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Revisiting Interest Rate – Exchange Rate Dynamics in South Africa: How Relevant is Pandemic Uncertainties?

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Abstract

This paper revisits the link between exchange rate and interest rate considering the role of uncertainty due to infectious diseases in the South African economy using monthly data from January 1985 to August 2020 within a nonparametric framework. First, we examine the relationship between the exchange-interest rates hypothesis and observe a significant positive link, especially during the pandemic. Second, we analyze the volatility spillover among exchange rates, interest rates and other macroeconomic fundamentals and find a strong connection with the interest rate being net receivers of shocks. Third, with evidence of nonlinearity in the variables, the nonparametric quantiles-based causality test shows that the spillover for each asset is driven by pandemic uncertainty around the median quantiles. Conclusively, this suggests that the role of global health news in influencing the South African financial cycle which consequently leads to capital flows and movements in the prices of assets across financial markets cannot be downplayed. Relevant policy implications can be drawn from these findings.

Keywords: exchange rate; interest rate; infectious diseases; spillovers; quantile causality.

JEL classification: C14; C22; E30; F31; I15.

1. INTRODUCTION

The recent COVID-19 outbreak has triggered the direction of the crisis in the world economy. Different activities in eliminating the outbreak have slowed down the global economy which has to inform different monetary responses by central bankers around the globe. The efficacy of monetary policy tools is key to the successful management of economic stability. The correlation between exchange rate and interest rates, conditional on an adverse risk premium shock is negative for expansionary depreciations and positive for contractionary ones. We expect interest rates to rise in case of the contractionary effect of depreciation. Interest rates also are predicted to rise in an event of an adverse net export shock in contractionary depreciation cases and to decrease in the event of expansionary ones.

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Furthermore, Sanchez (2005) observes that the interest rate tends to react differently to shocks depending on whether depreciations are expansionary or contractionary. The exchange rate is important in a globalized world because it facilitates payments and the US Dollar as the dominant global trading currency serves as a basis for linking markets (Fasanya, Oyewole, & Raheem, 2021).

The reality of the dynamic effect of the COVID-19 pandemic on every economy has been extensively discussed and analyzed which can hardly be debated. Ranging from preventive measures such as social distancing, self-isolation, and travel restrictions; this pandemic has large macroeconomic consequences such as a high unemployment rate, reduced manufacturing activities, constrained global demand & trade including tourism (Haroon & Rizvi, 2020; Nicola *et al.*, 2020; Shen *et al.*, 2020; Batool *et al.*, 2021; Fasanya, Adekoya, *et al.*, 2022; Karbassi Yazdi *et al.*, 2022). The pandemic has significantly affected the energy & commodity markets (Salisu & Vo, 2020; Shen *et al.*, 2020; Fasanya, Oyewole, & Odei-Mensah, 2021; Fasanya, Oyewole, & Oliyide, 2021; Periola-Fatunsin *et al.*, 2021), foreign exchange market (see Narayan, 2020; Fasanya, Oyewole, Adekoya, *et al.*, 2021), stock markets (Al-Awadhi *et al.*, 2020; Baker *et al.*, 2020; Salisu & Vo, 2020; Fasanya, Oyewole, & Oliyide, 2021; Fasanya, Periola, *et al.*, 2022), as well as policy uncertainties (see Al-Yahyaee *et al.*, 2020; Raheem *et al.*, 2022). The policy response to external shocks emanating from the financial crisis or infectious disease pandemics, such as the current Covid-19 pandemic crisis needs to be informed by the peculiar response of the economy to such shocks. This study's research question aims to establish whether the South African interest rate and exchange rate nexus exhibit either a "perverse" effect, i.e., a tightening of monetary policy causing exchange rate depreciation or an "orthodox" effect (causing an appreciation) in the face of an external shock such as a pandemic uncertainty. An understanding of the spillover effects between macroeconomic fundamentals (Hnatkovska *et al.*, 2013; Mpofu, 2013; Aye *et al.*, 2014)[1]and exogenous shocks such as uncertainties due to infectious diseases crisis are important if the policies put in place are to be effective in meeting macroeconomic objectives such as stable growth and price stability. To mitigate the macroeconomic effects of the pandemic, there is a growing literature by central bankers and monetary researchers that assess the extent of the pandemic's macroeconomic distortionary impacts and determine the optimal monetary policy response (Ataguba, 2020; Olofin *et al.*, 2021). Thus, we contribute to this debate by assessing the effects of the COVID-19 pandemic on the link between the exchange rate-interest rate nexus.

The motivation to study the exchange rate -interest rate nexus stems from the very role monetary authorities perform, which is to safeguard the financial system stability in two ways; (i) mitigate exchange rate excesses from spilling over to goods and services markets, thus threatening macroeconomic stability and (ii) and reduce the risk that given the unrelenting periods of either lower interest or higher interest will undermine financial sector soundness. With this understanding, the South African rand volatility is well documented in previous studies such as those of Ricci (2006); Arezki *et al.* (2014). Yet, there is little or no research which incorporates pandemic uncertainty in studying the South African exchange rate - interest rate nexus so far. An open economy such as South Africa is vulnerable to global financial spillover effects of both financial and non-financial shocks. Whilst theory is clear in the elucidation of the effects of financial shocks on other economic variables, the impact of non-financial shocks such as that of the current infectious disease pandemic remains unknown. A study similar to this one was undertaken by Olofin *et al.* (2021) and Ataguba

(2020); however, these studies differ in terms of the country's focus, the scope of pandemics, and measures of uncertainty, methodology and analyses.

Our work contributes to the existing literature in the following ways. First, we examine the connection between exchange rate and interest rate under a derived exchange rate model using a VAR framework for shocks and the TVP-VAR approaches for any evidence of spillovers. Second, we capture how infectious diseases affect the interactions between exchange rate and interest rate, which presents a gap in existing literature unlike most studies in the literature which relate infectious diseases, exchange rate and interest rate in separate settings. However, this contribution is supported by the novel application of the nonparametric quantile-in-causality approach which becomes our second contribution. Using the nonparametric quantile-in-causality approach, we are also able to investigate causality-in-variance and, thus, study higher-order dependencies. This is especially useful in cases where, causality in the conditional mean may not exist while, at the same time, higher-order interdependencies may turn out to be significant (Balcilar *et al.*, 2018).

The remainder of our work is structured as follows. Section 2 anchors the review of the literature while Section 3 describes the theoretical underpinnings and methodology of the study. Section 4 presents the analysis of the data, along with the interpretation of the results. Finally, Section 5 summarizes the conclusions.

