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Effect of exchange rate on inflation in the inflation targeting framework: Is the threshold level relevant?

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ABSTRACT

The continuous depreciation of the exchange rate in Ghana has raised concern about its effect on inflation and the economy at large. This paper examines the threshold effect of exchange rate pass-through (ERPT) on inflation using a monthly data from January 2002 to December 2018. The relevance of the exchange rate threshold in the Taylor rule has also been examined. Using the threshold autoregressive (TAR) method, the results of the ERPT model revealed that exchange rate depreciation beyond a monthly threshold of 0.70% has a significant positive pass-through effect on inflation, which gives credence to the relevance of threshold level. The results of the monetary policy rule model also showed that regardless of the threshold level of 0.51%, the exchange rate significantly influences the monetary policy rate positively. Therefore, paying proper attention to the exchange rate in the policy rule despite the threshold (0.51%) will prevent the exchange rate depreciation from exceeding the optimal level (0.70%) and hence no ERPT on inflation. Based on these findings, it is suggested that monetary regulators should view the exchange rate at any level essential to adjust the policy rate.

1. Introduction

The exchange rate of many developing countries (such as Ghana) over the years has been a critical issue of concern given its poor performance against the major trading currencies such as the US Dollar, Euro, and the Great British Pound. It is believed that exchange rate has the potency to influence domestic policies as poor exchange rate performance could translate into price instability in an economy, especially in import dependent countries like Ghana. From 2002 to 2006, the Bank of Ghana (BoG) had implicitly implemented inflation targeting (IT) and in 2007, IT was formerly launched as its monetary policy framework to control inflation. This led to a shift from traditional intermediate targets [direct controls (interest rate) and monetary targeting] to IT as its core monetary policy tool. With the IT framework, monetary authorities or regulators remains committed to price stability by using monetary policy rate to target inflation. The relevance of IT has been acknowledged in some advanced economies given its good economic performance since its inception in the 1990s (Mohammed, Hadrat, & Emmanuel, 2016; Abango, Yusif, & Issifu, 2019). However, this has not been the case for developing economies (such as Ghana) due to the feeble implementation of IT resulting from weak fiscal, financial, and monetary institutions (Mishkin, 2004). Economies are now more integrated than ever, with many external shocks, such as exchange rate shocks, that influence domestic economic activities through price instability. Mody (2004) reported that the interaction of emerging economies in international markets exposes them to external shocks, like exchange rate shocks, which tend to threaten policies that influence macroeconomic variables. Although the IT framework accounts for exchange rate in the monetary policy rule to accommodate external shocks arising from exchange rate to avoid price instability, the inflation that emanates from exchange rate depreciation continues to be the major problem of developing countries. This raises concerns about the relevance of the exchange rate threshold in the central bank (CB) policy rule. Thus, identifying the threshold value at which exchange rate depreciation influences domestic prices notifies the level of exchange rate that must be committed in the policy rule for effective IT implementation. Indeed, the exchange rate represents the channel through which external shocks are transmitted to most emerging economies. Therefore, determining the threshold at which such a transmission occurs becomes imperative.

The implementation of IT in Ghana has resulted in some reduction in

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the inflation rate and, in some cases, achieving the target of 8 % ±2 (in 2018–2021). For example, the inflation rate decreased from 19.25 % in 2009 to 15.49 %, 17.45 %, 12.37 %, 7.81 %, 7.14 %, 9.89 %, and 9.97 % in 2014, 2016, 2017, 2018, 2019, 2020 and 2021, respectively (World Bank, 2021). However, the issue of attaining a sustained inflation rate within the target range of 8 % ±2 still remains a problem (Bleaney, Morozumi, & Mumuni, 2020) and therefore the need for further empirical studies regarding the exchange rate movements transmission on inflation rate.

Ghana is an import dependent economy and exchange rate movements have some potential influence on the inflation rate. Frimpong and Adam (2010), and Adu, Karimu, and Mensah (2015) have established the existence of direct exchange rate pass-through (ERPT) to domestic prices. Given the current monetary policy stance of BoG, where commitment is made to price stability using the policy rate while allowing the exchange rate to float, continued cedi depreciation may tend to have a negative impact on domestic prices. For example, the Ghana cedi depreciated against the US dollar in 2010 by 2.5 %, worsening to 19.73 % in 2012 and improving to 8.79 % in 2013. In 2014, the situation worsened as the cedi depreciated by 45.96 %, reducing to 11.25 % in 2017 and 5.28 % in 2018. According to Alagidede and Ibrahim (2017), the abysmal performance of the Ghana cedi against the major trading currencies (US Dollar, Euro, and the British Pound) has generated debate among economists, politicians, policymakers, and investors. Instability in the value of the cedi has negative impact on the purchasing power of consumers and domestic businesses that heavily depend on imported raw materials, semi-finished and finished goods. With the established ERPT and the continued depreciation of the Cedi, one would curiously ask what level of the exchange rate depreciation that result in ERPT. Recently, studies (such as Corsetti, Dedola, & Leduc, 2010; Monacelli, 2013; Ozdemir, 2020) in line with the newer version of the Taylor-type rule recommend that the reaction functions of central banks have to be augmented with exchange rate such that adjustment in the policy rate should also be based on exchange rate performance, since economies are now relatively integrated. In line with that, we examine the threshold level of exchange rate depreciation that must be considered in the policy rule of the BoG.

Bawumia and Abradu-Otoo (2003), Frimpong and Adam (2010), Sanusi (2010), Adu et al. (2015) and Asafo (2019) have examined the relationship between exchange rate and inflation. These authors reported the existence of exchange rate pass-through to inflation (domestic prices) but failed to account for the threshold or the optimal level of exchange rate depreciation beyond which exchange rate influences domestic prices (inflation). Given that some level of depreciation is good for participation in the international market, it is important to consider the threshold level after which exchange rate depreciation affect inflation. This paper adopts the threshold autoregression model to test for the nonlinearity in the pass-through effects through which the threshold or optimal level of exchange rate depreciation is generated. Thus, the level of exchange rate depreciation that accounts for the existence of the pass-through effect of exchange rate to inflation is determined.

