The Short-Run and Long-Run Effects of Central Bank Rate on Exchange Rate Volatility in Indonesia

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Abstract

This research measures the short and long-run effects of central bank policy rate on the volatility of the exchange rate in Indonesia using the quarterly data from Q1 1992 to Q4 2019. The process involves applying an Autoregressive Distribution Lag estimation to investigate the effects of the variables. The exchange rate volatilities include Indonesia Rupiah to US Dollar (IDR-USD), Indonesia Rupiah to Singapore Dollar (IDR-SGD), Indonesia Rupiah to Australia Dollar (IDR-AUD), Indonesia Rupiah to British Pound Sterling (IDR-GBP), and Indonesia Rupiah to Euro (IDR-EURO). Several results were obtained and the first to show the adjustment time for exchange rate volatility to achieve long-run equilibrium was 1.77 quarters to 2.26 quarters using the ARDL estimation. Secondly, a decrease in the central bank rate was found to significantly reduce the exchange rate volatility in the short run and long run. These results are robust since Full Modified Ordinary Least Square (FMOLS) estimation was applied for all five models. Furthermore, it was found that in the long run, the central bank policy rate had a significant positive effect on the volatility of the Indonesia Rupiah against five foreign exchange rates. Therefore, it was suggested that the policymakers need to keep the interest rate of the central bank low and stable to ensure the Rupiah exchange rate stability.

Keywords: ARDL estimation, Central bank rate, Credit Gap, Exchange rate volatility, FMOLS, GARCH, Indonesia.

JEL Classification: E31; E52; F31.

1. Introduction

The Central Bank plays an important role in maintaining the stability of some macroeconomic variables such as the exchange rate, price, and finances in recent years [1, 2]. Currently, monetary policymakers are placing special attention on price and financial stability while exchange rate stability is always a secondary objective Fabris [3]; López-Villavicencio and Mignon [4]. Adeoye and Saibu [5] stated that domestic currency volatility is among the major sources of macroeconomic stability in emerging markets. Furthermore, the instability of currency in developing countries, most likely against the United States Dollar, has been reported to have a negative impact on economic fundamentals such as investment, consumption, and foreign trade [6]. However, the Central Bank can maintain the exchange rate stability through its reserve by selling the foreign currency when the domestic currency depreciates deeply, and vice versa [7].
The exchange rate has a crucial role in the development of an economic activity, particularly in terms of international trade and capital flows for small open economies [8, 9]. Therefore, the Central Bank in developing countries actively uses monetary policy to stabilise the exchange rate and avoid high volatility [10]. Exchange rate volatility is defined as large fluctuations around the balance value or short-term fluctuations around the exchange rate's long-term trends [11-13]. Also, exchange rate volatility is associated with unpredictability in the economy's relative prices. This means exchange rate stability is one of the most important factors that influence foreign investments, price stability, and economic growth [14-16].

Indonesia represents a unique example as a developing country to examine the relationship between the Central Bank rates and exchange rate volatility for three reasons. First, Indonesia applied a different exchange rate regime since the 1990s. Prior to the Asian Financial Crisis in 1997, the country ran a fixed exchange rate system. In this system, the Central Bank had full control of the monetary base [17-19]. However, since August 1997, Indonesia moved to a floating exchange rate regime in which the domestic currency is traded in the money market by following market mechanisms. This means the real currency is revealed based on market price without any government interference [20, 21] and the exchange rate depends on demand and supply [22, 23]. Second, Indonesia reformed the central bank in 1999, which led Bank Indonesia to be independent and free from political interference [24]. Third, the central bank of Indonesia has been implementing inflation targeting in the monetary policy framework since 2005 [25].

Figure 1 shows the growth rate of the Indonesia rupiah against five foreign currencies that are most frequently traded, namely the US dollar, the Singapore Dollar, the Australia Dollar, as well as the Great Britain Pound Sterling and Euro from 1992Q1 to 2019Q4, except for the Indonesia Rupiah to Singapore Dollar (IDR-SGD) from 1996Q1 to 2019Q4 and for IDR-Euro from 2000Q1 to 2019Q4. It can be seen that for the period 1992 to 1997, the movement of the Indonesia Rupiah against the US Dollar (USD), Singapore Dollar (SGD) and Australia Dollar (AUD) was relatively stable. In that period, Indonesia managed floating with a crawling band exchange rate system. Therefore, the Rupiah exchange rate movement was quite constant. However, in August 1997, the system was changed into a free-floating exchange rate. In the period 1998-2000, Indonesia experienced the Asian financial crisis, leading to a strong fluctuation of the Indonesia Rupiah against five foreign currencies. After 2000, the Central Bank of Indonesia interfered in the currency market to create a stable Rupiah. However, since it is traded freely in the financial market, the movement of the Rupiah against foreign currencies fluctuates.

