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Research article

COVID-19 and the effect of central bank intervention on exchange rate volatility in developing countries: The case of Uganda

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Abstract: The COVID-19 crisis has not only manifested as a tragic public health crisis but also as an unprecedented economic disruption characterized by economic deterioration, the sharp increase in market volatility and the blinding uncertainty about the impact of the pandemic, especially in the context of developing countries. It is therefore not surprising that central banks seeking to maintain macroeconomic and financial stability, which are critical for sustained economic development, have maintained the practice of central bank intervention, especially in developing countries. This paper empirically examines the effect of central bank foreign exchange interventions on the level and volatility of the Uganda shilling / US dollar exchange rate (UGX/USD). Utilizing daily data spanning the period December 30, 2016, to 1 December 2021, we estimate a foreign exchange intervention model within a GARCH theoretical framework. Empirical results indicate that foreign exchange interventions have had mixed impact on the volatility of the exchange rate. In addition, despite generating significant uncertainty, the COVID 19 pandemic adverse shock results in a 0.03 percent appreciation due to Uganda's policy response to the COVID-19 pandemic.

Keywords: central bank intervention; exchange rate volatility; inflation targeting regime; COVID-19

JEL Codes: C22, E52, E58, F31, I18

1. Introduction

Excessive exchange rate volatility remains a prominent concern in advanced, emerging and developing countries, especially for central banks seeking to maintain macroeconomic and financial stability, which are critical for sustained economic development. It is therefore not surprising that central bank intervention remains a common practice, especially in developing countries. Nonetheless, the efficacy of central bank foreign exchange intervention operations remains a highly contentious subject that continues to generate debate. Several studies find that the effectiveness of central bank intervention varies with choice of determinants, such as sample choice and monetary policy framework pursued, among other things (Catalán-Herrera, 2016; Disyatat & Galati, 2007; Ghosh et al., 2016; Mohanty & Berger, 2013), an indication that country-specific considerations should be taken into account. Thus, the efficacy of central bank intervention remains an empirical issue to be decided within the context of country-specific circumstances. In this paper, we empirically investigate the impact of central bank intervention operations in the Interbank Foreign Exchange Market (IFEM) aimed at maintaining foreign exchange rate stability. According to Bank of Uganda (BOU)'s stated policy objectives, intervention operations in the IFEM are aimed at curbing excessive volatility in the exchange rate and do not target a particular exchange rate level. While BOU typically exercises discretion in determining when and to what extent to intervene, in order to be considered successful or beneficial from a policy perspective, these intervention operations should reduce exchange rate volatility. Thus, the main aim of this study is to assess the impact of the Central Bank intervention on the level and volatility of the exchange rate in Uganda. In line with the above aim, the following are the specific objectives of the study.

1. To determine the efficacy of BOU's foreign exchange market intervention policy to calm excessive volatility in the IFEM.
2. To examine the effect of the overnight and CBR rates on the level and volatility of the exchange rate.

2. Overview of Uganda's foreign exchange market and intervention practices

The increased volatility associated with market determined exchange rates has significant impact on Uganda's macroeconomic stability and consequently on economic development. In view of this, Uganda, like many developing and emerging economies, continues to intervene in the interbank market with the policy aim of calming disorderly markets during periods of excessive exchange rate volatility. Accordingly, the central bank, BOU, only intervenes in the foreign exchange market to curtail excessive volatility without explicitly targeting any given level of the exchange rate. Nevertheless, as shown in Figure 1, exchange rate volatility has persisted despite BOU's intervention in the Interbank Foreign Exchange Market (IFEM). Therefore, the motivation of this study is to examine the efficacy of BOU intervention by determining whether empirical evidence is consistent with the central bank's objective of reducing excess exchange rate volatility through intervention in Uganda.

The foreign exchange market in Uganda consists of two tiers, the interbank or wholesale market and the client or retail market. Together, the two tiers have five broad categories of participants operating within them, namely, commercial bank dealers, other financial institutions and firms,

individuals, speculators and arbitragers, and the central bank. Commercial bank dealers operate in both the interbank and retail market, profiting from currency trading, and are often known as market makers, and they stand ready to buy and sell currency. Firms and individuals conduct transactions in the foreign exchange market for commercial and investment purposes, while arbitrageurs and speculators seek to profit from trading in the foreign exchange market. In the Ugandan foreign exchange market, the bulk of transactions comprises Spot transactions, although trading in Swaps, Forwards and derivatives is slowly picking up.

