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Examining the 2007 Redenomination of the Ghanaian Cedi on the Disinflation Process Using the Chow Structural Break Test and VAR

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ABSTRACT

Ghana has experienced high and variable rates of inflation over the past 40 years. While this is no longer the case, inflation remains stubbornly elevated relative to economies of similar size (Magnus & Fosa, 2011). Conventional disinflation policies involve countercyclical monetary policies, reducing fiscal expenditure, and comprehensive economic and political reform. These policies in turn can be bolstered by a currency redenomination; when the nominal value of all prices is reduced. A number of countries such as, Turkey (in 2005), Romania (in 2005), Belarus (in 2006 and 2016) have pursued this strategy, including Ghana (in 2007). The question of whether currency redenomination is an effective qualitative tool in the disinflation process is important because of its potential as an important tool for countries struggling with high and variable rates of inflation. Unfortunately, existing literature has been deficient, and no appropriate techniques have been employed to examine this question. Thus, the goal of this paper is to examine the impact of the Ghanaian currency redenomination in 2007 on the disinflation process using appropriate statistical techniques; the Chow Test and Vector Autoregression (VAR), then evaluate whether it may be an effective policy option for monetary authorities.

This paper employed monthly time series data from January 2000 to September 2017 provided by the Bank of Ghana. The results gathered in this paper showed that the Chow Test found a structural break before and after the date of redenomination. However, the bifurcated vector autoregression VAR(3) was inconclusive as to whether the policy itself directly affected the disinflation process. These results suggest that further research is needed to evaluate the potential of currency redenomination as a qualitative tool in the disinflation process.

Originality/value – This paper is one of few studies which has investigated the impact of currency redenomination, especially in Africa and Ghana specifically.

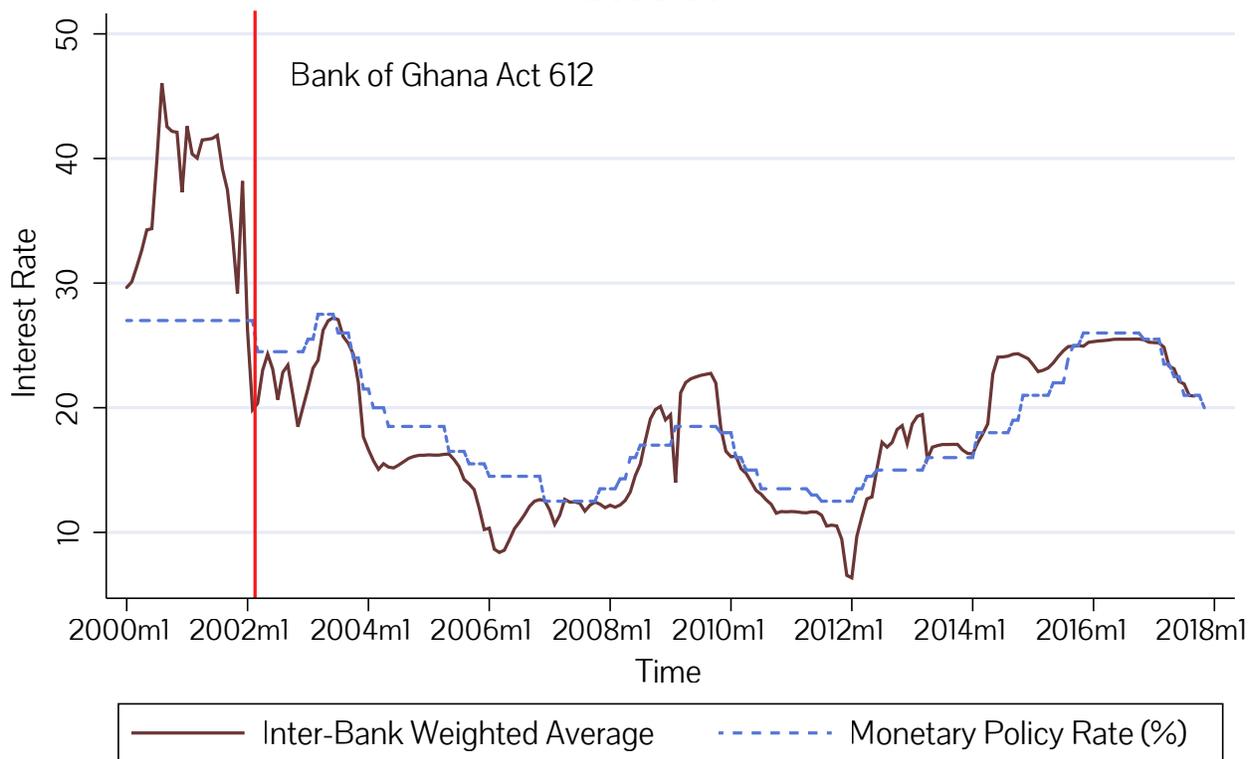
INTRODUCTION

Over the past 40 years, Ghana has experienced high and variable rates of inflation. Inflation is no longer as high compared to the politically turbulent 1970's and 1980's, yet remains stubbornly elevated compared to economies of similar size (Magnus & Fosa, 2011). Countries that suffer from high inflation must consequently deal with undesirable economic outcomes such as increasing uncertainty associated with a firm's expected profits, variable patterns of household saving and investment, and decreased purchasing power (Adom, Zumah, Mubarik, Ntodi & Darko, 2015).