Furthermore, unlike previous studies on Ghana (Sanusi, 2010; Adu et al., 2015; Asafo, 2019), this study contributes to knowledge by examining the relevance of the threshold level of the exchange rate depreciation in the policy rule. This will help monetary authorities to understand the level of exchange rate that requires the utmost attention when setting the policy rate via the policy rule to avert inflation. Studies such as Corsetti et al. (2010), Monacelli (2013), and Ozdemir (2020) have proven the relevance of augmenting the Taylor rule with exchange rate given that the exchange rate plays a vital role in an open economy. These authors shared the view that the reaction functions of central banks need to be augmented with exchange rate such that adjustment in the policy rate should also be based on exchange rate performance. In Turkey, Ozdemir (2020) postulates that explicit consideration of the exchange rate in the Taylor rule could be efficient since exchange rates now exhibit a major function in the transmission channels of inflation rates. The BoG through the IT implementation accounts for exchange rate in the policy rule. However, identifying the threshold level above which exchange rate deem feasible in the policy rule is important as agued above. Although the above studies have examined the relevance of the exchange rate in the policy rule, they did not address the threshold level at which the exchange rate must be important in the policy rule. In this regard, this study makes some contribution to literature and knowledge. First, this study determined the threshold level of exchange rate depreciation that accounts for the existence of ERPT to inflation. In addition, the level beyond which exchange rate depreciation must be incorporated into the policy rule to control inflation in Ghana is investigated.

In the rest of the paper, we present a brief review of the past literature in Section 2 followed by the methodological framework adopted, which is detailed in Section 3. Section 4 contains the results and the discussion, and finally, we conclude the study with policy implications in Section 5.

2. Literature review

This section focuses on both theoretical and empirical literature regarding exchange rate and inflation. The study specifically relies on the Taylor rule theory and the purchasing power parity theory as the theoretical underpinning.

2.1. Taylor rule theory

The Taylor rule, which determines the policy rate that stabilizes inflation and other macroeconomic variables was propounded by John Taylor in the 1993. The underlying intuition behind the rule is that changes in output, inflation, and other macroeconomic conditions determine how central banks should adjust the policy rate. Following Taylor (1993), the reaction function of many inflation targeting central banks took the form of Taylor-type rule. Although several versions of the theory exist depending on the commitment of the central bank, BoG uses the flexible inflation targeting framework where it takes into consideration other variables such as output growth and unemployment situation in addition to price stability. Taylor (1993) originally modelled the rule as follows.

$$I_t = \beta_0 + \beta_1(Y_t - Y^*) + \beta_2(INF_t - INF^*) \quad (1)$$

where I_t is the monetary policy rate, $(Y_t - Y^*)$ is the output gap (how actual output [Y] deviates from the potential output [Y^*]) and $(INF_t - INF^*)$ is the inflation deviation gap (the deviation of actual inflation [INF] from its targeted level of inflation [INF^*]). β_1 and β_2 are the relative weights the central bank attached to output and inflation gaps, respectively. From the rule, Taylor holds the view that adjustments of the policy rate depend on output and inflation gaps. The theory argues that policy rate should be increased anytime realized/expected inflation is above the target to curb inflation. The same reasoning holds for output deviation. Taylor claims that central banks determine the future interest rate according to realistic macroeconomic expectations. As a result, this theory serves as a fundamental basis for many empirical studies up to date (Woodford, 2001; Taylor & Taylor, 2004; Svensson, 2010).

Given that exchange rate remains crucial in an integrated economy, scholars have suggested the need to augment the Taylor rule with exchange rate so that monetary authorities may also adjust the policy rate based on the changes in exchange rate to reduce inflation. In this regard, Bleaney et al. (2020) employed ordinary least squares, logit, and probit models using monthly data for Ghana to analyse the relevance of exchange rate in the monetary policy rule. The study found an insignificant relationship between the policy rate and exchange rate movements, and therefore concluded that no weight should be assigned to the exchange rate in the policy rule. The insignificant relationship could be due to the linearity assumption considered by Bleaney et al. (2020). It is possible

that a certain level of exchange rate depreciation may matter in the policy rule. Therefore, considering the situation in nonlinearity form to obtain the exchange rate depreciation threshold may inform policy-makers with respect to the level of exchange depreciation beyond which it is important to consider the exchange rate in the policy rule. This study therefore seeks to consider this nonlinearity. For example, Castro (2011) investigated whether central banks' monetary policy is explained by the linear or non-linear nature of the Taylor rule in the Eurozone, the United Kingdom, and United States of America. The study indicated that the non-linear Taylor rule describes the monetary behaviours of the Bank of England and the European Central Bank, whereas the linear type describes the Federal Reserve of the United States. Similar to the study by Bleaney et al. (2020), Kurihara (2012) found a negative relationship between the call rate (policy rate) and the real exchange rate, signifying that the exchange rate does not matter in the monetary policy rule for the Czech Republic. Contrary to these studies, previous studies (such as Caporale, Helmi, Çatık, Ali, & Akdeniz, 2018; Tiryaki, Ceylan, & Erdoğan, 2018; Bekareva, Meltenisova, & Kravchenko, 2019; Ozdemir, 2020) showed that the exchange rate really matters in the monetary policy rule in emerging market economies. For example, Ozdemir (2020) investigated the relevance of exchange rate in the Taylor rule monetary policy of Turkey's central bank. Using the threshold vector autoregressive model and a monthly data, the study showed the relevance of the exchange rate in the reaction function and further indicates that policy implications could be deduced from the non-linear augmented Taylor rule than the linear form. It is obvious from the review that studies on Ghana with regard to the relevance of exchange rate threshold in the monetary policy rule within the Taylor rule rarely exist. Mention can only be made to Bleaney et al. (2020). However, their study fails to consider the relationship from a non-linear augmented Taylor rule perspective. This present study considers the non-linearity relationship by using the threshold autoregressive model.

2.2. Purchasing power parity (PPP) theory

The purchasing power parity (PPP) theory provides an avenue through which the transmission channel between exchange rate and inflation or domestic prices can be analyzed. The concept of PPP defines the ratio of price levels in terms of currencies between two countries for a common good. The theory argues that at a prevailing exchange rate in a foreign country, a unit of a domestic currency should be able to purchase an equal quantity of goods as the foreign currency. The implication is that for the PPP to hold, a depreciating domestic currency requires more units of domestic currency to afford goods worth the same unit of the foreign currency. Therefore, this leads to high prices for imported goods in the domestic country due to the exchange rate. The PPP therefore holds the view that differences in prices among two trading countries reflect the rate at which their currencies trade for each other. Given the PPP theory, several scholars have confirmed that exchange rate has a possible pass-through effect on domestic prices (inflation) both in Ghana and other parts of the world. For example, in the context of Ghana, studies (such as Sanusi, 2010; Frimpong & Adam, 2010; Adu et al., 2015; Amoah & Aziakpono, 2018, Asafo, 2019) have proven that exchange rates have a complete or incomplete pass-through effect on inflation, suggesting that exchange rate depreciation of the Cedi has a possible effect of increasing general price level (inflation). However, in a recent study by Duodu, Baidoo, Yusif, and Frimpong (2022), the exchange rate measured by the real effective exchange rate was found to influence inflation negatively, suggesting that the real effective exchange rate does not influence domestic prices in Ghana. It is worth mentioning that none of these studies on Ghana considered the threshold effect of exchange rate on inflation and therefore this study incorporates the threshold effect to broaden knowledge on exchange rate are and inflation relationship.