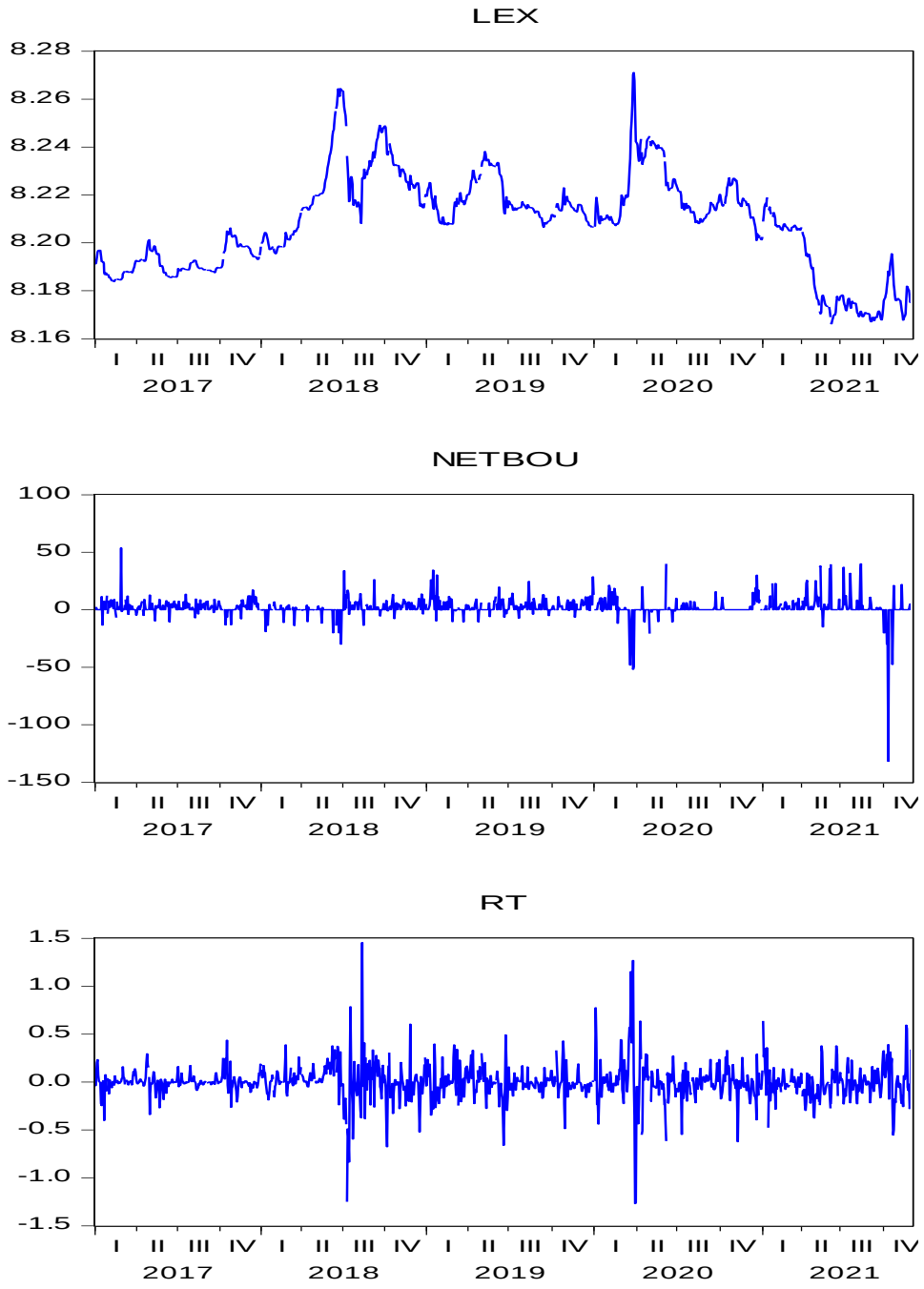

Figure 1. Foreign exchange rate developments and Bank of Uganda intervention.
Source: Bank of Uganda database.