This problem persists even if the country is already on the disinflation path. Conventional disinflation solutions may involve reducing fiscal expenditure and restrained monetary policies. In

other scenarios, disinflation policies may require a reduction in the monetization of government debt, fiscal consolidation, and comprehensive economic and political reform. The policies in turn can be bolstered through the redenomination of a currency when the nominal value of all prices is reduced. A number of countries such as, Turkey (2005), Romania (2005), Belarus (2006, 2016) have pursued this strategy, including the country in question, Ghana (2007). This raises the question of whether currency redenomination is an effective qualitative tool in the disinflation process. Specifically, the goal of this paper is to examine the impact of the Ghanaian currency redenomination in 2007 on the disinflation process using the Chow Test and Vector Autoregression, then evaluate whether it may be an effective policy option for monetary authorities.

Bank of Ghana Interest Rate & Interbank Weighed Average 2000-2017



GRAPH 1. *Graph 1 depicts poor monetary policy transmission before the 2002 Bank of Ghana Act 612 (shown with a vertical line), with significant spreads between the Inter-Bank Weighted Average (“IntBkWave”) and the BoG Monetary Policy Rate (“MPR”).*

INFLATION AND GHANA

As noted in the introduction, Ghana has had a history of high and variable rates of inflation. Inflation is the continual increase in the price level of goods and services in the economy, responding to variables like inflation expectation, money supply, growth in output, and government deficits. The quantity theory of money (“QTM”) as expressed by the equation of exchange, $MV = PY$, where M is money supply, V is the velocity of money, P is the price level, and Y is real GDP, indicates that: 1) changes in the money supply lead to proportional changes in the price level; where $P = (M \cdot V) / Y$ shows constant money velocity and GDP; and 2) the inflation rate, π is the growth rate of money supply minus the growth rate of aggregate output $\pi = \% \Delta M - \% \Delta Y$ (Mishkin, 2016). These implications of the quantity theory of money are evident in long run data, but not in short run data. Therefore, this paper will use time series data over the long run: January 2000 to September 2017. Additionally, the estimated coefficients of M2 growth are close to one in countries marked by high money growth and inflation (Maroney, 2002). This implies that in an

economy experiencing elevated inflation, the changes in the money supply lead to an approximate proportional change in the price level. It is also important to note that money growth may hit inflation rates with a lag, which suggests the need to include autoregressive distributed lag components in the analysis.

GHANA'S MONETARY POLICY AND INFLATION TARGETING FRAMEWORK

The Bank of Ghana (“BoG”) initially announced the public notice stating their intent to redenominate the Cedi in June 2007. The BoG Public Notice (2007) released the following statement:

The Bank of Ghana is planning to redenominate the current cedi by setting ten thousand cedis to one new Ghana Cedi (GH¢), which will be equivalent to one hundred Ghana Pesewas (Gp). That is $\text{¢}10,000 = \text{GH¢}1 = 100\text{Gp}$. New notes and coins will be issued to replace the existing notes and coins over a period of at least 6 months (p.1)

This announcement followed substantial economic and political reforms. In January 2002, the Bank of Ghana Act

612 was passed by the Parliament of Ghana. BoG Act 612 gave operational independence to the central bank, established an implicit inflation targeting (“IT”) framework, and created the Monetary Policy Committee (“MPC”) to oversee monetary policy (Burkel, 2008). The independence aspect of the law authorized the BoG to employ any measure available to achieve its primary objective of price stability (Bank of Ghana, 2015). Following the BoG Act 612, the MPC implemented institutional and operational reforms, such as accountability and transparency mechanisms to enhance the effectiveness of monetary policy (Bank of Ghana, 2015). Graph 1 depicts poor monetary policy transmission before the 2002 Bank of Ghana Act 612 (shown with a vertical line), with significant spreads between the Inter-Bank Weighted Average (“IntBkWave”) and the BoG Monetary Policy Rate (“MPR”). In May 2007, the BoG formally announced a full-fledged inflation targeting framework as their monetary policy strategy, with the redenomination policy following soon thereafter (Addison, 2008).