The effect of monetary policy, particularly the Central Bank rate on the volatility of the exchange rate is inconclusive. This is because Khin et al. [26]; Ali et al. [27]; Saha and Biswas [28] and Mirchandani [29] claimed there is a negative relationship between central bank policy rate and exchange rate volatility while Kuncoro [25]; Hassan and Dantama [30] and Adeoye and Saibu [5] found a positive relationship. According to Kilicarslan [12]; Khin et al. [26]; Hassan and Dantama [30]; Ali et al. [27]; Adeoye and Saibu [5]; Saha and Biswas [28]; Jabeen and Khan [31] as well as Mirchandani [29] it is possible to determine the exchange rate volatility through output gap, money per growth domestic product (GDP), and credit gap.

This paper closes with Kuncoro [25] regarding the effect of interest rate on exchange rate volatility. However, this paper extends the Indonesia Rupiah volatility not only against the US dollar but also against four other foreign exchange rates, namely the Singaporean Dollar, Australia Dollar, as well as Pound Sterling and Euro. Another focus is on adding to the literature on the relationship between the central bank policy rate and domestic currency volatility with emphasis on the short and long-run effects of these variables. This was motivated by the fact that Indonesia is an emerging economy that uses a floating exchange rate and has a volatile and unstable rupiah currency against USDollar, which causes a negative effect on the country's macroeconomic stability [32-34]. This study contributes by finding the determinant of Indonesian currency volatility to provide the monetary policymaker with the necessary information to prevent further volatility.

In this study, to establish the short- and long-run effects of the central bank policy rate on exchange rate volatility, an Autoregressive Distribution Lag (ARDL) estimation was used, which was developed by Wickens and Breusch [35]. The results found the error correction term to be statistically significant with a negative sign. This means there is a long-run relationship between domestic currency volatility and its main determinants with the coefficients of error correction term (ECT) found to be in the range of -0.4424 to -0.5647. Also, the central bank policy rate and credit gap were found to have a positive and significant influence on the volatility of the exchange rate for the long-run estimation while the output gap and money per GDP have a negative effect. The findings from the short-run estimation showed central bank policy rate and credit gap have a positive and significant influence on domestic currency volatility in all models. Meanwhile, the output gap and money per GDP have an insignificant influence on domestic currency volatility in all models. In addition, the Full Modified Ordinary Least Square estimation was used for a robustness check of the long-run relationship among the variables. The result of FMOLS showed a positive effect of the central bank policy rate on the Rupiah volatility against the US Dollar, Singaporean Dollar, Australia Dollar, as well as Pound Sterling and Euro.
Figure 1.
Growth rate Indonesia rupiah against five foreign exchange rates and central bank rate.

The remaining parts of this study are organised in such a way that the second section reviews related literature, and the third explores the data set, the construction methodology used, and the models. In addition, the fourth section presents the empirical findings, and the fifth is the concluding section.

2. Literature Review

Several studies examined the effect of different macroeconomic variables on exchange rate volatility. For example, Kuncoro [25] studied the influence of applying an inflation-targeting framework on the volatility of the exchange rate in Indonesia using monthly data from July 2005 to July 2016. The result found the target inflation set by the monetary authority to only succeed in stabilising inflation but unsuccessful in reducing exchange rate volatility. Also, a change in foreign exchange intervention and the interest rate was shown not to guarantee exchange rate stability. Moreover, Kilicarslan [12] investigated the determinants of the Turkish Lira against US dollar Volatility from 1974 to 2016 and used the Johansen cointegration test to prove the long-run relationship between money supply, domestic investment, trade openness, output, foreign direct investment, and government expenditure as explanatory variables with exchange rate volatility. Full modified ordinary least square estimation was also used to determine the effect of the explanatory variables on exchange rate volatility. The results showed money supply, domestic investment, and trade openness increased the volatility of the exchange rate while foreign direct investment, government expenditure, and output stabilised the Lira - US dollar volatility.
Khin et al. [26] investigated the relationship between domestic currency volatility, money supply, consumer price index, and interest rate in Malaysia between January 2010 and August 2016 using the vector error correction model. The results showed the existence of a positive relationship between domestic currency volatility, consumer price index, and money supply, while interest rate and domestic currency volatility have a negative relationship. Furthermore, Adeoye and Saibu [5] examined the influence of a change in the monetary instrument on domestic currency volatility in Nigeria from 1980 to 2009 with the application of some monetary policy instruments such as money supply, interest rate, foreign reserve, economic growth, and inflation to determine the exchange rate volatility. The results showed that money supply, inflation, and interest rate have a positive and significant influence on exchange rate volatility, while foreign reserve has a negative impact.