Once the decision to intervene is taken, the BOU publicly announces that it is in the IFEM market for the purposes of intervention. The announcement is publicly broadcast on the Reuters trading platform at the time of the intervention operation. The platform allows for the central bank's presence in the market to be visible to all participants instantly. Once the announcement goes out, the BOU dealing room then conducts intervention sales or purchases of foreign exchange. The BOU hits the banks on their quoted rates either on the sale or purchase side depending on the central bank's predetermined intervention target. However, the central bank does not announce the size of its intervention operations to the market. All rate quotes in the IFEM are good for a minimum US$ 250,000. Once the banks realize the central bank's presence in the IFEM, they begin to adjust their quoted rates. The intervention operations are conducted in the IFEM spot market when the market is deepest and at its most liquid during normal business hours. This is consistent with the findings of the survey by (Archer, 2005) of developing and emerging market economies, which showed that many interventions take place in the wholesale spot market because it was the market with the greatest liquidity.

Although Bank of Uganda's intervention in the Interbank Foreign Exchange Market has hitherto been motivated principally by the need to maintain foreign exchange market and exchange rate stability, the central bank also uses the foreign exchange market to build up reserves or to sterilize foreign exchange inflows. This activity of the central bank in the interbank foreign exchange rate market is not motivated by profit-making but rather aimed at influencing the exchange rate in a manner that will support financial sector stability and economic growth and development of the Ugandan economy. Where the prime objective is to build reserves, BOU purchases dollars in the IFEM via auction with preannounced quantities. The auction runs from 10:40 am to 11:00 am, and once the cut off time elapses, the system automatically ranks the bids starting with the best offer bids. All reserve acquisition transactions are highly transparent and predictable to minimize the effect on the exchange market. However, in periods of extreme volatility, where these transactions cannot be carried out without causing volatility in the market, BOU communicates to the entire market that they will stay the purchase of dollars for reserve build up. With regards to sterilizing foreign exchange inflows, BOU sells dollars in the IFEM in an auction process like that applied for the build-up of reserves. These transactions are also highly transparent and predictable. During the period under study, the central bank did not conduct any sterilization operations, and as such the analysis focuses on reserve build up operations.

3. Literature overview

Although intervention is widely practiced in many central banks for various reasons, empirical evidence of the efficacy of foreign exchange intervention operations is mixed (Disyatat & Galati, 2007; Fratzscher et al., 2019; Katusiime & Agbola, 2018; Neely, 2008; Takagi, 2014).[1] The effectiveness of the central bank's intervention policy is premised on the fact that it holds better information than the market and has the ability to influence market outcomes (Dominguez, 1998; Sarno & Taylor, 2002). This is no easy feat given that central bank intervention actions are often limited in size and run counter

[1]See Chamon et al. (2019), Edison (1993), Menkhoff (2013) and Sarno and Taylor (2002) for a survey of the theoretical and empirical literature.

to prevailing market sentiment, with the aim of realigning market outcomes policy makers do not like to stated policy goals (Fratzscher et al., 2019). Although there are diverse central bank intervention goals, and the emphasis placed on different goals may vary, common motivations for foreign exchange market interventions include dampening exchange rate volatility, accumulating international reserves and reducing risks to monetary and financial stability (Mihaljek, 2005; Mohanty & Berger, 2013). Thus, the effectiveness of any central bank foreign exchange market intervention operation should be assessed with respect to the goals of the central bank's intervention policy (Fratzscher et al., 2019).

Although central bank intervention is a common practice in developing countries, few studies have investigated the effectiveness of central bank intervention in these countries. Data constraints have significantly hampered research on the impact of central bank intervention on exchange rate volatility in these economies (Disyatat & Galati, 2007; Guimarães & Karacadag, 2004). However, a priori, central bank interventions are expected to be more effective in these economies due to their structural characteristics (Disyatat & Galati, 2007).[2] This is consistent with the results of Goyal and Arora (2012), who found that in India, central bank intervention not only affects exchange rate volatility but also the level of the exchange rate, despite policy statements that there is no exchange rate target. A number of studies also find that central bank intervention successfully reduced exchange rate volatility, including Domaç and Mendoza (2004) for Mexico and Turkey, Shah et al. (2009) for Pakistan and Broto (2013) for Chile, Colombia, Mexico and Peru. Meanwhile, Tuna (2011) found that in Turkey, intervention operations increase exchange rate volatility. In addition, Seerattan and Spagnolo (2009) found that monetary policy impacts the sensitivity of the foreign exchange market to central bank intervention. Among the few studies in the Ugandan context is Lorna K. & Frank W. Agbola, who evaluated the impact of central bank foreign exchange intervention on the degree of fluctuation of the Uganda Shillings / US dollar (UGX/USD) exchange rate, in an inflation targeting environment. Their empirical results show that the intervention has mixed impact on foreign exchange rate volatility, while the inflation targeting framework can curtail short term exchange rate shocks. In addition, an increase in the 7-day interbank rate tends to exacerbate exchange rate volatility.

