HIDESANDSKIN
Correlation	-5.1	79.3	73.4	16.3	-25.7	18.0	-13.4	-57.6
Variable	EXP_PRINC_PYRETHRUM	EXP_PRINC_TEA	EXP_PRINC_WOLFRAM	EXP_RE_EXP	EXP_REX_FUEL	EXP_REX_NON_FUEL	EXP_TEA_VAL	EXP_TEA_VOL
Correlation	1.7	85.3	39.4	96.9	77.1	93.9	94.1	88.7
Variable	EXP_TOT	USGDP	EuroGDP	US_PMI	Euro_PMI			
Correlation	87.7	43.6	45.4	11.2	30.2			

Table 3: Lag length selection and estimated results for the ARMA benchmark model

ARMA order	Akaike	Schwarz	Hannan-Quinn
0,0	5.893520	5.928124	5.907081
0,1	5.720025	5.823838	5.760710
1,0	* 5.692344	* 5.796157	* 5.733029
1,1	5.722835	5.861253	5.777082
* indicates best model			

Table 4: Estimation results of ARMA(1,0)

Dependent Variable: GDP_Y				
Method: ARMA Maximum Likelihood (BFGS)				
Sample: 2007Q1 2022Q1				
Included observations: 61				
Convergence achieved after 4 iterations				
Coefficient covariance computed using outer product of gradients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7.184786	1.097048	6.549197	0.0000
AR(1)	0.488333	0.164880	2.961747	0.0044
SIGMASQ	15.66831	1.274495	12.29374	0.0000
R-squared	0.237548	Mean dependent var		7.050914
Adjusted R-squared	0.211256	S.D. dependent var		4.570819
S.E. of regression	4.059401	Akaike info criterion		5.692344
Sum squared resid	955.7668	Schwarz criterion		5.796157
Log likelihood	-170.6165	Hannan-Quinn criter.		5.733029
F-statistic	9.035175	Durbin-Watson stat		1.920439
Prob(F-statistic)	0.000384			
Inverted AR Roots	.49			

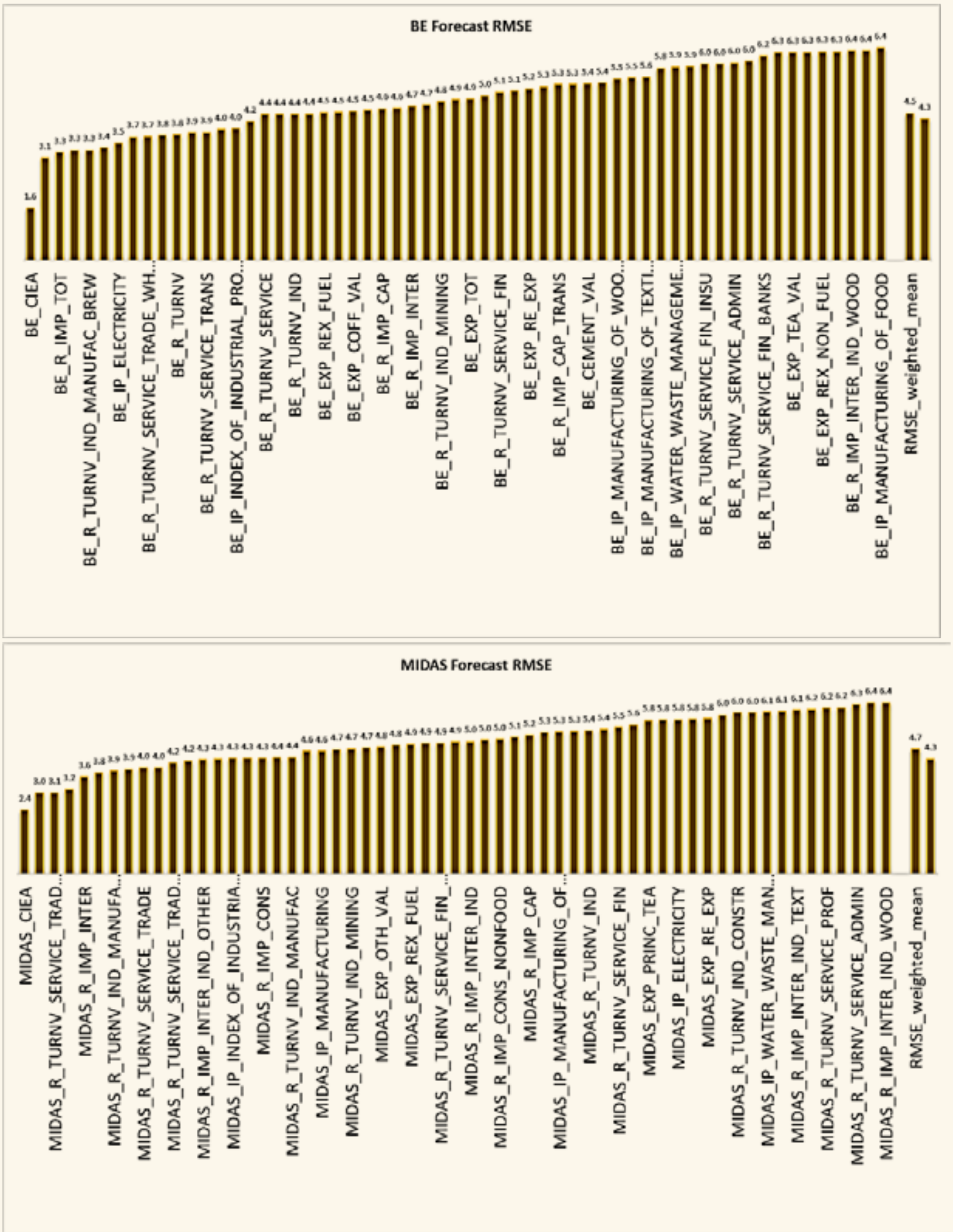
Table 5: **Table 3: ARMA test results for agriculture sector model**

ARMA order	Akaike	Schwarz	Hannan-Quinn
0,0	12.070	12.103	12.083
0,1	10.870	10.970	10.909
1,0	7.607	7.708	7.647
1,1	* 7.553	* 7.687	* 7.606
* indicates best model			
RMSE			
Na#ve model	2.306		
ARMA (1,1)	2.127		

Table 6: Best performing indicators for Non_agriculture GDP nowcast

Bridge Equation	MIDAS
CIEA	CIEA
total turnovers of all manufacturing industries	Total imports
Total imports	Petroleum services turnovers
Industrial products intermediate goods imports	Total turnovers
Turnovers of brewery industries	Intermediate goods imports
Turnovers of other manufacturing industries	VAT
Index of industrial production of electricity	Turnovers of brewery industries
Index of industrial production of metal, machinery and equipment	Services sector's turnovers
Turnovers for wholesale and retail trade	Trade services turnovers
Index of industrial production of all manufacturing industries	Real estate turnovers
Total turnovers	Turnovers for wholesale and retail trade
Index of industrial production of chemicals, rubber and plastic	Energy sector turnovers
Transport services turnovers	Other Industrial products intermediate goods imports
VAT	Index of industrial production of chemicals, rubber and plastic
Index of industrial production	index of industrial production
Energy sector turnovers	coffee exports
Services sector total turnovers	Consumer goods imports
Other Industrial products intermediate goods imports	Index of industrial production of furniture and other manufacturing industries
Industry sector total turnovers	total turnovers of all manufacturing industries
Turnovers for hotel and restaurants	Total exports
	Index of industrial production of all manufacturing industries

Figure 6: RMSEs ranking of Bridge equations and MIDAS' GDP nowcast



DETERMINANTS OF COMMERCIAL BANKS' EFFICIENCY IN RWANDA

Mathias Karangwa[a], Callixte Kamanzi[b]

[a] *Senior Principal Economist, Research Department, National Bank of Rwanda*

[b] *Senior Economist, Research Department, National Bank of Rwanda*

Abstract

This study investigates the drivers of cost efficiency of 10 Rwandan commercial banks for the 2012Q1-2021Q3 period, using the true fixed effects model, which makes it possible to integrate unobserved bank-specific heterogeneity in the inefficiency function at the mean level. This study is in line with the central bank's role of ensuring financial stability. The study builds on Gisanabagabo and Ngalawa (2017), the only study about the subject matter in Rwanda, to make the necessary adjustments: First, this study uses a larger sample with respect to time and number of commercial banks; Second, the study also uses a more flexible translog cost function, rather than a linear function and it models heterogeneity across banks as part of the inefficiency term rather than using individual dummy variables as this may lead to over-parameterization; Finally, the study deals with correlation among variables in both the inefficiency function and the cost function by implementing a single-step estimation procedure. Empirical estimations show that credit risk positively affects inefficiency while intermediation ratio, bank funding structure, and capital ratio negatively affect inefficiency, especially since 2018. The estimated efficiency score stands at 81.3 percent compared to 88.56 percent obtained by Gisanabagabo and Ngalawa (2017), and the differences are due to the employed methodologies and samples. The paper recommends that Rwandan commercial banks should strengthen existing measures to further mitigate credit risk, and increase intermediation, funding structures, and capitalization so as to deal with macro-financial shocks.

***Key Words**: Stochastic Frontier, Cost Efficiency, Rwandan Commercial Banks, Panel.*

***JEL Classification Numbers**: C23, C24, D21, G21, G28.*

1. Introduction

Availability and efficient use of financial resources are one of longstanding economic development challenges. In a developing country like Rwanda, where the banking sector is dominant, banks can influence economic performance if they can efficiently perform their intermediation role (Levine, 1997). Efficient intermediation implies that commercial banks can efficiently mobilize savings and channel them to productive activities and thus impact economic growth and development. In addition, commercial banks need to be efficient so as to be able to cushion themselves from competitors and macro-financial shocks. Commercial banks are considered to be efficient if: (1) they can generate high profits; (2) they are well-capitalized and able to mitigate risks; and (3) they can offer good quality financial products to clients at favorable prices (Berger et al., 1993b). For a central bank that cares about financial sector stability and economic growth, the analysis of commercial banks' efficiency is a very important exercise as it can lead to recommendations that can inform policy geared towards improving efficiency.

As noted by Karangwa and Nyalihama (2018), Rwanda's financial sector has continued to grow following financial liberalization that started in 1995 and the putting in place of a more regulatory and supervisory framework conducive to financial sector development. Before 1995, there were 5 banks in Rwanda (Karangwa and Nyalihama, 2014). However, the number of banks increased from 8 in 1995 to 18 in 2017 (Karangwa and Nyalihama, 2018) and then to 16 as at the end of March 2020 (Kigabo, 2021). As of the end March 2021, the number of banks still stood at 16, including 11 commercial banks, 3 microfinance banks, 1 development bank, and 1 cooperative bank (NBR, 2022).

In its vision 2050, Rwanda aspires to attain an upper middle-income status by 2035 and a high-income status by 2050, with an annual GDP per capita of US$4,035 and US$12,476, respectively. This ambitious long-term development agenda will be achieved by recording high sustained economic growth, supported by a well-developed and efficient financial system. Despite the noticeable expansion of Rwanda's financial sector, especially in the post-1995 period, financial sector development is still impeded by some structural challenges. For example, the deposit-to-GDP ratio stood at 17.4 percent in 2017, private credit by deposit money banks to GDP ratio stood at 19.9 percent, while bank credit to bank deposits ratio stood at 114.1 percent during the same period. These numbers imply that the mobilization of savings by the banking system is still not enough to cover the demand for credit in the economy.

Like most of its East African peers, the table 1 indicates that by 2019, Rwanda still had high bank overhead costs to total assets ratio (6.5 percent) compared to 1.3 percent for a high-income country like Singapore with a highly developed financial system. The net interest margin, which is one of the measures of the efficiency of intermediation, stood at 9.3

percent in Rwanda compared to 1.9 percent in Singapore and 3.7 percent in South Africa, indicating that intermediation efficiency is still low in Rwanda.

The main cause of intermediation inefficiency in Rwanda has been reported to be credit risk (non-performing loans or loan loss provisions), overhead costs, loans' market concentration, the real economy (inflation or economic activities), and alternative financial investment opportunities, especially the treasury bills (Karangwa and Nyalihama, 2014; Kigabo et al., 2016; Karangwa and Nyalihama, 2018; Kigabo and Barebereho, 2007) noted that the lending rate is more rigid compared to the deposit rate. The volatility in the deposit rate was mainly driven by the fact that the deposit market is dominated by large depositors with negotiating power, the emergence of new competing investment opportunities like T-bills, and economic activities that affect the balance sheets of depositors. Conversely, the rigidity in the lending rate was influenced by operating costs, loans' market provisions, and loan loss provisions as a measure of credit risk.

While intermediation efficiency in Rwanda has been studied, the wider scope of banks' efficiency has not been adequately investigated. Intermediation efficiency is one aspect of bank efficiency as the latter may include either cost efficiency or profit efficiency, which are basically two sides of the same coin as per the duality theorem (i.e., there is a duality between cost minimization and profit maximization). The only study on Rwanda that examined cost efficiency was by Gisanabagabo and Ngalawa (2017). The study estimated a linear cost function and a linear function for the inefficiency term using annual data on seven (7) Rwandan commercial banks covering the period 2007-2013.

The Gisanabagabo and Ngalawa (2017) study was based on the intermediation approach, where operating income was used as the output, whereas operating cost was used as the input. They measure total costs as total interest paid on deposits and borrowed funds plus non-interest operating costs. The output (i.e., operating income) is divided into the total amount of interest income and total non-interest income. Other included variables are the price of capital normalized by the price of labor, the ratio of the price of funds to the price of labor, a time trend, and dummy variables capturing bank-specific characteristics. The price of capital is measured as the depreciation of both physical capital and intangibles, while the price of labor is the total bill for wages, salaries, and other fringe benefits. The price of funds is measured as the total amount spent as interest on deposits and borrowed funds. The bank-specific variables are management, foreign, and government. Foreign equals 1 if majority shareholders are foreign and 0 otherwise, government equals 1 if major government intervention occurred to prevent bank bankruptcy and 0 otherwise; management equals 1 if a bank had a minimum of 2 CEOs in the 2007-2013 period and 0 otherwise. These measures of bank heterogeneity are considered as the only explanatory variables in the linear inefficiency model.

This paper addresses the identified research gaps in the Gisanabagabo and Ngalawa (2017) study. First, the study used fewer observations (i.e., annual data for 2007-2013), which we address by using 2012Q1-2021Q3 data for 10 (rather than 7) commercial banks.

Second, the use of a linear cost function has also been contested in the literature, where more data consistent functional forms, such as the Cobb-Douglas and Translog functions, are more preferred. A linear cost function assumes that the effect of each variable on total cost is the same over time. In this paper, we use a flexible translog function as in Gunes and Yildirim (2016) because it permits substitution effects among inputs and is claimed to be a relatively dependable approximation to reality (Battese and Coelli, 1995).

Third, the inclusion of dummy variables to capture bank-specific heterogeneity may lead to over-specification of the cost function, leading to underestimation of the inefficiencies. To overcome this, we allow the heterogeneity to be part of the inefficiency distribution and thus account for unobserved bank-specific heterogeneity at a mean level in cost efficiencies. We then specify a time-varying inefficiency function with a vector of time-variant variables hypothesized to influence bank efficiency (Greene and Segal, 2004). These time-variant drivers of inefficiency are usually balance sheet variables (Berger et al., 1993b). Fourth, since the sample of Rwandan commercial banks is not random, we estimate the flexible translog cost function assuming true fixed effects (Farsi et al., 2006). Fifth, this study is further supported by the fact that since 2013, there have been increased investments, especially in technology (e.g., software) and digital financial infrastructure, aimed at scaling up the operational efficiency of commercial banks. Thus, it is worth investigating whether this has affected the cost efficiency of banks.

Table 1: Financial structure and intermediation for selected economies

Country	Year	WBIG	LL-GDP	PC-GDP	BD-GDP	BC-BD	BO-TA	NIM	BC
Burundi	2017	LIC	23.4	14.6	18.5	79.0	4.3	9.6	91.9
Kenya	2017	LMIC	36.0	29.6	32.7	90.5	6.0	9.4	36.6
Rwanda	2017	LIC	19.5	19.9	17.4	114.1	6.5	9.3	58.2
Singapore	2017	LIC	127.6	125.0	118.6	105.4	1.3	1.9	89.3
South Africa	2017	UMIC	42.9	64.4	57.9	111.1	3.6	3.7	76.7
Tanzania	2017	LIC	20.9	13.2	16.7	79.2	7.2	9.4	48.9
Uganda	2017	LIC	16.6	13.4	17.4	77.4	6.7	10.3	54.2

WBIC: World Bank Income Group; LIC: Low-Income Country; LMIC: Lower-Middle Income Country; UMIC: Upper-Middle Income Country; LL-GDP: Liquid Liabilities to GDP (in percentage); PC-GDP: Private Credit to GDP (in percentage); BD-GDP: Bank Deposits to GDP (in percentage); BC-BD: Bank Credit to Bank Deposits (in percentage); BO-TA: Bank Overhead costs to Total Assets (in percent); NIM: Net Interest Margin (in percentage); BC: Bank Concentration (in percentage).

Source: Financial structure database of Beck et al., 2019, 18th October 2019.

Finally, unlike in the Gisanabagabo and Ngalawa (2017) study, we estimate the cost function and the inefficiency function simultaneously rather than following a two-step procedure, where the cost function is estimated first, inefficiency scores are derived and then used in the estimation of the inefficiency function (Kalirajan, 1981). The estimation of inefficiency using the two-step procedure is quite flawed, as noted by Coelli (1996). This is because the factors that are included in the inefficiency function are also included as some of the explanatory variables in the cost function, which makes the estimated inefficiencies not independently and identically distributed. The solution to this is the use of a single-step estimation procedure to control for correlation between variables included in the cost function and those included in the inefficiency function (Kumbhakar, 1996).