LITERATURE REVIEW

Redomination in Theory

Existing literature that addresses the theoretical and practical aspects of redenomination includes: *Impact of Currency Redenomination on Inflation Case Study Turkey* (Židek & Chribik, 2015), *A Tale of Two Cedis: Making Sense of a New Currency* (Dzokoto, Young, & Mensah, 2010), *The National Currency Re-Denomination Experience in Several Countries: A Comparative Analysis* (Ioana, 2009), and *Dropping Zeros, Gaining Credibility? Currency Redenomination in Developing Economies* (Mosley, 2005). As stated previously, redenomination means that the face value of banknotes and coins in circulation is changed. Through redenomination, all prices in the economy are reduced by the same nominal value. Theoretically, no market subject is directly affected (harmed or advantaged) by the process and is usually accompanied by issuing of new banknotes and coins (Židek & Chribik, 2015). Currency redenomination is often considered to be a part of broader economic and political reforms. Specifically, redenomination can be seen as part of an effort by the central bank to communicate across a new set of standards and commitments to establish confidence in the economy, build credibility, and facilitate the disinflation process.

There are two primary ways in which redenomination can facilitate such efforts by the central bank to control high and variable inflation. Firstly, the redenomination can be implemented at the end of the necessary reforms, to symbolize the commitment of the central bank authorities. Thus, the new currency would simply serve as a reminder to individuals and market participants of the central bank’s commitment to price stability. Necessary policies preceding the redenomination would

include institutional reforms such as increasing the statutory independence of their central bank (Mosley, 2005). For example, in preparation for its entry into the European Union, Romania’s central bank in 2005 portrayed its currency redenomination process as demonstrating that “the days of hyperinflation are over and the new currency will help keep things that way” (BBC, 2005). Thus, in Romania, redenomination was used at the end of a macroeconomic stabilization process, indicating to the ECB authorities that Romania was ready to enter the European Union.

Secondly, the currency redenomination can be implemented concurrent to the disinflation process. The principle for employing redenomination during the disinflation process is the assumption that the Money Illusion Effect may influence inflation expectation. The Money Illusion Effect refers to a “tendency to make biased judgments about the real value of transactions on the basis of their nominal values” (Dzokoto et al., 2010, p.521). Mosley (2005) hypothesizes such an effect may complement the disinflation process because the lower nominal value convinces citizens that a return to high inflation is unlikely. Explicit commitments to specific macroeconomic targets, in conjunction with redenomination may improve the effectiveness of the monetary authorities. In economic theory, efforts to influence market actors through commitments regarding future monetary policy are called “forward guidance” (Kuroda, 2017). Policies intended to influence expectations are considered important qualitative tools by economists. For example, John Richard Hicks, considered one of the most influential economists of the 20th century, identified concepts such as “forward-looking monetary policy” and the “announcement effect” (Kuroda, 2017). Today, the idea that central banks can increase the effectiveness of monetary policy by influencing inflation expectation and demonstrating their strong intention to achieve price stability forms a theoretical pillar of qualitative monetary policy in many countries (Kuroda, 2017).

Additionally, currency redenomination is also viewed as a policy for the government to reassert monetary sovereignty. If citizens lose confidence in their national currency, they may begin to use foreign currencies that are perceived as more credible (Mosley, 2005). A loss in a currency’s credibility could affect both a government’s legitimacy and ability to conduct monetary policy. If widespread foreign currency substitution (commonly dollarization) exists, the central bank may no longer control the money supply, rendering it unable to provide lender of last resort functions (Mosley, 2005). Currency redenomination, then, is a method by which governments can attempt to reverse certain currency substituting behavior: if citizens are confident that the new redenominated currency will hold its value, they may be willing to shift from using foreign currencies to the domestic (Mosley, 2005).

Redomination in Practice

Approximately 50 countries have implemented redenomination as part of an economic reform process over the last 85 years (Ioana, 2005). The first country to ever conduct redenomination was in 1923 Weimar-era Germany, which cut 12 zeroes to combat hyperinflation (Ioana, 2005). Typically, when redenominating, countries will place “New” in front of the name of their currency, before dropping after several years of use. This policy was adopted by many countries such as Belarus, Bulgaria, Poland, Turkey, and Russia. In other countries such as Argentina, Israel, and Brazil, different names were assigned to the new currency in order to avoid confusion with the old currency (Ioana, 2005).