2. LITERATURE REVIEW

In replete literature, there is harmony in the way monetary policy affects the exchange rate (Meese & Rogoff, 1983). However, there is no consensus on the way interest rate - exchange rate nexus, especially during a pandemic crisis work. A plethora of studies on pandemics have been conducted due to ongoing risks posed by the COVID-19 disease globally. Before COVID-19, there were previous pandemics and epidemics that impacted the global economy, such as the 1957 and 1958 H2N2 virus, the 1968 H3N2 virus, the 2009 and 2010 Swine Flu, the 2014e2016 Ebola virus, the 2012 MERS virus, and, at the height of them, the 1918 H1N1 virus pandemic (see inter alia, Salisu *et al.*, 2020). The COVID-19 pandemic bears striking semblance with the 1918 pandemic in terms of biological features (both are respiratory diseases spread through contacts and droplets); coverage of transmission (the 1918 influenza spread to about one-third of the global populace while COVID-19 has recorded close to nine million confirmed cases worldwide in just about six months); and health response (quarantine, isolation, use of disinfectants, calls for better hygiene, and restrictions on travels and gatherings). The Spanish flu pandemic of 1918 is one of the deadliest pandemics in recorded human history (Taubenberger & Morens, 2006). Analysing the impact of the Spanish flu pandemic on the economic performance of Sweden, Karlsson *et al.* (2014) find that this pandemic has caused an increase in poverty and unemployment. Jonung and Roeger (2006) examined production lost due to illness and death during the pandemic in Europe using reductions in GDP growth and/or decline in the level of GDP in trade and tourism. Comparing the result to similar studies for the United States and Canada, a pandemic would most likely not be a severe threat to the European economy, though it is a huge toll on human suffering. However, McKibbin and Sidorenko (2006), find that a mild pandemic has significant consequences for global economic output and as the scale of the pandemic increases, so do the economic costs. Pandemics have equally greatly affected the tourism and related industries with an almost 50% fall in hotel occupancy in Taiwan (Chou *et al.*, 2004). This is also corroborated by the findings of Beutels *et al.* (2009) which investigate the impact of the SARS outbreak on different economic and social indicators in Beijing using the cross-correlation function and conclude that leisure activities, transportation and tourism sectors suffered the most.

Hnatkovska *et al.* (2013) argue that the absence of a clear empirical relationship between interest rates and the exchange rate is more pronounced from the perspective of practitioners. The question this research aims to investigate is the interest rate and exchange rate nexus during a period of infectious disease outbreak uncertainty. The uncertainty surrounding the emergence of the disease notwithstanding, even as the outbreak persists, several strands of studies have emerged to examine its macroeconomic impact of it at the global, continental and country levels. The study by McKibbin and Fernando (2020), which is an extension of McKibbin and Sidorenko (2006), explores seven different scenarios of how COVID-19 might evolve in the coming year. In Fernandes (2020), the economic impact of the COVID-19 crisis across industries, and countries is investigated. The study shows that in the sample of 30 countries covered, a median decline of -2.8% in GDP in 2020 is observed. In other scenarios, the study shows that GDP is expected to fall more than 10%, and in some countries, more than 15%. Ataguba (2020) argues that it is only one part of the bigger picture of economic impact. Citing Africa in particular, with its high disease burden, poorly developed infrastructure and safety nets and weak health systems, the impact of the pandemic is expected to be severe in the continent. Using the same argument, a country-level impact analysis is not only desirable but inevitable to guide the policy authorities. At a more sectoral level, Abodunrin *et al.* (2020) critically examine the impact of COVID-19 on the global economy and explain that the pandemic has tormented all sectors and suggest measures such as tax relief and work allowance for the recovery of different sectors.

Using a non-parametric framework, Fasanya, Oyewole, and Oliyide (2021) reveal that energy stocks' predictability driven by pandemic uncertainty is prevalent around the lower and upper quantiles for both the full sample of data and for the COVID-19 sample period. However, in another study, Fasanya, Oyewole, and Odei-Mensah (2021) show that energy futures predictability driven by health-based uncertainty is prevalent around the lower and median quantiles; and predictability is observed to be strongest for the West Texas Intermediate oil futures when the market is in a normal mode. Ramelli and Wagner (2020), explored the feverish stock price reaction to COVID-19 where they examined how the markets adjust to the sudden emergence of previously neglected risks, and the result suggests that the health crisis has morphed into an economic crisis, particularly as the aggregate market has been underperforming since the outbreak, which is amplified through financial channels. Some other studies such as Salisu and Vo (2020), Salisu *et al.* (2020) and Fasanya, Periola, *et al.* (2022) conclude that the effect of COVID-19 observed cases on stock prices are rather varying across countries and limited, the spillover effects orchestrated through the recent oil and financial market volatility cannot be overlooked. Batool *et al.* (2021) show that transportation and accommodation sectors are negatively impacted by COVID-19-related lockdown while the other sectors of the sharing economy such as freelance work, streaming services and online deliveries are seeing a surge in searches. In a study by Hoque *et al.* (2020), they examine the impact of COVID-19 on the tourism industry in the case of China and observe those travel restrictions have been placed to control the spread of Coronavirus from China to other countries impacted its tourism industry to a great extent. More specifically, Abiad *et al.* (2020), even a contained outbreak of this magnitude will cost $156 billion to the global economy, most of which will be bear by the consumption and tourism sectors. Karbassi Yazdi *et al.* (2022) focus on the performance of

Iranian banks during the COVID-19 pandemic. They reveal the performance of Iranian banks and their respective ranking of them including a model for benchmarking. Their empirical outcomes provide useful guidance for a better understanding of performance measurement in the banking sector in Iran. Oliyide *et al.* (2022) examine the influence of COVID-19 cases in India on the country's sectoral stock indices and discover that COVID-19 has had a negligible influence on the returns of these stocks; however, it causes them to fluctuate significantly. In a recent study, Fasanya (2022) examines the role of uncertainty due to pandemic on the predictability of sectoral stock returns in South Africa and finds that pandemic uncertainty has a negative and statistically significant effect on the different sector returns, implying that sector stock returns decline as the pandemic outbreak becomes more pronounced. The current paper modifies and extends that earlier papers on the exchange-interest rate model by augmenting with uncertainty due to infectious diseases, using data that captures the greater interdependence in the world economy and in particular South Africa's macroeconomic response to this uncertainty. The following section presents the theoretical model and the methodology used to analyse the results of this study.

3. THEORETICAL MODEL AND METHODOLOGY

3.1 The monetary model of exchange rate determination.

Following Dornbusch *et al.* (1980), we derive the real money determination in the manner outlined below. By assuming that income elasticities and interest rate semi-elasticities between two trading countries are not different, we can construct exchange rate equations using the real money balances as follows:

$$m_t - p_t = \lambda y_t - \theta i_t \tag{1}$$

$$m_t^* - p_t^* = \lambda y_t^* - \theta i_t^* \tag{2}$$

Solving for price differential between the two countries, the next equation is obtained:

$$p_t - p_t^* = (m_t - m_t^*) - \lambda(y_t - y_t^*) + \theta(i_t - i_t^*) \tag{3}$$

From the purchasing power purity assumption that $e_t = p_t - p_t^*$. Therefore, we can rewrite the exchange rate equation as follows:

$$e_t = (m_t - m_t^*) - \lambda(y_t - y_t^*) + \theta(i_t - i_t^*) + \propto q_t \tag{4}$$

where q_t is the variant expansion of the model which could be espoused, for example, dynamics of price stability or trade movements risk premium. According to the above equation "faster money growth in the home country relative to the other country leads to a depreciation of the exchange rate, while fast output growth, achieved by raising money demand, results in an appreciation. A rising risk premium leads to a depreciation of the exchange rate.