In the one-step procedure, the inefficiency effects are well-defined as a function of the bank-specific factors and combined directly into the maximum likelihood (ML) estimation. Our focus on commercial banks is based on the fact that they account for about 67 percent of the total assets for the entire financial sector (NBR, 2022; Kigabo, 2021), while 10 commercial banks for which data were existing for the 2012q1-2021q3 period are chosen. This study is built on the following research questions:

(1) What is the degree of efficiency in Rwanda across the selected commercial banks and across time? (2) What are the driving factors for commercial banks' efficiency in Rwanda?

The remainder of this paper is structured as follows: Section 2 highlights the literature on bank efficiency. Section 3 gives the methodology employed in the empirical analysis. Section 4 discusses financial sector development in Rwanda and also presents the results from the empirical estimations. Lastly, Section 5 concludes the paper.

2. Literature review

For a developing country, the attainment of sustainable economic growth and development requires the contribution of a stable and efficient banking system (Gunes and Yildirim, 2016). A banking system that can efficiently mobilize resources and channel them to their most productive use is needed to promote economic growth (Freixas and Rochet, 2008). According to Cihák et al. (2012), banks are likely to be more efficient if they can screen and identify firms with the most profitable investments and when they can monitor the use of funds and scrutinize the managerial performance of corporations that borrowed from them as this reduces wastage of resources and fraud by corporate insiders.

Generally, bank efficiency means the ability of a bank to produce maximum output using a minimum amount of inputs (Kablan, 2010). Studies on bank efficiency generally focused on the measurement of cost efficiency (Lelissa, 2014), profit efficiency (Isik and Hassan, 2002), or both profit and cost efficiency (Ncube, 2009).

In the aftermath of the 2008 global financial crisis, researchers and policymakers focused on unpacking the causes of financial fragility and the measures to ensure financial stability. Recently, attention has shifted to assessing bank efficiency amidst complexities brought about by financial innovations, cross-border operations, interconnectedness, and emerging regulations (Kiemo and Kamau, 2021).

Studies on bank efficiency across the world have generally focused on the measurement of inefficiency levels as well as ascertaining the main factors behind such inefficiencies so as to inform policy reforms. Both cost and profit efficiency levels have been reported to be lower in developing countries compared to developed countries. Bank efficiency is expected to improve, especially in the aftermath of reforms such as privatization and financial liberalization, foreign entry of new banks, mergers and acquisitions, as well as changes in macroeconomic and regulatory conditions (Tecles and Tabak, 2010).

Most of the studies on bank efficiency have been conducted for the case of developed countries (Berger and Humphrey, 1997), Asian countries (Maggie and Heffernan (2007); Aigner et al. (1977) and Latin America (Carvallo and Kasman, 2005), while few studies have covered African, particularly Sub-Saharan Africa (Miencha, 2015). The little interest in Sub-Saharan Africa has been due to the low level of financial development, a nascent banking sector, a limited number of market activities, and a lack of good quality data (Chen et al., 2009).

For the case of Central and Eastern Europe, Kasman and Yildirim (2006) investigated cost and profit efficiency for the eight countries that had become new members of the European Union. Their study used data covering 190 banks for the period 1995-2002. They used country-specific variables so as to account for the differences in macroeconomic and financial conditions among these countries. Based on the estimations from the Fourier flexible cost and profit functions, their findings indicate that foreign banks are generally more efficient compared to domestic banks. They also indicate that the banking systems in these countries are cost/profit inefficient: on average, cost efficiency stood at 0.2 while profit efficiency stood at 0.36, and that efficiency levels are not improving over time. Also, cost and profit efficiency scores vary across countries and across different size groups.

Berger and Humphrey (1997) surveyed 130 frontier efficiency studies for 21 countries. Though these studies use different methodologies and cover different institutional types and data, the general conclusion is that there is a prevalence of inefficiency in financial institutions across the world. On average, 20 percent of the increase in costs is due to inefficiency, which dominates scale and scope economies. Hasan et al. (2009) estimated a translog cost frontier using data for 152 countries and found that mean efficiency for the banking sector ranged between 28 percent and 91 percent.

A study by Kiyota (2009) covering 29 Sub-Saharan (SSA) countries during the 2000-2007 period concluded that there was a relative increase in cost inefficiency, standing between 1.05 percent and 1.06 percent for the countries included in the sample. Their findings are based on the estimation of a translog cost function. Kablan (2010) found that Sub-Saharan banks are cost-efficient but argues that efficiency levels could be further improved via better functioning judicial and legal systems as well as the increased access to information on borrowers to help curb the problem of high non-performing loans, highlighted as a major impediment to efficiency in SSA.

A study by Kablan (2007) on West African Monetary Union (WAMU) member countries covering the period 1993-1996 concluded that the banking sector was generally cost-efficient, with an average efficiency score of 67 percent. Their findings are based on estimations from a translog cost function.

At the country level, most studies found that the banking institutions were cost-efficient. For the case of Ethiopia, Data Envelopment Analysis (DEA) estimations using data covering the 2008-2012 period indicate that the average efficiency of the banking sector stood at 86.7 percent, meaning that only 12.3 percent of resources were wasted. Estimations from a translog cost function covering data for 8 South African commercial banks indicated an improvement in cost efficiency over time, from 40.4 percent in 2000 to 66.2 percent in 2005 (Ncube, 2009). Hasan et al. (2009) concluded that the mean efficiency of the banking sector stood at more than 90 percent in Micronesia, Ethiopia, and Honduras.

Some studies justify high-cost efficiency scores with policy reforms such as privatization and financial liberalization/financial sector reforms. These were generally carried out on a group of emerging countries (Fries and Taci, 2005) as well as on a single-country basis (Hauner and Peiris, 2005). These reforms were often put in place as a response to certain macro-financial shocks. For example, in response to the banking crisis of the 1980s, monetary authorities adopted strict regulatory measures to ensure financial stability by setting up a single supervisory body for WAEMU countries and for Central African countries, respectively. In other SSA countries, the role of supervision was entrusted to central banks (Kablan, 2010).

In line with the above, Hauner and Peiris (2005) used the DEA method to estimate efficiency scores for Ugandan commercial banks covering the period 1999-2004 and concluded that cost efficiency stood at an average of 92.6 percent, supported by the privatization of the largest commercial bank (i.e., Uganda Commerical Bank) that led to increased competition. However, findings regarding the effect of policy reforms on the cost efficiency of banks are quite mixed. For example, financial liberalization helped to increase cost efficiency in Taiwan (Chen, 2001) but led to reduced/weak cost efficiency in Croatia Kraft et al. (2006) and Korea (Hao et al., 2001).

In the case of East Africa, Podpiera and Cihak (2005) concluded that banks were generally inefficient in Kenya, Tanzania, and Uganda despite the banking reforms carried out in those countries and the entry of foreign banks. Other studies link efficiency levels with macro-financial shocks. For example, due to the global financial crisis, inefficiency increased from 8.56 percent to 13 percent for Tanzanian banks. (Aikaeli, 2006) findings were based on the estimation of a translog cost frontier using data for Tanzania for the 1998-2004 period. However, DEA results showed that commercial banks were technically efficient, with efficiency scores standing at 96.1 percent under the Constant Returns to

Scale (CRS) assumption and at 97.5 percent under the Variable Returns to Scale (VRS) assumption. For Kenya, Kamau (2011) found that commercial banks' efficiency scores were low, owing to the global financial crisis. These mixed findings are partly due to differences in methodology, that is, parametric (stochastic frontiers) versus non-parametric (Data Envelopment Analysis).

The studies that associate efficiency levels and the age of the bank (i.e., old versus new) include Kraft et al. (2006), who argued that old banks are more likely to be efficient compared to new ones. Their argument is that the old banks have gained business experience, have better managerial efficiency, and thus operate closer to the efficiency frontier. Studies that analyze the effect of bank ownership structure on bank efficiency are quite varied in terms of empirical findings and scope.

With respect to scope, some studies focus on assessing efficiency levels for publicly versus privately owned banks, while others focus on domestic versus foreign banks. For the case of Kenya, the average efficiency score for public banks was relatively higher compared to private banks, though the difference is not all that big. Hasan and Marton (2003) concluded that banks with foreign ownership were more efficient compared to those with domestic ownership, and this could be related to the fact that foreign banks tend to import modern technologies, such as the computerization of bank processes and use of Automated Teller Machines, from their home countries (Kablan, 2010). Conversely, domestic banks were found to be more efficient compared to foreign banks for the case of Malaysia (Tahir et al., 2010). For the case of Ghana, Buchs and Mathisen (2005) found that foreign banks were more efficient in generating revenue (interest, commissions, and fees).

The entry of foreign banks can be beneficial if they own a big share of banking system assets and import innovative intermediation methods. Some studies have argued that foreign bank penetration is higher in Anglophone countries than in Francophone African countries and that in the former, banks tend to be efficient owing to better management and technology (Kirkpatrick et al., 2008). Increased entry of foreign banks was also found to reduce inefficiency in the case of 11 transition economies (Bonin et al., 2005). A combination of entry of foreign banks and privatization was found to positively affect efficiency in 22 developing countries (Boubakri et al., 2005).

While studies on measurement and drivers of efficiency have been extensively studied for individual African countries and sub-regions, Gisanabagabo and Ngalawa (2017) did the only study on Rwanda. Using data for seven (7) Rwandan commercial banks for the 2007-2013 period, the stochastic frontier estimations showed that average efficiency stood at 88.56 percent but varied across banks with respect to bank ownership (foreign versus domestic) and management as measured by the tenure of the bank's executive officers

(CEOs). Foreign ownership increased efficiency while the short tenure of CEOs increased inefficiency. The paper argues that foreign ownership is linked to the importation of new technologies and better management practices. In this study, we build on the Gisanabagabo and Ngalawa (2017) paper and make certain modifications to address the research gaps mentioned in the introduction section.

4. Methodology

The empirical literature has focused on the estimation of efficiency scores as well as on the determination of the drivers of efficiency (De Abreu and Ceglia, 2018). Both the Data Envelopment Analysis (DEA) and Stochastic Frontier Approach (SFA) have been used to measure the degree of efficiency of firms, particularly of financial institutions such as banks. Being a parametric method, the SFA is more advantageous compared to the DEA (i.e., a non-parametric method).

The main challenge highlighted in most of the studies is the estimation of the efficiency frontier, which is defined by the efficiency levels of the best-performing firms in the sample. For the case of commercial banks, there is generally no sufficient information regarding their production and cost-management technologies. Thus, researchers rely on accounting data from the banks' financial statements regarding costs, inputs, outputs, revenues, and profits to impute efficiency levels and to define the efficiency frontier. Both parametric and non-parametric approaches have been used to measure efficiency levels and to estimate the efficiency frontier. The Non-parametric approaches put relatively less emphasis on the specification of the best practice frontier. Being mathematical programming tools, they assume that there are no random errors.

In reality, however, there are likely to be random errors due to, for example, measurement errors that can lead to biased estimation of efficiency levels. Conversely, the parametric approach imposes a functional form (and the associated behavioral assumptions) that pre-defines the shape of the frontier. The main drawback of the parametric approach is that the misspecification of the functional form leads to a biased estimation of the efficiency frontier and efficiency scores of the firms in the sample. There is generally no consensus regarding which of the two approaches is better in terms of yielding efficiency scores that are close to reality (Berger et al., 1993a).

There is consensus that the SFA has advantages over the DEA. First, the SFA enables the decomposition of the error term into a random and inefficient term, with the former capturing measurement error and exogeneous shocks. Second, the SFA results are not greatly contaminated by outliers. The SFA estimates the frontier, which is the possible maximum output given a set of inputs. The best performing banks are on the frontier, while the relatively inefficient ones are below the frontier. The frontier and bank-level efficiency scores are determined from estimations of a given objective function, which are generally production, cost, and profit functions. The objective function can be linear, Cobb-Douglas, Constant Elasticity of Substitution (CES), Fourier transformation, and translogarithmic, among others. Third, the SFA enables the identification of variables that significantly affect efficiency.

Even though "…the choice between the various parametric models and estimation procedures is based primarily on ease of use and/or the apparent reasonableness of underlying assumptions, rather than on any strong theoretical foundation" (Berger and Humphrey, 1997), the SFA is generally more advantageous compared to the other parametric approaches, namely, the Distribution Free Approach (DFA) and the Thick Frontier Approach (TFA). The main weaknesses of the DFA are that: (1) it assumes that the inefficiency of a particular firm/bank is stable over time. This is unrealistic since inefficiency levels can vary over time due, for example, to deterioration in bank management; (2) it does not impose a distribution assumption of the inefficiency term. In fact, the inefficiency term can follow any distribution as long as estimated inefficiencies are positive, and (3) the mean of the random error converges to zero over time. The TFA is often criticized based on the fact that: (1) it does not impose a distribution assumption on both the random error and the inefficiency term; (2) it does not provide exact point estimates of efficiency for individual firms as it is mainly designed to help in estimating the general level of overall efficiency.

The DEA is simply a mathematical programming tool in which several input-output combinations are used to generate efficiency scores for each firm. The most efficient firm (s) define the envelope surface, and the efficiency scores for other firms are computed relative to this envelope surface. In this paper, we estimate the cost function, and this choice is based on the fact that the specification of the cost function enables us to include multiple outputs in measuring efficiency (Kablan, 2010).

In our study, we use the SFA to estimate a translogarithmic cost function for 10 Rwandan commercial banks whose data are available on a quarterly basis for the period 2012Q1-2021Q3. The translog function is flexible as it takes into account complementarities between explanatory variables and also imposes no restrictions on the functional form (Kablan, 2010).

Empirical evidence shows that the translog function is a fair representation of actual data and is also more flexible since it enables substitution among inputs (Battese and Coelli, 1995). We define the cost function in its generic form along the lines of Aigner et al. (1977) and Meeusen and Van Den Broeck (1977) as follows:

$$C_{it} = C(y_{it}, w_{it}, \beta)\, exp(u_{it})\, exp(v_{it}) \qquad (1)$$

Where "i" denoted bank, with i=1,…., 10. Likewise, "t" denoted time, with t=2012Q1,…, 2021Q3. y_{it} stands for output of bank "i" at a time "t," and as noted above, this can be more than one output; w_{it} is a vector of input prices for bank "i" at time "t"; β is a vector of parameters; u_{it} is the non-negative error term representing bank-level inefficiency; v_{it} is the random error term, capturing measurement errors and exogenous shocks, assumed to be i.i.d $N(0, \delta^2)$. For this model to hold, u_{it} is assumed to be independently distributed of v_{it}.

As already mentioned, a translogarithmic version of equation (1) will be estimated. Aside from the functional form, we need to provide theoretical backing for the modelling of the inefficiency term (u_{it}). Another issue that needs to be settled out is the choice of outputs, inputs, and the vector of input prices. For the case of commercial banks, the outputs and inputs are quite hard to define.

However, three approaches have been used to address this issue, namely, the intermediation approach (Chortareas et al., 2016), the value-added approach (Berger et al., 1987), and the user-cost approach (Hancock, 1985). The three approaches provide guidelines on classifying balance sheet items as either outputs or inputs.

The intermediation approach assumes that banks transform collected deposits and other purchased inputs (such as physical and financial capital) into different categories of bank assets, such as loans and investment in securities.

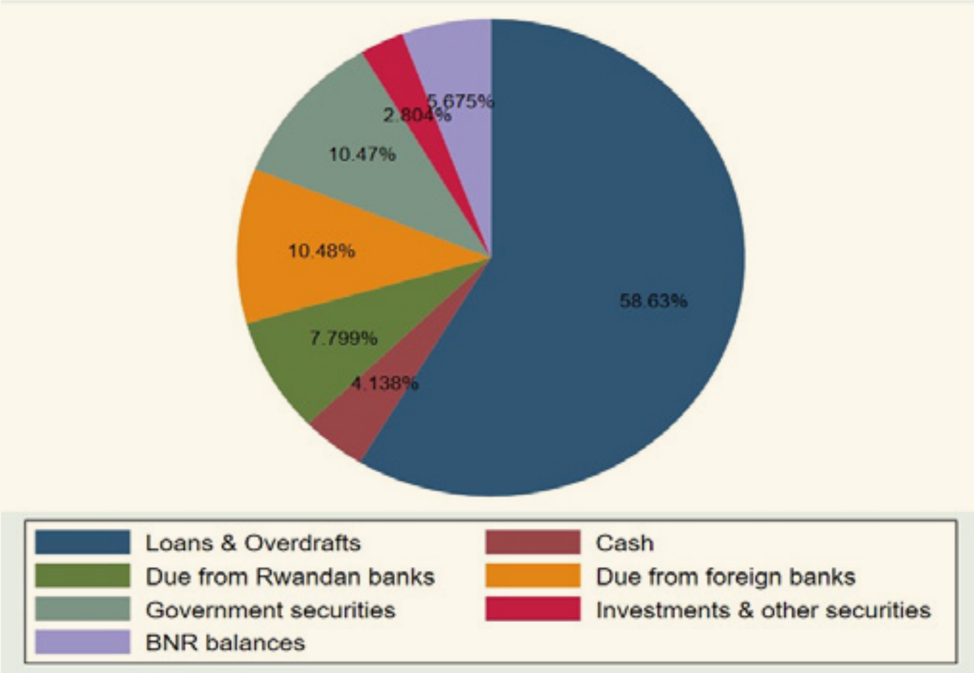
To perform the intermediation role, the bank incurs costs such as interest paid on borrowed funds and operating expenses. Under this approach, deposits, liabilities, labor, and capital are regarded as inputs, while assets such as loans are regarded as outputs.

The user-cost approach classifies outputs and inputs based on the criterion of the contribution of a financial product to the bank's net income. A financial asset is considered as an input if its financial performance exceeds the opportunity cost of funds. Liability becomes an asset when its financial cost is below the opportunity cost (Hancock, 1985). The value-added approach classifies the banks' balance sheet items (i.e., assets and liabilities) as either outputs or inputs based on their contribution to value-added or because they are associated with the consumption of real resources (Berger et al., 1987).