4. Methodology

This section describes the methods applied to test the hypothesis that BOU's intervention activity in the IFEM calms excessive exchange rate volatility. The study applies a GARCH estimation framework and daily data for the period December 30, 2016, to December 1, 2021, a total of 1227 trading days, excluding weekends and holidays, to examine the efficacy of central bank intervention in Uganda. In line with Nelson (1991), Engle (2001) and Kim et al. (2000), a parsimonious EGARCH (1, 1) model is specified as follows:

$$r_t = \beta_0 + \beta_1 r_{t-1} + \beta_2 r_{t-2} + \beta_3 r_{t-3} + \beta_4 \Delta CBR + \beta_5 \Delta overnight + \beta_6 order\ flow + \beta_7 net\ BOU\ Action + \beta_8 targeted\ sales + \beta_9 targed\ Purchases + \quad (1)$$

[2]According to the authors, emerging market economies tend to have a higher intervention size relative to market turnover, capital controls, financial regulations, lower market sophistication and stringent reporting requirements, which give the central bank greater control over markets.

$$\beta_{10} intervention\ sales + \beta_{11} intervention\ purcahses + \beta_{12} reserve\ build\ up$$
$$+\beta_{13} COVID19 + \varepsilon_t$$

$$\varepsilon_t = \sigma_t, z_t, \{z_t|\Omega_t \sim \psi_t(0,1,v)\}$$

$$\ln \sigma_t^2 = \omega + \alpha \left| \frac{\varepsilon_{t-1}}{\sqrt{\sigma_{t-1}^2}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \lambda \log \sigma_{t-1}^2 + \beta_{14} \Delta CBR + \beta_{15} \Delta overnight +$$
$$\beta_{16} order\ flow + \beta_{17} net\ BOU\ Action + \beta_{18} targeted\ sales + \beta_{19} targed\ Purchases \quad (2)$$
$$+\beta_{20} intervention\ sales + \beta_{21} intervention\ purcahses + \beta_{22} reserve\ build\ up$$
$$+\beta_{23} COVID19$$

where γ_t is the natural log difference of the UGX/USD exchange rate (s_t), computed as $r_t = \ln\left(\frac{s_t}{s_{t-1}}\right) * 100$, and ε_t is the error term. ω is a constant term, α is the ARCH term, λ is the GARCH term, and γ is the asymmetric term or leverage effect. $\gamma \neq 0$ indicates the presence of asymmetry, while $\gamma < 0$ shows that negative shocks generate more volatility than positive shocks of equal magnitude. In addition, λ measures the persistence of conditional volatility irrespective of anything happening in the market, such that when λ is relatively large, volatility takes a long time to die out following a crisis in the market. The EGARCH is covariance stationary provided $\lambda < 1$.

The exchange rate data used in this study are average mid quotes expressed as Ugandan shillings / US Dollar (UGX/US$), so that a rise in the exchange rate is a depreciation. The focus is on the UGX/US$ exchange rate since the US dollar accounts for the foreign currency transactions in Uganda. The net BOU intervention variable captures the aggregate effect of BOU intervention operations in the IFEM at time *t* and is derived as net purchases of USD arising from all Central Bank activities in the IFEM, in millions of USD. According to leaning against the wind theory, for the mean equation, the expected sign for this variable is negative because the central bank will purchase dollars even when faced with a depreciating currency (Edison, 1993; Kearns & Rigobon, 2005; Mohanty & Berger, 2013). Intervention is said to be effective in Equation 2 if an increase in net purchases of dollars lowers the volatility of exchange returns. The reserve build-up variable is a dummy control variable capturing effects of BOU foreign exchange purchases in the IFEM as part of BOU's foreign exchange reserve accumulation framework and takes on the value of 1 when these purchases occur and 0 otherwise. It is hypothesised that reserved build up results in a currency appreciation and thus is expected to carry a negative sign in Equation 1 and 2. We also include intervention dummy variables to control for the specific effects of BOU sale and purchase intervention operations in the IFEM that take the value of one when BOU purchase or sale intervention occur and 0 otherwise. The expected signs for BOU sale and purchase intervention operations are positive and negative, respectively, for Equation 1, consistent with the theory on leaning against the wind, and negative in Equation 2. In addition, we include dummy variables to capture the effects of targeted purchase or sale intervention operations that take the value of one when they occur and 0 otherwise. In Equation 1, consistent with the leaning against the wind hypothesis, targeted purchase and sale interventions are expected to carry negative and positive signs, while in Equation 2, targeted purchase and sale interventions are expected to carry a negative sign. Consistent with market microstructure literature, we include an order flow variable in the model given its documented close relation to macroeconomic fundamentals and its power to predict daily exchange