Jabeen and Khan [31] investigated the main factors influencing the Pakistan Rupee exchange rate volatility using the monthly data from April 1982 to November 2011. The process involved the application of autoregressive conditional heteroskedasticity (ARCH) estimation to analyse the effect of trade openness, foreign reserve volatility, inflation, and output volatility on exchange rate volatility. The results showed that trade openness and foreign reserve volatility have a positive effect on the Pakistan Rupee exchange rate volatility while inflation and output volatility stabilised the rate. Furthermore, Mirchandani [29] examined the effect of macroeconomic variables such as interest rate, inflation, GDP, foreign direct investment, and current account on domestic currency volatility in India using annual data for the period 1991 to 2010. The results found a negative influence of interest rate, inflation, and current account on exchange rate volatility, while GDP and foreign direct investment have a positive influence on domestic currency stability.

3. Data and Methodology

3.1 Data

This study used time-series quarterly data from 1992 to 2019 and some other secondary data were obtained online from the official publication of the World Bank’s Global Financial Development Database and International Financial Statistics published by the International Monetary Fund (IMF). Moreover, the exchange rate was defined as the bilateral rate of the Rupiah against the US dollar, Singaporean Dollar, Australia Dollar, Pound Sterling and Euro. Therefore, an increase in IDR was assumed to cause the opponent exchange rate depreciation and vice versa.

The Central Bank rate was defined as the interest rate set by Bank Indonesia as a reference for commercial banking institutions in extending credit and is usually expressed as a percentage (%). This rate has been assumed by Mirchandani [29]; Saha and Biswas [28]; Ali et al. [27] and Khin et al. [26] to have a positive effect on domestic currency volatility due to higher interest rate usually associated with the increase in central bank rate. This normally boosts capital inflow to domestic businesses due to its ability to attract investors, thereby stabilising the exchange rate.

Several control variables with significant effects on exchange rate volatility were added in accordance with previous studies such as output gap as observed in Kilicarslan [12]; Hassan and Dantama [30]; Adeoye and Saibu [5]; Saha and Biswas [28] as well as Mirchandani [29] which was measured as the difference between the actual output (y) and the potential output (y*). In this study, the Hodrick-Prescott filter was used to compute the potential output. The HP filter is the most accepted in the empirical macroeconomics literature. Moreover, Adeoye and Saibu [5]; Hassan and Dantama [30] and Kilicarslan [12] showed the positive influence of money per GDP on the domestic currency volatility due to the increasing demand for credit. Therefore, credit gap was also added as an explanatory variable [29] and defined as the difference between credit to GDP and its long-term trend.

3.2 Methodology

The exchange rate return was calculated as the percentage change in the daily Indonesia Rupiah against the US dollar, Singaporean Dollar, Australia Dollar, Great British Pound and Euro over the same period from the previous day.

\[ R_t = \frac{S_t - S_{t-1}}{S_{t-1}} \times 100 \]  

(1)

where \( S_t \) is the exchange rate level at time \( t \). Equation 1 describes how to calculate the exchange rate volatility.

The GARCH (1,1) model was used to measure exchange rate volatility because it performed best in modelling the volatility of stock returns or exchange rate volatility. Furthermore, it is relatively simple to set up and calibrate because it relies on past observations. The compact representation of the GARCH (1,1) model is specified as follows:

\[ \begin{align*}
R_t &= a_0 + b_0 R_{t-1} + \varepsilon_t h_t^{1/2} \\
h_t &= \alpha_1 + \sum_{i=1}^{p} \theta_i h_{t-i} + \sum_{i=1}^{q} \theta_i \varepsilon_{t-i}^2 
\end{align*} \]  

(2)

Equations 2 and 3 present the mean and variance equations of GARCH estimation.