Since deposits constitute elements on which the customers bear opportunity cost and since they play a role in the creation of value-added for the bank, they are considered as both outputs and inputs as per user-cost and value-added approaches, just like deposits, loans also contribute to the creation of the bank's value-added and are thus also considered as outputs.

In view of the above, we will follow the intermediation approach as in Gunes and Yildirim (2016), whereby the total cost of the bank is defined as the sum of interest and non-interest expenses. Since loans and government securities have the biggest share in total bank assets, we shall use them as the only two outputs. This is premised on the fact that the main activities of banks in Sub-Saharan are: taking deposits, giving out loans, and investing in securities (Kablan, 2010). The importance of loans and securities is also evidenced by their respective big share in total assets (see figure 1).

Figure 1: Average share in total assets (net), in percent



Source: Authors' Estimation

Just like in other Sub-Saharan African countries, banks in Rwanda have adopted a strategy that gives deposits a large share in the output combinations they offer, given the lower intermediation ratio, suggesting that banks face challenges regarding the transformation of deposits into credit to the private sector (Kablan, 2010).

Regarding input prices, we include the price for labor and physical capital as the first input price. The second input price is the price for loanable funds. The table below precisely defines the variables included in the translog stochastic cost frontier estimation (ignore time-index (t) and bank index (i)).

Table 2: Variable descriptions

Variable	Description
Inc	Natural log of the ratio of cost_tot to w2, due to normalization
cost_tot	Total expenses, containing: Interest expense-deposits; Other interest expenses; Provisions for bad debts; Salaries, wages and staff costs; Premises, depreciation and transport; and, Other expenses.
Iny1	Natural log of output 1: Loans and overdrafts (net)
Iny2	Natural log of output 2: Government securities
Lnw	Natural log of the ratio of w1 to w2, due to normalization
w1	expense_nonint/assets_tot: used as a proxy for the price of labor and capital
expense_nonint	Total non-interest expenses composed of Provisions for bad debts; Salaries wages and staff costs; Premises, depreciation and transport; and, Other expenses.
assets_tot	Total assets (net)
Lnassets	Natural log of assets_tot
w2	expense_int/assets_tot: Used as a proxy for the price of loanable funds
expense_int	Total interest expenses composed of Interest expense-deposits; and, Other interest expenses.
Intermediation ratio	Ratio of total net loans to total deposits
Bank funding structure	Ratio of total deposits to total liabilities
Liquidity ratio	Ratio of liquid assets to total net assets
Credit risk	Natural log of Non-Performing Loans (NPLs)

As noted in the introduction, conditioning bank inefficiency on a set of dummy variables to capture bank-specific characteristics is not a good idea as it may lead to over-specification of the cost function and underestimation of inefficiency levels, a problem that is solved by using the modified true fixed effects model (Greene, 2004). The original true fixed effects model treats time-invariant bank-specific heterogeneity and time-varying inefficiency separately by integrating dummy variables, such as for management quality, ownership structure, and the degree of government intervention into the cost function. The same dummy variables are again used in the time-varying inefficiency function. This is the approach used by Gisanabagabo and Ngalawa (2017), which yields a biased estimation of inefficiency, worsened by the two-step estimation procedure since some of the explanatory variables in the cost function are similar and thus correlated with those in the inefficiency model. The best way is to exclude time-invariant fixed effects from the cost function and include them only in the inefficiency function, which is the basis of the modified true fixed effects model.

Consequently, we follow the modified true fixed effects model (Greene, 2004; Gunes and Yildirim, 2016), where heterogeneity is embedded in the inefficiency distribution. The inefficiency distribution is defined by mean cost inefficiency (μ_{it}) and the variance of inefficiency (δ_u^2):

$$u_{it} = |N(\mu_{it}, \delta_u^2)| \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (2)$$

This way, unobserved time-invariant bank-specific heterogeneity (ξ_i) can be accounted for by defining an equation for mean cost inefficiency:

$$\mu_{it} = \xi_i + \eta' z_{it} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots .. (3)$$

In equation (2) u_{it} stands for the inefficiency term, while in equation (3), η denotes parameters to be estimated. Mean cost inefficiency is conditioned on the time-variant z_{it} correlates, extracted from the banks' balance sheets. These are[1]: lassets (-), used to control for the impact of scale bias on inefficiency2; intermediation ratio (-); bank funding structure (-); capital ratio (-); and finally, credit risk (+). As mentioned before, "i" denotes bank, with i=1,...., 10. Likewise, "t" denotes time, with t=2012Q1,..., 2021Q3.

However, we need to define a probability distribution for the inefficiency term. With a half-normal distribution, most banks tend to be clustered around full efficiency, unlike when a truncated normal distribution is assumed (Greene, 1990). Thus, we assume that the inefficiency term follows a truncated normal distribution with a heterogenous mean across

[1] Expected signs are put in parentheses, showing whether the variable increases (+) or reduces (-) inefficiency. Justifications are given in Gunes and Yildirim (2016).

banks. The efficiency score for an individual bank is computed as the ratio of the cost of the most cost-efficient bank (i.e., one with zero or least costs) to the cost of the bank in the equation. To ensure that cost efficiency lies within the boundary of 1 and 0, the generic form of the cost efficiency function can be stated as:

$$CE_{it} = \exp(-u_{it}) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (4)$$

From the foregoing theoretical background, we define our empirical translogarithmic cost function as follows:

$$lnC_{it} = \beta_0 + lny_{1it} + lny_{2it} + \ln w_{it} + 0.5 * (lny_{1it} * lny_{2it}) + 0.5 * (lny_{1it} * lnw_{it}) + 0.5 * (lny_{2it} * lnw_{it}) + 0.5 * lny_{1it}^2 + 0.5 * lny_{2it}^2 + 0.5 * lnw_{it}^2 + \varepsilon_{it} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (5)$$

Where ε_{it} is the composite error term, decomposed into the random errors (v_{it}) and the inefficiency term (u_i) as follows:

$$\varepsilon_{it} = v_{it} - u_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. \ldots \ldots \ldots (5)$$

As noted above, we assume a modified true effects model based on assumptions embedded in equation (2) and equation (3) above. The true fixed effects model is more valid for this study; given that we do not randomly select the sample of banks from a large pool but rather pick commercial banks operating in Rwanda. Data on bank-specific variables are obtained from the quarterly balance sheets of 10 out of 11 licensed commercial banks over the 2012Q1-2021Q3 period. One bank is not considered due to insufficient data coverage within the sample period. To accommodate for the dynamic nature of bank efficiency, we estimate a time-varying decay true effects model.

To estimate the translogarithmic cost function, we assume symmetry regarding the square terms and cross-products, respectively. This implies starting with 0.5 as the coefficient on cross-products and square terms. We also normalize total costs and price for labor and capital (w_1) by the price for loanable funds (w_2) to ensure linear homogeneity of the cost function. In addition, we impose regularity conditions by including capital ratio among the z_{it} correlates in the mean cost inefficiency equation.

The assumptions of linear homogeneity, regularity conditions, and symmetry ensure that the cost function is monotonically increasing in input prices and outputs and concave in input prices, which is consistent with economic theory.

The parameters of the translog cost function (equation 5) and the of the inefficiency model (equation 3) must be estimated simultaneously, in a single-step procedure as noted in Greene (2005), to correct for biases that may result from the potential correlation between variables included in the cost function and those included in the inefficiency function. We use the maximum likelihood method in the estimation, where the likelihood function is formed using the following parameterizations:

$$\lambda = \frac{\sigma_v}{\sigma_u} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (7)$$

$$\sigma = \sqrt{\sigma_u^2 + \sigma_v^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (8)$$

To carry out the estimations, we use the "sfpanel" command and make use of the true fixed effects options as documented in the Stata journal (Belotti, F. et al., 2013). In addition, we derive variables of the translog function using the automated Stata module by Du, K. (2017). Single-step maximum likelihood estimation of the cost function and inefficiency model gives the bank-specific intercepts (denoted as alpha in Stata). A joint significance of these coefficients can then be tested for the validity/presence of fixed effects.

5. Financial sector development in Rwanda and drivers of commercial banks' efficiency

This section begins by summarizing the financial sector developments that have affected intermediation efficiency over the years. We then proceed to give empirical estimations for the stochastic cost frontier, separated into two parts: estimation results for the cost function and the estimation results for the inefficiency function. We then present some graphics showing efficiency and inefficiency levels across banks and across time. Thereafter, we give conclusions and policy recommendations.

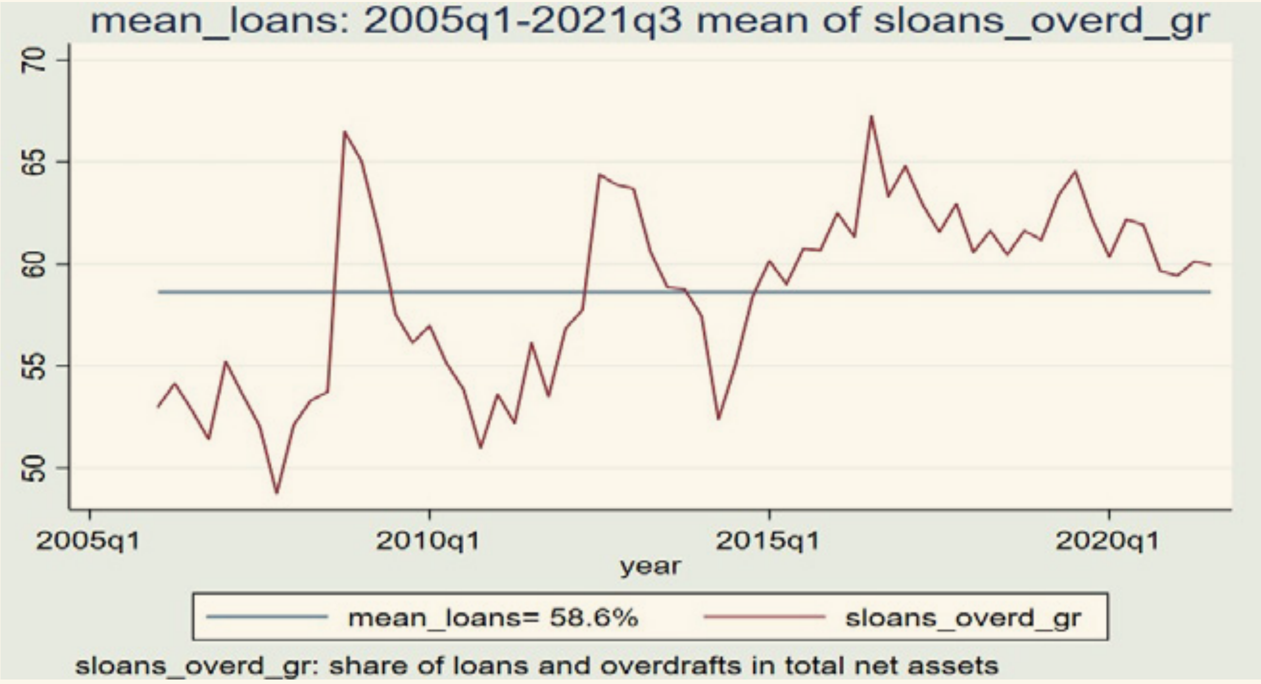
4.1 Summary financial sector developments in Rwanda

As noted in the introduction, Rwanda's financial sector has progressively become more liberalized since 1995. A preliminary assessment by the IMF (2011) in 2011 indicated that financial liberalization had led to the increased entry of new banks and thus to competition, resulting into intermediation efficiency as measured by declining net interest margins and/or interest of the measures of the efficiency of intermediation, stood at 9.3 percent in Rwanda compared to 1.9 percent in Singapore and 3.7 percent in South Africa.

The interest rate spread remains high due to high and rigid lending rates, among other factors. Commercial banks largely rely on deposits from the social security fund and other financial corporations (i.e., insurance companies, MFIs, and SACCOs), with an average share in total deposits of 45.4 percent between 2015 and 2019. This means that banks compete to attract large depositors by offering them favorable remuneration on their deposits, which increases the cost of funds and contributes to high lending rates (Kigabo, 2021). In addition to the high cost of funds, Rwanda, just like most of its East African peers, still has high bank overhead costs to total assets ratio (6.5 percent) compared to 1.3 percent for a high-income country like Singapore with a highly developed financial system as noted in table 1.

In view of the above and in line with empirical evidence, factors like cost of funds, credit risk, overhead costs among others, have been highlighted as drivers of the observed high interest rate spread in Rwanda (Kigabo et al., 2016; Karangwa and Nyalihama, 2018). The main activity of commercial banks in Rwanda is lending, given that the average share of loans and overdrafts (gross) in total assets (net) stood at around 58.6 percent between 200Qq1 and 2021Q3 while the share has been generally above 50 percent, ranging between 48.8 and 67.2 percent.

Figure 2: The share of loans in total assets (percent)

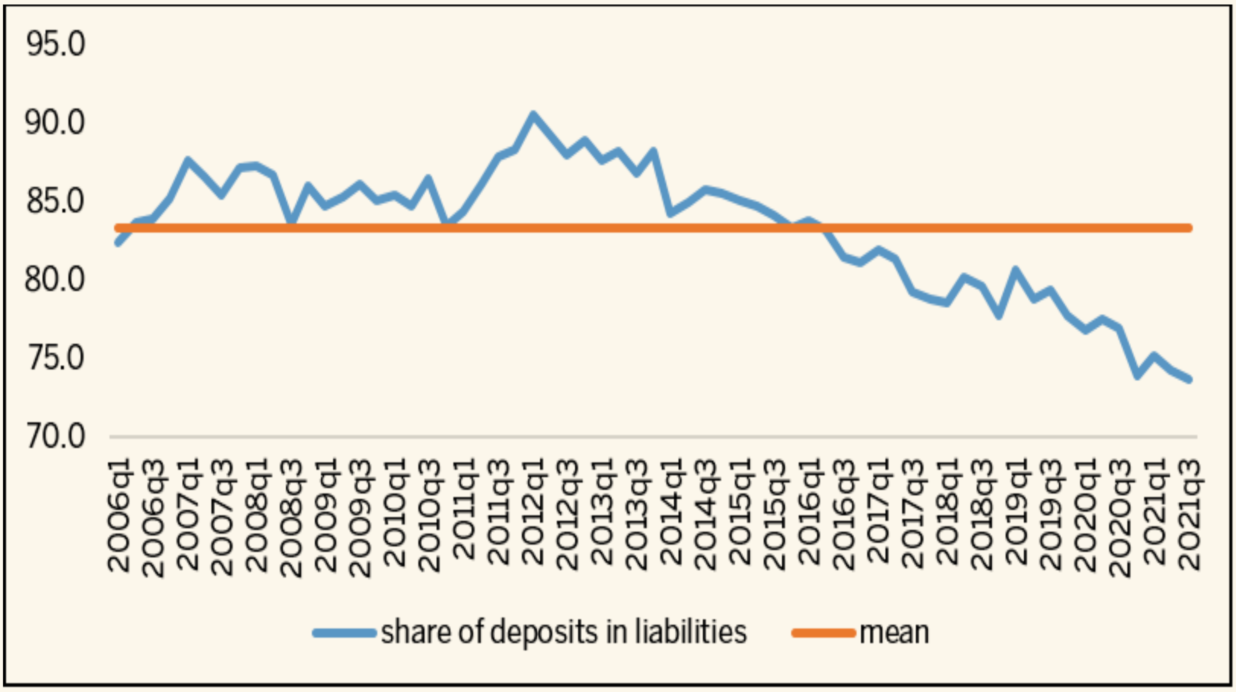


Source: Authors' Estimation

To be able to give out credit, the main source of funds for commercial banks in Rwanda is deposits, explaining why deposits have a large share in total liabilities. Though the share of deposits in total liabilities has been declining in recent periods, it is still high, standing at 83.3 percent and ranging between 73.7 percent and 90.5 percent for the 10 commercial banks during the 2006Q1-2021Q3. However, most of these deposits are short-term, leading to mismatches between long-term investment needs and short-term deposits.

In addition to the deposit market power in favor of the social security fund and other financial corporations, the loans market became concentrated since 2018, indicating the increase in loans market power for some banks (Kigabo, 2021).

Figure 3: Share (percent) of deposits in total liabilities



Source: Authors' Estimation

With such power, dominant banks can influence the setting of price (i.e., lending rate) or apply a market segmentation strategy by (1) applying lower lending rates to big borrowers relative to small ones; (2) concentrating their activities in urban areas with relatively high economic activities; and,(3) lending to less risky sectors of the economy (Kablan, 2010; Kigabo, 2021).

4.2 Empirical results

As explained in Gunes and Yildirim (2016), the main focus is on the interpretation of the determinants of inefficiency for commercial banks in Rwanda. Apriori, the intermediation ratio, bank funding structure, capital ratio, and bank size are expected to negatively affect inefficiency, while credit risk is expected to positively affect inefficiency.

Table 3: Single-step estimation results for the stochastic frontier cost function

Cost function		Inefficiency function	
lny_1	1.27	Intermediation ratio	-7.62^{***}
	(1.41)		(-5.38)
lny_2	-0.21	Bank funding structure	-6.10^{*}
	(-0.45)		(-1.82)
lnw	2.53^{**}	Capital ratio	-34.14^{***}
	(2.16)		(-3.30)
$0.5*(lny_1 * lny_2)$	-0.06	Credit risk = ln(NPLs)	0.51^{*}
	(-0.88)		(1.73)
		Bank size =ln(total assets)	0.66
			(1.24)
		σ_v _constant	-3.91^{***}
$0.5*(lny_1 * lnw)$	-0.25^{*}	E(σ_u)	0.498
	(-1.91)	σ_v	0.142***
$0.5*(lny_2 * lnw)$	0.08		
	(0.90)		
$0.5*lny_1^2$	0.00		
	(0.08)		
$0.5*lny_2^2$	0.05^{**}		
	(1.98)		
$0.5*lnw^2$	0.01		
	(0.08)		

z statistics are in parentheses. **Source:** Own estimations. **Significance levels:** * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Note that we considered that our sample of 10 commercial banks is not random. To formally test for this, we use a joint significance test for the following null hypothesis: The Ho is actually a test for the presence of fixed effects. The chi-square statistic is 31.97 with a p-value of 0.000, which leads us to reject the Ho and conclude that the time-invariant bank-specific effects are statistically significant, thus justifying the use of the fixed-effects model.