In 2005, the Turkish monetary authorities implemented the exchange rate of one New Turkish Lira (YTL) for 1 million of (old) Turkish Lira. The decision to redenominate the currency was presented as part of a structural economic reform package backed by the International Monetary Fund (Ioana, 2009). There was a transitional period until January 2008. As Židek and Chribik (2015) indicate, the impacts of redenomination were obvious; credibility of the New Turkish Lira increased, accounting statements were simplified, and general handling of the currency was easier for all market subjects. The nominal value of the New Turkish Lira became comparable with other currencies $1 \text{ EUR} = 1.6361 \text{ YTL}$, $1 \text{ USD} = 1.3448 \text{ YTL}$. Additionally, following the redenomination, inflation in Turkey stayed in single digits or close. The successful redenomination process was followed by implementation of the explicit inflation targeting framework in 2006. Židek and Chribik (2015) concluded that the process of redenomination had several consequences in Turkey. Apart from improving daily cash operations with the currency and enhancement of the accounting systems, there was an additional psychological impact. Redenomination helped the monetary authorities convince the international market participants that the central bank was committed to price stability. Židek and Chribik (2015) used econometric techniques to show that the redenomination process in Turkey had an impact on disinflationary development, by revealing a structural break in the inflationary trend in the country. Additional case studies include Israel (1985) and Ukraine (1996). Israel suffered severe hyperinflation, reaching 485.8% in November 1984, prior to the economic stabilization program. A short while after the economic stabilization program, the redenomination of the currency was enacted, and inflation stabilised to manageable levels thereafter (Ioana, 2009).

Overall, the success of redenomination is varied. In some cases, the timing of redenomination is correct and succeeds in reducing high levels of inflation. In other cases, governments are not able to rein in inflation immediately after redenomination, and they may take multiple attempts at currency reform (Mosley, 2005). Argentina

(after the Peso Crisis) and Brazil during the 1980s and early 1990s exemplify this pattern (Mosley, 2005).

REDOMINATION IN GHANA

In the case of Ghana, the BoG implemented their decision on July 2nd, 2007 to redenominate the old cedi by setting ten thousand cedis to one new Ghana Cedi (GH¢). New notes and coins were issued to replace the old ones, with both in physical circulation together over a period of 6 months. After the transition period, the old notes and coins ceased to be legal tender, however citizens were still able to exchange them for new notes and coins at any commercial bank or at the Bank of Ghana (Bank of Ghana, 2007). Some of the reasons that the Bank of Ghana cited for redenomination were: 1) difficulties in maintaining bookkeeping and statistical records (due to the large number of zeros in most transactions); 2) strain on payment systems such as ATMs; 3) high transaction costs at the cashiers, and; 4) problems with accounting software (Dzokoto et al., 2010). Commercial banks also faced high costs during cash-based transactions because of the large quantities of notes necessary for the process. Due to the low values of the notes, Ghanaian bank customers often had to face the additional prospect of carrying suitcases and bags filled with cash to conduct larger purchases and deposits. Thus, the main objectives of the currency redenomination outlined by the Bank of Ghana include a reduction in transactions costs and risks of carrying large volumes of notes, simplification of accounting records, reduction in volume and time of transactions, facilitation of the use of vendor machines and car parking meters, and improvements in the efficiency in payments systems (Bank of Ghana, 2009). Furthermore, Ghana News Agency (2006) reported on December 4th, 2006, that Dr. Paul Amoako Acquah, the Governor of the Bank of Ghana at the time, stated:

The redenomination will free the economy to do business in the most efficient way, based on the cedi as a means of exchange; and with continued commitment to prudent and disciplined economic policies, would serve as a store of value for all, both within and outside the banking system.

The statement from the BoG Governor implies that the currency redenomination was used in conjunction with explicit commitments to prudent macroeconomic policies in order to improve the effectiveness of central bank policies. However, the redenomination also faced significant opposition. Critics of Ghana’s redenomination predicted that the prices of goods and services would increase rather than decrease as a consequence of changing the nation’s currency, which was in contrast to the BoG official stance regarding price changes (Dzokoto et al., 2010). The Bank of Ghana anticipated that some price rounding would occur, but expected it to be negligible (Bank of Ghana, 2007). There were also concerns that the

process would be an outright failure like in Zimbabwe, force price increases due to rounding up of prices by street vendors or cause substantial confusion particularly in demographics that lacked basic financial or mathematical literacy (Dzokoto et al., 2010).

Nevertheless, ex post analyses and reports suggest that Ghana's redenomination exercise has been largely successful. The *Post-Redenomination Survey of Banks, Consumers And Retailers* (2009) report based on a survey conducted by the Research Department of the Bank of Ghana suggested that most of the objectives of the currency redenomination had been achieved. The report was conducted to ascertain the extent to which the expected benefits of the re-denomination exercise has been effectuated over two years after its implementation (Bank of Ghana, 2009). Among the 20 out of 24 banks that responded to the survey, the consensus was that the most of the Bank of Ghana's objectives have been achieved (Bank of Ghana, 2009). For example, out of the 16 commercial banks operating ATMs, "13 said efficiency had improved 'very much' whereas 3 (18.8 %) indicated that they had not seen much improvement in efficiency" (Bank of Ghana, 2009). Additionally, respondents to the survey enumerated that "some of the benefits of the redenomination were small volumes, faster transaction, faster counting of money, reduction in the overall risks of carrying large sums of money, reintroduction of the culture of using coins etc" (Bank of Ghana, 2009). From the perspective of banking processes and daily transactions, the currency redenomination was arguably successful. However, the question remains on whether redenomination itself contributed to the disinflation process in Ghana as well.