With respect to other studies, Gagnon and Ihrig (2004), Adolfson (2007) and Posedel and Tica (2007) indicated that there exists an exchange rate pass-through effect on inflation. For instance, using monthly data, Posedel and Tica (2007) employed a threshold regression and observed that exchange rate pass-through exist in Croatia with an exchange rate threshold of 2.69 %. This implied that exchange rate depreciation in Croatia only affects inflation when exchange rate depreciation is above 2.69 %. The study further observed that the lag value of nominal exchange rate depreciation was significant at the higher regime. Similarly, Aleem and Lahiani (2014) employed the threshold vector autoregression model and showed that in Mexico, exchange rate above the threshold level 0.7 % exhibit significant pass-through while being insignificant below the threshold level. Other studies such as Faryna (2016) and Mohammed and Bashir (2018) have validated the existence of exchange rate pass-through in Ukraine and Nigeria, respectively. In particular, Faryna (2016) observed that above the threshold levels of 3 % and 16 %, exchange rate depreciation has a larger ERPT impact on Ukraine inflation. Mohammed and Bashir (2018) noted that ERPT effect on Nigerian import prices only exists beyond the threshold values of 9.63 % and 10.99 %. However, Sajid, Muhammad, and Siddiqui (2018) argued that in Pakistan, exchange rate depreciation has insignificant threshold (1.46 %) effects on inflation rate.

Furthermore, some studies have considered foreign exchange reserves and fear of floating in inflation-exchange rate relationship. In particular, Lin and Wang (2005) examined foreign exchange reserves and inflation in 5 East Asian nations and observed that when foreign exchange reserves increase, the inflation rate will rise, while the exchange rate effect is effective. Similarly, Hervé (2016) explored foreign exchange reserve and inflation relationship in 4 West African countries and found that foreign exchange reserves lead to increase in inflation rate. Indicating that reduction in foreign exchange reserves will stabilize an economy. Honig (2005) in the study of fear of floating and domestic liability dollarization indicated that domestic liability dollarization causes fear of floating in the developing countries, indicating that these nations can regain flexibility in the choice of exchange rate regime to overcome fear of floating to stabilize exchange rate. Again, Feridun (2012) investigated liability dollarization, exchange market pressure (EMP), and the fear of floating in Turkey and found that liability dollarization causes EMP. Feridun argued that foreign currency liabilities in banks promote selling pressure on exchange market and fear of floating.

3. Methodology

3.1. Empirical model specification

The study first specifies the empirical model for the exchange rate pass-through on inflation and thereafter builds the model for the relevance of exchange rate in monetary policy rule within the Taylor rule setting.

With respect to the exchange rate pass-through on inflation, this study follows the work of Aleem and Lahiani (2014) and Bernanke, Laubach, Mishkin, and Posen (2018) who modified the PPP theory to account for the behaviour of the Central Banks by including the policy rate as shown in Equation (2).

$$INF_t = \alpha + \varphi_1 INF_t^f + \varphi_2 EXR_t + \varphi_3 MPR_t + \varepsilon_t \quad (2)$$

where *INF, INF^f, EXR*, and *MPR* denote domestic inflation (price), foreign inflation (price), exchange rate, and monetary policy rate, respectively. ε is the error term that is assumed to be normally distributed with zero mean and constant variance. The inclusion of the monetary policy rate (*MPR*) by Aleem and Lahiani (2014) and Bernanke et al. (2018) is based on the fact that IT central banks may try to insulate exchange rate movement for effective inflation targeting. Therefore, neglecting the policy variable may not explain the actual relationship between the exchange rate and domestic inflation. Furthermore, Equation (2) is augmented by incorporating output (*Y*) as well as the lags of the explanatory variables following Aleem and Lahiani (2014). The

Table 1
Brief variable description.

Variable	Measurement/proxy	Expected sign	Source
Inflation (*INF*)	Monthly consumer price index (CPI)	–	BoG database
Inflation gap (*INF* – *INF**)	Difference between CPI and the targeted inflation rate of 8 %.	Positive on *MPR*	BoG database
Monetary policy rate (*MPR*)	Monthly policy rate (%)	Negative on *INF*	BoG database
Exchange rate (*EXR*)	The ratio monthly percentage change of domestic currency (Cedi) to a unit of the foreign currency (US Dollar)	Positive on *INF* and *MPR*	BoG database
Output (*Y*)	Composite index of economic activity (CIEA)	Negative on *INF*	BoG database
Output gap (*Y* – *Y**)	Difference between trend from the CIEA and the actual CIEA.	Positive on *MPR*	BoG database

Note: BoG denotes Bank of Ghana.

inclusion of output (Y) accounts for the influence of domestic output fluctuations on inflation rate. The lags of the explanatory variables were captured to assess how the past information (specifically, exchange rate depreciation) influence domestic inflation since policymakers depend on past information for current policies (Aleem & Lahiani, 2014). However, in the modified version of Equation (3), the foreign price (INF^f) is assumed in this study to influence domestic prices through the exchange rate in the world market. Hence, foreign price is ruled out in Equation (3).

$$INF_t = \alpha + \varphi_1 Y_t + \varphi_2 Y_{t-1} + \varphi_3 EXR_t + \varphi_4 EXR_{t-1} + \varphi_5 MPR_t + \varphi_6 MPR_{t-1} + \varepsilon_t \tag{3}$$

where Y denotes the output and the φs are the parameters to be estimated. Y_{t-1}, EXR_{t-1}, MPR_{t-1} are the lags of output, exchange rate and monetary policy rate, respectively.