Empirical results show that the intermediation ratio has a significant (at 1 percent) negative effect on commercial banks' inefficiency in Rwanda, given that banks with a high capacity to collect deposits and convert them into loans are considered more efficient.

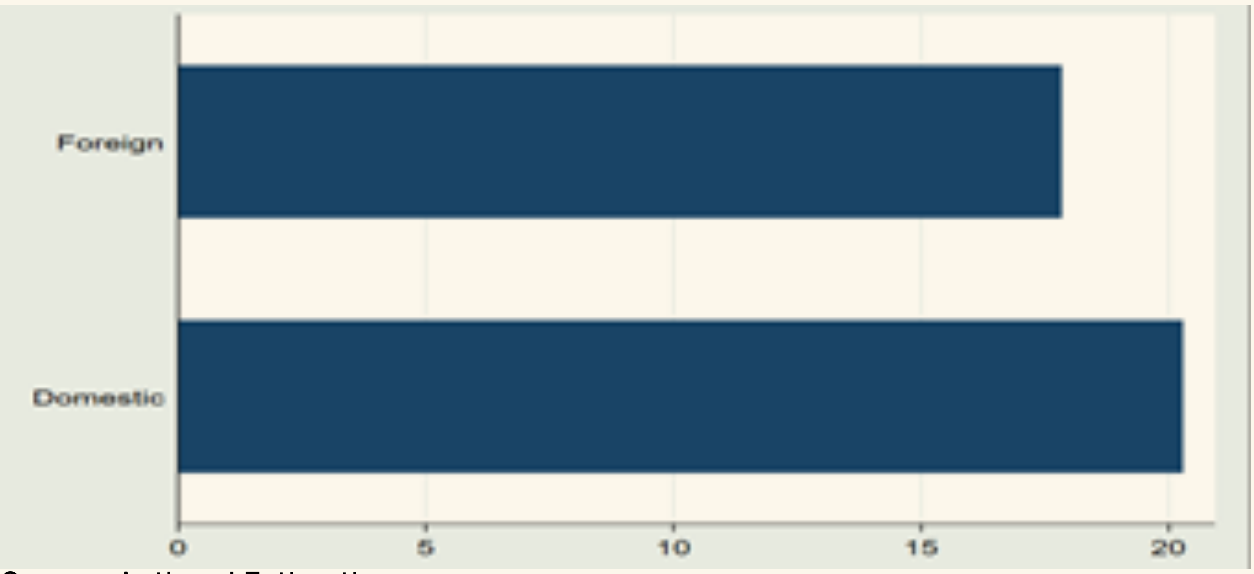
The capital ratio also has a significant (at 1 percent) negative effect on inefficiency, implying that the higher the capital ratio, the lower the inefficiency. This is because a particular bank is well-capitalized either due to good quality management or efficient risk mitigation measures, all of which help cut inefficiencies.

Contrary to expectation, the log of total assets has a positive sign. However, it is statistically insignificant, implying that bank size does not explain differences in inefficiencies. As expected, credit risk, measured by the log of Non-Performing Loans (NPLs), has a positive marginally significant (at 10 percent) effect on commercial banks' inefficiency in Rwanda since banks with poor credit risk management measures tend to face operational challenges. The bank funding structure, which measures the coverage of liabilities by deposits, has a negative significant effect on inefficiency since a bank that can meet its obligations (i.e., liabilities) using mobilized savings is much more likely to increase its efficiency levels.

In line with the above empirical results, the estimated average efficiency score for the 10 Rwandan commercial banks included in the sample is 81.3 percent, compared to 88.56 percent obtained by Gisanabagabo and Ngalawa (2016). Differences could be a result of the use of different number of banks, time-period, functional form of the cost function, and the estimation technique. However, the efficiency scores vary across banks3, time, and bank ownership.

Regarding bank ownership, it is clear that domestically-owned banks are more efficient than foreign-owned banks. The average inefficiency score for domestically-owned banks is estimated at 20.2 percent, compared to 18.8 percent for foreign-owned banks.

Figure 4: Inefficiency scores by bank ownership



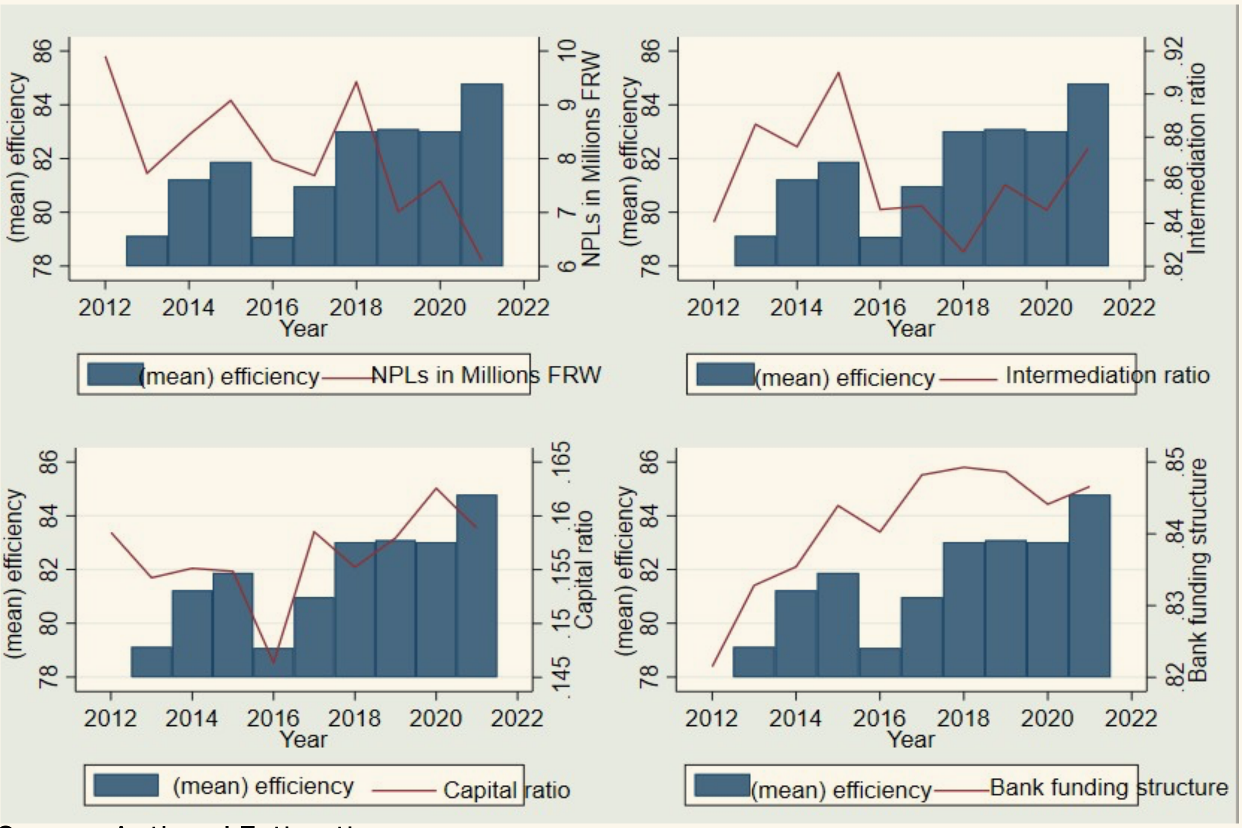
Source: Authors' Estimation

The domestically-owned banks are Bank of Kigali, Banque Populaire du Rwanda, and Cogebanque, while foreign banks are Access Bank, Bank of Africa (BOA), ECOBANK, Equity Bank, GT Bank, I and M, as well as the Kenya Commercial Bank (KCB). Obviously, domestic banks have a large share in both the loan and deposit markets and have been on the market for quite long compared to foreign banks.

[3] Due to the sensitivity of the data, we do not report efffiency levels by bank.

The period 2018-2022 was generally characterized by the increase in efficiency levels for the 10 Rwandan commercial banks due to the decline in credit risk, increase in the intermediation ratio, increase in the bank funding structure, and increase in the capital ratio.

Figure 5: Efficiency levels by time



Source: Authors' Estimation

Given these developments in the Rwandan commercial banking industry, an updated study to complement Gisanabagabo and Ngalawa (2016)'s findings is highly important.

6. Conclusion and policy recommendation

This study builds on the Gisanabagabo and Ngalawa (2016) empirical analysis of the drivers of cost efficiency for Rwandan commercial banks. The study employs a translog cost function and estimates a true fixed effects model using a single-estimation approach to be able to integrate unobserved bank heterogeneity in the inefficiency function at the mean level and thus control for the potential correlation between drivers of inefficiency and some of the explanatory variables in the cost function.

In line with increased financial sector reforms, empirical estimations (Table 3) and figure 5 show that, especially since 2018, intermediation ratio, bank funding structure, and capital ratio positively affect the efficiency levels of the ten Rwandan commercial banks included in the sample, whereas NPLs have a significant negative effect on efficiency levels.

Bank size does not seem to influence differences in efficiency scores across time and across banks. The choice for the true fixed effects is based on the fact that our sample is not randomly selected from a large pool of commercial banks. This is further validated by the test for the validity of the fixed-effects model.

Empirical findings also show that domestically-owned banks are more efficient than foreign-owned banks. This could be attributed to the fact the former has operated in Rwanda for quite some time and, therefore, could have established operational mechanisms to mitigate risks and manage costs. On average, the efficiency score is estimated at 81.3 percent compared to 88.56 percent obtained by Gisanabagabo and Ngalawa (2016), and the cited gaps could be a source of discrepancy.

As a policy recommendation, Rwandan commercial banks can generally record further reductions in inefficiencies if they put in place or strengthen existing measures to mitigate credit risk, increase intermediation, and increase their funding structures and capitalization, as these can help to deal with macro-financial shocks.

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RE-ASSESSING RWANDA'S EXCHANGE RATE AND EXTERNAL SECTOR COMPETITIVENESS

Yves Muvunyi[a], Wilberforce Nuwagira[b], Emmanuel Ngarambe Bahati[c]

[a] *Senior Statistician, Statistics Department, National Bank of Rwanda*

[b] *Senior Principal Economist, Research Department, National Bank of Rwanda*

[c] *Senior Statistician, Statistics Department, National Bank of Rwanda*

Abstract

This paper re-assesses Rwanda's real exchange rate and external sector competitiveness using three complementary approaches proposed by the IMF's consultative group on exchange rate issues (CGER). We use quarterly data, covering the period 2000Q1-2020Q4 and 5-year period medium-term projections. In terms of estimation strategy, we employ a triangulation of methods, including ordinary least squares (OLS) to estimate the current account determination model and the estimation of trade semi-elasticities and for the reduced form equilibrium exchange rate (ERER) model, particularly the behavioral equilibrium exchange rate (BEER) model, we use dynamic ordinary least squares (DOLS) along with its complementary estimators such as fully modified ordinary least squares (FMOLS) and Canonical cointegration regression (CCR) as robustness checks. For the external sustainability (ES) model, we rely on trade elasticities obtained from the first model together with a few assumptions relating to the economy's potential growth rate and inflation rate. The results indicate that the current account and the RER are influenced by economic fundamentals. The estimated exchange rate misalignment levels from the three approaches point to the same direction. The current research obtains an average exchange rate gap for the three models of 13.4 percent, implying that Rwandan currency is overvalued in real effective terms by 13.4 percent, pointing to adverse effects on external competitiveness. The important policy implications arising out of these empirical findings include maintaining exchange rate flexibility to cushion adverse external shocks, but also effective monitoring of exchange rate developments remains vital to avoid higher levels of volatility which could lead to poor performance of the country's tradable sector.

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

JEL Classification Numbers: F41, C22

1. Introduction

In an increasingly integrated global economy, the exchange rates play a pivotal role in many countries' external sector competitiveness and in ensuring macroeconomic performance and stability (Nuwagira and Kigabo, 2014). In order to appraise a country's competitiveness position, it is preferable to examine the deviation of its Real Exchange Rate (RER) from an estimated benchmark or equilibrium level, as referred to the misalignment conditions. It is known that significant and persistent RER misalignments have implications on the country's potential economy, hence it increases its vulnerability (Jongwanich, 2009).

There are several studies on the three methodologies of the External Sector Assessment, developed by the IMF's Consultative Group on Exchange Rate Issues (CGER) and followed by the Research Department, namely the Macroeconomic Balance (MB), the reduced-form Equilibrium Real Exchange Rate (ERER) and the External Sustainability (ES) (Cubeddu, 2018). According to IMF, these models help to review countries' international competitiveness, with the aim to understand and evaluate the current account and exchange rate development, and their current relationship. Secondly is to estimate the current account determination model, based on the current macroeconomic fundamentals, and to indicate the level of exchange rate adjustment needed to reconcile the underlying current account and the current account norm balances.

From the year 2010 to 2020, Rwanda's level of openness increased significantly by 15.8 percentage points to 54.3 percent, where exports of goods and services recorded an average annual increase of 12.2 percent while imports of goods services registered an average increase of 8.7 percent. However, the current account (CA) deficit increased by 5.6 percentage points, since the imports bill remains persistently higher than exports receipts. The CA deficit is financed by the Financial Account (FA) and the Capital Account (KA) flows that registered an average growth of 13.3 percent. As a result, the Net International Investment Position deteriorated. However, the nominal exchange rate against the dollar recorded annual depreciation of 4.7 percent for the period under review, with lower volatility compared to regional peer currencies. (Dvornak et al., 2003).

When the standard deviations of the nominal exchange rate of the East African Community (EAC-5) against the US dollar from 2000 to 2020 are computed, Rwanda's standard deviation is the lowest with 0.049, followed by that of Kenya and Tanzania, 0.054; Uganda with 0.073 and lastly Burundi with 0.077.

Table 1: Summary of Rwanda External Sector Statistics

	2010	2012	2015	2016	2017	2018	2019	2020
CA % GDP	-6.5	-9.7	-12.7	-15.3	-9.5	-10.1	-11.9	-12.1
Credit % GDP	22.2	24.1	24.3	24.6	28.2	29.2	28.3	25.8
Debit % GDP	28.7	33.8	37.0	39.9	37.6	39.3	40.2	37.8
Openness % GDP	38.3	45.7	51.4	52.6	53.8	55.8	57.9	54.1
FA & KA % GDP	8.2	7.9	9.1	12.5	9.5	10.9	11.5	14.0
IIP net % GDP			-36.6	-42.6	-47.0	-51.0	-56.2	-68.0
Assets % GDP			15.5	18.3	19.1	21.1	20.2	24.2
Liabilities % GDP			52.1	60.8	66.1	72.1	76.4	92.2
Reserves Coverage (months)	4.5	4.1	3.6	3.9	4.2	4.5	5.9	5.9
Nominal ER (% Change)	2.6	2.3	5.4	9.4	5.6	3.6	4.5	4.9
T-o-T (index 2017 = 100)	161.0	104.6	89.0	91.9	100.0	97.4	85.7	83.9

Source: National Bank of Rwanda

Studies on Rwanda's External Sector Assessments are very few despite its crucial role on economic activities and external sector performance since it helps to understand the relationship between Rwanda's international trade and the exchange rate development, and the adjustment gap of the tradable goods prices. For instance, Muvunyi et al. (2019) used the External Sustainability (ES) methodology to evaluate the Rwandan Current Account Deficit vulnerability to the level of Net Foreign Assets. Nuwagira and Muvunyi (2016) studied the impact of the real exchange rate on Rwanda's external competitiveness, using the Behavioral Equilibrium Exchange Rate (BEER) method to determine the level of the exchange rate misalignment and proceeded to test the Marshall-Lerner condition.

In this paper, the main objective of this study is to re-assess Rwanda's real exchange rate and external sector competitiveness, based on the current account determination model and the reduced form real exchange rate determination model, along with the associated level of real exchange rate misalignment. While the two previous papers relied on just one method, the current assessment explores the three complementary methodologies suggested by the IMF to have different perspectives from the different methodologies, a key contribution of this paper.

Our main findings are the following. First, the results showed that the evolution of real exchange rate is mainly determined by Rwanda's openness, government expenditures, terms of trade and relative productivity (Balassa–Samuelson effect). The results from the reduced form equilibrium exchange rate revealed alternating episodes of undervaluation and overvaluation though the size of misalignment is not very high, especially in the last decade.

However, as assumed earlier, the recent overvaluation of the RER is much higher than that in the previous studies mentioned above. Specifically, the real exchange rate deviates from its long-term equilibrium by 7.6 percent. These results are similar to those from the external sustainability approach, which suggested a depreciation of 17.7 percent, meaning that the real exchange rate is overvalued and thus real exchange rate should depreciate by 17.7 percent to close the gap between the underlying current account deficit and the NFA stabilizing current account deficit. Lastly, the macroeconomic balance approach also suggested a 15.1 percent depreciation to close the gap between the underlying current account and the current account benchmark or norm.

The rest of the paper is structured as follows. Section 2 briefly discusses the theoretical and empirical literature on External Sector Assessment Methodologies. Section 3 describes the complementary approaches proposed by the IMF's CGER that are used in the current analysis. Section 4 estimates and discusses results. Section 5 draws up conclusions and recommendations.

2. Literature Review

The Macroeconomic Balance (MB) approach computes the difference between the projection of current account balance in the medium term at prevailing exchange rates and an estimated equilibrium current account balance, referred to as "CA norm. The adjustment on the exchange rate that would close the gap between the two current account balances is then estimated using the prevailing country's macroeconomic fundamentals (Cubeddu, 2018).