By letting $z_t = i_t - i^*{}_t$ based on the supposition that interest rate parity is associated with the efficient market hypothesis (EMH), and further assume that the expected rate of depreciation is a function of the gap between the current and equilibrium rate of the exchange rate and of the expected long-run inflation differential between the domestic and foreign countries (Basurto & Ghosh, 2001), as given by equation (5):

$$Let\ \ z = -\mu(e - \bar{e}) + (\pi - \pi^*) \tag{5}$$

Substituting for $z_t = i_t - i^*{}_t$ and simplifying obtains the following results in (6):

$$e - \bar{e} = -\frac{1}{\mu}[(i_t - \pi) - (i_t{}^* - \pi^*)] \tag{6}$$

In the long run: $i_t - i^*{}_t = \pi - \pi^*$ we can write (4) as follows:

$$\bar{e} = (\bar{m} - \bar{m}^*) - \lambda(\bar{y} - \bar{y}^*) + \theta(\bar{\pi} - \bar{\pi}^*) + \propto q_t \tag{7}$$

Substitute (7) into (6)

$$\bar{e} = (\bar{m} - \bar{m}^*) - \lambda(\bar{y} - \bar{y}^*) - \frac{1}{\mu}(i_t - i^*{}_t) + (\theta + \frac{1}{\mu})(\bar{\pi} - \bar{\pi}^*) + \propto q_t \tag{8}$$

Let $\frac{1}{\mu} = \gamma$ and $\left(\theta + \frac{1}{\mu}\right) = \rho$

So (8) becomes:

$$\bar{e} = (\bar{m} - \bar{m}^*) - \lambda(\bar{y} - \bar{y}^*) - \gamma(i_t - i^*{}_t) + \rho(\bar{\pi} - \bar{\pi}^*) + \propto q_t + \epsilon_t \tag{9}$$

Frankel (1979) combined the Keynesian assumption of sticky prices with the Chicago assumption that there is a secular rate of inflation, and by combining these assumptions, he concluded "that the exchange rate (ER_t) is negatively related to the nominal interest rate differential ($INTD_t$), but positively related to the expected long-run inflation differential ($INFD_t$).

The baseline model is constructed by excluding income “to avoid possible multicollinearity in determining variables of exchange rate following studies by Faulkner and Makrelov (2008); Volkov and Yuhn (2016) which show that non-monetary factors significantly influence the level of the rand. The econometric model is shown below in equation (10).

$$ER_t = \beta_0 + \beta_1 DM_t + \lambda DY_t + \gamma INTD_t + \rho INFD_t + \alpha PI_t + \epsilon_t \tag{10}$$

where ER_t is the level of the exchange rate between the rand and the US dollar expressed as the number of units of rand needed to purchase one US dollar, DM_t is the logarithmic difference in the money supply (M2) between South Africa and the United States. Money supply shocks affect the exchange rate for the flexible exchange rate (Flood & Rose, 1999). DY_t is the logarithmic difference in output between South Africa and the United States, while $INTD_t$ is the interest rate differential and $INFD_t$ is the logarithmic difference in inflation between South Africa and the United States, and lastly, the PI_t is the equity market volatility index which proxy for pandemic uncertainties.

3.2 Methodology

The methodological approach for this paper is anchored on the VAR framework which involves the time-varying parameters vector autoregression (TVP) model and non-linear causality technique. Vector autoregressive model of n vector of time series sequence z_t assumes that a k^{th} order vector autoregressive representation of the sequence exists which takes the following form:

$$\Delta z_t = \alpha\beta' z_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \, \Delta z_{t-i} + \alpha\beta'_0 t + \vartheta D_t + \delta_0 + \epsilon_t \tag{11}$$

The assumption here is that $z_{k`+1}, \dots \dots z_0$ are assumed to be fixed, Δ is the first difference operator and ϵ_t is the innovation distributed with zero means and positive definite covariance matrix Φ of short-run parameters. The number of cointegrating vectors, r is given by $\alpha\beta$ where $\alpha \, and \, \beta$ are full column rank matrices of dimension n x r. β coefficient contains the long-run parameters. δ_0 coefficient is the deterministic trend often introduced as a result of model selection based on the stationarity of the data generating process. Both Vector autoregression (VAR)[2] and the Granger causality approach is used for this analysis[3]. The number of lags is chosen based on Schwartz Information Criterion (SIC) or Akaike Information Criterion (AIC) and the number of lags with the lowest value is chosen. The first step is to create the projection of the exchange rate determination using univariate autoregression then followed by nonlinear autoregressive distributed lags. The following section presents the spillover approach used to examine the connection between exchange rate and interest rate in a South African context.

The next section presents the TVP-VAR model used to analyse our results. First, we examine the connectedness measures between exchange rate and interest rate using the time-varying parameters vector autoregression (TVP) model. Secondly, we examine the causal effect of pandemic uncertainty on the exchange rate–interest nexus via a nonlinear causality test. Following Antonakakis *et al.* (2020), we compute the generalised impulse response functions and generalized error variance decomposition which are necessary for measuring the dynamic connectedness as follows:

$$\tilde{\rho}_{ij,t}(H) = \frac{\sum_{t=0}^{H-1} \alpha^2{}_{ij,t}}{\sum_{j=1}^{m} (\sum_{t=1}^{H-1} \alpha^2{}_{ij,t})} \tag{12}$$

where $\sum_{j=1}^{n} \tilde{\rho}_{ij,t}(H) = 1$, and $\sum_{i,j=1}^{n} \tilde{\rho}_{ij,t}(H) = m$

In (12), the numerator is a cumulative effect of a shock in a variable I, while the denominator is the cumulative effect of all shocks. We also present the total connectedness index by using the GFEVD:

$$C_t(H) = \frac{\sum_{j=1,i\neq j}^{m} \tilde{\rho}_{ij,t}(H)}{\sum_{i,j=1,}^{m} \tilde{\rho}_{ij,t}(H)} * 100 \tag{13}$$

$$\frac{\sum_{j=1,i\neq j}^{m} \tilde{\rho}_{ij,t}(H)}{m} * 100$$

In the next round of estimation, we adopt the Balcilar *et al.* (2018) method that extends the frameworks of Nishiayama *et al.* (2011) and Jeong *et al.* (2012) by developing a test for a second moment to determine nonlinear causality. Jeong *et al.* (2012), denote that the variable x_t(Pandemic uncertainty index) does not cause y_t(the exchange rate-interest nexus) in a $\sigma - quantile$ with respect to the lag-vector of {$y_{t-1}, \ldots, y_{t-q}, x_{t-1}, x_{t-q}$} if:

$$Q_\sigma(y_t|y_{t-1}, \ldots .. y_{t-q}, x_{t-1}, \ldots .. x_{t-q}) = Q_\sigma(y_t|y_{t-1}, \ldots .. y_{t-q}) \tag{14}$$

While x_t causes y_t in the σ^{th} quantile with respect to {$y_{t-1}, \ldots, y_{t-q}, x_{t-1}, x_{t-q}$} if:

$$Q_\sigma(y_t|y_{t-1}, \ldots .. y_{t-q}, x_{t-1}, \ldots .. x_{t-q}) \neq Q_\sigma(y_t|y_{t-1}, \ldots .. y_{t-q}) \tag{15}$$

Therefore, they adopted the non-parametric granger quantile causality method as suggested by Nishiayama *et al.* (2011). To show the causality in higher order moments, they assume.