Regarding the relevance of the exchange rate threshold in the policy rule (IT[1]) of the BoG, this present study relies on the Taylor rule and augments it with the exchange rate following past studies by Svensson (1999) and Ozdemir (2020). Equation (4) is the modified Taylor rule following Ozdemir (2020).

$$\begin{aligned} MPR_t =& \phi_0 + \phi_1 MPR_{t-1} + \phi_2 (Y_t - Y^*) + \phi_3 (INF_t - INF^*) + \phi_4 EXR_t \\ &+ \phi_5 EXR_{t-1} + \varepsilon_t \end{aligned} \tag{4}$$

where MPR is the monetary policy rate, $(Y_t - Y^*)$ is the output deviation gap, $(INF_t - INF^*)$ is the inflation deviation gap and EXR is the exchange rate. MPR_{t-1} and EXR_{t-1} are the lags of monetary policy rate and exchange rate, respectively. The inclusion of the lags is based on the fact that an expectation is formed based on past information. Therefore, it is imperative to incorporate the lag of the exchange rate in the model. ϕ_4 and ϕ_5 represent the weight the central bank should assign to the exchange rate if it wants to adjust the policy rate in response to exchange rate movements. If a positive relationship is established in the pass-through model [Equation (3)], then, the response of exchange rate (ϕ_4/ϕ_5) and inflation rate (ϕ_3) to the policy rate [Equation (4)] has the same sign. If this is the case, then, it is obvious that targeting exchange rate movement and inflation rate by one policy variable could be compatible.

3.2. Data and variable description

This study relies on monthly secondary data spanning January 2002 to December 2018. The study period is based on the availability of data and the fact that it falls within the adoption of both an implicit and explicit inflation targeting period in Ghana. The data for our study are extracted from the Bank of Ghana database. Specifically, inflation rate was measured by monthly average change in the consumer price index (CPI) whereas the inflation gap is measured as the difference between the actual inflation rate (measured with CPI) and the targeted inflation rate of 8 %. Monetary policy rate was measured by the monthly policy rate. The exchange rate was measured by the monthly percentage change in the ratio of the domestic currency (Cedi) to a unit of the foreign currency (US Dollar). With regard to output and output gap, the study uses the composite index of economic activity (CIEA) as a measure of output since the BoG uses the CIEA in its monetary policy rule. For the output gap, the study follows the Hodrick-Prescott filter with a smoothing parameter $\lambda = 14{,}400$ to generate the CIEA trend and then subtract it from the actual CIEA to obtain the output gap. The choice of the study variables and its measurement are influenced by previous studies (Caporale et al., 2018; Tiryaki et al., 2018; Bekareva et al., 2019; Ozdemir, 2020). Table 1 is the summary of the description of the variables.

3.3. Identification method

This study relies on the threshold autoregressive technique (TAR) proposed by Tong (1978). The choice of this estimator is based on its ability to account for non-linearity and to generate a threshold level through which exchange rate pass-through may exist and may matter in the policy rule. This estimation method allows an exogenous variable called a threshold variable to split the sample in the model into two or more regimes (usually low and high regimes). Due to the objectives of this study, the exchange rate is considered a threshold variable where the performance of the exchange rate is classified into high and low regimes depending on the threshold value. Following Munir, Mansur, and Furuoka (2009), the general non-linear specification of the TAR is specified in Equation (5).

$$M_t = (A_{01} + \sum_{i=1}^{p} A_{1i} \boldsymbol{X_t}) d[EXR_t \le \tau] + \left(A_{02} + \sum_{i=1}^{p} A_{2i} \boldsymbol{X_t}\right) d[EXR_t > \tau] + \varepsilon_t \tag{5}$$

where M_t is the dependent variable [inflation in equation (3) and monetary policy rate in equation (4)] while $\boldsymbol{X_t}$ represents a vector of independent variables including the lag variables. d[.] is the dummy indicator function and τ is the threshold value, which separates the threshold variable into low and high regimes. In this study, exchange rate depreciation above the threshold value is known to be the high regime, whereas the low regime is the periods in which exchange rate depreciation is below the threshold value. EXR_t is the exchange rate depreciation denoting the threshold variable. The expressions $EXR_t \le \tau$ and $EXR_t > \tau$ indicate the low and high regimes, respectively. $A_{01}, A_{02}, A_{1i} and A_{2i}$ are the regime-dependent parameters to be estimated. The specific estimable model form of Equation (5) is expressed in Equations (6) and (7).

$$\begin{aligned} INF_t =& (\alpha_1 + \varphi_{11} Y_t + \varphi_{12} Y_{t-1} + \varphi_{13} EXR_t + \varphi_{14} EXR_{t-1} + \varphi_{15} MPR_t \\ &+ \varphi_{16} MPR_{t-1}) d[EXR_t \le \tau] + (\alpha_2 + \varphi_{21} Y_t + \varphi_{22} Y_{t-1} + \varphi_{23} EXR_t \\ &+ \varphi_{24} EXR_{t-1} + \varphi_{25} MPR_t + \varphi_{26} MPR_{t-1}) d[EXR_t > \tau] + \varepsilon_t \end{aligned} \tag{6}$$

$$\begin{aligned} MPR_t =& (\phi_1 + \phi_{11} MPR_{t-1} + \phi_{12} (Y_t - Y^*) + \phi_{13} (INF_t - INF^*) + \phi_{14} EXR_t \\ &+ \phi_{15} EXR_{t-1}) d[EXR_t \le \tau] + (\phi_2 + \phi_{21} MPR_{t-1} + \phi_{22} (Y_t - Y^*) \\ &+ \phi_{23} (INF_t - INF^*) + \phi_{24} EXR_t + \phi_{25} EXR_{t-1}) d[EXR_t > \tau] + \varepsilon_t \end{aligned} \tag{7}$$

where all variables are as defined previously. To assess the non-linearity within the TAR estimation, this study uses the Wald (1943) test of parameter equality across regimes. The null hypothesis of the test proposes a symmetric effect [i.e. there exist equal parameters (linear) in

[1] In particular, the flexible inflation targeting framework.

Table 2
Descriptive statistics.

Variable	Observation	Mean	Standard Deviation	Minimum Value	Maximum Value
INF	204	14.658	5.370	8.39	33.63
EXR	204	0.892	1.452	−7.583	10.045
MPR	204	18.405	4.461	12.5	27.5
Y	204	18.613	7.125	3.48	43.16
(Y – Y)*	204	−0.012	0.310	−1.384	1.810
(INF – INF)*	204	6.658	5.370	0.39	25.63

Note: *INF, EXR, MPR, Y, (Y – Y*),* and *(INF – INF*)* represent inflation rate, exchange rate, monetary policy rate, output, output gap, and inflation gap, respectively.

both low and high regimes]. However, the alternate suggests asymmetric effect [i.e. unequal coefficients (nonlinear) in both low and high regimes].