Chinn and Prasad (2003) used the MB approach to determine the factors that directly and indirectly affect the current account fluctuations. They used cross-section and panel data models to 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, and 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 estimate the exchange rate adjustment to reduce the gap between the current national saving and the 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 and Couharde (2003) tried to determine the macroeconomic balances between major countries vis-à-vis their exchange rates, since these fluctuations may cause world macroeconomic instability. They went further from the MB model in order to have panel exchange rate equilibrium in selected industrial countries, by applying the fundamental equilibrium exchange rate, using data until 1995, with the medium-projection up to 2000. They suggested adjustment of the Dollar, Yen and Euro, to be aligned with the fundamentals.

The reduced-form Equilibrium Real Exchange Rate (ERER) approach directly estimates an equilibrium real exchange rate for each country as a function of medium-term fundamentals such as the net foreign asset (NFA) position of the country, relative productivity differential between the tradable and non-tradable sectors, and the terms of trade (Cubeddu, 2018).

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; Dvornak et al., 2003). 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, RER undervaluation improves them, mostly in developing countries.

Sekkat et al. (2011) found evidence supporting the view of Rodrik (2008) and showed that using a sample of 52 developing countries and utilizing 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.

As mentioned above, Nuwagira and Muvunyi (2016) studied the impact of the real exchange rate on Rwandan external competitiveness, using the Behavioral Equilibrium Exchange Rate (BEER) method to determine the level of the real exchange rate misalignment and compute the Marshall- Lerner condition. The long-run BEER drew a relationship between the REER with the economic fundamentals, and the estimated coefficients highlighted that the real exchange rate is influenced by economic fundamentals.

Some of the factors play a role towards exchange rate undervaluation (for instance; the increase in government expenditure and the decrease of terms of trade) and other factors lead to the real exchange rate overvaluation (for instance; the increased in net foreign assets and the productivity gains). In addition, the study found that the Marshall-Lerner condition does not hold for Rwanda, since the sum of exports and imports elasticities are less than in absolute terms. In addition, Nuwagira and Kigabo (2014) examined the medium-term projections suggesting a small depreciation in order to close the gap.

REER misalignment in Rwanda using quarterly data, spanning the period 2000Q1 to 2012Q4 using the ERER approach. The results from their study indicate the existence of alternating episodes of overvaluation and undervaluation with the level of misalignment ranging between 0.04 percent and 2.3 percent.

In addition, the study found that the Marshall-Lerner condition does not hold for Rwanda, since the sum of exports and imports elasticities are less than in absolute terms. In addition, Nuwagira and Kigabo (2014) examined the medium-term projections suggesting a small depreciation in order to close the gap.

The third strand of literature relates to the external sustainability (ES) approach. Muvunyi et al. (2019) used the ES methodology to evaluate the Rwandan Current Account Deficit vulnerability to the level of Net Foreign Assets, for the period 2010 to 2018 and considered 2019 – 2021 as medium-term projections period. The ES calculates the difference between the actual current account balance and the current balance that would stabilize the NFA position of the country at a desired benchmark level (Cubeddu, 2018). The results show that the current account gap at the current account gap at the benchmark was higher, but it would be lower with the medium-term projections, suggesting a small depreciation in order to close the gap.

Lastly, Marola (2016) in his study conducted on a sample of 7 Latin American countries found that the rate of return on assets equals to liabilities, the ES adjustment is needed for trade, but when they differ, thus the adjustment must be on both trade and financial account. He argued that the net international liabilities increase due to two sources, the income current account (primary income) and non-income current account (trade in goods and services and secondary income). Therefore, since the primary income is mostly composed of return on capital investment and interest payment of loan, based on the financial stocks, thus, the non-income current account is the one that could help to stabilize the financial stocks compared to the former.

In synthesis, the empirical literature on the real exchange rate misalignment remains mixed at best. Some studies suggest that real exchange rate deviations affect both the current account balance and economic growth. However, deviations of the real exchange rate from its equilibrium level affect the current account balance and economic growth in different ways. For instance, Rodrik (2008) indicates that while RER overvaluation harms growth and current account balance, the RER undervaluation improves them, especially in developing economies' vulnerabilities rose due to the coronavirus pandemic and prolonged low international commodity prices, which weighed on the external sector performance.

Countries; thus, the desired outcome is the one articulated by the Washington consensus that highlights the importance of the competitive real exchange rate to export promotion and, ultimately economic growth, while ensuring that it remains consistent with macroeconomic objectives in the medium term. Moreover, there is paucity of empirical studies in the case of Rwanda. Most previous studies have largely relied on the reduced form equilibrium exchange rate model, especially the behavioral equilibrium exchange rate (BEER).

In contrast to the previous studies which assessed external sector adjustment using one approach, this study brings together all the three approaches for a better understanding of the issue and hence provides solid evidence on the implications of RER misalignment on economic activities. The use of three complementary methods as suggested by the IMF's CGER is a key contribution of this paper. In addition,

3. Methodology

The methodological approach to conducting the external sector assessment follows the complementary approaches proposed by the IMF's CGER. The RER assessment is based on the equilibrium notion, particularly consistence in the internal and external balance over the medium to long term. The CGER analytical approaches include macroeconomic (MB) balance, the equilibrium real exchange (ERER) model and the external sustainability approach (ES).

3.1. Macroeconomic Balance (MB) Approach

The macroeconomic balance approach estimates the difference between the current account balance projected over the medium term at the ongoing exchange rates and the estimated current account norm. The MB approach is implemented in 3 steps (IMF, 2006). Firstly, the estimation of the equilibrium relationship between the current account and a set of economic fundamentals.

Secondly, computing the current account norm from this relationship as a function of the level of fundamentals projected to prevail in the medium term. Thirdly, computing the real exchange rate adjustment that would restore the balance between the current account norm and the underlying current account. The macroeconomic balance is modelled from the intertemporal approach to a current account, where the current account balance is an accounting identity linked to the saving-investment gap. The identity reflects the intertemporal nature of the current account and the role of consumption smoothing (Sachs, 1981, Obstfeld & Rogoff, 1995, and Obstfeld, 2004). The model specification is kin to Chinn and Prasad (2003) but customized to the country specifics and the general form of the model is specified as:

$$ca_t = \alpha + \beta ca_{t-1} + \varphi x_t + \varepsilon_t \text{................} (1)$$

Where ca_t is the current value of the current account balance as a percentage of GDP, ca_{t-1} is the lagged value of the current account balance as a percentage of GDP, x_t is a vector of explanatory variables, including real GDP growth, fiscal balance, population, old age dependency, government consumption, investment as a percentage of GDP and net foreign assets (NFA). α, β and φ are parameters to be estimated and ε_t is the error term. The variables used are draw for the previous studies, especially IMF's Methodology for CGER Exchange Rate Assessments.

3.1.1 Estimation Strategy

The current account determination model is estimated through a single equation approach given that this paper assesses the exchange rate in a country-specific context. We apply cointegration-based estimators such as dynamic ordinary least squares (DOLS) pioneered by (Stock & Watson, 1993) and further developed by (Kao & Chiang, 2000) and (Mark & Sul, 2003).

3.1.2. Definition of Variables and Data Sources

The variables included in equation 1, along with the indicators derived from the estimated relationship are constructed as follows:

Current account balance as a percentage of GDP is the sum of trade balance, services balance, primary income balance and secondary income balance divided by GDP, calculated as $ca = \frac{tb + sb + pib + sib}{gdp}$.

Lagged current account balance is a percentage of GDP (ca / gdp_{t-1}). Government budget balance is calculated as the difference between government's revenue less expenditure, usually expressed as a percentage of GDP. Per capita GDP growth measures the growth GDP divided by population and is calculated as: $ngdppc\_gr = ngdppc - ngdppc_{t-1} - 1$

Population growth is measured as $pop\_gr = pop_t - pop_{t-1} - 1$. Government expenditure is the total government expenditure, including recurrent and capital spending of each individual country divided by GDP. Old age dependency is defined as the ratio of population aged 65 and older to population aged 30 to 64 and data is obtained in 5-year frequency, requiring interpolation to obtain the missing data points. Oil balance.

Current account norm is constructed by multiplying each explanatory variable by its corresponding coefficient, then sum them up and the constant. The elasticity of current account balance to real exchange rate is given by:

$$\frac{\Delta ca}{y}\frac{\Delta rer}{rer} = -|\varepsilon_x|\frac{x}{y} + (1-|\varepsilon_m|)\frac{m}{y}$$

Where $\frac{\Delta ca}{y}\frac{\Delta rer}{rer}$ denotes the current account elasticity to real exchange rate, $|\varepsilon_x|$ is the export elasticity, y is GDP and therefore $\frac{x}{y}$ is export to GDP ratio, $|\varepsilon_m|$ is import elasticity and $\frac{m}{y}$ is import to GDP ratio.

Under MB approach, the exchange rate misalignment is defined as the difference between the underlying current account and the current account norm divided by the trade elasticities. $\left(\frac{reer_t - ereer_t}{ereer_t}\right) = \frac{uca_t - ca_t^{norm}}{\varepsilon_{x,m}}$.

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 $reer = \sum_{t=1}^{k} neer_{it} * \frac{p^*}{p}$. All the series are expressed in natural logs and nominal GDP is measured in US dollars. We use quarterly data, covering the period 2000Q1-2020Q4 and data is sourced from World Bank's world economic outlook database (WEO) and National Bank of Rwanda database.

3.1.3 External Sustainability Approach

The external sustainability (ES) approach computes the difference between the actual current account balance and the balance that would stabilize the net foreign assets (NFA) position of a given country at some benchmark level. Computationally, this approach makes use of elasticities obtained from the macroeconomic balance approach, where the current account gap is translated into the RER adjustment that would bring the current account balance in consistency with its NFA stabilizing level over the medium term. While the complementary approaches are estimated by econometric models, ES approach does not rely on econometric estimations, but on a few assumptions relating to economy's potential growth rate and inflation rate. Given its simple structure, the ES acts as a benchmark against which to compare the results from the above econometric approaches.

The link between the current account norm and the NFA position is obtained by imposing the steady state conditions on balance of payment identity. The point of departure is a simple balance of payments identity expressed as the sum of current account balance, capital account balance, and financial account balance, including reserves plus net errors and omissions, which is by construction zero. The identity is specified as:

$$CA_t + KA_t + FA_t + E_t = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Let's assume that capital gains accruing from valuation changes is given by:

$$KG_t = KG_{At} - KG_{It} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where KG_{At} and KG_{It} are capital gains on assets and liabilities, respectively. Substituting equation 4 into the Balance of payments identity yields.

$$NFA_t - NFA_{t-1} = CA_t + K_t + KG_t + E_t \ldots\ldots\ldots\ldots (5)$$

Dividing through equation 5 by nominal GDP yields.

$$ca_t + k_t + kg_t + e_t = NFA_t - \frac{NFA_{t-1}}{GDP}\frac{GDP_{t-1}}{GDP_t} = nfa_t - nfa_{t-1} + \frac{g_t}{1+g_t} nfa_t \quad (6)$$

Where the lower case letters are ratios to GDP and g_t is the nominal GDP growth. For simplicity, we assume no capital transfers $(k_t = 0)$, no capital gains $(kg_t = 0)$ and no errors and omissions $(e_t = 0)$, thus the current account balance and the nominal GDP growth are generally the key drivers of the $\frac{nfa}{GDP}$.

The current account norm that would be consistent with the steady state level of NFA is thus given by.

$$ca_t^s = \frac{g_t}{(1+g_t)} nfa_t^s \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

If we decompose the nominal GDP growth into real growth and inflation using GDP deflator π_t, we obtain.

$$ca_t^s = \frac{g_t + \pi_t}{1 + g_t + \pi_t} nfa^s \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

3.1.4 Definition of Variables and Data Sources

The series in equation (8) are constructed as follows. Net foreign assets is calculated as difference between assets and liabilities $nfa = total\ Assets - total\ liabilities$, this definition follows (Lane & Gian Milesi-Ferretti, 2007). Nominal GDP in U.S. dollars is the nominal gross domestic product in USD. Real GDP growth rate in (LCU), defined as Real GDP Annual Change, in LCU (in percent) and given by. $rgdppc\_gr = rgdppc - rgdppc_{t-1} - 1$.

Real effective exchange rate given by $reer = \sum_{t=1}^{k} neer_{it} * \frac{p^*}{p}$. Inflation rate is the change in the consumer price index (percentage) calculated as $\inf = \left(\frac{cpi_t - cpi_{t-1}}{cpi_{t-1}}\right) * 100$. Current account balance in USD is the sum of trade balance, services balance, primary income balance and secondary income balance, calculated as $ca = tb + sb + pib + sib$. While current account as a share of GDP is given by $ca = \frac{tb + sb + pib + sib}{gdp}$

3.1.5 Equilibrium Real Exchange Rate Approach

The reduced form equilibrium exchange rate approach estimates the equilibrium real exchange rate (ERER) and computes the deviation of the actual exchange rate from its equilibrium value. Its empirical assessment presents a challenge in the sense that the equilibrium real exchange rate is unobservable. 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 tradable and non-tradables, respectively. The ERER is defined by (Nurkse, 1945) as the value of RER that induces both the internal and external equilibrium, given sustainable values of relevant variables achieving this objective. The deviation from the equilibrium RER is known as real exchange rate misalignment. To estimate ERER and obtain measures of real exchange rate misalignment, we follow behavioral equilibrium exchange rate approach by (Clark & MacDonald, 1998). The BEER approach computes the equilibrium exchange rate as a function of economic fundamentals. This paper uses fundamentals that are similar to Berg & Miao, (2010) and MacDonald & Vieira (2010). Our empirical model is thus specified as:

$$reer_t = \alpha + \alpha_1 tot_t + \alpha_2 open_t + \alpha_3 nfa_t + \alpha_4 prod_t + \alpha_5 gov_t + \varepsilon_t \text{.... (9)}$$

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

3.1.6 Estimation strategy

The estimate the relationship specified in equation (2), we apply single equation dynamic ordinary least squares estimator (DOLS) developed by Stock and Watson (1993) and further developed by Kao & Chiang (2000) and Mark & Sul (2003).

This approach improves OLS by circumventing the problem of small sample bias and dynamic sources of bias owing to the fact that it corrects for endogeneity by adding leads and lags. Indeed, (Kao & Chiang, 2000) argue that DOLS performs better in small samples, a result that is confirmed by (Rahman, 2017) using Monte Carlo simulations.

This estimation technique is used, along with complementary estimators such as fully modified ordinary least squares (FMOLS) and canonical cointegration regression (CCR). After estimating the ERER model, we derive sustainable values of economic fundamentals by decomposing RER into their permanent and cyclical components, implemented via (Hodrick & Prescott, 1997) HP filter and finally compute the misalignment indicator 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).

3.1.7 Definition Variables and Data Sources

The series in equation (3) 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 & Gian Milesi-Ferretti, 2007). Relative productivity proxied by real per capita GDP is calculated as nominal GDP divided by the population and its growth rate is given by

$ngdppc\_gr = ngdppc - ngdppc_{t-1} - 1$. Terms of trade is the ratio between a country's export prices and its import prices, computed as $tot = \frac{export\ prices}{import\ prices} * 100$.

Government expenditure is the total government expenditure, including recurrent and capital spending divided by GDP. Openness is measured as the sum of exports and imports divided by GDP, calculated as $open = \frac{x+m}{gdp}$. All the series are expressed in natural logs and nominal GDP is measured in US dollars. We use quarterly data, covering the period 2000Q1-2020Q4 and data is sourced from IMF's world economic outlook database (WEO) and National Bank of Rwanda database.

4. Estimation Results

4.1. Results of Macroeconomic Balance Model

This section reports the results from the three complementary models used in the assessment of external sector sustainability. We first present the results of the macroeconomic balance model. Under this model, the coefficient of the lagged current account is positive and statistically significant, suggesting the presence of adjustment process in the current account. The coefficient of population growth turns out be negative and statistically significant, implying that higher population decreases savings, thus the current account. This result is line with ((Higgins, 1998). Fiscal balance emerges positive and statistically significant, this is due to the fact a higher government budget balance increases national savings and thereby increasing the current account balance, a result that is consistent with (Ahmed, 1986) and (Chinn, 2005) .The coefficient of output growth is negative and significant, indicating that economies that are lower stages of development such as Rwanda import more than they export, leading to a reduction in the current account balance. The coefficient of oil balance is negative and statistically significant, implying that higher oil prices deteriorates the current account balance for the net importers of oil like Rwanda. Generally, our results indicate that Rwanda's current account balance is in line with the economic fundamentals. Building on the estimated results of the current account determination model, we proceed with the estimation of both the underlying current account norm. For the underlying current account, we take the unadjusted current account balance as a percentage of GDP, taking 2020 as the benchmark year. This is because the cyclical factors such as the output gap turned out insignificant.

The current account norm is calculated by multiplying projected medium term value of each explanatory variable by their respective coefficient estimates. In computing the norms, medium-term values of the current account balance, fiscal balance, population growth, oil balance, output growth, are sourced from the World Economic Outlook (WEO) database.

We also estimated trade elasticity, obtained by estimating the individual export and import demand functions. From these two functions, the estimated semi-elasticities with respect to exchange rate are used to compute the total trade elasticity as follows.

$$\varepsilon_{x,m} = (-0.32)*(0.21) + (0.41-1)*(0.34) = -0.27$$

Given the underlying current account (-12.2), current account norm (-8.02), which gives a current account gap of -4.18 and the trade elasticity (-0.27), the real exchange rate gap under macroeconomic balance is computed as.

$$\frac{uca - ca^{norm}}{\varepsilon_{x,m}} = (-12.1-(-8.02))/-0.27 = 15.1$$

This result indicates 15.1 percent overvaluation, which implies that the Rwandan currency should depreciate in real terms by 15.1 percent to close the gap between the underlying current account and the current account norm.