DATA EXPLANATION

For the examination of the impact of the 2007 Ghanaian currency redenomination on the disinflation process, the Chow Test will be conducted on time series data provided by the Statistical Department, Bank of Ghana. The statistical software Stata was used for the time series data analysis. Data entering the models were adjusted for a monthly time series. For clarity, the variables used will be presented in Table 1 along with characteristics, explanation, and the source.

During the statistical analysis, the possibility of measurement error in data was taken very seriously as it would threaten the internal validity of the analysis. Measurement error in data is a risk as it may lead to regression coefficients that do not represent the true betas. The Bank of Ghana Act 612 (2002) specifically stipulates that one of the primary responsibilities of the Monetary Policy Committee is to provide credible and reliable statistical data and advice necessary for the formulation of monetary policy (Bank of Ghana, 2015). The Bank of Ghana made it a priority to assemble a detailed data set on the

Variable	Explanation	Source
CLEARreal	Composite Index of Economic Activities (real)	Bank of Ghana
INF-YOY	Overall Inflation	Bank of Ghana
M2	Broad Money (M2) (GHC'm)	Bank of Ghana
MPR	Monetary Policy Rate (%)	Bank of Ghana

TABLE 1.

economy in "all the major macroeconomic sectors of the economy including the latest data on the budget, monetary data, inflation data, and external sector data" (Bank of Ghana, 2015). Moreover, the Bank of Ghana recognized the lack of quarterly GDP data published by the Ghana Statistical Service, the agency with the primary responsibility to publish such data. Therefore, the Bank made an effort to assemble its own data to construct a "Composite Index of Economic Activity" that incorporated data on retail sales, port activity, new vehicle registrations, and job vacancies (Bank of Ghana, 2015).

STATISTICAL FRAMEWORK AND ANALYSIS

As the currency redenomination was a major change in macroeconomic policy, there is most likely a discrete break in the macroeconomic data at a definite date. This study adopts a similar statistical analysis as Židek and Chribik (2015) to test whether the redenomination process caused a structural break in the data. The Chow Structural Break Test will be conducted to determine whether non-stationarity arises from a break in the coefficients of the population regression function due to the currency redenomination (Stock & Watson, 2011). However, the macroeconomic time series data were suspected to be non-stationary, with a stochastic trend (Stock & Watson, 2011). To verify non-stationarity, the augmented Dickey-Fuller test for a unit root was applied.

As shown in Table 2, the augmented Dickey-Fuller test at four lags indicated non-stationarity in the case of the three variables, *mpr*, *lnciereal*, and *lnm2*; the variable *lnfyoy* did not indicate non-stationarity at the 5% level. Accordingly, a standard OLS estimator using the time series data would have a non-standard distribution, potentially leading to biased estimators, inefficient forecasts, and misleading inferences (Stock & Watson, 2011). Consequently, the stochastic trend in the time series data was eliminated using the first difference of the series to achieve stationarity.

The modified time series data were again tested using the augmented Dickey-Fuller test at four lags. The MacKinnon approximate P-value for $Z(t)$ shown in Table 3 indicates that the null hypothesis H_0 , of non-stationarity is rejected at the 5% and the 1% critical value. After con-

ADF Test	infyoy	mpr	lnciareal	lnm2
with Constant	0.0334	0.3602	0.4530	0.3425
with Constant & Trend	0.0248	0.7723	0.0000	0.5562

TABLE 2.

ADF Test	dmp	dlnciareal	dlnm2
with Constant	0.0000	0.0000	0.0000
with Constant & Trend	0.0002	0.0000	0.0000

TABLE 3.

firming non-stationarity, the Chow Test was conducted.

To conduct a Chow Test on the effect of redenomination, a relatively standard regression model was prepared:

$$infyoy_t = \beta_0 + \widehat{\beta}_1 dln(m2)_t + \widehat{\beta}_2 dln(ciareal)_t + \widehat{\beta}_3 d(mpr)_t + \mu_t$$