Given that the presence of unit root or nonstationary variables leads to spurious estimates (Pesaran, 2007), this study employs the Augmented Dickey–Fuller (ADF) by Dickey and Fuller (1979), Phillips-Perron (P—P) by Phillips and Perron (1988), and the Zivot and Andrews (Z-A) unit root test by Zivot and Andrews (2002) to establish the absence of unit root or otherwise. In both the ADF and the P—P, the null hypothesis of nonstationary variables is tested against the alternative hypothesis of stationary variables. However, in the Z-A test, the null hypothesis of a unit root with no structural break is tested against the alternative hypothesis of stationarity with structural break. To further ensure that the TAR models do not exhibit serial correlation and heteroscedasticity, robust standard errors are employed in the estimations.

4. Results and discussion

This section focuses on the results and the discussion of the study. The section begins with the descriptive statistics and trend analysis of the variables, and this is followed by the results of the stationarity test. The non-linearity test as well as the TAR estimation results are also presented.

4.1. Descriptive statistic and trend analysis

In Table 2 and Fig. 1 are the descriptive statistics and trend analysis, respectively. In Table 2, it is observed that the monthly average inflation in Ghana is about 14.66 % with minimum and maximum values of 8.36 % and 33.63 %, respectively. The monthly average of 14.66 % leaves no doubt that inflation is a challenge in the Ghanaian economy as inflation poses threat to the economy. Exchange rate depreciation, which is the variable of interest in this study, is observed to have an average value of 0.89 % with minimum and maximum values of −7.58 % and 10.05 %, respectively. The average value of exchange rate depreciation indicates that the monthly depreciation of the Ghana cedi is quite moderate compared with the monthly threshold value of 0.70 %. Regarding monetary policy rate and output growth, it is revealed that the mean value of monetary policy rate and output growth in Ghana are 18.41 % and 18.61 %, respectively. Generally, the mean values of the monetary policy rate and the output growth are observed to correspond to each other, suggesting that the monetary policy rate set in Ghana has an influence on output growth.

Furthermore, it is observed that the average value of the output gap and the inflation gap are approximately −0.01 % and 6.66 %, respectively. The mean values of output gap and the inflation gap reveal that, the output deviation is relatively smaller compared with the inflation deviation. This suggests that Ghana usually does well in its output targets than it does in achieving its inflation targets. Given the standard deviations, it can be concluded that generally, the variables deviate around their means with few exceptions.

With regard to the trend analysis of exchange rate depreciation, monetary policy rate and inflation in Ghana, Fig. 1 reveals that monetary policy rate and inflation on average show a similar trend over time, although there exist some variations. For instance, for the period 2002, the monetary policy rate goes beyond that of inflation, and this was the same from 2010 through to 2018. Inflation overlaps the monetary policy rate in the period 2003 to 2004, and this also happens in the period 2008 to 2009. It is also observed that monetary policy rate on average responds to the inflation rate in Ghana. This is because, in periods of higher inflation, the monetary policy rate is above the inflation rate to offset the rise in inflation, as argued by the Taylor rule.

Regarding the exchange rate depreciation, this study shows that exchange rate depreciation is relatively stable from 2002 to 2007 although there exist smaller fluctuations. These relatively stable periods of exchange rate depreciation can be attributed to the effectiveness of the implicit IT monetary policy adopted from 2002 to 2006. It could also be attributed to the relief from Highly Indebted Poor Countries (HIPC) that relieved Ghana from servicing external debt, which resulted in more

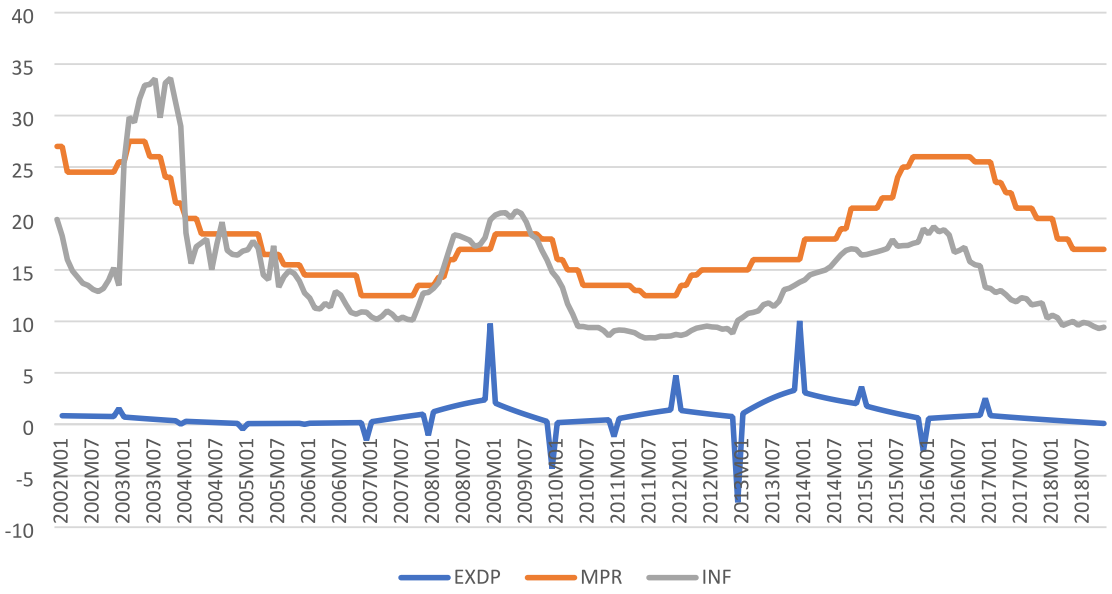

Fig. 1. Trend analysis of exchange rate depreciation, inflation, and monetary policy rate.

Table 3
Stationarity test results.

	ADF		P—P		Z-A		
Variable	*I*(0)	*I*(1)	*I*(0)	*I*(1)	*I*(0)	*I*(1)	Remarks
INF	−2.607	−6.652***	−2.649	−12.027***	−3.081	−12.154***	Stationary
EXR	−4.397***	−12.722***	−9.274***	−30.149***	−5.787***	−13.048***	Stationary
MPR	−1.638	−5.747***	−2.021	−14.325***	−2.741	−6.424***	Stationary
Y	−3.853**	−11.690***	−6.079***	−26.309***	−4.491	−16.410***	Stationary
(*Y* – *Y**)	−1.432	−11.098***	−4.161	–23.358***	−4.049	−15.894***	Stationary
(*INF*– *INF**)	−2.607	−6.652***	−2.649	−12.027***	−3.081	−12.154***	Stationary

Note: *INF, EXR, MPR, Y,* (*Y* – *Y**), and (*INF* – *INF**) represent inflation rate, exchange rate, monetary policy rate, output, output gap, and inflation gap, respectively. *** denote rejection of the null hypothesis of unit root at 1% error level. 5.57, −5.08, and −4.82 are the critical values of the Zivot-Andrew's test.