$$y_t = h(V_{t-1}) + \vartheta(U_{t-1})\tau_t \tag{16}$$

where τ_t is the white noise process, and h(.) and $\vartheta(.)$ equal the unknown functions that satisfy pertinent conditions for stationarity. Although this specification allows for non–granger–type causality from U_{t-1} to y_t^2 when $\vartheta(.)$ is a general nonlinear function. Equation (16) is reformulated to account for a null hypothesis and alternative hypothesis for causality in variance in (17) and (18), respectively as follows:

$$H_0 = P\left\{F_{y_{t|W_{t-1}}}\left\{Q_\sigma\left(y_t\middle|W_{t-1}\right)\right\} = \sigma\right\} = 1 \tag{17}$$

$$H_1 = P\left\{F_{y_{t|W_{t-1}}}\left\{Q_\sigma\left(y_t\middle|W_{t-1}\right)\right\} = \sigma\right\} < 1 \tag{18}$$

We obtain the feasible test statistic for testing the null hypothesis in (17). With the inclusion of the Jeong *et al.* (2012) approach, Balcilar *et al.* (2018) overcome the issue that causality – in mean implies causality in variance. Both infer the causality in higher order moments through the use of the following model:

$$y_t = h(V_{t-1}, U_{t-1}) + \tau_t \tag{19}$$

Thus, the higher order quantile causality is:

$$H_0 = P\left\{F_{y_{t^k|W_{t-1}}}\{Q_\sigma(y_t|W_{t-1})\} = \sigma\right\} = 1 \tag{20}$$

$$H_1 = P\left\{F_{y_{t^k|W_{t-1}}}\{Q_\sigma(y_t|W_{t-1})\} = \sigma\right\} < 1 \tag{21}$$

for k = 1, 2, ….., k.

In summary, we test that x_t Granger causes y_t in σth quantile up to the kth moment.

4 EMPIRICAL STRATEGY AND RESULTS

4.1 Data Sampling

The data used in this study was collected from the Bureau of Statistics South Africa (Stats SA), South Africa Reserve Bank (SARB), Federal Reserve Bank of St. Louis (FRED), and World Bank (WDI) and International Monetary Fund (IMF)[4]. The variables collected are nominal interest rate which is the prevailing interest in the market; real interest rate which is the interest rate obtained by controlling for inflation; nominal exchange rate which refers to the nominal exchange rate for the South African rand per US dollar; monetary base –money supply (M2) which is used to proxy money supply volatility, consumer prices-inflation for both countries was used to proxy price volatility, real output was used to proxy productivity shocks of the respective countries. The infectious disease index (PI) is used to proxy for pandemic uncertainty which is collected from the Kroema website[5]. The pandemic crisis Index which is a proxy pandemic crisis is adapted from Baker *et al.* (2019). The dimension of the data is monthly for all variables. Variable inclusion was strictly based on the availability of data and whether it fully accounted for pandemic uncertainty. The results are presented with a brief discussion on a statistical description of the data distribution. All necessary time series transformations were performed before the empirical analysis was undertaken. The dimension of the data is monthly from January 1985 to August 2020.

4.2 Empirical Results

4.2.1 Preliminary Analysis

Table no. 1 below shows the descriptive statistics of all variables used in this analysis. The monthly infection (PI_t) has an average of 1.25 and a standard deviation of 0.38, the average consumer price index between South Africa and the USA ($INFD_t$) is 8 and the standard deviation is 4.50, showing greater volatility between South Africa and the USA inflation rate. The log difference of M2 between the two countries (DM_t) is -2.37 per average and a standard deviation of 0.73. The average exchange rate (rand-dollar-EXR_t) for the duration of the study is R7.12/$ and a standard deviation of 3.97, again showing significant volatility between the two currencies. The average interest rate differential between the two countries ($INTD_t$) is 10.41 and has a standard deviation of 3.68. The differential average of output index (DY_t) for SA and USA is -0.001 and the standard deviation is 0.001.

Table no. 1 – Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
time	428	513.5	123.697	300	727
PI_t	428	1.246	.377	.91	2.26
EXR_t	428	7.022	3.976	1.933	18.576
DM_t	428	-2.366	.731	-3.904	-1.596
DY_t	428	-.001	.011	-.052	.041
$INTD_t$	428	10.406	3.682	-8	20.5
$INFD_t$	428	8	4.497	-.288	20.426

Note: Source of data used to construct the above variables are as follows: The pandemic crisis Index which is a proxy pandemic crisis is adapted from Baker *et al.* (2019)[6]. DMt-is the log difference of M2 for USA and SA; INFDt- is the log difference between SA and USA CPI; EXRt -is the rand dollar exchange rate; DYt is the log difference of output between SA and USA; INTDt -is the interest rate differential between SA and USA. The number of observations is 428 which spans from January 1985 to August 2020.

All variables have minimum kurtosis, thus following normal distribution, the skewness of the variables is equal to zero, which implies all variables follow a standard normal distribution. Figure no. 1 below presents the exchange rate-interest rate differential for South African monthly data. The variables do not track each other initially especially before South Africa liberalised its capital account in 1995, following the termination of the dual exchange rate system (Mpofu, 2013) but track each other well thereafter, which might be due to economic reforms undertaken after independence. After the 2013-rand dollar exchange rate and the interest rate took their trajectory - the interest rate differential kept rising while the exchange rate declined. The variation in interest differential ($INTD_t$) can be since South African interest rates are higher than those of the USA.

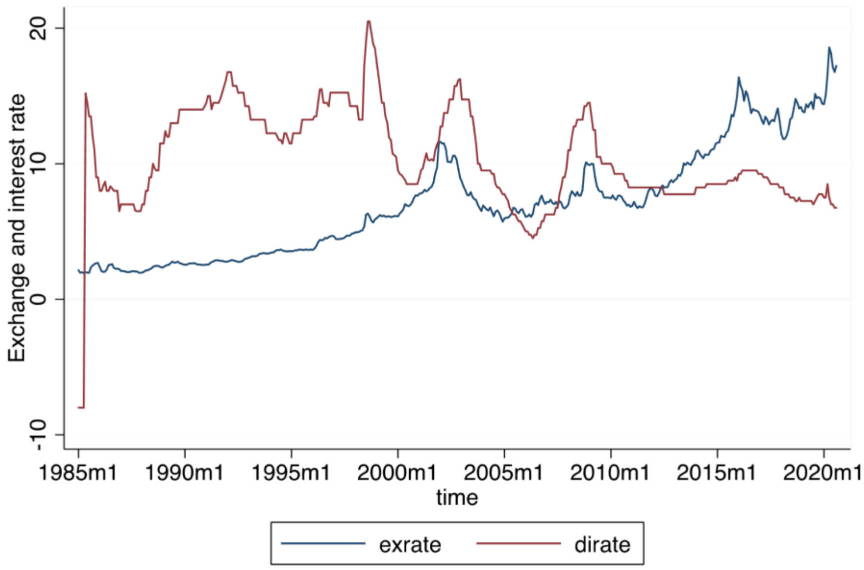


Figure no. 1 – Plot Exchange rate – interest rate for SA-USA
Source: authors' computation