Where *infyoy* = overall inflation, *dlnm2* = percentage change in broad money (GHC' million), *dlnciareal* = first difference of the Composite Index of Economic Activities (real) growth, *dmp* = first difference of the Bank of Ghana monetary policy rate, μ_t = residual, and *t* = months. This basic time series regression model will enable the use of the Chow Test. It is important to note however, that the coefficients of this model do not capture the linear interdependencies of the redenomination hypothesized in this paper. The null hypothesis of “no break” can be tested using a binary variable interaction regression, as the date of the hypothesized structural break is known (Stock & Watson, 2011). Let τ denote the hypothesized break date of July 2007, when the Bank of Ghana implemented the currency redenomination process, and let the data be bifurcated so that $denom_t(\tau)$ is a binary dummy variable that equals 0 before the break date and 1 after. Then the regression including the binary break dummy variable and all interaction term is:

$$infyoy_t = \beta_0 + \widehat{\beta}_1 dln(m2)_t + \widehat{\beta}_2 dln(ciareal)_t + \widehat{\beta}_3 d(mpr)_t + \widehat{\gamma}_0 denom_t + \widehat{\gamma}_1 (denom_t * dlnm2) + \widehat{\gamma}_2 (denom_t * dlnciareal) + \widehat{\gamma}_3 (denom_t * dmp) + \mu_t$$

If there is no structural break, then the regression function is the same over both parts of the bifurcated sample data set, so the terms involving the binary break dummy variable, $denom_t$, do not enter the equation (Stock & Watson, 2011). That is, under the null hypothesis H_0 of no break, $\gamma_0 = \gamma_1 = \gamma_2 = 0$. Under the alternative hypothesis H_A of break, the regression function coefficients are differ-

ent before and after the break date τ . Thus, the hypothesis of a break can be tested using the F-statistic that tests the null hypothesis that $\gamma_0 = \gamma_1 = \gamma_2 = 0$ against the alternative hypothesis that at least one of the γ 's are nonzero (Stock & Watson, 2011).

F(4, 185) =	15.56
Prob > F =	0.0000

The resulting P-value of the Chow Test for a break in July 2007 is zero to four decimal places, $Prob>F=0.0000$. This means the null hypothesis H_0 , which says the stochastic trend in inflation (*infyoy*) is the same for the bifurcated dataset, can be rejected. Based solely on the Chow Test however, it is not possible to say that redenomination was unequivocally, the cause of the break. Nonetheless, the obtained test result shows at the 5% level that there is a structural break in the bifurcated data and thus, the currency redenomination may have impacted the overall disinflation process.

To further examine the redenomination, another statistical technique known as Vector Autoregression (“VAR”) was used. A VAR provides a better understanding of the linear interdependencies among multiple time series. A VAR is a set of *k* time series regressions, in which the regressors are lagged values of all *k* series (Stock & Watson, 2011). The VAR model captures the overall inflation rate in Ghana, which is expressed by the variable, *infyoy*. This study adopts a simplified version of the VAR model specified in Židek and Chribik (2015): where the model is a set of five time series regressions with lagged values, and *infyoy_t* = overall inflation rate, *dlnm2* = percentage change in broad money (GHC' million), *dlnciareal* = first difference of the Composite Index of Economic Activities (real) growth, *dmp* = first difference of the Bank of Ghana monetary policy rate, μ_t = residual, and *t* = months. Here,

Selection-order criteria

Sample: 2000m11 - 2016m3

Number of obs = 185

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-605.868				.000508	6.60398	6.63925	6.69101
1	37.962	1287.7	25	0.000	6.3e-07	-.086076	.125567*	.436144*
2	77.0562	78.188	25	0.000	5.4e-07	-.238445	.149567	.718958
3	102.986	51.86*	25	0.001	5.4e-07*	-.248499*	.315882	1.14409
4	116.468	26.964	25	0.358	6.1e-07	-.123979	.616771	1.70379
5	125.179	17.422	25	0.866	7.3e-07	.052116	.969236	2.31507
6	138.391	26.424	25	0.385	8.4e-07	.179554	1.27304	2.87769
7	149.428	22.074	25	0.631	9.8e-07	.330504	1.60036	3.46382
8	164.034	29.212	25	0.255	1.1e-06	.442872	1.8891	4.01137

Endogenous: infyoy dlncieareal dlnm2 dmpr denom

Exogenous: _cons

FIGURE 1.

the VAR will be conducted on the bifurcated dataset, for both the sample before and after the redenomination. Then, by comparing the coefficients from the VAR for the two samples, the effects of the redenomination can be examined.

To construct a robust VAR model, the optimal number of lags to include in the regression was estimated using VAR lag selection procedures on Stata (Židek & Chribik, 2015). Figure 1 depicts the Stata analysis conducted to determine the number of lags chosen to minimize the Final Prediction Error ("FPE") and Akaike Information Criteria ("AIC"). The estimated lag length with the lowest value of information criteria was three. The equation with overall inflation *infyoy* as the dependent variable was used. The results of the bifurcated VAR(3) model are shown in Figure 2.