Table 4
Nonlinearity test results.

Model	Chi-square statistic	P-value
Exchange Rate Pass-Through	47.73	0.000
Taylor Rule	17.43	0.004

Note: The null hypothesis of equal parameters (linear) in both low and high regimes is tested against the alternate hypothesis of unequal coefficients (non-linear) in both low and high regimes. The threshold variable is exchange rate movement.

foreign reserve accumulation. For the periods 2009, 2012, and 2014, Ghana experienced a sudden rise in exchange rate depreciation as shown in Fig. 1. It is interesting to note that, in periods of higher exchange rate depreciation, Ghana also experienced higher inflation. This could confirm the establishment of exchange rate pass-through on domestic prices in Ghana. Furthermore, we observed that from 2003 to 2004, exchange rate depreciation was lower but there was higher inflation. This suggests that although exchange rate depreciation could be lower, poor economic management and other determinants of inflation could result in higher inflation. For instance, the increase of 2.5 percentage points of value-added tax to fund the National Health Insurance Scheme around 2004 could lead to inflationary pressure during such period.

4.2. Stationarity test results

Presented in Table 3 are the results of the stationarity test. It is revealed that all the variables (inflation, exchange rate depreciation, monetary policy rate, output, output gap, and inflation gap) used for the analysis show the absence of non-stationarity. The variables are stationary at either levels [*I*(0)] or first difference [*I*(1)]. Specifically, the ADF and P—P tests indicate that all variables are stationary at the first difference, except for exchange rate depreciation and the output which are stationary at the level, [*I*(0)]. However, the Z-A test that accounts for structural breaks shows that all the variables exhibit stationarity at the first difference except for the exchange rate that exhibits stationarity at levels. Therefore, series that were stationary at the first-differenced were considered as such in the estimation. Given the absence of unit root, this study proceeds with TAR estimates.

4.3. Nonlinearity test results

The nonlinearity test results using the Wald test of nonlinearity in the parameters across different regimes is reported in Table 4.

The results show that there exists a nonlinear relationship between exchange rate depreciation and inflation, and exchange rate depreciation and the monetary policy rate. This is because the probability values of 0.000 and 0.004 indicate the rejection of the null hypothesis of equal (linear) parameters in the low and high regimes. This means that periods with high changes in exchange rate depreciation tend to have a greater effect on domestic inflation and monetary policy rate than periods of moderate or low changes in exchange rate depreciation. Furthermore,

Table 5
Exchange rate pass-through effect on inflation results (Equation (6).

Variable	Linear model	Non-Linear model	
		Low Regime	High Regime
EXR	0.123	−0.037	0.598***
	(0.135)	(0.167)	(0.211)
MPR	−0.088	−0.059	0.887***
	(0.589)	(0.680)	(0.324)
Y	0.107*	0.178**	−0.014
	(0.058)	(0.074)	(0.057)
EXR_{t-1}	0.191	−0.039	0.342**
	(0.180)	(0.566)	(0.168)
MPR_{t-1}	1.028*	1.302*	−0.311
	(0.598)	(0.676)	(0.317)
Y_{t-1}	0.208***	0.271***	0.134***
	(0.055)	(0.077)	(0.050)
Constant	−8.818***	−15.689***	−0.549
	(2.107)	(2.099)	(2.031)
BIC	1123.619	510.894	
Threshold Value		**0.701**	

Note: Inflation is the dependent variable and exchange rate is the threshold variable. INF, EXR, MPR, and Y represent inflation rate, exchange rate, monetary policy rate, and output, respectively. In the parenthesis are the robust standard errors corrected for autocorrelation and heteroscedasticity.

Table 6
Exchange rate threshold in the Taylor rule results (Equation (7).

Variable	Linear model	Nonlinear Model	
		Lower Regime	Higher Regime
EXR	0.0004	−0.051	−0.053***
	(0.022)	(0.046)	(0.020)
(*INF* – *INF**)	0.004	0.021	0.039**
	(0.016)	(0.028)	(0.017)
(*Y* – *Y**)	0.078	0.280**	0.157
	(0.085)	(0.121)	(0.151)
MPR_{t-1}	0.979***	0.895***	0.964***
	(0.014)	(0.043)	(0.016)
ER_{t-1}	0.156***	0.273***	0.098**
	(0.043)	(0.066)	(0.043)
Constant	0.172	1.308**	0.410**
	(0.206)	(0.577)	(0.043)
BIC	401.464	−173.716	
Threshold Value		**0.514**	

Note: Monetary policy rate represents the dependent variable and exchange rate is the threshold variable. *MPR, EXR,* (*INF* – *INF**), and (*Y* – *Y**) represent monetary policy rate, exchange rate, inflation gap, and the output gap, respectively. The standard errors are robust for autocorrelation and heteroscedasticity.

the nonlinearity of exchange rate in Ghana is primarily driven by changes in economic fundamentals, differences in economic agents, business cycle structure, geopolitics and economic episodes as documented by Jammazi, Lahiani, and Nguyen (2015). Consequently, the different changes in exchange rate depreciation tend to have different effects on inflation, which makes the ERPT effect nonlinear, as

supported by the results in Table 4. Therefore, this means that fitting a model that generates a linear relationship in the perceived nonlinear relationship would be misleading.

4.4. Analysis of TAR estimates

The results of the exchange rate pass-through are reported in Table 5 whereas that of the relevance of augmenting the Taylor policy rule with exchange rate is given in Table 6. It is worth mentioning that the study estimates both linear and nonlinear estimates of the models using the linear model as a baseline model for comparison purposes.

Beginning with the effect of exchange rate pass-through (ERPT) on inflation in Table 5, it is observed that the exchange rate depreciation has a monthly threshold value of 0.70 % for the nonlinear model. This implies that the yearly threshold value of exchange rate depreciation is 8.4 %, which seems realistic as Ghana in some cases has experienced exchange rate depreciation of about 8.4 %. Interestingly, unlike other previous studies (especially those on Ghana) that reported the existence of ERPT effect on domestic inflation in a linear setting, this study reveals that although there exists an ERPT effect on domestic inflation, this effect is not present in a linear setting, as the depreciation of exchange rate is revealed to be insignificant, albeit positive.