rate movements (Rime et al., 2010). The order flow variable is derived as the gap between the total purchases and sales in the foreign exchange market. The expected sign for this variable is positive, which implies that an increase in order flow leads to exchange rate depreciation under Equation 1, while under Equation 2 order flow is expected to carry a negative sign. Further, we include a dummy variable to capture the effect of the COVID-19 pandemic on exchange rate volatility in the IFEM, although the expected sign for the pandemic effect is indeterminate for both Equations 1 and 2. Importantly, the impact of monetary policy on the level and volatility of the exchange rate is captured by the central bank rate (CBR) while the overnight rate is used to capture the effects of short-term interest rate movements in the broader economy. The central bank rate (CBR) and overnight rates are expected to carry a negative sign under Equation 1 because an increase these interest rates supports domestic currency appreciation, while they are expected to reduce exchange rate volatility and thus carry a negative sign under Equation 2.

5. Empirical results and discussion

Table 1 presents the descriptive statistics for series employed in the analyses. The mean is negative, suggesting that exchange returns decreased slightly over time.

Table 1. Descriptive statistics of variables employed in the analyses.

Variable	Description	Mean	Std. Dev.	Maximum	Minimum
r_t	Natural log of nominal UGX/USD exchange rate return (Average)	−0.001	0.180	1.454	−1.268
CBR	Central Bank Rate	8.849	1.515	12.000	6.500
Overnight	Overnight interbank money market interest rate	8.034	1.457	12.900	4.000
Order flow	Order flow (US$ millions)	2.365	10.135	52.495	−70.950
Net BOU Action	Net BOU purchases of foreign currency in the foreign exchange market (US$ millions)	1.965	8.089	53.700	−131.700
Targeted sales	Dummy for Targeted sale intervention activity			1	0
Targeted purchase	Dummy for Targeted purchase intervention activity			1	0
Intervention sales	Dummy for BOU sale intervention activity			1	0
Intervention Purchases	Dummy for BOU purchase intervention activity			1	0
Reserve build-up	Dummy for BOU Reserve build-up activity			1	0
COVID19	Dummy for COVID-19 pandemic			1	0

Unit root tests were carried out to ascertain the dynamic properties of the data employed in estimation. Table 2 presents the results of unit root tests carried out on all variables of interest included

in the study. The central bank rate and overnight interbank money market rate variables are found to be non-stationary and contain a unit root, while exchange rate returns, Order Flow and Net BOU Intervention activity are found to be stationary, implying that the variables do not contain a unit root at 5% levels of significance. Thus, all variables are included in the model in their level forms, with the exception of the UGX/USD exchange rate, central bank rate and overnight interbank money market rate variables. Consequently, the study takes the first difference of these variables in order to ensure that they are difference-stationary before proceeding to the estimation of the selected model.

Table 2. Results of unit root tests of variables employed in the analyses.

Variables	Augmented Dicky Fuller (ADF) test		Phillips-Peron (PP) test		Kwiatkowski-Phillips-Schmidt-Shin	
	Level	First Difference	Level	First Difference	Level	First Difference
Central Bank Rate	−1.409	−35.110***	−1.407	−35.111***	3.651	0.119***
Overnight interbank money market interest rate	−4.240***		−20.564***		3.036	0.095***
Order flow	−32.564***		−34.620***		0.154***	
Net BOU purchases of foreign currency in the foreign exchange market (US$ millions)	−9.347***		−28.768***		0.059***	
Log nominal UGX/USD exchange rate (Average)	−2.264	−13.223***	−2.058	−21.637***	0.784	0.119***
Asymptotic critical values						
Significance level	ADF		PP		KPSS	
1%	−3.430		−3.430		0.739	
5%	−2.860		−2.860		0.463	
10%	−2.570		−2.570		0.347	

Notes: The figures in this table are unit-root test statistics. The asterisks ***, ** and * denote significance at the 1%, 5% and 10% level, respectively.