RESULTS & INTERPRETATION OF VECTOR-AUTOREGRESSION MODEL

The results of the bifurcated VAR(3), show that the coefficients for lags are different between the two datasets. In the pre-redenomination VAR, a one percent change in the first lag (L1) of the inflation rate, *infyoy*, relates to a 1.07% increase in the inflation rate in the current period. However, in the post-redenomination VAR, a one percent change in the first lag (L1) of the inflation rate *infyoy*, relates to a 1.44% increase in the overall inflation rate in the current period. Several of the other variables such as the *dmpr* and *dlnm2* are significantly different when comparing between the pre-redenomination VAR and the post-redenomination VAR. For example, the $dmpr_{t-1}$ has a coefficient of 0.67 pre-redenomination and a coefficient

of 0.19 post-redenomination. Thus, the results show that the coefficients of the VAR pre-redenomination and post-redenomination are significantly different. Conducting a Granger causality test allows us to jointly test the significance for all the lags for each variable in the bifurcated VAR. Granger causality means that if a variable X, Granger-causes Y, then X is a useful predictor of Y, given other variables in the regression (Stock & Watson, 2011). A Granger causality test is administered by testing the null hypothesis that the estimated coefficients on the lagged values of each variable are jointly zero (Stock & Watson, 2011). Failure to reject the null hypothesis is equivalent to failing to reject the hypothesis that a variable does not Granger-cause the dependent variable. Figure 3 shows the results of the Granger causality test for the pre-redenomination VAR.

The first is a Granger causality Wald test that the coefficients on the three lags of *dlncieareal* are jointly zero. As the $P > \chi^2$ is 0.038, the null hypothesis that *dlncieareal* does not Granger-cause overall inflation *infyoy* can be rejected at the 0.05 level. This means that *dlncieareal* is a useful predictor of *infyoy*, given the other variables in the regression. Additionally, the $P > \chi^2$ of 0.038 shows that past lags of *dlncieareal* appear to contain information that is useful for forecasting changes in the inflation rate, beyond that contained in past values of *infyoy* (Stock & Watson, 2011). However, the Wald test that the coefficients on the three lags of *dlnm2* are jointly zero show the null hypothesis cannot be rejected. Overall, the $P > \chi^2$ is 0.021, thus the null hypothesis that all the variables do not Granger-cause overall inflation can be rejected.

Figure 4 shows the results of the Granger causality test for the post-redenomination VAR. For the post-re-

Vector autoregression						Vector autoregression					
Sample: 2007m2 - 2016m3			Number of obs = 110			Sample: 2000m6 - 2007m1			Number of obs = 80		
Log likelihood = 63.08781			AIC = -2.2015966			Log likelihood = 70.15597			AIC = -.4538993		
FPE = 9.65e-06			HQIC = .3161955			FPE = 7.55e-06			HQIC = .1668654		
Det(Sigma_ml) = 3.73e-06			SBIC = 1.074994			Det(Sigma_ml) = 2.03e-06			SBIC = 1.094418		
Equation	Parms	RMSE	R-sq	chi2	P>chi2	Equation	Parms	RMSE	R-sq	chi2	P>chi2
infyoy	13	.512223	0.9850	7236.939	0.0000	infyoy	13	2.62055	0.9340	1131.276	0.0000
dlncieareal	13	.342071	0.4225	80.49074	0.0000	dlncieareal	13	.041515	0.3441	41.97227	0.0000
dlnm2	13	.030504	0.1849	24.94844	0.0151	dlnm2	13	.032948	0.2707	29.69547	0.0031
dmpr	13	.495315	0.2869	44.26102	0.0000	dmpr	13	.607406	0.3061	35.28545	0.0004

	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]			Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
infyoy							infyoy						
infyoy							infyoy						
L1.	1.44157	.0976851	14.76	0.000	1.25011	1.633029	L1.	1.06986	.109409	9.78	0.000	.855422	1.284297
L2.	-.4090871	.1704797	-2.40	0.016	-.7432213	-.074953	L2.	-.0323043	.1590159	-0.20	0.839	-.3439697	.2793611
L3.	-.0519323	.1046335	-0.50	0.620	-.2570102	.1531456	L3.	-.0940169	.1098956	-0.86	0.392	-.3094083	.1213745
dlncieareal							dlncieareal						
L1.	-.0261317	.1394801	-0.19	0.851	-.2995078	.2472443	L1.	10.52767	6.931475	1.52	0.129	-3.057769	24.11311
L2.	.0142	.1587717	0.09	0.929	-.2969869	.3253868	L2.	18.13681	7.002175	2.59	0.010	4.412801	31.86082
L3.	.0368334	.1338157	0.28	0.783	-.2254407	.2991074	L3.	15.40255	6.882747	2.24	0.025	1.912611	28.89248
dlnm2							dlnm2						
L1.	1.610185	1.576354	1.02	0.307	-1.479411	4.699782	L1.	-2.770926	8.633502	-0.32	0.748	-19.69228	14.15043
L2.	-2.143782	1.589878	-1.35	0.178	-5.259886	.9723229	L2.	-15.74373	8.741216	-1.80	0.072	-32.8762	1.38874
L3.	2.163939	1.584275	1.37	0.172	-.9411828	5.269061	L3.	10.56907	8.455151	1.25	0.211	-6.00272	27.14086
dmpr							dmpr						
L1.	-.1886383	.0985146	1.91	0.056	-.0044467	.3817234	L1.	.6689033	.4692886	1.43	0.154	-.2508855	1.588692
L2.	.1516441	.0865662	1.75	0.080	-.0180225	.3213107	L2.	1.196725	.4573131	2.62	0.009	.3004078	2.093042
L3.	-.0944856	.0862742	-1.10	0.273	-.2635799	.0746088	L3.	.483927	.4834147	1.00	0.317	-.4635484	1.431402
_cons	.2347575	.184745	1.27	0.204	-.127336	.5968511	_cons	1.265062	.7636313	1.66	0.098	-.2316277	2.761752