From the nonlinear model (Table 5), it is observed that the exchange rate has a significant positive pass-through effect on inflation in Ghana only when the exchange rate depreciation is above a threshold level of 0.70 %. The coefficient from the high regime (EXR $>$ 0.70) indicate that exchange rate and previous exchange rate influence inflation to rise by about 0.60 % and 0.34 % for a percentage increase in exchange rate at a 1 % and 5 % significance level respectively, with other covariates held constant. Both the exchange rate and its previous level confirmed that there exists an incomplete effect of ERPT on inflation. The high importation of foreign goods into the Ghanaian economy could be the reason exchange rate has a positive effect on inflation. This is because a higher exchange rate (depreciation) decreases the strength of the Ghanaian Cedi against other foreign currencies, such as the US dollar. As a result, more Cedi is required for fewer goods at the international market, which in turn increases the prices of imported goods and this also translates into higher domestic prices. Although the present findings are consistent with some past studies on Ghana (see Frimpong & Adam, 2010; Adu et al., 2015; Asafo, 2019), this study, however, finds the presence of ERPT in a nonlinear setting. In other parts of the world, the outcome of this study is consistent with Aleem and Lahiani (2014), who also concluded that the exchange rate has a positive transmission effect in the high regime. Fig. A1 (see the Appendix) gives a clearer picture of the existence of the ERPT in the higher regime. Generally, it is observed that Ghana's exchange rate depreciation is mostly high above the 0.70 % threshold value, and these are the periods of which the results in Table 5 indicate that the exchange rate depreciation has a pass-through effect on inflation.

Regarding the monetary policy rate, the linear (in terms of its lag) and nonlinear model in Table 5 exhibits a significant positive impact on inflation. The nonlinear model shows that the positive significant effect of the monetary policy rate on inflation exists in the high regime, whereas the lag of the monetary policy rate shows that the positive effect occurs in the lower regime. Whiles the coefficient at the high regime shows that inflation in Ghana increased by about 0.89 % for a percentage increase in monetary policy rate at 1 % significance level, the lag of monetary policy rate at the low regime suggests that a percentage increase in monetary policy rate causes inflation to increase by about 1.30 % at a 10 % significance level. Although the monetary policy rate is set to reduce inflationary pressure in an economy, this outcome is plausible. This is because, in the presence of weak or poor central bank independence (frequent interference of governments), as seen in the case of Ghana, monetary policy rate can cause inflation. Furthermore, many households and small formal and informal investors in Ghana mainly borrow from informal sources at a very high rate, and their service to the loan is usually done outside the banking system and away from the impact of the monetary policy rate. Consequently, higher cost of borrowing from the informal sources by households and small investors that dominate the investment landscape triggers higher prices. The positive impact of monetary policy rate on inflation is in line with Aleem and Lahiani (2014).

With respect to output, it is revealed that output influences inflation positively in the linear and non-linear models. Although the effect of output is found to be significant at the low regime, the lag of output suggests that output in both regimes is statistically significant. An increase in output is expected to decrease inflation; however, in an environment of a higher cost of inputs or intermediate goods, the cost of production increases. As a result, prices of output increase even though output continues to expand, and this influences inflation positively. This could be the reason why output positively influences inflation in Ghana, since most inputs for production are imported, which comes with a higher cost. From the results, the coefficient of output at the lower regime indicates that a percentage increase in output induces inflation to rise by about 0.18 % whereas the lag of output suggests that a percentage increase in output causes inflation to rise by about 0.27 % and 0.13 % at the low and high regimes respectively. Sajid et al. (2018) reported similar findings for Pakistan. However, the findings of this study contradict the study by Aleem and Lahiani (2014) who opine that output does not affect inflation.

Moving to the estimate of the threshold effect of the exchange rate in the Taylor rule reported in Table 6, it is observed that the exchange rate is significant in the reaction function of the BoG. While the immediate effect of the exchange rate significantly affects the monetary policy rate negatively in the nonlinear model, the linear model shows that the immediate effect of the exchange rate has no significant impact on the monetary policy rate. The lag of exchange rate is revealed in both the linear and nonlinear models to significantly influence monetary policy rate positively at a 1 % significance level. Because monetary regulators may pay much attention to past or previous information, this study focuses on the previous level of the exchange rate for the analysis. The significance of the previous exchange rate in both models stresses the importance of the exchange rate in the BoG reaction function. The coefficient of previous exchange rate in the nonlinear model indicates that a percentage increase in past exchange rate depreciation is associated with 0.27 % and 0.10 % increase in monetary policy rate at 1 % significance level in the low and high regime respectively, holding other variables constant. These results suggest that in the presence of a pass-through effect of the exchange rate on inflation, as revealed in this study, the regulators must upwardly adjust the monetary policy rate to curb inflation. The implication of this finding is that the Bank of Ghana and the Monetary Policy Committee (MPC) should give maximum attention to exchange rate depreciation in their decisions regarding the implementation of monetary policy. This is possible if monetary regulators adjust the policy rate in line with the performance of the exchange rate. The estimates further show that exchange rate depreciation regardless of whether is below or above the threshold level of 0.51 % is relevant in the BoG reaction function. However, it is observed that the effect is greater in the low regime than in the high regime, which is consistent with the findings by Caporale et al. (2018). Therefore, this finding shares the same view as previous studies (such as Corsetti et al., 2010; Caporale et al., 2018; Ozdemir, 2020), which argued that it is relevant to argument the Taylor rule with exchange rate. However, in this study, we find that the exchange rate remains essential in the policy rule regardless of the threshold of exchange rate level.

Furthermore, it is observed that the previous year's monetary policy rate significantly affects the current monetary policy rate positively at a 1 % significance level in both models. The coefficient shows that the past monetary policy rate induces the monetary policy rate to rise about 0.90 % and 0.96 % in the high and low regime, respectively, with other factors held constant. This implies that when setting monetary policy rate for an economy, monetary regulators have to consider previous