Table 2: Macroeconomic Balance Estimation Results

Dependent variable: CA/GDP				
Variables	**Coefficient**	**Standard Err**	**T-Stat**	**P-Value**
Lagged CA/GDP	0.080	0.055	14.47	0.000
Population growth	-0. 174	0.097	-1.79	0.077
Fiscal balance	0.043	0.021	2.03	0.046
Output growth	-0.377	0 .212	-1.78	0.080
Oil balance	-0.312	0.146	-2.13	0.036
Old age dependency	0.162	0.398	0.41	0.684
Constant	1.881	2.077	0.91	0.368

Source: Authors' Estimations

4.2. Results of External Sustainability

This subsection reports the results of external sustainability approach. Under this approach, the computations are not based econometric estimation, but rather on the assumptions about the potential growth rate of the economy. The data requirements for the external sustainability include the construction of the current account balance that would stabilize Rwanda's NFA/GDP at benchmark level, here we consider the last data point for which complete data is available, thus we use net international investment position (NIIP) for the year 2020 as the benchmark level of NFA/GDP. Secondly, we use 5-year average medium term growth in nominal GDP, which is 7.03 percent and the National Bank of Rwanda's medium term inflation target of 5 percent. Based on this information, we compute the NFA stabilizing current account as follows.

$$ca^{s} = \frac{g+\pi}{1+g+\pi} nfa^{benc} = \frac{0.07+0.05}{1.07+0.05} * (-68) = -7.3$$

Given the NFA stabilizing current account balance, the underlying current account and the trade elasticity obtained under the macroeconomic balance model, the exchange rate gap under external sustainability approach is calculated as the difference between the underlying current account and the NFA stabilizing current account at a benchmark level of NFA.

$$Es = \frac{uca - ca^{s}}{\varepsilon_{x,m}} = \frac{(-12.2-(-7.3))}{-0.27} = 17.7$$

This result indicates that the exchange rate is overvalued by 17.7 percent and points to the level of exchange rate adjustment that is needed to restore the balance between the underlying current account and the balance that stabilizes the NFA/GDP at some benchmark level, thus Rwandan currency should depreciate by 17.7 percent for the underlying current account to improve -12.1 percent of GDP to the NFA stabilizing level of -7.3 percent of GDP.

4.3 Results of Behavioral Exchange Rate Model

Table 2 reports the results of the reduced form model based on single equation cointegration estimators such as DOLS, FMOLS and CCR, with a particular emphasis on DOLS. We estimated the long-run relationship between REER and a set of economic fundamentals. The parameter estimates are presented in columns (2) -(4). All variables included in our empirical set up are statistically significant, with expected signs, implying that the real exchange rate is in line with economic fundamentals. The coefficient of openness is positive and statistically significant due to trade restrictions in terms of higher tariffs, resulting in high demand for non-traded goods and leading to higher domestic prices that induce real exchange rate appreciation. The positive and statistically significant coefficient of terms of trade indicate that the income effect dominates, meaning that improvement in terms of trade raises demand for locally produced goods (non-traded) hence non-traded goods prices increase relative to traded goods, thus appreciating Rwanda's currency.

Government expenditure turns out to be positive and statistically significant, this is because higher government expenditure translates into higher demand for non-traded goods inducing the rise in prices of non-traded goods leading to the real appreciation of real effective exchange rate. The coefficient of productivity is positive and statistically significant, suggesting that productivity improvement relative to trading partners generates real exchange rate appreciation, a phenomenon well known in literature as "Balassa- Samuelson effect".

Finally, the coefficient of NFA is positive and statistically significant, which implies that that increase in long-run capital inflows appreciate real exchange rate. Indeed, over the recent past, Rwanda has received enormous amounts of capital flows and can therefore afford a more appreciated REER, while retaining the ability to restore the external balance through financing the associated current account deficits.

Table 3: BEER Estimation Results

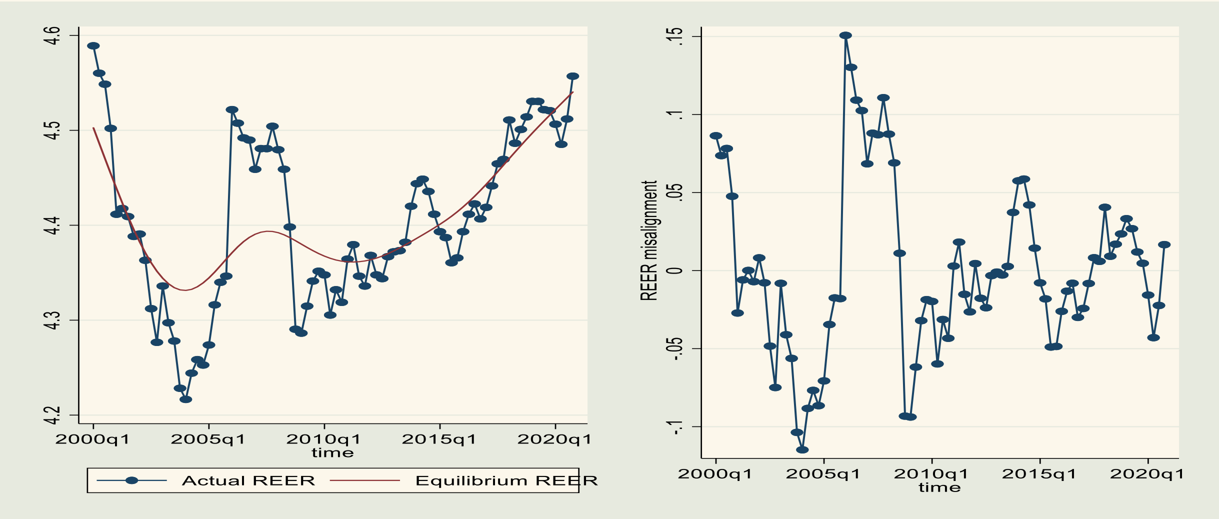
	(1)	(2)	(3)
VARIABLES	DOLS	FMOLS	CCR
Openness	0.029***	0.031***	0.031***
	(0.007)	(0.009)	(0.008)
Terms of trade	0.244***	0.127*	0.126*
	(0.059)	(0.071)	(0.076)
Government expenditure	0.539***	0.425***	0.430***
	(0.078)	(0.104)	(0.110)
Productivity	0.000***	0.000**	0.000*
	(0.000)	(0.000)	(0.000)
Net foreign assets	0.006*	-0.000	0.000
	(0.004)	(0.002)	(0.003)
Constant	1.775***	2.633***	2.621***
	(0.355)	(0.442)	(0.456)
Observations	72	74	74
R-squared	0.727	0.201	0.141

4.3 Exchange Rate Misalignment

The estimated results of the equilibrium exchange rate model, along with the (Hodrick & Prescott, 1997) HP filter are used to obtain sustainable values of economic fundamentals, whereby HP filter decomposes REER into their permanent and cyclical components 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, we identify alternating episodes of overvaluation and undervaluation. While overvaluation and undervaluation are not desirable for the attainment of long-run REER stability, the level of misalignment is not persistent and not very high. Taking the last five years, corresponding to 20 quarters, Rwanda's real effective exchange rate is overvalued by 7.6 percent, suggesting that Rwandan franc should depreciate by 7.6 percent in real effective terms to bring back the REER to its sustainable levels. Generally, this level of misalignment is not too high and the associated episodes are not persistent to induce a negative effect on external sector competitiveness.

Figure 1: Evolution in REER Misalignment



Source: Authors' Estimations

5. Conclusion

The main objective of this paper is to re-assess the exchange rate and external sector competitiveness in Rwanda using three complementary approaches, the macroeconomic balance, the external sustainability and the reduced form ERER proposed by IMF's Consultative group on Exchange rate issues to measure the consistency of the current account balance and real effective exchange rate with their underlying economic fundamentals. We use quarterly data, spanning the period 2000Q1-2020Q4. With regard to the estimation techniques, we use OLS for the current account determination model and the estimation of trade elasticities and for the behavior equilibrium exchange rate model, we apply single equation cointegration techniques, especially DOLS and its alternative specifications such as FMOLS and CCR are used as robustness checks.

The results indicate that both the current account and the real effective exchange rate are influenced by their underlying economic fundamentals. The estimated exchange rate misalignment levels from the three approaches point to the same direction are broadly in line with IMF external sector assessment for Rwanda that was conducted in 2019, which obtained the exchange rate gap of 19.4 percent.

The current research obtains an average exchange rate gap for the three models of 13.4 percent, implying that Rwandan currency is overvalued in real effective terms by 13.4 percent, which has ripple effect on the external sector position, particularly export competitiveness. As such, the exchange rate adjustment required to bring the current account and the REER to their sustainable levels is to depreciate Rwandan currency by 13.4 percent in the medium term. However, external sector competiveness is still strong, but there is still potential to improve.

The important policy implications that arise out of these empirical findings include maintaining moderate exchange rate flexibility to cushion adverse external shocks, but also effective monitoring of exchange rate developments remains vital to avoid higher levels of volatility which could lead to poor performance of the country's tradable sector. Implementing fiscal consolidation and structural reforms to further improve the business climate and boost competitiveness that would bring the current account balance to a level consistent with economic fundamentals. Strengthen strategies to facilitate diversification of the country's export base to improve the current account balance.

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FINANCIAL FLOWS VOLATILITY AND ECONOMIC GROWTH IN SSA COUNTRIES: EXTENDED CASE OF RWANDA

Patrick Mugenzi[a], Wilberforce Nuwagira[b], Annie Uwimana[c]

[a]*Economist, Monetary Policy Department, National Bank of Rwanda*

[b] *Senior Principal Economist, Research Department, National Bank of Rwanda*

[c]*Senior Economist, Statistics Department, National Bank of Rwanda*

Abstract

Previous research has documented a positive relationship between financial flows and economic growth, but the volatility of financial flows, a common feature of financial flows, has not attracted similar attention. This paper examines the effect of the volatility in financial flows on economic growth for 23 Sub-Saharan African (SSA) countries in general and Rwanda in particular. The paper uses annual data covering the period 2000-2019, transformed into non-overlapping 3-year averages for the case of SSA, while quarterly data covering the period 2000Q1 to 2019Q4 is used for the case of Rwanda. The empirical findings show that financial flows accelerate growth, a result that is consistent with those reported in the empirical literature. However, despite the fact that financial flow volatility appears negative, it is not statistically significant, implying that financial flow volatility does not seem to affect economic growth in SSA countries. For the case of Rwanda, we employed single equation cointegration-based estimators such as dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS), and Canonical cointegration regression (CCR) as complementary models to estimate the long-run effect of financial flows volatility on economic growth. All the disaggregated capital flows and the control variables such as investment share to GDP and government expenditure to GDP are positive and statistically significant. Financial volatility measure negatively affects economic growth in Rwanda. In as much as financial flow volatility does not affect economic growth in the case of SSA, the negative effect is evident for Rwanda, suggesting that capital flows management policies limit potential financial flow volatility that would emanate from excessive and short-term capital flows should be pursued.

Key Words: *Economic growth, financial flows, Volatility.*

JEL Classification Numbers: *F43, F21, 047.*

1. Introduction

In the new global economy, financial flows have substantially contributed to economic growth and development through technology transfer, remittances, and foreign aid from developed to developing countries. However, the patterns and cycles of financial flows have received considerable critical attention by both researchers and policymakers since they can potentially distort the economic growth trend. Over the recent past, a considerable body of literature around the theme of the effect of the financial flow on economic growth has sprung up, especially after the global financial crisis that occurred in 2008. It has been documented that the crisis led to high volatility in short-term loans and portfolio investments, with sudden reversals or stops, in low-income countries (Massa, 2016). However, the level of capital inflows to sub-Saharan African (SSA) countries has increased over time, with the magnitude of external financial flows to SSA expanding from 2% of GDP in 1990 to about 6% of GDP in 2017 driven primarily by private capital flows such as Foreign Direct Investment and portfolio investment (Ndiweni & Lumengo, 2021). Although there has been a considerable increase in private capital flows, there are significant variations in the growth of its various components (Agbloyor, et al., 2014).

Financial flows are in different forms, and their effects are distinctly heterogeneous. Financial flows [4]include Foreign Direct Investment (FDI), Foreign aid (Aid), Remittances, Portfolio investment, and other investments that contribute to the increase in the households' savings, and taxes and boost the countries' production, which ultimately improves the exports of the country. In contrast, external borrowing, which is also a component of financial flows, appears in the form of countries' liability, but there is no prior fact that this type has an adverse effect on growth. There has been little agreement to date on whether financial flows affect positively or negatively the economic growth of a country. Needless to say, volatility stands out as the underlying feature in these components of financial flows. As such, the effects of this volatility on economic growth have increasingly gained attention and have been studied by researchers. Several studies have documented that volatile flows and economic growth have a negative relationship (Milesi-Ferretti & Tille, 2011).

While some research has been carried out on the relationship between financial flows and economic growth in both developed and developing countries (Aizenman et al., 2013; Agbloyor et al., 2014; Nyang'oro, 2017; Combes et al., 2019; Mowlaei, 2018), there

[4] *Note that the terms financial flows and capital flows are used interchangeably in this study.*

has been very few studies that have investigated the effects of volatile financial flows on economic growth. The few studies on the volatility of capital flows and economic growth largely concentrated on developed countries and some emerging economies (Neanidis, 2019). Due to economic, political, and institutional differences between those economies and less developed economies, policy recommendations from these studies are less relevant for the SSA countries. This paper seeks to investigate the relationship between the volatility of capital flows and economic growth in Sub-Saharan African countries for the period of 2000 to 2019, an area that remains unexplored in the literature. Our analysis is extended to the case of Rwanda to understand the country-specific effects of capital flows volatility.

Evidently, this matter is worth investigating since it would bring forth the level of financial instability for the recipient economies given the nature of financial flows: an upsurge in capital flows leads to a currency appreciation, an improved balance sheet of borrowers, easier credit conditions, an increase in non-tradable prices and overall inflation, thus generating a financial risk of a sudden stop and inciting financial instability in recipient countries (IMF, 2017).

The effect of financial flows on economic growth is particularly relevant in the African context since private capital flows are largely viewed by African policymakers and development partners as an important investment vessel for addressing the continent's growth challenges. Generally, the financial flows in Sub-Saharan African (SSA) countries have for long been largely dominated by foreign aid and grants from advanced countries. As a result, shocks in rich countries, such as the global financial crisis of 2008/2009 and the 2011-12 European sovereign debt crisis, had detrimental effects on capital inflows to SSA. Similarly, global shocks such as the 2014 plunge in international oil prices and the recent global COVID-19 pandemic have also reshaped the composition of capital inflows and the structure of financing in SSA countries. As a result, the goal of this research is to look at the consequences of volatile financial flows on the economic growth of Sub-Saharan African countries, and then a particular investigation on Rwanda is further explored.

Furthermore, examining the growth and volatility of different components of financial flows could give useful information in the design of capital flow management policies for SSA countries, but also in Rwanda's case. Consequently, we first performed baseline analysis to examine the effect of financial inflows and their volatility on economic growth and then extended the analysis by exploring individual effects of financial flows components such as Foreign Direct Investment (FDI), Foreign aid (Aid), Remittances, Portfolio investment, and other investment.

The novelty of this paper also lies in using the Bias-Corrected Least Squares Dummy Variable (BC-LSDV) estimator developed by Kiviet (1995), which iteratively corrects the bias until unbiased estimates of the true parameters are obtained as opposed to using GMM estimators, which provide a suitable econometric strategy to estimate the effects of financial flows on economic growth but suffer from small sample bias. System GMM (SGMM) deals with endogeneity, but its efficiency depends on (1) the absence of higher-order serial correlation; (2) the availability of large samples; (3) the absence of dynamic panel data bias (Nickel bias). The BC-LSDV estimator deals with Nickel-bias and is also more efficient in small samples. Indeed, Bun (2005), using monte Carlo simulation, indicates that in small samples, BC-LSDV outperforms SGMM, given that it has the lowest root mean square error (RMSE). Furthermore, BC-LSDV is insensitive to serial correlation, endogeneity, heteroskedasticity, and nickel bias.

For the case of Rwanda, we employ DOLS to estimate the effect of financial flows volatility on economic growth. This method is used along with its complementary models, such as fully modified ordinary least squares (FMOLS) and canonical cointegration regression (CCR), to check for robustness. The application of the DOLS estimator is motivated by the fact that it controls for the endogeneity and is efficient in small samples.

The remainder of this paper is structured as follows: Section 2 highlights the extant literature on volatile financial flows and economic growth, Section 3 details the methodology employed in the empirical analysis, in Section 4 we present the results from the empirical estimations, and finally, in Section 5, we conclude the paper.

2. Literature review

Generally, Capital flows are evaluated based on the Solow growth model and its extensions. According to these models, capital flows are driven by capital productivity, where capital flows come from developed countries to developing countries. Capital flow is widely considered as an utmost important component of economic growth in both developing and developed countries. As a result, various studies have been conducted to investigate capital flow due to its composite effect on economic growth (Kapingura, 2017; Combes et al., 2019; Aizenman et al., 2013; Tamajai, 2000; Leblebicioğlu & Madariaga, 2015; Agbloyor et al., 2014; Agbloyor et al., 2020).

Several theories support the view that private capital flows increase domestic capital for economic growth. Some focus on private capital flows and economic growth, others on the nexus between the volatility of capital flows and economic growth. Alley (2015) studied the relationship between private capital flows and economic growth in Sub-Saharan African countries and found that private capital flows do not merely have a positive effect on economic output and growth but also that the effects of private capital flows shocks are negative, however, and are thus culpable for poor response of the region's economic performance to inflows of private capital (Alley, 2015).

Some authors have also suggested that private capital flows have a negative impact on economic growth. For example, the study by Elikplimi et al. (2020), after decomposing private capital flows into relevant components, found that foreign direct investment, foreign equity portfolio investment, and private debt flows all have a negative impact on economic growth in Africa.