Table no. 2 below shows the correlation for all the series used in this study, where pandemic uncertainty index (PI_t) is the only positively correlated with output (DY_t)[7] but not correlated to other variables. The pandemic uncertainty volatility index is negatively correlated with exchange rate volatility (EXR_t), the money supply (DM_t), interest rate differential ($INTD_t$) and inflation rate ($INFD_t$), but all of them are insignificant. This finding is interesting since one would expect the correlation to be highly pronounced during the period of the pandemic crisis. The dollar rand exchange rate is positive and significantly correlated with Money supply (DM_t) and output (DY_t). The exchange rate is influenced in the same direction as the changes in output and money growth. High output means high export which only results from a low exchange rate (a weaker rand). Similarly increase in money supply (M2) for South Africa will result in a weaker rand, ceteris paribus; a weaker rand will bolster exports. At the same time, it is negatively and significantly correlated with interest rate differential ($INTD_t$) and inflation ($INFD_t$). Inflation adversely affects the exchange rate. The growth of money supply (M2) is negative and significantly correlated with interest rate differential ($INTD_t$) and inflation ($INFD_t$). An increase in the money supply not backed by real productivity often results in inflation. It is only positively and significantly correlated with the growth of output (DY_t). This makes sense since increased productivity is often reflected in an increase in prices. The growth of output (DY_t) is positive and significantly correlated with interest differential ($INTD_t$), contrary to one's expectation of interest affecting output adversely through harming investment. Interest rate differential ($INTD_t$) is positively correlated with the growth of output (DY_t). All correlations are consistent with the theory with exception of output growth (DY_t) and interest rate differential ($INTD_t$). There is extensive evidence of variable relationships to warrant our analysis. The high correlation between exchange rate (EXR_t) and growth of money (DM_t) of 0.82 and that of growth of money (DM_t) and inflation differential ($INFD_t$) of 0.81 are likely to cause multicollinearity issues and the results will be estimated including and excluding them and the superior one will be reported.

Table no. 2 – Pairwise correlations

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
(1) PI_t	1.000					
(2) EXRt	-0.005	1.000				
(3) DM_t	-0.005	0.821*	1.000			
(4) DY_t	0.023	0.108*	0.214*	1.000		
(5) $INTD_t$	-0.055	-0.274*	-0.200*	0.258*	1.000	
(6) $INFD_t$	-0.015	-0.629*	-0.806*	-0.004	0.268*	1.000

Note: *** p<0.01, ** p<0.05, * p<0.1. The pandemic uncertainties index is adapted from Baker *et al.* (2019). DM_t-is the log difference of M2 for USA and SA; $INFD_t$- is the log difference between SA and USA CPI; EXR_t -is the rand dollar exchange rate; DY_t is the log difference of output between SA and USA; $INTD_t$ -is the interest rate differential between SA and USA.

Source: authors' computation

Estimating empirical results using time series data requires the variables to be stationary, implying unit root tests should be done before carrying out analysis. Figure no. 2 below shows that variables are not stationary at level. The volatility is highly pronounced in the pandemic index. Notable results in the ongoing COVID crisis are evident in the output variable.

Figure no. 3 below shows that all variables become stationary after differencing. Similarly, when the variables are differenced, the volatility remains but all variables evolve around the mean of zero. The structural break caused by the ongoing pandemic persists in all variables.

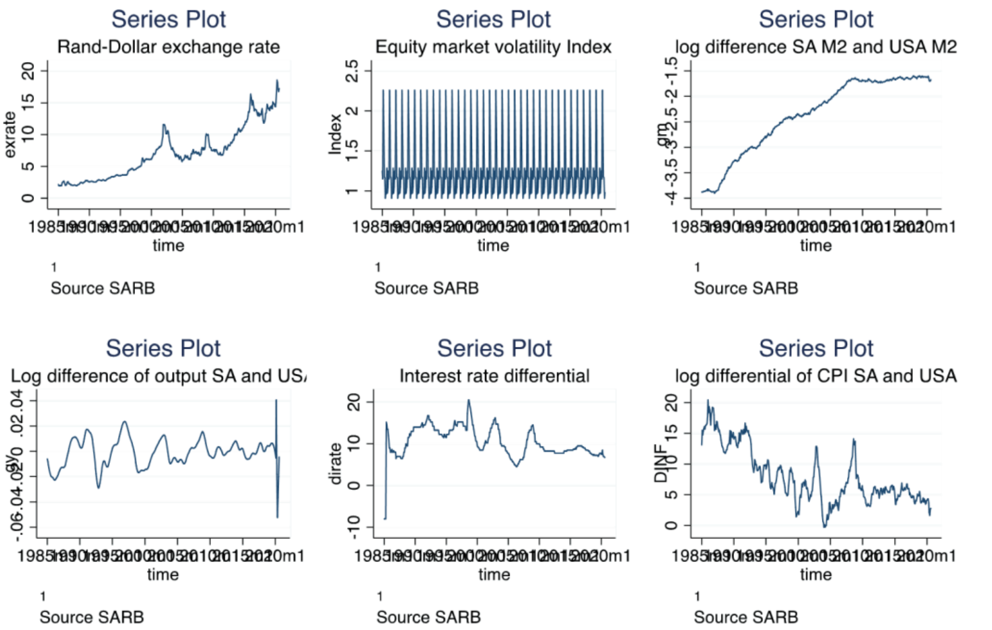


Figure no. 2 – Plot of variables before differencing
Source: authors' computation

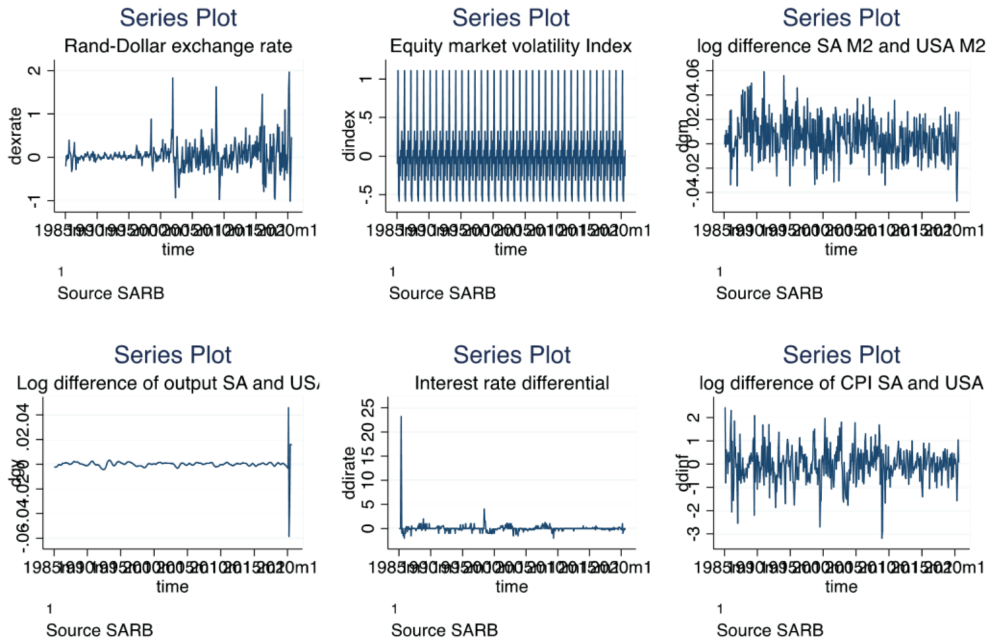


Figure no. 3 – Plot of variables after differencing
Source: authors' computation

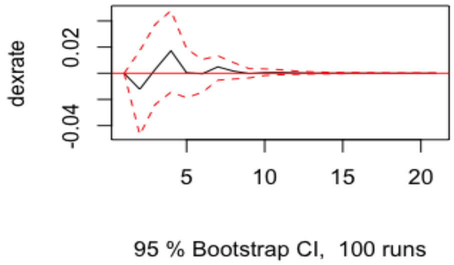
4.2.2 VAR Estimation Results.