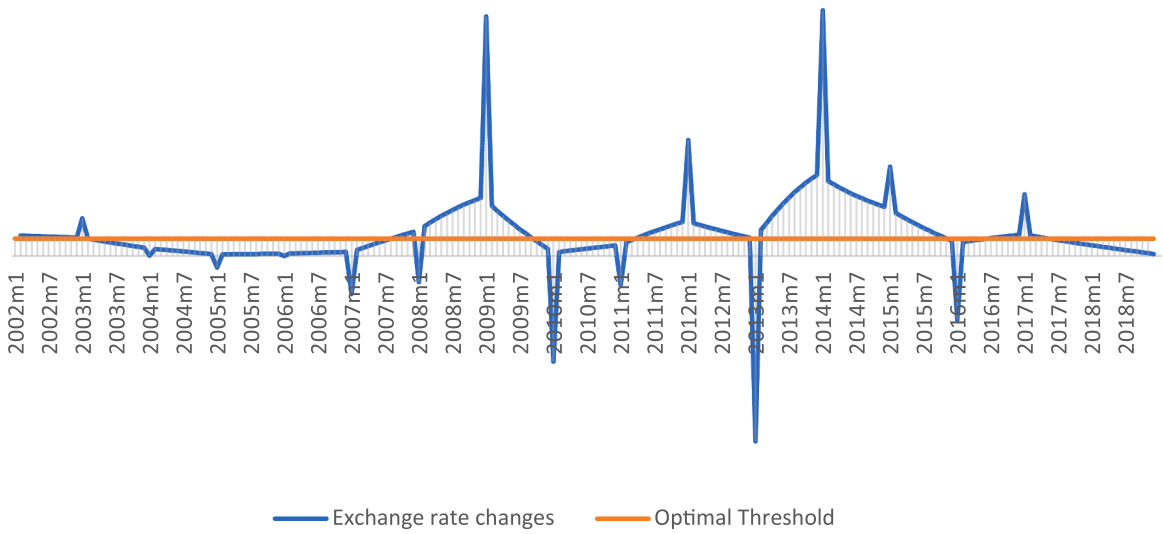

Fig. A1. Regime classification based on the exchange rate depreciation threshold value

year's monetary policy rate. This outcome is consistent with the study by Kurihara (2012) which found that the previous year's MPR highly explained the current MPR. Concerning inflation gap and output gap, the results show that both inflation gap and output gap have no impact on monetary policy rate in the linear model. However, the nonlinear model shows that both the inflation gap and the output gap have a significant positive impact on the monetary policy rate. Specifically, the nonlinear model reveals that the inflation gap and output gap significantly influence the monetary policy rate positively in the high and low regime, respectively, at a significant 5 % level.

The coefficients from Table 6 (nonlinear model) show that a positive deviation of inflation from its target (inflation gap) by one percent is associated with a 0.04 % increase in monetary policy rate when other covariates are held constant. This outcome seems realistic as monetary regulators intending to stabilize prices within the economy tend to increase the policy rate to prevent price instability. This is because, as monetary authorities increase the monetary policy rate, the cost of borrowing for households becomes higher and savings become attractive. As a result, the demand for goods and services falls and this induces wages and other costs to fall as well. Therefore, the general price level also falls. Kurihara (2012), Tiryaki et al. (2018), Bekareva et al. (2019), and Ozdemir (2020) reported similar results. With regard to the output gap, the results from the nonlinear model show that a positive deviation of actual output from the potential output by one percent causes monetary policy rate to increase by about 0.28 % at the low regime, holding other variables constant. This finding could be attributed to the fact that a positive output gap means employment exceeds the natural level and as a result puts upward pressure on wages and that translates to increase in other prices. Consequently, the general price level within the economy goes up and hence, inflation, which calls for a higher monetary policy rate to curb such a situation. This outcome is consistent with previous studies (Tiryaki et al., 2018; Bekareva et al., 2019; Ozdemir, 2020) which argue that output gap positively influences monetary policy rate.

5. Conclusion and policy implications

This study has analyzed the threshold effect of exchange rate pass-through on inflation in the context of Ghana using a monthly data from January 2002 to December 2018. Furthermore, the study examined the relevance of exchange rate threshold in the Taylor rule. The threshold autoregressive (TAR) method was employed for the analysis. The results showed that exchange rate depreciation beyond a monthly threshold of 0.70 % (that is, a yearly threshold of 8.4 %) has a significant positive pass-through effect on inflation, giving credence to the relevance of threshold level. In addition, the results indicated that the exchange rate regardless of the threshold level of 0.51 % significantly influences the monetary policy rate positively. It is also observed that monetary policy rate and output influence inflation positively. Regarding the output gap and inflation gap, the results revealed a significant positive impact on the monetary policy rate. It is established based on the findings that a pass-through effect of exchange rate on inflation exist only when depreciation of the exchange rate exceeds the threshold of 0.70 %. Therefore, the study concludes that the exchange rate irrespective of the optimal level of 0.51 % remains essential in the reaction function of the BoG given its positive effect on the policy rate in both the low and high regimes.

Regarding the implications of the study, the findings imply that the dynamics of exchange rate depreciation has different impacts on domestic prices in Ghana. Thus, changes in economic fundamentals, differences in economic agents, business cycle structure, geopolitics, and economic episodes tend to produce different effects of ERPT on inflation, in particular, a higher positive effect on inflation when exchange rate depreciation is above the threshold. Therefore, this study suggests based on the ERPT effect that monetary regulators, policymakers, and other stakeholders should work toward reducing exchange rate depreciation below the threshold to curb inflation. The BoG could do this by adopting suitable and efficient policy interventions through its forex forward trading by injecting enough foreign currency to meet the excess demands. However, it is must be emphasized that this intervention remains effective depending on the level of exchange rate reserves. Additionally, policymakers must create a more favourable investment environment for public–private partnerships to establish import substitution industries. This will help reduce the demand for foreign currency for imports and this will in turn strengthen the domestic currency against foreign currency. Again, the study suggests that the government should intensify its campaign on the consumption of made-in-Ghana goods through public education. This will ensure an import reduction and, therefore, a reduction in demand for foreign exchange, which will result in a reduction in the depreciation of the currency. Furthermore, we suggest creating domestic buffers through budget surpluses. This will help reduce the country's debt level and the cost of debt servicing and this will in turn reduce capital flight that result from foreign investors repatriating their investments. This again will strengthen the domestic currency as demand for foreign currency for repatriation will decline. Regarding the relevance of the exchange rate threshold in the policy rule, this study suggests that the monetary policy committee should view the exchange rate at any level essential in adjusting the policy rate to

prevent ERPT on inflation. That is, in a period of higher depreciation, the policy rate should be raised to make investment in the money market attractive. Doing this will ensure the attraction of foreign investment, which will in turn increase the demand for the local currency and, hence, strengthen the Ghanaian Cedi.

CRediT authorship contribution statement

Matthew Kwabena Valogo: Conceptualization, Data curation, Formal analysis, Writing – original draft. **Emmanuel Duodu:** Conceptualization, Data curation, Formal analysis, Writing – original draft. **Hadrat Yusif:** Conceptualization, Data curation, Formal analysis, Writing – original draft. **Samuel Tawiah Baidoo:** Conceptualization, Data curation, Formal analysis, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

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