Before estimating a GARCH-type model, it is important to ascertain the presence of heteroscedasticity or ARCH effects. This will determine whether the application of GARCH estimation techniques is appropriate. The study used the Lagrange Multiplier ARCH Test (ARCH-LM test) to test for the presence of ARCH effects and Ljung-Box Statistics to check for correlation in residuals of the exchange rate return series computed from an auxiliary test regression. As shown in Table 3, there is clear evidence that the return series exhibit ARCH effects, indicated by ARCH-LM test and the Ljung-Box Q-statistics for squared residuals. Meanwhile, the Ljung-Box Q statistic of 4.8 is much larger than 0.05, indicating a failure to reject the null hypothesis that the residuals do not suffer from serial correlation. Given that heteroscedasticity is a pre-condition for applying the GARCH modeling framework, the result provides justification for the next stage in the analysis, which involves volatility modeling using the GARCH models.

Table 3. Preliminary tests.

Diagnostic Test	Test statistic
ARCH LM test	137.2 (0.00)
Ljung-Box Q Statistics	4.8 (0.18)
Ljung-Box Q Statistics (squared)	299.50 (0.00)

Note: Numbers in parentheses are the p-values for the ARCH coefficient.

The results of the EGARCH estimation for the mean and variance equations are presented in Table 4 below. The EGARCH (1, 1) estimation output is divided into two sections, with panel A providing results for the mean equation and panel B presenting results for the variance equation.

Table 4. Empirical results of the EGARCH (1, 1) and GARCH models.

Panel A: Mean equation Variable	EGARCH model	GARCH model
Exchange rate return (−1)	0.571***	0.476***
	16.52	9.39
Exchange rate return (−2)	−0.288***	−0.274***
	−7.98	−4.96
Exchange rate return (−3)	0.076***	0.060
	3.30	1.36
Central Bank Rate	−0.019	−0.078
	−0.89	−0.96
Overnight rate	−0.002	0.000
	−1.44	−0.04
Order flow	0.001***	0.002***
	7.44	2.69
Net BOU Action	−0.003***	−0.003**
	−8.53	−2.39
Targeted interventions (sale)	−0.041***	−0.015
	−5.68	−0.53
Targeted interventions (Purchases)	−0.002	0.024
	−0.06	0.56
BOU Intervention (sale)	−0.130**	−0.069
	−2.07	−0.93
BOU Intervention (Purchase)	−0.141	−0.231***
	−1.29	−2.91
Reserve Build Up dummy	−0.040***	−0.076***
	−7.54	−3.63
COVID-19	−0.027***	−0.026
	−4.12	−1.64
Constant	0.038***	0.044***
	10.99	3.09

Continued on next page

Panel B: Variance Equation		
Variable	EGARCH model	GARCH model
ω	−0.027***	0.017***
	−4.12	7.66
α	0.683***	0.147***
	16.02	4.76
γ	−0.049*	
	−1.78	
β	0.827***	0.528***
	51.27	8.46
Central Bank Rate	0.835***	0.017**
	3.25	2.00
Overnight rate	0.155***	0.002
	5.61	1.38
Order Flow	−0.001	0.0002**
	−0.39	−2.08
Net BOU Action	0.012**	0.0002
	2.57	−1.40
Targeted interventions (sale)	−0.454***	−0.014***
	−3.79	−5.40
Targeted interventions (Purchases)	0.172	−0.003
	0.53	−0.93
BOU Intervention (sale)	0.824***	0.003
	2.80	0.34
BOU Intervention (Purchase)	0.646	0.015
	1.48	0.84
Reserve Build Up dummy	−0.477***	−0.006**
	−8.76	−2.55
COVID-19	−0.038	−0.003***
	−1.12	−2.73

Notes: Z-statistics are in parentheses, while asterisks denote the significance of coefficients, with ***, ** and * indicating significance at the 1%, 5% and 10% level, respectively.

The results reported in Table 4 Panel A show that the net impact of all central bank activity in the IFEM, captured by the Net BOU Action variable, significantly affects the level of the exchange rate, resulting in an appreciation of the UGX/USD exchange rate by 0.003 percent following an increase in net BOU purchases by 1 million US dollars. The BOU's net purchase activity is consistent with leaning against the wind in the literature (Kearns & Rigobon, 2005; Mohanty & Berger, 2013) and affirms BOU's stated policy of not expressly targeting any particular level of the exchange rate and only intervening to smooth the path of the exchange rate, since the central bank's actions in the IFEM are not successful in reversing the trend of the exchange rate. However, out of all the investigated forms of central bank activity, only BOU sale interventions, targeted sale interventions and reserve build up actions in the IFEM, captured by the respective dummy variables, have a significant impact on exchange rate level. From Table 3, targeted sale interventions, reserve build up actions and BOU sales intervention in the IFEM statistically and significantly affect the level of the exchange rate, resulting

in exchange rate appreciation of 0.04 percent, 0.04 percent and 0.13 percent, respectively, at conventional confidence levels.