They then suggested that strong financial markets are needed for private capital flows to impact economic growth positively. The study, which accounts for potential endogeneity of the explanatory variables in a dynamic panel data and controls for country-specific effects, found that capital inflows promote higher economic growth, independent of any effects on the investment rate, but only in economies where the banking sector has reached a certain level of development (Bailliu, 2000).

Several methods have been used in the study of the link between capital flows and economic growth. One method employed by Soto (2000) is a dynamic panel with yearly data estimated during the 1986-1997 period. He came up with two conclusions. First, FDI and portfolio capital flows have a robust positive association with growth. Second, portfolio bond flows are not significantly correlated with economic growth. He also found that in economies with undercapitalized banking systems, bank-related inflows are negatively correlated with the growth rate.

Remarkable contributions have been made by Opperman & Adjasi (2017), who examined the underlying factors of volatility patterns for FDI, portfolio capital, and cross-border bank lending inflows for sub-Saharan Africa using a panel framework with data from 1990 to 2011. Their findings were that global liquidity lowers FDI volatility while private sector credit increases volatility, global liquidity increases portfolio equity volatility with the growth and quality of macroeconomic policies, which are seen as major pull factors in reducing volatility; and the quality of macroeconomic policies and openness of trade are important pull factors to reduce the volatility of bank cross-border lending, while financial openness increases volatility.

Pagliari & Hannan (2017) studied capital flow volatility and constructed three measures of volatility for total capital flows and some key instruments but also shed light on the determinants of volatility. They discovered that gross inflows in Emerging Markets and Developing Economies (EMDEs)show that portfolios and other investments are two and four times more volatile than FDI, respectively, using three metrics of volatility such as rolling window standard deviation, GARCH (1,1), conditional variance and ARIMA (1,1,0) to track its change over time. Their results suggest that push factors can be more important than pull factors in explaining volatility and that the characteristics of volatility can be different from those of the flows levels.

Prior research such as Yoon & Kim (2015) investigated the cost of foreign capital flows in developing market economies. Only in the event of a crisis, they discovered that volatility in all four forms of foreign capital flows (i.e., FDI, foreign equity investment, bank loans, and foreign bond investment?) is positively associated with stock market volatility.

Foreign exchange market volatility is amplified during a crisis by higher volatility in foreign direct investment, foreign equity investment, and bank loans, whereas it is mitigated during non-crisis periods. However, in the event of a crisis, the volatility of foreign bond investments has the biggest beneficial effect on foreign exchange rate volatility but has no effect in non-crisis periods.

They continue by stating that the potential costs of foreign capital flows in emerging market economies should encourage policymakers to implement capital flow management or macroprudential measures to safeguard both macroeconomic and financial stability.

Even though many researchers studied capital flows, a closer look at the literature, however, reveals a number of gaps and shortcomings as far as the effect of capital flow volatility on economic growth is concerned. Carp (2014) examined how financial globalization and capital flows volatility affect economic growth. He focused on how financial globalization can cause a rise in capital flows volatility, which can have disturbing effects on economic growth. The results showed that, in times of macroeconomic imbalances, financial globalization is not a blessing for the economy because it stimulates capital flow volatility and negatively influences the economic development of the countries in Central and Eastern Europe.

Previous studies can only be viewed as a beginning step toward a better understanding of the impact of capital flow volatility on economic growth, which has yet to be thoroughly investigated. The few studies on the volatility of capital flows and economic growth largely concentrated on developed countries and some emerging economies (Neanidis, 2019). Due to economic, political, and institutional differences between those economies and less developed economies, policy recommendations from these studies are less relevant for the SSA countries. This paper addresses the need for a study on the relationship between volatility of capital flows and economic growth in

Sub-Saharan African countries for the period of 2000 to 2019, which is so far lacking in the literature.

3. Methodology

a. Theoretical Growth Model

The theoretical model underpinning our methodology is based on the endogenous growth model, which is crucial in explaining the role of capital flows in economic growth. The model builds on the two-factor neo-classical model propounded by Solow (1956) and is extended to incorporate the role of technological change. The endogenous growth model takes the form of a Cobb-Douglas function specified as:

$$y_t = A^{\lambda} k_t^{\alpha} l_t^{\beta} \quad \text{...} (1)$$

Where y_t is Total output, k_t is Capital input, l_t is Labour input, and A is Total factor productivity while α and β are output elasticities for capital and labour, respectively. The responsiveness of output to changes in the amount of labor or capital utilized in production is measured by output elasticity and λ allows for factors changing the efficiency of the production process. In the context of this study, our focus is the output responsiveness to changes in capital flows.

From the theoretical foundations of profit-maximization, capital and labour are the shares of GDP that they receive in a perfectly competitive market equilibrium such that the marginal revenue product of capital (MPK) equals the rental price (R) and the marginal product of labour (MPK) equals the wage (W). Marginal products of capital and labour are derived by differentiating equation (1) with respect to capital and labour, respectively. These are then multiplied by unit price (p) to obtain MRPL and MRPK as below.

$$MRP_L = P\beta A^{\lambda} K^{\alpha} L^{\beta-1} = W \quad \text{............................} (2)$$

$$MRP_K = P\alpha A^{\lambda} K^{\alpha-1} L^{\beta} = R \quad \text{..........................} (3)$$

Solving this system simultaneously for L allows us to eliminate labour from the equation for output in equation (1). This results in the equation below:

$$y_t = A^{\lambda} \left(\frac{\alpha k_t}{\alpha} \middle| \frac{R}{w} \right) \alpha k_t^{\alpha} \quad \text{.............} (4)$$

Taking natural logarithms, we obtain

$$\ln y_t = \alpha_0 + \alpha_1 \ln A + \alpha_2 \ln k_t \quad \text{... (5)}$$

b. Empirical growth regressions

i. Panel data model specification for SSA

To empirically estimate the effect of financial flows on economic growth in SSA, we adopt dynamic panel data techniques. Our specification is based on previous empirical studies (Barro, 1991; Mankiw et al., 1992; Levine & Renelt, 1992; Barro & Sala-i-Martin, 2004). To estimate the effect of net financial flows on economic growth, we specify a dynamic specification given the potential inertia associated with economic growth. We specify two growth regressions. In the first equation, we disaggregate financial flows into various components and estimate along with other control variables as independent variables and GDP per capita growth as the dependent variable, constituting our main model, and in the second equation, we lump together all the financial flows as one indicator, and this constitutes an alternative model to investigate whether the growth regression is robust to the use of total flows. The models are thus specified as:

$$\begin{aligned} y_{i,t} &= \beta_0 + \beta_1 y_{i,t-1} + \beta_2 totalflowsvol_{i,t} + \beta_3 fdi_{i,t} + \beta_4 pi_{i,t} + \beta_5 aid_{i,t} \\ &+ \beta_6 remit_{i,t} + \beta_7 \chi'_{i,t} + \eta_i + \varpi_t + \varepsilon_{i,t} \end{aligned} \quad \text{... ... (6)}$$

$$\begin{aligned} y_{i,t=} &\alpha + \alpha_1 y_{i,t-1} + \alpha_2 totalflows_{i,t} + \alpha_3 totalflowsvol_{i,t} \\ &+ \alpha_4 X'_{i,t} + \mu_i + \lambda_t + \varepsilon_{i,t} \end{aligned} \quad \text{.............. (7)}$$

Where $i = 1 \ldots N$ and $t = 1 \ldots T$ denote country and year respectively $y_{i,t}$ is the real GDP per capita growth, $y_{i,t-1}$ is the lagged value of real GDP per capita growth, $totalflows_{i,t}$ lumps together different financial flows components, including Foreign Direct Investment (FDI_{it}), Foreign aid (Aid_{it}), Remittances ($remit_{it}$), and Portfolio investment (PI_{it}), $totalflowsvol_{i,t}$ is the generated financial flows volatility, $\chi_{i,t}$ is a vector of control variables, including trade openness, terms of trade, population growth, investment share to GDP, and government consumption as a share of GDP. μ_i are country fixed effects to control for unobserved heterogeneity, $\lambda_{i,t}$ are the time effects to capture shocks that are common to all sampled countries, $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ are coefficients to be estimated, and $\varepsilon_{i,t}$ is the error term. In equation 6, $fdi_{i,t}$ is a foreign direct investment in the country i at a time t, $pi_{i,t}$ is portfolio investment, $aid_{i,t}$ is the aid grants, and $remit_{i,t}$ stands for remittances, $\chi'_{i,t}$ is a set of control variables. β_i where $(i = 0,....,7)$ are coefficients to be estimated, η_i are country fixed effects to control for unobserved heterogeneity, ϖ_t are the time effects to capture shocks that are common to all sampled countries, and $\varepsilon_{i,t}$ is the error term.

ii.Time series model specification for Rwanda

In the case of Rwanda, we use a single equation cointegration-based estimator, especially the dynamic ordinary least squares model (DOLS) by Stock and Watson (1993). Their approach improves the OLS estimator by coping with small sample and dynamic sources of bias, given that it corrects for endogeneity in explanatory variables by including leads and lags of first differences of the regressors and for serially correlated errors by a generalized least squares (GLS) procedure. We specify our model as follows.

$$y_t = X_t M' + \sum_{i=p}^{i=q} \Delta X_{t-1} + \varepsilon_t \quad \text{..................................} (8)$$

Where y_t is the per capita GDP growth used as a dependent variable. X_t is a vector explanatory variable, including foreign direct investment, openness, remittances, official development assistance, investment as a percentage of GDP, government expenditure as a percentage of GDP, portfolio investment, population growth, and financial volatility. M is parameters to be estimated $(\beta = 0,................9)$. $\sum_{i=p}^{i=q} \Delta X_{t-1}$ denotes leads and lags of the first differences of the explanatory variables. p and q denote the length of leads and lags, respectively. ε_t is the error term.

iii. Estimation Methods for SSA

In this subsection, we describe the econometric technique used to estimate the effect of financial flows and economic growth. We begin model estimation with static panel techniques such as pooled ordinary least squares, random effects, and fixed effects estimators as baseline models. However, due to a number of issues associated with these estimators, such as the presence of unobserved time and country-specific effects, these techniques are challenged. This is often mitigated by allowing into the baseline model time dummies and country-specific effects. However, the methods used to account for country-specific effects, or difference estimators, tend not to be appropriate owing to the dynamic nature of the regression (Loayza, et al., 2005). Besides, most of the explanatory variables, including financial flows tend to be endogenous to economic growth in the sense that higher capital flows may increase investment and boost economic growth, but sustained economic growth in the recipient country is likely to send out positive signals about the country's macroeconomic stability and attract more capital inflows, and thus, we need to control for reverse causality.

Cognizant of the fact that the presence of endogeneity could lead to biased results, we use dynamic panel techniques by Arellano & Bond (1991); Arellano & Bover (1995), and Blundell & Bond (1998) to account for endogeneity emanating from reverse causality and Nickell (1981) bias due to initial income variable, $y_{i,t-1}$.

Dynamic panel estimators such as difference generalized methods of moments (DGMM), generalized methods of moments (GMM), and system generalized methods of moments (SGMM) control for endogeneity. Despite the fact that SGMM developed by Arellano & Bover (1995) and Blundell & Bond (1998) is used with an additional set of moments, combining the first difference equation using lagged levels as instruments with an additional equation in levels, using lagged first differences as instruments, instruments proliferation is likely to lead to the loss of efficiency given that it leads to over-fitting of endogenous variables and less precise estimates of the optimal weighting matrix[5]. Roodman (2009) underscores the effect of instruments proliferation on the Hansen test of joint validity, which tests the exogeneity of the instruments based on the J statistics of the Sargan-Hansen test. The null hypothesis implies the joint validity of the instruments. In other words, a null hypothesis rejection shows that the instruments are not exogenous, and hence the GMM estimator is inconsistent.

Secondly, much as GMM estimators provide a suitable econometric strategy to estimate the effects of financial flows on economic growth, its estimators suffer from small sample bias; this is particularly the case in macro panels, thereby producing biased and inaccurate estimates.

To correct the bias, we implement bias correction methods for dynamic panel data; specifically, the bias-corrected least squares dummy variable estimator (BC-LSDV) developed by Kiviet (1995), which iteratively corrects the bias until unbiased estimates of the true parameters are obtained. Recent research has followed this approach to

[5] Barajas, et al.(2013) *suggest that the number of instruments should be less or equal to the number of cross-sections in the regressions to avoid over-identification of instruments. However, literature is not clear on the determination of the maximum number of instruments to be used in each case.* Roodman (2009) *proposes lag limits options based on a relatively arbitrary rule of thumb, that instruments should not be higher than individual units in the panel.*

correct for the bias in fixed effects. (Kiviet, 1998; Bun & Kiviet, 2003; Bruno, 2005; Bun & Carree, 2006) extend this estimator to cases with heteroscedasticity and unbalanced panels. Judson & Owen (1999) strongly support BC-LSDV when N is small, as in most macro panels. Indeed, Bun & Kiviet (2003), using Monte-Carlo simulation, indicate that in small samples, the BC-LSDV estimator outperforms consistent IV-GMM estimators such as Anderson-Hisao (AH), Arrellano and Bond (AB), and Blundell and Bond (BB) estimators given that it has the lowest mean square error. Accordingly, this paper employs bias corrected least squares dummy variable estimator.

iv. Estimation Method for Rwanda

Given the fact that the OLS estimator is known to yield biased and less consistent results, a number of estimators have been proposed, especially DOLS. Kao and Chiang (2000) contend that DOLS performs better in small samples, a result that is corroborated by Rahman (2017) using monte Carlo simulation. In the context of this study, we employ DOLS to estimate the effect of financial flows volatility on economic growth in Rwanda. This method is used along with its complementary models, such as fully modified ordinary least squares (FMOLS) and canonical cointegration regression (CCR), to check for robustness.

v. Data

The variables presented in models (6) and (7) are constructed as follows. Total flows cover all the net financial flows included in our specification and are given by $totalflows = fdi + pi + aid + remit$. The total flows volatility is based on the Z score metric, which indicates how financial flows deviate from the mean. Real gross domestic product per capita is real gross domestic product divided by population.

$$z\_score = \frac{x-\mu}{\sigma} \quad \text{..................................} \quad (9)$$

Investment is measured as the share of GDP for each of the countries included in our sample. fdi is the net foreign direct investment, including equity, reinvested earnings, and debts from affiliates, measured in USD. pi is the net portfolio investment measured in USD. Aid is aid flows including budgetary grants, non-budgetary grants, and project grants. $remit$ is the inbound remittances measured in USD. Trade openness is measured as the sum of exports and imports divided by real gross domestic product.

Government expenditure is the total government expenditure, including recurrent and capital spending of each individual country divided by GDP. For population, we consider the population growth rates of each of the countries included in our sample.

Terms of trade (Tot) is the ratio of export prices to import prices. All the series are transformed into natural logarithms except for the variables expressed as shares of GDP. We do not control for education like most growth regressions because data on education is not available for many countries included in our sample, and interpolation still leads to a severe loss of observations.

We use annual data spanning the period 2000-2019 for 23 countries, divided into non-overlapping 3-year periods, where variables are three-year averages of annual data to eliminate short-term fluctuations. The sample selection is based on the availability of data. Thus, the included countries are those for which data on the relevant variables are available. Data is sourced from World Bank's world development indicators (WDI), the International Monetary Fund's world economic outlook (WEO), and the National Bank of Rwanda (BNR).

For Rwanda, Data was obtained from different sources, including world development indicators, and the BNR database, especially annual and quarterly balance of payments statistics output tables; some series were interpolated from annual series to quarterly series. We used data series from 2000Q1-2019Q4. We used quarterly to have sufficient data points for a country-specific regression.

4. Empirical results and discussion

This section highlights the underlying features of variables in the data description with the results summarized in Table 1, and the findings from empirical estimation are reported in subsection 2.

a. Data Analysis

Table 1 below summarizes the statistical description of the variables. Turning our attention to the volatility of financial flow variables and other control variables in the sample, we strongly argue that the variables are generally not that much volatile as witnessed by the standard deviations (also look up figure 2). However, a few variables, such as net foreign direct investment (fdi_gdp) and terms of trade (tot), show a relatively high deviation from the countries' average, and that indicates high variability of these variables across countries.