In this section Vector Autoregressive (VAR) models are undertaken using the transformed data. The multivariate time series theory followed in this study is adopted from Lütkepohl (2005). The first order of action is to establish whether the series process is stable. If the series process is not stable it can become explosive or it can produce irrelevant results. The series process is said to be stable if its reverse characteristics polynomial has no root in and on the complex unit circle. The next step before performing VAR is to establish an adequate number of lags using AIC, HQ, SC and FPE. The number of appropriate lags to be chosen for our analysis is two for our VAR analysis, since the AIC become significant in the second lag.

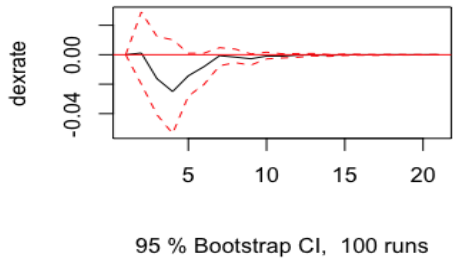
In summary, the exchange rate is mostly influenced by output growth and the pandemic uncertainty in the South African context and inflation seems to be strongly influenced by the exchange rate, output growth, interest rate and the pandemic uncertainty. The notable results are that the relationship between inflation and interest rate seems to break down in the South African context. This is consistent with the argument of Meese and Rogoff (1983) who argue that monetary model variables fail to adequately predict exchange rate volatility, implying that exchange rate swings are driven by non-monetary factors. One would expect the interest rate and inflation to be negatively related but the finding shows otherwise. This could be since inflation in South Africa is managed through the interest rate. Another interesting finding is that there is a positive relationship between real exchange rate volatility and output which is consistent with the finding of Calderón (2004).

4.2.3 Impulse response results.

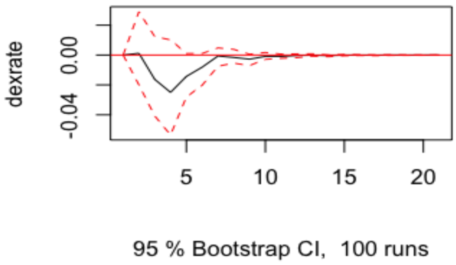
The impulse response plots trace the dynamic impact of a shock or change of an input to a system and are interpreted based on significance; magnitude and sign. The middle line in IRFs displays the response of the dependent variable to a one standard deviation shock in the explanatory variables. The dotted lines represent confidence bands. When the horizontal line in the IRFs falls between confidence bands, the impulse responses are said to be not statistically significant. Impulse response gives insights on policy implications resulting from a change in macroeconomic framework. The graphs below show the impulse response function for a VAR of the exchange rate, interest rate differential, growth rate of the price level (DINF), output (DY_t), money supply (DM_t) and the pandemic uncertainty index. The initial shock of the exchange rate resulting from inflation tends to decrease the exchange rate and then increase in the short run. The same can be said for exchange rate with real interest rate, inflation and pandemic uncertainty index. Interestingly the shocks from price inflation have similar effects on the exchange rate as those of interest rate differential. From our results below we see that the shocks are not persistent overtime for all variables[8].



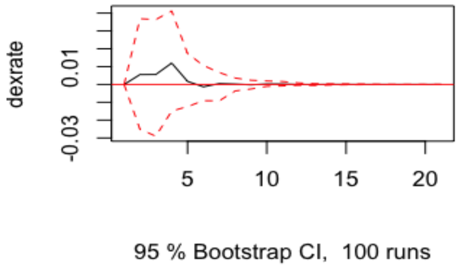
4(a): Response of Exchange rate to an inflation shock



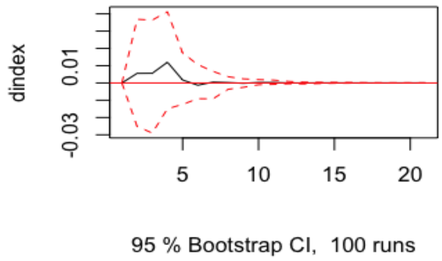
4(b): Response of Exchange rate to Money supply differential shock



4(c): Response of Exchange rate to GDP differential shock



4(d): Response of Exchange rate to interest rate differential shock



4(e): Response of Exchange rate to inflation differential shock

Figure no. 4 – Impulse Response Plots

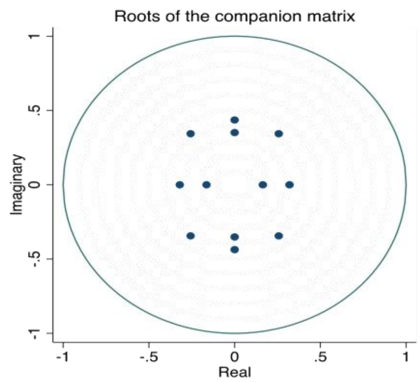


Figure no. 5 – Stability test of the variables used in the analysis

For the system to be stable, all eigenvalues must be within the unit circle. The VAR results for the used series satisfy the stability condition, and therefore we can proceed with our analysis.

4.2.4 Spillovers Analysis

Below, we report the time-varying covariance structure as opposed to the constant parameter rolling window VAR approach. Note that the Diebold and Yilmaz (2009, 2012) approach allows the measurement of interdependence across a network of variables, thus providing a way for one to be able to analyse both the idiosyncratic influence (i.e. own) and the influence by others (i.e., network). Diebold and Yilmaz (2012) provide elaborate merit of this approach.

Table no. 3 below depicts the connectedness approach which shows how a shock in one variable spills over to other variables. First, each variable transmits its shocks to all other variables. Second, the directional connectedness shows the shock received from other variables. Net directional connectedness is the difference between the total connectedness to others and can be interpreted as the power of a variable or its influence on the whole variable network. From these results, we see that the net influence of interest rate differential is -15.5 and -14.5 for output growth. Interestingly that is the largest influence in our study. The negative sign means that the interest rate differential and output growth are driven by the network, while exchange rate, money growth and inflation rate drive the network. The highest receiver of the shock from all the remaining variables combined is the exchange rate with a value of 48.7 followed by the growth of money whose value is 29.3. In addition, we see that among the variables pairs, exchange rate and growth of money receive more shocks than they give. Output growth and interest rate receive more shocks than they give, thus leading to their negative net spillover values of -14.5 and -15.5. It is clear that when it comes to volatility spillovers between the exchange rate and the interest rate in a South African context, evidence of the transmission of such shocks exists.

Table no. 3 – Average Dynamic Connectedness Results.