Ali et al. [27] and Weber [36] were used as a reference in investigating the effects of the central bank policy rate on exchange rate volatility. The basic model in our study is:

\[ ERVol_t = \beta_0 + \beta_1 CBrate_t + \varepsilon_t \]  

(4)

Equation 4 presents that exchange rate volatility is explained by the central bank policy rate. Thus, our model in this paper is:

\[ ERVol_t = \beta_0 + \beta_1 CBrate_t + \beta_2 Output\ Gap_t + \beta_3 Money\ per\ GDP_t + \beta_4 Credit\ Gap_t + \varepsilon_t \]  

(5)

Equation 5 describes that exchange rate volatility is explained by central bank policy rate, output gap, money supply and credit gap. Where ERVol is exchange rate volatility (IDR-USD, IDR-SGD, IDR-AUD, IDR-GBP, and IDR-EURO volatilities); CBrate is central bank rate. The econometric methodology used in the model was the multiple regression equation through the application of Autoregression Distribution Lag (ARDL). This model makes it simple to examine both
the short- and long-term volatility of ER. The ARDL model \((p, q, \ldots, q)\) which was defined for the same \(q\) in the explanatory variables as follows:

\[
y_t = \alpha_0 + \alpha_1 + \sum_{j=1}^{p} \beta_j y_{t-j} + \sum_{j=0}^{q} \gamma_j x_{t-j} + \epsilon_t \quad (6)
\]

Equation 6 presents the long-run equation of ARDL. Meanwhile, Equation 7 explains the short-run equations of ARDL.

The conditional error correction is described by:

\[
\Delta y_t = \alpha_0 + \alpha_1 t - \varphi (y_{t-1} - \theta x_t) + \sum_{j=1}^{p-1} \psi_j y_{t-j} + \sum_{j=0}^{q-1} \omega_j \Delta x_{t-j} + \epsilon_t \quad (7)
\]

Where \(\varphi = 1 - \sum_{k=1}^{p} \gamma_k\) represents the speed of adjustment and \(\theta = \frac{\sum_{k=0}^{q} \beta_k}{\varphi}\) denotes the long-run coefficients.

Thus, the model in Equation 5 becomes:

\[
\Delta ER_{vol_t} = \alpha_0 + \alpha_1 \Delta CBrate_t + \beta_1 CBrate_{t-1} + \alpha_2 \Delta Output\ Gap_t + \beta_2 Output\ Gap_{t-1} + \alpha_3 \Delta Money\ per\ GDP_t + \beta_3 Money\ per\ GDP_{t-1} + \alpha_4 \Delta Credit\ Gap_t + \beta_4 Credit\ Gap_{t-1} + \varphi ER_{vol_{t-1}} + \epsilon_t \quad (8)
\]

Equation 8 presents the ARDL model in this study after including all variables.

4. Empirical Results and Discussion

4.1. Descriptive Statistics

Table 1 shows the variables used and the minimum value for exchange rate volatility was found to be 0.0049 while the highest was 0.1332. Furthermore, the central bank policy rate was recorded to have a minimum value of 4.25% in Q3 of 2017 and a maximum value of 62.79% in Q1-Q4 1998 during the country’s economic and financial crisis. It was discovered that even though the average economic growth achieved by Indonesia was relatively high in the region of 4.8995%, the maximum value was 8.2200% in Q4 of 1995 while the minimum was -13.12679 in Q4 of 1998. Meanwhile, the money per GDP had an average growth rate of 43.679% with the highest ratio recorded to be 57.261% while the lowest was 36.002%.

The average inflation during the study period was 11.489 with a minimum value of -0.5957 and a maximum of 100.55. Meanwhile, the average credit gap was -2.8169 with a maximum of 57.900 and a minimum of -37.600. An additional fact was related to the foreign reserve variable which was converted in the form of a logarithm with the average value found to be 10.643 with a maximum of 11.751 and a minimum of 9.1716.