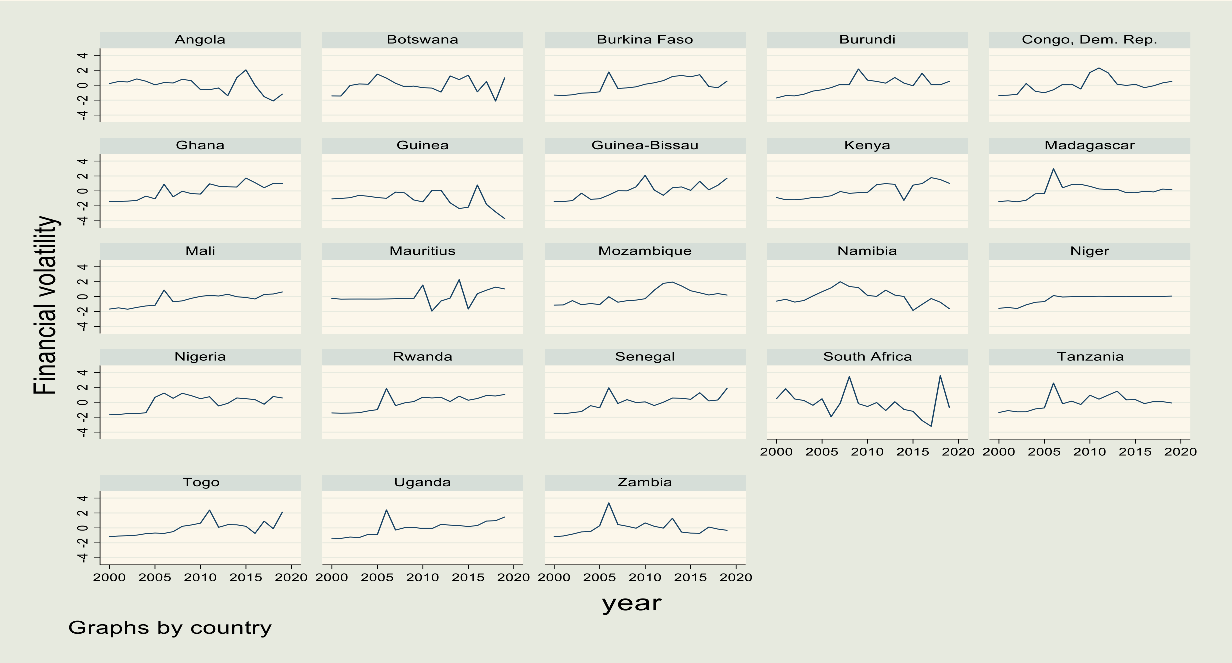
Table1: Descriptive statistics of the variables

VARIABLES	(1) N	(2) Mean	(3) p50	(4) Sd	(5) min	(6) Max
rgdppc_gr	460	2.13	2.40	3.08	-15.04	12.46
Ltflows	434	0.22	0.30	1.27	-5.64	3.46
fin_vol	460	-0.09	-0.03	1.03	-3.71	3.57
fdi_gdp	460	3.48	2.51	4.59	-6.37	39.46
Lremit	435	-2.04	-2.00	2.21	-11.38	3.19
Loda	460	-0.91	-0.71	1.23	-4.67	2.43
Pi	460	-0.32	0.00	2.76	-19.63	14.30
gov_gdp	459	2.62	2.69	0.43	-0.05	3.33
inv_gdp	460	3.06	3.05	0.38	1.63	3.99
Ltot	460	4.76	4.71	0.31	3.06	5.52
Lopen	460	-0.76	-0.78	0.45	-2.05	0.82
Lpop_gr	460	0.86	1.00	0.57	-3.43	1.72

Source: Authors' Estimations

Looking at the trends in the figure below, it is clear that there is no evidence of financial flow volatility in the selected Sub-Saharan African countries; this calls for a further empirical investigation to ascertain whether financial flows volatility affects economic growth.

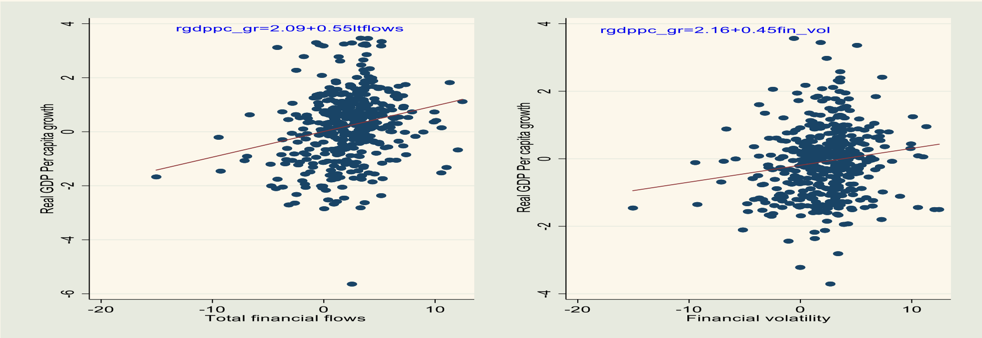
Figure 1: Financial flows Volatility



Source: Authors' Estimations

In this subsection, we first assess cross-country correlations between financial flows and economic growth and financial flows volatility and economic growth as presented in figure 2, respectively. The scatter plots in figure 2 describe, which is the baseline of our analysis, financial flows appear to be positively correlated with economic growth; however, the volatility of these flows diminishes the weight of positive influence on the growth, as it is evidenced by somewhat less inclined line in the scatterplot. In addition, the regression equation shows an insignificant positive relationship between financial flows volatility and economic growth.

Figure 2: Financial volatility and growth



Source: Authors' Estimations

b. Empirical results

This subsection presents the empirical results for both the selected SSA countries and the specific case of Rwanda. The results are arranged in general to a specific manner. We first present results for SSA countries, followed by results for Rwanda.

4.2.1 Main Results for SSA

Table 2 reports the ordinary least squares (OLS), fixed effects (FE), and Bias-corrected least squares dummy variable estimators on the effect of financial flows volatility on economic growth. The results are presented in columns (1) - (3). OLS and FE are used as baseline regressions; thus, we emphasize on the BC-LSDV estimator for the interpretation of results. We begin our analysis by evaluating the effect of the disaggregated financial flows on economic growth. The results indicate that the lagged dependent variable is positive and statistically significant across all the estimators, suggesting that past observations of economic growth are key in determining the present and future growth trajectory.

This is in line with the theory of cumulative causation in economic growth developed by Myrdal (1957) and Kaldor (1970), who contend that initial conditions determine economic growth in a self-sustained and incremental way. Turning to the variable of interest, which is financial flows volatility, its coefficient appears with the correct sign, but it is statistically insignificant. The coefficients on terms of trade, official development assistance (ODA and aid flows are used interchangeably) are positive and statistically significant at a 5 percent level, while foreign direct investment as a share of GDP is positive and statistically significant at 10%, suggesting that it has a positive impact on growth.

The coefficient of openness is positive and statistically significant at a 10 percent level of significance, implying that openness matters for growth, given that as economies get more liberalized, the more it fosters growth. On the other hand, population growth depresses economic growth, and investment as a share of GDP emerges with a negative sign and is statistically significant, which is trivial.

Table 2: Growth and disaggregated capital flows

VARIABLES	(1) OLS	(2) FE	(3) BC-LSDVC
Dependent variable: GDP per Capita Growth			
Lagged GDP per capita growth	0.272***	0.210**	0.351***
	(0.086)	(0.086)	(3.115)
Government expenditure	-0.020	-0.053	-0.068
	(0.046)	(0.086)	(-0.824)
Openness	0.892*	1.704*	1.894*
	(0.479)	(0.868)	(1.663)
Terms of Trade	1.103**	4.044***	3.693***
	(0.448)	(0.884)	(2.800)
Investment	-0.003	-0.094*	-0.101**
	(0.026)	(0.049)	(-2.233)
Population growth	-0.859***	0.405	0.342
	(0.230)	(0.866)	(0.286)
Financial Volatility	0.194	-0.121	-0.122
	(0.329)	(0.407)	(-0.349)
Remittances	0.126	0.231	0.210
	(0.153)	(0.287)	(0.817)
ODA	0.522**	2.158***	2.235***
	(0.194)	(0.704)	(3.540)
FDI	0.034	0.162**	0.162*
	(0.040)	(0.074)	(1.662)
Portfolio investment	0.192**	0.222	0.186
	(0.081)	(0.157)	(1.238)
Constant	-0.882	-9.287**	
	(2.270)	(4.429)	
Observations	136	136	136

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Authors' Estimation

4.2.2 Robustness checks for SSA

To investigate whether the relationship between financial flows volatility is robust to different model specifications, our empirical analysis further probed to find out the effect of aggregated financial flows on economic growth, and the results are summarized in table 3. OLS and FE remain baseline estimators, while BC-LSDV is the main estimator. Similar to our main results, the coefficient of the lagged dependent variable, which is economic growth, is positive and statistically significant across all the estimators, confirming the presence of persistence in economic growth. The coefficient of the variable of interest does not seem robust to changes in model specification, given that in the last two decades, financial volatility appears to be quite low in most of the countries studied. The coefficient of total flows is positive and marginally significant, implying that total flows stimulate economic growth. Terms of trade and trade openness emerge with positive and statistically significant coefficients, suggesting that both terms of trade and trade openness matter for growth.

To further check for the sensitivity of our baseline model, we also applied the heterogenous panel data estimators such as mean group, pooled mean group, and dynamic fixed effects estimators, a class of estimators that were proposed by (Pesaran & Smith, 1995) and further developed by (Pesaran, et al., 1999); (Pesaran, 2006); (Chudik & Pesaran, 2013) and applied by (Eberhardt & Presbitero, 2015) The estimated results reported in (Appendix A) do not seem to provide plausible results. The coefficient of financial volatility is positive in the long-run under pooled mean group estimator and dynamic fixed effects, a result that is trivial, and this could be due to the fact these estimators are more suitable for large T and large N, yet our sample is small, with only 20 time periods and 23 cross-sections.

To sum up, our empirical results support the popular view that foreign aid and FDI flows are associated with a positive effect on economic growth. Remarkably, Foreign aid has a higher positive coefficient than other financial flows, which confirms a greater contribution to the economic development of Sub-Saharan African countries (SSA countries).

As a matter of fact, the budget of many countries in SSA relies heavily on foreign aid, with over 36% of government expenditure on average in 2017-2019[6] , and thus higher inflows of this type undoubtedly support economic growth. Despite the fact that the coefficient of financial flows volatility is statistically insignificant, it appears with a negative sign under fixed effect and BC-LSDVC specifications, implying that financial volatility is considered as a push factor for negative economic growth as per results reported in Table 2. Other control variables such as terms of trade, foreign direct

[6] *These statistics were calculated by the author using World Bank data, where 30 SSA countries were considered. We considered only these countries based on the fact that they have updated numbers at least for the period 2017 to 2019. Though Somalia has updated number, we have decided to remove it while calculating the average percentage Net ODA in government expenditure for it appeared to be an outlier in the dataset.*

investment, and trade openness appear to be strong contributors to growth in the SSA countries 'economic growth.

Table 3: Growth and total capital flows

	(1)	(2)	(3)
VARIABLES	OLS	FE	BC-LSDVC
GDP per capita growth (lagged?)	0.083**	0.178*	0.351***
	(0.032)	(0.092)	(3.693)
Total flows	0.069	0.867	0.985*
	(0.059)	(0.634)	(1.817)
Government expenditure	0.004	0.526	0.557
	(0.184)	(1.090)	(0.472)
Terms of Trade	0.298	3.534***	3.105***
	(0.271)	(1.040)	(2.645)
Openness	0.201	2.419*	2.608***
	(0.144)	(1.273)	(2.709)
Financial volatility	0.093	0.209	0.142
	(0.115)	(0.403)	(0.432)
Population growth	-0.107**	0.292	0.468
	(0.040)	(1.074)	(0.438)
Investment	-0.122	-0.591	-0.740
	(0.202)	(0.982)	(-0.670)
Constant	0.202	-11.440**	
	(1.424)	(5.390)	
Observations	126	134	134

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.

4.2.3 Estimation results for Rwanda

Table 4 reports the results of DOLS, FMOLS, and CCR estimators in columns (1) - (3). Given that financial flows as regressors are inclined to simultaneity bias in the model, we rely on the DOLS estimator for interpretation of results since it is robust in the presence of simultaneity as well as small sample bias compared to other alternative estimators (Stock & Watson, 1993). The findings are more encouraging for the Rwandan case since they present a significant effect for most of the variables. To be more precise, FDI, Openness, remittances, investment, government expenditure, portfolio investment, and financial volatility are positively associated with economic growth. The results are consistent with that of Combes et al. (2019). Variable of interest, which is financial volatility, is negative and statistically significant, suggesting that financial flows' volatility depresses economic growth in Rwanda but becomes insignificant in the alternative specifications.

The coefficient of population growth is positive and statistically significant in alternative. Nevertheless, model estimators in columns 2 and 3 showed. A credible reason for this could be that the alternative estimators fail to adjust simultaneity bias.

Table 4: Results of capital flows and Rwanda's growth

	(1)	(2)	(3)
VARIABLES	DOLS	FMOLS	CCR
FDI	0.055***	0.112***	0.106***
	(0.011)	(0.017)	(0.024)
Opennness	0.327***	0.341***	0.340***
	(0.042)	(0.060)	(0.055)
Remittances	0.164***	0.070***	0.074***
	(0.015)	(0.020)	(0.027)
ODA	0.153***	-0.056	-0.052
	(0.033)	(0.040)	(0.053)
Portifolio Investment	0.603***	0.112	0.122
	(0.051)	(0.072)	(0.083)
Population growth	0.003	0.048*	0.056**
	(0.017)	(0.025)	(0.028)
Investment	0.027***	0.026***	0.027***
	(0.002)	(0.004)	(0.005)
Government expenditure	0.027***	0.012	0.013
	(0.004)	(0.007)	(0.008)
Financial Volatility	-0.052***	0.037	0.035
	(0.020)	(0.026)	(0.032)
Constant	4.314***	5.658***	5.581***
	(0.226)	(0.338)	(0.424)
R-squared	0.997	0.977	0.981

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

4.2.4 Robustness checks for Rwanda

To establish whether the effect of financial flows' volatility on economic growth in Rwanda is robust to aggregating the financial flows, we estimated the model by including the total financial flows but excluding the individual components that make up this variable. Table 5 reports the results of the aggregated financial flows and economic growth.

The coefficient of total capital flows is positive and statistically significant, implying that an increase in the total capital flows induces economic growth in Rwanda. The coefficient of financial volatility turns out to be positive and statistically in the DOLS specification but insignificant in alternative specifications. Control variables such as investment, government expenditure, degree of openness, and population growth are positive and significant in line with economic theory. Generally, financial flows volatility is less robust than aggregating capital flows.

Table 5: Growth and Total Capital Flows in Rwanda

VARIABLES	(1) DOLS	(2) FMOLS	(3) CCR
Total flows	0.205***	0.179***	0.175***
	(0.009)	(0.019)	(0.021)
Openness	0.068**	0.308***	0.290***
	(0.028)	(0.078)	(0.065)
Population	0.005	0.073**	0.082***
	(0.014)	(0.029)	(0.024)
Investment	0.600***	0.659***	0.709***
	(0.055)	(0.119)	(0.134)
Government expenditure	0.233***	0.405***	0.422***
	(0.029)	(0.094)	(0.102)
Financial Volatility	0.051***	0.012	0.013
	(0.007)	(0.014)	(0.016)
Constant	3.145***	2.844***	2.631***
	(0.182)	(0.464)	(0.512)
R-squared	0.994	0.985	0.988

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

5. Conclusion

The main objective of this paper is to empirically assess the effect of financial flows volatility on economic growth in a panel of 23 SSA countries, spanning the period 2000-2019, converted into non-overlapping 3-year averages, and extend the analysis to the specific case of Rwanda.

The empirical analysis begins with the construction of a financial flows volatility indicator using the Z-score metric. The generated financial flows volatility is incorporated in the growth regression, together with a number of control variables. To estimate the growth regression, we apply dynamic panel data techniques, particularly the BC-LSDV estimator as our main model, while OLS and FE estimators as the baseline regressions.

The main results indicate that the financial flows accelerate economic growth in SSA. However, financial flows volatility is negative but statistically insignificant, implying that financial flows volatility does not seem to affect economic growth. To that end, the fact could be that the portfolio investment that has been found to be much more volatile than FDI in low-income countries (LICs) is insignificant. This could be due to the fact portfolio investment is a small component of financial flows. Control variables such as terms of trade, trade openness, and foreign direct investment emerged as positive and statistically significant. Our results are less robust to the aggregation of financial flows.

For Rwanda, all the disaggregated capital flows and the control variables such as investment share to GDP and government expenditure to GDP are positive and statistically significant. However, the financial volatility measure depresses economic growth in Rwanda.

The empirical results point to important policy implications. For the case of Rwanda, the coefficient on financial flows volatility is negative and significant, implying that it hurts economic growth if not well managed, suggesting that there is a need to pursue capital flows management policies to limit potential financial flows volatility to avoid their adverse effect on economic growth. Building good macro-policies and strong institutions tend to attract less volatile types of capital and are less vulnerable to large swings in capital flows. In terms of future areas for research, exploring other financial flows volatility measures would provide a different perspective to this study.

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Appendix A

VARIABLES	(1) PMG	(2) PMG	(3) DFE	(4) DFE	(5) MG
		Dependent variable: GDP per capita Growth			
		Short-Run Results			
Error correction term		-0.089***		-0.142***	
		(0.027)		(0.015)	
ODA		-0.040		-0.039***	
		(0.050)		(0.015)	
Openness		-0.200***		-0.129***	
		(0.055)		(0.036)	
Terms of Trade		-0.076		-0.032	
		(0.098)		(0.045)	
Investment		0.158***		-0.005	
		(0.061)		(0.036)	
Government Expenditure		-0.179**		-0.099***	
		(0.070)		(0.038)	
Portfolio Investment		-0.039		0.003	
		(0.240)		(0.003)	
Remittances		0.636***		0.018**	
		(0.241)		(0.009)	
FDI		-0.010		-0.001	
		(0.011)		(0.002)	
Financial Volatility		0.132*		-0.009	
		(0.079)		(0.010)	
		Long-Run Results			
ODA	0.619***		0.409***		0.045
	(0.060)		(0.097)		(0.091)
Openness	0.476***		-0.214		-0.212*
	(0.125)		(0.197)		(0.125)
Terms of Trade	-0.167		0.744***		0.314
	(0.205)		(0.232)		(0.200)
Investment	-0.777***		0.038		0.324***
	(0.173)		(0.213)		(0.122)
Government Expenditure	-0.020		-0.067		0.021
	(0.191)		(0.224)		(0.179)
Portifolio Investment	-0.033***		-0.024		-0.002
	(0.003)		(0.027)		(0.299)
Remittances	0.101**		-0.043		1.569***
	(0.045)		(0.032)		(0.580)
FDI	-0.133***		-0.005		-0.017
	(0.009)		(0.016)		(0.017)
Financial Volatility	0.177***		0.152*		0.566
	(0.017)		(0.081)		(0.495)
Constant		0.743***		-0.018	-0.222
		(0.244)		(0.199)	(1.382)

NATIONAL BANK OF RWANDA
BANKI NKURU Y'U RWANDA

KN 6 AV.4 | P.O.BOX: 531 Kigali Rwanda
(+250) 788 199 000
info@bnr.rw
Swiftcode: BNRWRWRW
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