To (i)	exr	dm	dy	INTD	INFD	FROM
exr	48.7	31.3	1.1	2.0	16.9	51.3
dm	29.3	44.6	0.7	0.6	24.8	55.4
dy	7.6	5.1	79.5	2.7	5.1	20.5
INTD	7.8	5.8	2.0	73.5	11.0	26.5
INFD	15.0	26.6	2.3	5.8	50.3	49.7
Contribution to others	59.7	68.9	6.0	11.2	57.6	203.4
NET directional connectedness	8.3	13.5	-14.5	-15.5	7.9	TCI
NPDC transmitter	2.0	0.0	4.0	3.0	1.0	40.7

Notes: Values reported are variance decomposition for the estimation of TVP-VAR models for the conditional volatility (CV) obtained from DCC-GARCH model. Variance decompositions are based on a 10 step -ahead forecast. In both periods, a TVP VAR lag length of order 1. The pandemic crisis Index which proxy pandemic crisis is adapted from Baker *et al*. (2019). DM_t-is the log difference of M2 for USA and SA; $INFD_t$- is the log difference between SA and USA CPI; EXR_t -is the rand dollar exchange rate; DY_t is the log difference of output between SA and USA; $INTD_t$ -is the interest rate differential between SA and USA.

Source: authors' computation

Connecting these spillover transmissions to the infection uncertainty, the South African exchange rate –interest rate nexus is an important factor driving the financial market through its monetary policy set by SARB. Therefore, the connectedness between exchange rate and interest rate can be driven by infectious disease uncertainty first by affecting local financial market liquidity and investors' decisions. Thus the ongoing pandemic uncertainty in the economy that drives fluctuations in exchange rate-interest rate may induce volatility shocks to other parts of the economy.

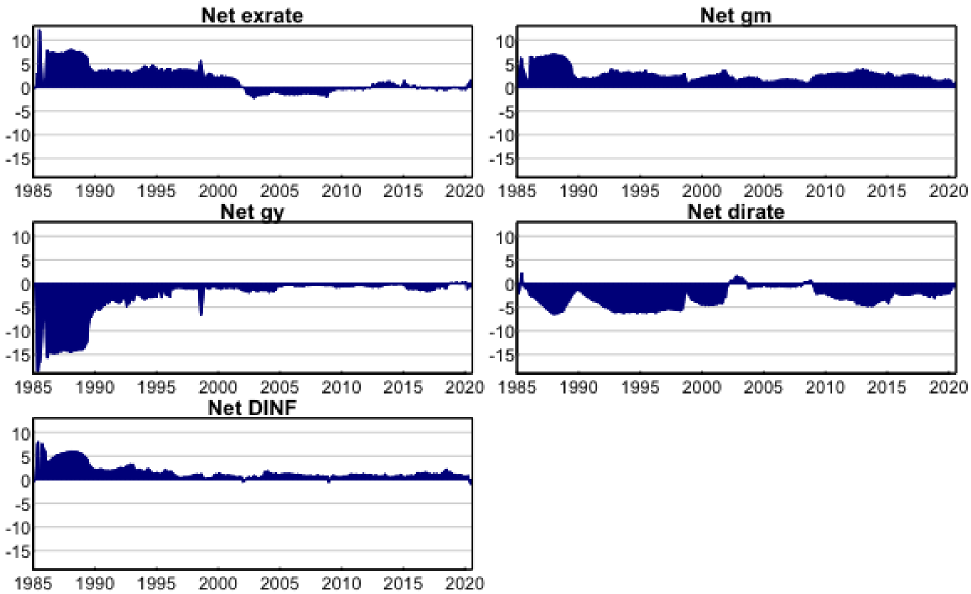


Figure no. 6 – Net Total Directional Connectedness
Source: authors' computation

4.2.5 Non-parametric causality Analysis

In this section, we examine the role of pandemic uncertainty on the connectedness between dollar-rand net exchange rate and net pandemic uncertainty, net exchange rate, net inflation, net output, and net money supply. We achieve this by investigating the causal effect of pandemic uncertainty on total and net spillovers for South Africa. The results in Table no. 4 below show that pandemic uncertainty does influence the exchange rate-interest rate nexus. All variables are significant, therefore we can conclude that the granger-causal between pandemic uncertainty and all other variables in the analysis.

Figures no. 7 and no. 8 summarize the results of the causality in a quantiles test we conducted for both conditional mean and variance for net spillovers and total spillovers with the pandemic uncertainty. Overall, the results show strong evidence supporting the rejection of the null hypothesis of the no granger causality. The causal evidence shows that at the median, the pandemic uncertainty is a strong predictor for volatility in the exchange rate – interest rate in a South African context, and tends to weaken at the extremes. The weaker connectedness at the extreme quantile suggests that the exchange rate –interest rate nexus is sensitive to the degree of exchange rate –interest rate movements. When markets are stable the connectedness between exchange rate-interest rate nexus and pandemic uncertainty seems to be less pronounced. To avoid committing misspecification bias errors in our estimation we proceed and perform quantile-based causality tests for our data below.

Table no. 4 – Causality test results

Pandemic Uncertainty does not cause	F-statistic	P-value
Total spillovers	1.8366***	0.0760
Net_exr	2.5974**	0.0113
Net_Pi	3.0039**	0.0038
Net_Dm	15.646**	2.2e-16
Net_Dy	7.4099**	7.296e-09
Net_INTD	15.039**	2.2e-16
Net_INFD	3.482**	0.0010

Note: This table presents the causality test results and ** represents a rejection of the underlying null that pandemic uncertainty does not granger cause exchange rate-interest rate at a 5% level of significance.

Source: authors' computation

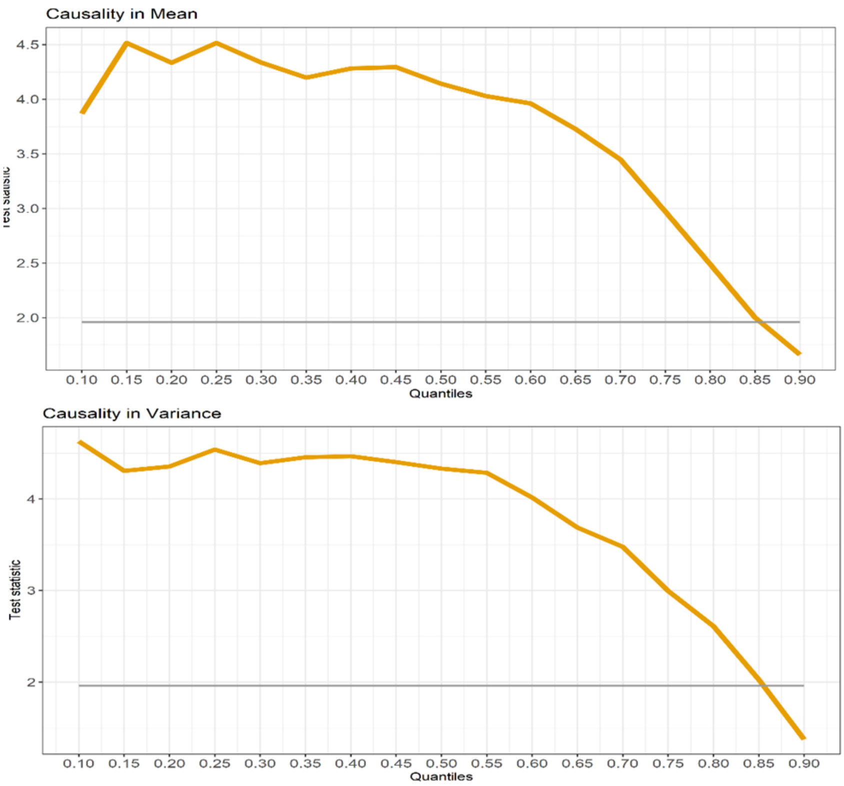


Figure no. 7 – Non-linear causality in mean and variance for total spillovers

Source: authors' computation

Figure no. 8 shows the quantile-based (nonlinear) causality tests in conditional mean and variance for Net spillovers connectedness at a 10% critical value. In general, there is no large variation between the mean and variance of total and net spillovers connectedness for our data and therefore we can conclude that the nonlinearity causality is present in our data-substantiate the need for time-varying parameter autoregression analysis contrary to the normal VAR.