| Variables                  | Mean  | Std Dev. | Min.  | Max.  |
|----------------------------|-------|----------|-------|-------|
| IDR-USD Volatility         | 0.02  | 0.03     | 0.01  | 0.13  |
| IDR-SGD Volatility         | 0.00  | 0.01     | 0.00  | 0.02  |
| IDR-AUD Volatility         | 0.00  | 0.01     | 0.00  | 0.01  |
| IDR-GBP Volatility         | 0.00  | 0.01     | 0.00  | 0.01  |
| IDR-EURO Volatility        | 0.00  | 0.01     | 0.00  | 0.01  |
| Central Bank Rate          | 12.1  | 11.2     | 4.25  | 62.7  |
| Output Gap                 | 0.01  | 0.04     | -0.10 | 0.25  |
| Money per GDP              | 43.6  | 5.81     | 36.0  | 57.2  |
| Credit Gap                 | -2.81 | 15.9     | -37.6 | 57.9  |

Notes:
- IDR-USD Volatility is Indonesia Rupiah to US Dollar volatility.
- IDR-SGD Volatility is Indonesia Rupiah to Singapore Dollar volatility.
- IDR-AUD Volatility is Indonesia Rupiah to Australia Dollar volatility.
- IDR-GBP Volatility is Indonesia Rupiah to US British Pound Sterling volatility.
- IDR-EURO Volatility is Indonesia Rupiah to EURO volatility.

4.2. ARDL Bound Test Cointegration

The ARDL bound test was carried out to check long-run cointegration. In this test, the null hypothesis of no cointegration \((H_0: \beta_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0)\) against the alternative hypothesis \((H_1: \beta_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0)\) was used. Also, the F statistic value calculated by the model in Equation 1 compared to the critical value of the F statistic. If the F statistic is higher than the upper bound, then we reject the null hypothesis.

The results in Table 2 showed that the F statistic is higher than the value of the upper bound. Therefore, the null hypothesis is rejected and there is a long-run relationship between variables in the five models.
Table 2. Bound Test

| Model 1. Dependent Variable IDR-USD Volatility | ARDL Bound Testing | Cointegration | F-statistic: 6.2130 K: 4 |
|------|------------------|---------------|-------------------------|
| Null Hypothesis: No level relationship | 10% | I(0) | 1.9 |
| | 5% | I(1) | 3.01 |
| | 2.5% | I(0) | 2.26 |
| | 1% | I(1) | 3.48 |
| | 1% | I(0) | 2.62 |
| | 1% | I(1) | 3.9 |
| | 1% | I(0) | 4.07 |
| | 1% | I(1) | 4.44 |

| Model 2. Dependent Variable IDR-SGD Volatility | ARDL Bound Testing | Cointegration | F-statistic: 6.7029 K: 4 |
|------|------------------|---------------|-------------------------|
| Null Hypothesis: No level relationship | 10% | I(0) | 2.2 |
| | 5% | I(1) | 3.09 |
| | 2.5% | I(0) | 2.56 |
| | 1% | I(1) | 3.49 |
| | 1% | I(0) | 2.88 |
| | 1% | I(1) | 3.87 |
| | 1% | I(0) | 3.29 |
| | 1% | I(1) | 4.37 |

| Model 3. Dependent Variable IDR-AUD Volatility | ARDL Bound Testing | Cointegration | F-statistic: 6.9245 K: 4 |
|------|------------------|---------------|-------------------------|
| Null Hypothesis: No level relationship | 10% | I(0) | 2.45 |
| | 5% | I(1) | 3.52 |
| | 2.5% | I(0) | 2.86 |
| | 1% | I(1) | 4.01 |
| | 1% | I(0) | 3.25 |
| | 1% | I(1) | 4.49 |
| | 1% | I(0) | 3.74 |
| | 1% | I(1) | 5.06 |

| Model 4. Dependent Variable IDR-GBP Volatility | ARDL Bound Testing | Cointegration | F-statistic: 6.4786 K: 4 |
|------|------------------|---------------|-------------------------|
| Null Hypothesis: No level relationship | 10% | I(0) | 1.9 |
| | 5% | I(1) | 3.01 |
| | 2.5% | I(0) | 2.26 |
| | 1% | I(1) | 3.48 |
| | 1% | I(0) | 2.62 |
| | 1% | I(1) | 3.9 |
| | 1% | I(0) | 3.07 |
| | 1% | I(1) | 4.44 |

| Model 5. Dependent Variable IDR-EURO Volatility | ARDL Bound Testing | Cointegration | F-statistic: 6.4641 K: 4 |
|------|------------------|---------------|-------------------------|
| Null Hypothesis: No level relationship | 10% | I(0) | 1.9 |
| | 5% | I(1) | 3.01 |
| | 2.5% | I(0) | 2.26 |
| | 1% | I(1) | 3.48 |
| | 1% | I(0) | 2.62 |
| | 1% | I(1) | 3.9 |
| | 1% | I(0) | 3.07 |
| | 1% | I(1) | 4.44 |