According to the results in Table 4 panel A, an increase in order flow by 1 million USD leads to a depreciation of the nominal exchange rate of 0.001 percent, indicating a statistically significant relationship between order flow and the nominal exchange rate at all conventional confidence levels. The results are consistent with the findings of Rime et al. (2010) and Menkhoff et al. (2016) and suggest that order flow contributes to the information aggregation process in the IFEM, assisting market participants to interpret price implications of new information concerning expectations and macroeconomic fundamentals. In addition, the COVID-19 pandemic has a statistically significant effect on the UGX/USD exchange rate at all conventional confidence levels, resulting in a 0.03 percent appreciation. This may be due to the surge in donor flows aimed at combating the effects of the COVID-19 pandemic and the muted demand for foreign currency during this period, thus causing the domestic currency to appreciate. Although the COVID-19 pandemic was a significant adverse shock that generated uncertainty in the IFEM, the policy response to COVID-19 resulted in the surge in both donor and portfolio inflows, which may have provided a strong supply of US dollars in the market. However, the study finds no statistically significant effect of the central bank rate and overnight interbank money market rates variables on the UGX/USD exchange rate.

The results of the variance equation presented in Table 3 panel B show that the estimated coefficients α and β are positive and significant at all conventional confidence levels. This evidence satisfies the non-negativity of the conditional variances for the EGARCH models. The high α coefficient estimate suggests that the size of the shock has a significant effect on exchange rate return volatility, such that the larger the shock to conditional variance is, the higher the volatility. In addition, the large and significant β coefficient indicates that not only is past volatility useful in predicting future volatility, but exchange rate volatility is also rather persistent, such that exchange rate shocks die out slowly. Also, we find evidence of asymmetric return-volatility, since the coefficient γ is negative and statistically significant, suggesting that exchange rate volatility reacts asymmetrically to good and bad news in IFEM. Since γ is less than zero, this means that negative shocks increase volatility more than the positive shocks of equal magnitude. Nevertheless, γ is only significantly different from zero at the 10 percent significance level, an indication that only a weak argument can be made that the sign of the shock influences exchange rate volatility.

In line with the main purpose of this study, we investigate the effect of overall and disaggregated BOU actions on the conditional variance of the nominal exchange rate. The study finds that aggregate central bank actions in the IFEM, captured by the Net BOU Action variable, are associated with an increase in exchange rate volatility, which is contrary to expectations. Specifically, net BOU intervention activity tends to increase exchange rate volatility by 0.01 percent, which is statistically significantly different from zero at the 5 percent confidence level. Likewise, BOU sale intervention operations significantly affect exchange rate volatility, resulting in a 0.8 percent increase in exchange volatility, and the effect is statistically significant at all conventional confidence levels. The study's finding of increased exchange rate volatility following the central bank's sale intervention may be the result of endogeneity biases, lagged effect of intervention or the level of opaqueness in BOU's intervention operations aimed at calming disorderly markets. According to Dominguez (1998), publicized interventions have their greatest effects when the central bank action is seen as a credible

and unambiguous source of information about market conditions. However, BOU, like many central banks in DEMs, conducts its intervention operations with limited disclosure. Thus, our result may be a result of the opaqueness in BOU's intervention operations, which may add further confusion in periods of turbulence because the central bank's ambiguous signals exacerbate market uncertainty and thus volatility. In addition, since interventions may display their full effects over days or weeks, short-term horizons may not be sufficient to establish the effectiveness of intervention (Pasquariello, 2007). Indeed, central bank practitioners argue that their intervention actions require at least a few days to have maximal effect on volatility (Neely, 2008). Further, Central Banks respond to extreme volatility during intervention operations, and endogeneity biases may then affect both significance and interpretation of estimates of the effect of Central Bank interventions on exchange volatility (Kim et al., 2000; Pasquariello, 2007).