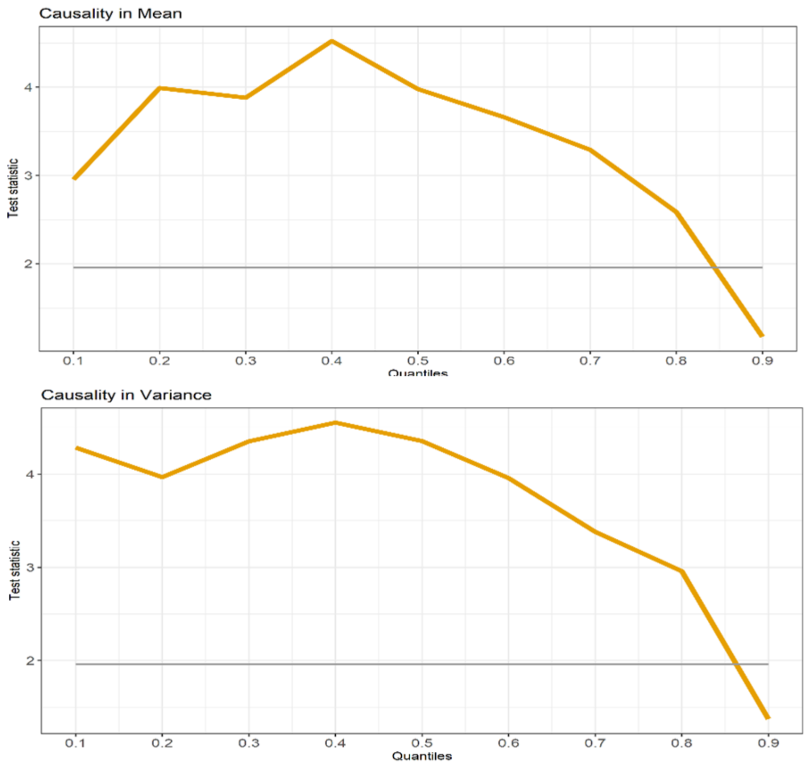


Figure no. 8 – Non-linear causality in mean and variance for net spillovers
Source: authors' computation

5. CONCLUSION AND IMPLICATION FOR POLICY

This paper investigates the exchange rate-interest rate nexus in South African data. Using VAR and TVP models, the study has two objectives: First, it tests the hypothesis that there is no exchange rate-interest nexus in South Africa. Second, it examines whether pandemic uncertainty volatility drives exchange rate volatility in South Africa. The results show that the pandemic uncertainty plays a significant role in explaining the interest rate exchange rate nexus in South Africa. The hypothesis that there is a rand-dollar exchange rate nexus during pandemic uncertainty is significant, therefore we fail to reject the null hypothesis under VAR specification. These results are consistent with those of Hnatkovska *et al.* (2013) who argue that there is no monotonic relationship between exchange rate and interest rate.

From the connectedness of variables analysis, we see that interest rate differential and output growth are driven by the network, while exchange rate, inflation, and money supply growth drive the network. These results suggest that the policymakers should pay more attention to real factors and exogenous factors such as infectious diseases uncertainty if they are to reduce exchange rate volatility, e.g. it is important to evaluate the costs of increasing pandemic uncertainty and understand the relationship between interest rate and exchange rate nexus. Other variables such as output growth, exchange rate, and money supply play a strong role in influencing the network and tend to drive the network. In short, results show a strong connection between infectious diseases uncertainty and exchange rate and interest rate. Lastly having established the robust evidence of a nonlinear relationship between exchange rate and infectious diseases uncertainty and the connectedness among the variables, policymakers need to incorporate movements of exogenous shocks such as infectious diseases uncertainties since it seems to be one of the drivers of the connectedness between the exchange rate and interest rates in South Africa. The findings of this paper contribute to the literature on the relationship between the real interest rate and the exchange rate when accounting for the risk premium in the South African context. The findings also serve as a roadmap for further investigations and analysis in other countries with similar patterns to those of South Africa. The transmission of financial crises into the economy has been at the epicentre of academic research, especially in the aftermath of each global financial crisis such as that of 2007-2009 and the ongoing Covid-19 pandemic since 2019. In the same spirit, the COVID pandemic is a global event which is likely to adversely affect the financial markets, both interest rate and exchange rate. To avoid rising inflation in the foreseeable future, the Reserve bank can attempt to mitigate the shock by pursuing a monetary tightening policy stance to stabilize the exchange rate. The reserve bank can implement monetary tightening by engaging in open market operations which absorb money from circulation and thus lead to an upward move in the interest rate. Yet this policy might result in a counter-productive scenario whereby further depreciation instead of appreciation of the exchange rate occurs. The monetary authority's effort to curtail the effect of such exogenous shocks to the exchange rate and the interest rate will be of interest to various stakeholders and policymakers. The major setback of this paper is the use of the mean-based measure of connectedness but it provides a starting point for future research which uses the frequency domain approach or the Time-varying parameter (TVP) modelling approach for exchange rate dynamic, e.g. rand–euro exchange dynamic nexus.

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Notes

[1] The relationship between the exchange rate and other macroeconomic variables such as the interest rate, the inflation rate, the GDP and the money supply (M2) affect the exchange rate directly, while non-macroeconomic variables such as the pandemic index variable affect the exchange rate indirectly. Exchange rate movements often stem from investors' expectations of expected profit, expected rate of returns, or speculation and hedging. Movements arising from exogenous factors are termed non-fundamental (Mpofu, 2013; Appleyard & Field, 2017).

[2] Vector autoregressions is an atheoretical approach whichconsiders a group of endogenous variables, whereby each variable is regressed with its lagged values and lagged values of the other variables. The predictive power of each variable for each of the others is determined.
[3] A variable x_t is said to Granger- cause the variable y_t if current y_t is predicted better from previous values of x_t as well as previous values of y_t than from previous values of y_t alone. That is to say, x_t Granger causes y_t if it has some incremental power to improve the prediction of y_t. Granger-causality establishes whether there is a long-term relationship between the variables.
[4] The South Africa bureau of statistics can be accessed through http://www.statssa.gov.za and the WDI data https://databank.worldbank.org/source/world-development-indicators and FRED can be accessed by https://fred.stlouisfed.org and IMF can be accessed through https://www.imf.org/en/Home.
[5] https://knoema.com/WPAUIN2020/world-pandemic-uncertainty-index.
[6] https://drive.google.com/open?id=1E9o758AnsJA6DHX4dc_xuvaMoYzDhy4G.
[7] The variables are differences of logarithmic variables at level.
[8] The results of forecast error decomposition (FEVD) which decomposes the variance of the forecast error into the contribution from each exogenous shock are available on request.

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