**Note:**
- IDR-USD Volatility is Indonesia Rupiah to US Dollar volatility.
- IDR-SGD Volatility is Indonesia Rupiah to Singapore Dollar volatility.
- IDR-AUD Volatility is Indonesia Rupiah to Australian Dollar volatility.
- IDR-GBP Volatility is Indonesia Rupiah to British Pound Sterling volatility.
- IDR-EURO Volatility is Indonesia Rupiah to Euro volatility.

4.3. Autoregression Distribution Lag Estimation Result

Table 3 shows the results of the regression analysis conducted for the independent variables in the exchange rate volatility using an autoregression distribution lag estimation and central bank policy rate, output gap, money per GDP, and credit gap were discovered to have a significant effect. For the long-run estimation, the central bank policy rate was found to have a positive and significant influence on the volatility of the exchange rate in all five models. The output gap has a negative and significant influence on the volatility of the exchange rate in all five models, while the money per GDP has a positive effect at a 5% significant level in models 1 and 2. Also, the money per GDP has a negative influence on domestic currency volatility but the effect is insignificant in the model for IDR-SGD volatility. The credit gap was found to have a positive effect on domestic currency volatility at a 1% significant level for IDR-USD, IDR-GBP, and IDR-EURO volatilities but has a negative insignificant for models IDR-SGD and IDR-AUD volatilities.

On the other hand, the short-run estimation showed the central bank policy rate has a positive and significant influence on the volatility of the domestic currency in all models. Meanwhile, the output gap has a negative but insignificant influence on the exchange rate volatility in all models. The effects of money per GDP on the exchange rate volatility were found to be positive in all except for model 2. In addition, credit gap has a positive and significant effect on models 1, 3, and 5.

The adjustment coefficients of ARDL estimation for models 1 to 5 were found to be negative and significant at 1% with the speeds recorded to be between -0.4424 and -0.5501 for five models. The relevance of the lagged ECT implies that the model in this study for exchange rate volatility is properly described. These coefficients show approximately 44% to 56% of the disequilibrium observed in the short-run is corrected in the long run, with the adjustment time for exchange rate volatility to achieve long-run equilibrium estimated from 1.77 to 2.1 quarters. When the integrated variables diverge from their long-term relationship, the ECT serves as a force to bring them back into alignment. In general, the model is suitable for forecasting and policy modeling.
The long-run effect of the central bank policy rate, output gap, money per GDP, and credit gap on exchange rate volatility was first analysed. The central bank policy rate was found to have a positive influence on exchange rate volatility. This means an increase in the rate can cause a rise in domestic currency volatility and vice versa. The result specifically showed a 1% increase (decrease) in the central bank policy rate produced approximately 0.0785 to 0.6350 standard deviation increase (decrease) to the mean ratio of the domestic currency volatility. Furthermore, the lowest is for IDR-SGD volatility (0.0785) and the highest is for IDR-USD volatility (0.6350). The result of this study supports the exchange rate overshooting hypothesis developed by Dornbusch [37]. This is also in accordance with Adeoye and Saibu [5]; Hassan and Dantama [30] and Kuncoro [25]. The positive influence was associated with higher commercial banks' interest rates usually produced from an increase in the central bank policy rate. This consequently boosts the capital inflow to the domestic market due to its ability to attract investors, thereby enhancing the exchange rate volatility. However, this result contradicts Mirchandani [29]; Saha and Biswas [28]; Ali et al. [27]; Khin et al. [26] that interest rate has a negative impact on exchange rate volatility.

The output gap was discovered to have a negative influence on domestic currency volatility. Also, the findings related to the negative relation between the output gap and ER volatility are consistent with the prior theory of indirect policy described by Taylor [38]. This is in accordance with a previous study by Kilicarslan [12] as well as Hassan and Dantama [30]. The reduction was mainly observed to be the improvement in the national income due to the increase in the output gap that causes more stability in the macroeconomic conditions of the country as well as its exchange rate. Meanwhile, Adeoye and Saibu [5]; Saha and Biswas [28] and Mirchandani [29] had a contradictory result that the volatility of the exchange rate became higher with the increase in the output gap.