In contrast, targeted sale intervention and reserve build up activities are associated with decline in exchange rate volatility of approximately 0.5 percent and 0.5 percent, respectively, which are statistically significantly at all conventional confidence levels. Importantly, the study finds that the central bank rate and overnight rate have positive and statistically significantly effects on exchange rate volatility, contrary to expectations. A percentage increase in the central bank rate and overnight interbank interest rate results in respective increases in exchange rate volatility of 0.8 percent and 0.2 percent, and the effects are statistically significant at all conventional confidence levels. This is an indication that the monetary policy stance and domestic money market conditions impact exchange rate volatility. This result might be a consequence of interest rate increases which attract short term capital flows and thereby increase exchange rate volatility. Despite the negative coefficient suggesting the COVID-19 pandemic resulted in a reduction in exchange rate volatility, likely due to imposed strict lockdowns that dampened market activity, the coefficient is statically insignificant.

Table 5. Diagnostics test results for EGARCH and GARCH models.

Diagnostics	EGARCH model	GARCH model
Adjusted R-squared	0.321	0.341
Durbin-Watson stat	2.07	1.91
Schwarz criterion	−1.52	−1.03
Hannan-Quinn criter.	−1.59	−1.10
Q-statistic probabilities (Lag 1)	0.18	0.06
Q-statistic probabilities (Lag 3)	0.35	0.01
Q-statistic probabilities (Lag 7)	0.22	0.06
ARCH LM test	0.74	0.00
Covariance stationarity	0.83	0.67

Note: Numbers in parentheses are the p-values for the arch coefficient. ***, ** and * respectively represents statistical significance at the 1%, 5% and 10%.

Table 4 above reports the results of diagnostic tests carried out on the standardized residuals of the EGARCH (1, 1) estimation to confirm that it provides a sound theoretical framework for examining the behavior of exchange rate returns. The study fails to reject the null hypothesis that there is no evidence of an ARCH-effect and concludes that the EGARCH (1, 1) specification is a superior model.

GARCH (1, 1) is considered to be one of the simplest and most robust of the family of volatility models (Engle, 2001). We perform an additional robustness check by estimating an augmented version of the traditional GARCH (1,1) model. We find that the estimated GARCH (1, 1) model, whose results are also reported in Table 4, is fairly similar to our EGARCH model. Further, using popularly known model selection criteria to assess the "goodness of fit" of the specified models, the study finds that all applied information criteria presented in Table 5, namely, Schwarz criterion (BIC) and the Hannan-Quinn criterion (HQ), favor the EGARCH (1,1) model, which has slightly smaller (more negative) values. Thus, according to these criteria, the EGARCH (1,1) model is the preferred model to correctly identify the true data generating a process for the analyzed dataset.

6. Conclusions

The study contributes towards a better understanding of the varying effectiveness of various policy instruments under the control of the central bank. According to the BOU's policy, the central bank does not target any level of the exchange rate but focuses only on minimizing excessive exchange rate volatility through intervention in the IFEM. This paper examines the efficacy of such official intervention during the sample period under review and finds evidence suggesting that while the BOU does not explicitly target any exchange rate level but intervenes in the IFEM to curb excessive volatility, BOU activity in the IFEM has mixed effects on the volatility of the exchange rate. Contrary to the BOU's stated policy objective, BOU intervention sales not only significantly affect the level but also its volatility, resulting in both an appreciation of the exchange rate and an increase in volatility. On the other hand, targeted sales significantly appreciate the level of the exchange rate, contrary to the BOU's stated policy objective, but this intervention activity assists in dampening exchange rate volatility. Consistent with the BOU's stated policy objective, reserve build-up purchases are not successful in reversing the trend of the exchange rate and reduce exchange rate volatility. This is consistent with the literature on leaning against the wind and affirms BOU's stated policy of not expressly targeting any level of the exchange rate and only intervening in the IFEM to build reserves. The empirical results suggest targeted purchases and BOU purchase intervention operations do not significantly affect the level and volatility of the exchange rate. Overall, the net impact of all BOU actions (Net BOU purchases) in the IFEM marginally appreciates the level of the exchange rate. This affirms BOU's stated policy of not expressly targeting any level of the exchange rate, although the net effect of all these BOU actions taken together results in a slight increase in exchange rate volatility, which is in contrast with BOU's stated policy of only intervening in the IFEM to smooth exchange rate volatility. The study finds no statistically significant effect of the CBR and overnight interbank rates on the level of the exchange rate, which is consistent with the view that sterilized intervention does not affect prices or interest rates directly. However, the study finds that the CBR and overnight rates have positive and statistically significantly effects on exchange rate volatility, an indication that monetary policy and domestic money market conditions impact exchange rate volatility.

Conflict of interest

The author declares no conflicts of interest in this paper.

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