FIGURE 2.

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
infyoy	dlncieareal	8.4198	3	0.038
infyoy	dlnm2	4.564	3	0.207
infyoy	dmpr	8.8858	3	0.031
infyoy	ALL	19.496	9	0.021

FIGURE 3.

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
infyoy	dlncieareal	.16907	3	0.982
infyoy	dlnm2	3.5549	3	0.314
infyoy	dmpr	7.4068	3	0.060
infyoy	ALL	11.962	9	0.215

FIGURE 4.

denomination VAR, the first, second, and third Granger causality Wald test show that the null hypotheses cannot be rejected at the 5% level. As these null hypotheses were not rejected, the post-redemption VAR is not statistically significant, and the variables jointly do not conclusively Granger-cause overall inflation, *infyoy*. Thus, in examining the bifurcated VAR, it can be stated that the coefficients were nominally different. However, the Granger causality test showed that the post-redemption VAR was statistically insignificant, therefore, inconclusive as to whether the autoregressive distributed lag components had any information that is useful for forecasting changes in the overall inflation rate.

DISCUSSION

As outlined in the introduction, the goal of this paper was to examine the impact of the Ghanaian currency redenomination in 2007 and determine whether the process contributed to the disinflation process. According to the Bank of Ghana's own survey, the process of redenomination had several consequences. Aside from the ease in day-to-day transactions, the Ghanaian banking sector experienced simplification of accounting records and reduction in transactions costs and risks of carrying large volumes of notes. Furthermore, Ghanaian banks also reported experiencing facilitation of the use of vendor machines and car parking meters, and improvements in the efficiency in payments systems (Bank of Ghana, 2009). Additionally, redenomination may have contributed to the disinflation process by helping the monetary authorities convince the market that the central bank was committed to reducing inflation. To examine the impact of redenomination on the inflation rate, two statistical analyses were used. A Chow Structural Break Test was conducted to determine whether a structural break existed in the time series variable for overall inflation. The resulting P-value of the Chow Test for a break in July 2007 was zero to four decimal places, $Prob > F = 0.0000$. A P-value less than 0.05 meant the null hypothesis H_0 , which says that the regression function coefficients are the same before and after the break, was rejected. Based solely on the Chow Test however, it is not possible to say that redenomination is the direct cause of the break. Moreover, it is clear that the Chow Test alone will not allow for the currency redenomination to be distinguished from other government and central bank policies. Therefore, a bifurcated vector autoregression was also conducted to examine the dynamic causal effect of redenomination. Examining the output of the bifurcated vector autoregression, all of the coefficients were significantly different pre-redemption and post-redemption. However, the Granger causality test showed that when testing the post-redemption VAR, the null hypothesis was not rejected. This meant the lags of each variable did not Granger-cause the overall inflation and

thus, was inconclusive as to whether the autoregressive distributed lag components had any information useful for forecasting changes in the overall inflation rate. While the significantly different coefficients for the pre-redemption and post-redemption was promising, the statistical insignificance was discouraging. Thus, it can only be concluded that while the Chow Structural Break Test found a structural break in inflation before and after the redenomination, the bifurcated vector autoregression, VAR(3), was inconclusive as to whether the policy itself directly affected the disinflation process.

Furthermore, it is important to note that the implementation of the May 2007 Inflation Targeting framework and the June 2007 redenomination are only a month apart. Thus, it is extremely unlikely that the effects of the IT framework and the redenomination on disinflation can be separated by solely looking at time series data. A better approach to examine the impact of redenomination, as a qualitative tool in the disinflation process, is to study countries that have introduced a formal inflation targeting framework. The effect of redenomination can then be isolated by examining whether countries that have conducted both redenomination and inflation targeting saw a faster shift of expectations towards the inflation target. These conclusions indicate that economists should devote more attention to the potential of currency redenomination as a qualitative tool in the disinflation process. Further empirical examination of currency redenomination may lead to better tools in the future for countries struggling with high and variable inflation rates.

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