Money per GDP was also found to have a negative influence on exchange rate volatility. This means an increase in this variable usually leads to a subsequent reduction in domestic currency volatility and vice versa. The findings related to the negative relation between money and ER volatility are consistent with the prior theory of neutrality of money by Lucas Jr [39]. Therefore, an increase in the money per GDP was discovered to have the ability to cause a reduction in exchange rate volatility which is in accordance with Jabeen and Khan [31]; Ali et al. [27] and Khin et al. [26]. The negative relationship between the output gap and exchange rate volatility is due to the supply shock effect. When the economy is overheating, higher productivity drives the firms to increase output. The extra level of output leads to an increase in export and a decrease in imports, which will stabilise the exchange rate. This is in accordance with Adeoye and Saibu [5]; Hassan and Dantama [30]; Kilicarslan [12] that money supply has a positive relationship with domestic currency volatility.

The credit gap was also analysed and a contrast effect was found on IDR volatility. Credit gap has a positive and significant effect on IDR-USD, IDR-GBP, and IDR-EURO volatilities but has a positive insignificant for models IDR-SGD and IDR-AUD volatilities. A positive influence was observed with coefficients of 0.0695, 0.0520 and 0.0471 with a 1%
level of significance for models IDR-USD, IDR-GBP, and IDR-EURO volatilities, respectively. This was observed to have supported Mirchandani [29] with the positive effect discovered to be due to the ability of an increase in credit to lower demand for capital inflow from overseas or foreign direct investment (FDI), thereby enhancing the exchange rate volatility.

The focus on the short-run coefficients showed the central bank rate has a significant influence on the volatility of the exchange rate with a positive sign in the models of IDR-USD, IDR-AUD, IDR-GBP, and IDR-EURO volatilities and coefficients ranging from 1.1179 to 1.4704. These results mean that an increase in the central bank rate leads to a decrease in the volatility of the exchange rate. However, the central bank rate has no significant effect on IDR-SGD volatility. The results of this study also showed that there are no significant effects of output gap and money per GDP on IDR volatility in the short run. Credit gap also has a positive and significant effect on IDR volatility only for models of IDR-USD, IDR-AUD, and IDR-EURO volatilities.

The short-run money per GDP was found to have a negative and significant effect in models 1 and 2. However, no significant effect of economic growth, inflation, credit gap, and foreign reserve was found on the volatility exchange rate for all the models in the short run.

4.4. Diagnostic Checks

In this step, diagnostic tests were applied including Heteroscedasticity test, autocorrelation test, Normality test and functional test. Furthermore, the tests of cumulative sum of recursive residuals (CUSUM) and squares of recursive residuals (CUSUMSQ) were carried out to check the stability of long-run coefficients and short-run dynamics.

Table 4.

| Tests               | Model 1: IDR-USD Volatility | Model 2: IDR-SGD Volatility | Model 3: IDR-AUD Volatility | Model 4: IDR-GBP Volatility | Model 5: IDR-EURO Volatility |
|---------------------|------------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|
| Heteroskedasticity  | Fstat=0.63                   | Fstat=0.15                  | Fstat=0.78                  | Fstat=1.52                  | Fstat=0.72                   |
|                     | Prob=0.70                    | Prob=0.15                   | Prob=0.56                   | Prob=0.17                   | Prob=0.78                    |
| Serial Correlation  | Fstat=1.51                   | Fstat=0.32                  | Fstat=0.25                  | Fstat=1.18                  | Fstat=2.20                   |
| LM test             | Prob=0.23                    | Prob=0.27                   | Prob=0.77                   | Prob=0.31                   | Prob=0.11                    |
| Ramsey_Reset test   | Fstat=2.51                   | Fstat=2.55                  | Fstat=0.93                  | Fstat=1.16                  | Fstat=0.07                   |
|                     | Prob=0.12                    | Prob=0.11                   | Prob=0.33                   | Prob=0.28                   | Prob=0.78                    |

Notes:  
- Breusch-Pagan-Godfrey Heteroscedasticity test; Breusch-Godfrey serial correlation LM test, Jarque-Berra (Normality test); and Ramsey-Reset test.
- IDR-USD Volatility is Indonesia Rupiah to US Dollar volatility
- IDR-SGD Volatility is Indonesia Rupiah to Singapore Dollar volatility
- IDR-AUD Volatility is Indonesia Rupiah to Australia Dollar volatility
- IDR-SGD Volatility is Indonesia Rupiah to Singapore Dollar volatility
- IDR-GBP Volatility is Indonesia Rupiah to US British Pound Sterling volatility
- IDR-EURO Volatility is Indonesia Rupiah to EURO volatility

The results of Table 4 of diagnostic tests reveal that the models of this study are free from heteroscedasticity as well as serial correlation problem, and the data are normal. These results imply that the models are consistent and efficient. From Figure 2, CUSUM and CUSUMSQ tests concluded that the models are stable and the estimated results are reliable.

4.5. Robustness Tests

In this section, we undertake FMOLS estimate to provide a robustness check for the influence of central bank rates on exchange rate volatility. FMOLS was used to calculate the output's long-run elasticity. This technique takes endogeneity and serial correlation into account as well. Table 5 presents the result of FMOLS estimation for four models.

Table 5.

| Variable            | Model 1: IDR-USD Volatility | Model 2: IDR-SGD Volatility | Model 3: IDR-AUD Volatility | Model 4: IDR-GBP Volatility | Model 5: IDR-EURO Volatility |
|---------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------|
| Central Bank Rate   | 0.99*** (0.09)              | 0.05* (0.03)                | 0.60*** (0.05)              | 0.74*** (0.07)              | 0.74*** (0.07)               |
| Output Gap          | -19.58 (13.2)               | -0.89 (1.04)                | -16.1* (8.78)               | -17.1 (10.4)                | -17.1* (10.2)               |
| Money per GDP       | -0.18*** (0.02)             | -0.03 (0.02)                | -0.09*** (0.01)             | -0.12*** (0.02)             | -0.12*** (0.02)             |
| Credit Gap          | 0.14*** (0.04)              | -0.01 (0.01)                | 0.09*** (0.02)              | 0.12*** (0.03)              | 0.1100*** (0.0315)          |
| R²                  | 0.69                        | 0.89                        | 0.61                        | 0.68                        | 0.68                        |
| Adjusted R²         | 0.67                        | 0.88                        | 0.59                        | 0.66                        | 0.66                        |

Notes:  
- The symbols *, **, and *** denote statistical significance at 10 per cent, and 1 per cent respectively.
- IDR-USD Volatility is Indonesia Rupiah to US Dollar volatility.
- IDR-SGD Volatility is Indonesia Rupiah to Singapore Dollar volatility.
- IDR-AUD Volatility is Indonesia Rupiah to Australia Dollar volatility.
- IDR-GBP Volatility is Indonesia Rupiah to US British Pound Sterling volatility.
- IDR-EURO Volatility is Indonesia Rupiah to EURO volatility.
The fully modified ordinary least square estimation was performed to check the robustness of the long-run results obtained from the ARDL estimation. The advantage of this technique can correct the endogeneity bias and serial correlation in the model. Therefore, this estimation allows for standard normal inference [40]. The result of the FMOLS estimation confirmed the significant positive effect of the central bank policy rate on exchange rate volatility for all models. This
result is in accordance with the result of the main estimation using ARDL estimation of the positive relationship between the central bank policy rate and exchange rate volatility.

5. Conclusion

This study established the short-run and long-run effects of the central bank policy rate on exchange rate volatility in Indonesia for the quarterly data from Q1 1992 to Q4 2019. The Autoregressive Distribution Lag estimation was used to investigate the effect of independent variables including central bank rate, output gap, money per GDP, and credit gap on ER volatility. Furthermore, ER volatility of the Indonesia Rupiah against US, Singapore, and Australian Dollars, as well as the Pound Sterling and Euro was developed.

The results showed the central bank policy rate has a significant effect on exchange rate volatility in Indonesia both in the short and long run. Furthermore, the output gap and money per GDP have negative effects on ER volatility in the long-term but have insignificant effects in the short term. Moreover, credit gap has a significant positive effect on ER volatility in Indonesia both in the short- and long-term. These results are robust since the FMOLS estimation was used for all five models, it was found that in the long run, the central bank policy rate has a significant positive effect on the volatility of the Indonesia Rupiah against five foreign exchange rates.

The implication of these results is that the policymakers need to keep the central bank interest rate low and stable to ensure the Rupiah exchange rate stability. Therefore, to avoid a big change in ER in the long term, policymakers need to have careful monetary policy management.

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