Does Renewable Energy Use Enhance Exchange Rate Appreciation and Stable Rate of Inflation?

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Research Article

Keywords: Currency exchange rate, Rate of Inflation, Use of renewable energy

Posted Date: July 26th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-683790/v1>

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Version of Record: A version of this preprint was published at Environmental Science and Pollution Research on October 3rd, 2021. See the published version at <https://doi.org/10.1007/s11356-021-16758-2>.

Abstract

The current study is aimed at investigating the causal link among the use of renewable energy, rate of currency exchange and the rate of inflation of Brazil with the ARDL model. The findings of the ECM show that in the long-run a bidirectional causal association between exchange rate and renewable energy of Brazil exists. This shows that the rate of currency exchange causes use of renewable energy, and the use of renewable energy causes the rate of currency exchange in Brazil. Inflation rate also causes renewable energy and exchange rate of Brazil in the long-run. The rate of adjustment to equilibrium is also very low, below 50%, indicating that it will take long to adjust to long-run equilibrium. In the short-run, we ascertain that renewable energy use in Brazil has a significant negative effect on the rate of currency exchange, showing that a rise in the use of renewable energy in Brazil significantly cause the exchange rate to appreciate. Thus, on top of lowering carbon-dioxide emissions and global warming effects, renewable energy use in Brazil significantly improves the currency's value. Therefore, the use of renewable energy should be promoted and nations should shift to using renewable energy. This move will also encourage zero carbon in the future.

1. Introduction

Renewable energy use is rising on the world as nations are attempting to shift from using fossil fuels that are hazardous to the environment. Fossil fuels are known for emitting carbon-dioxide to the environment which end up causing global warming and greenhouse effect. The United Nations has long started campaigns to promote use of renewable energy as a way to reduce greenhouse effects. Thus, nations are working towards achieving zero carbon in the future. Renewable energy sources include those sources of energy such as, hydro power, solar power, wave, wind and tidal among many others. Renewable energy sources of energy are thus environment friendly, hence are preferred as the best alternative that can help reduce global warming.

The studies by Becker and Fischer (2013); Salim and Rafiq (2012); Shahbaz, et al., (2020) provide the change by nations to the using renewable energy sources as necessary and crucial for the purpose of reducing the effects of global warming in the world. The prices of fossil fuels are also rising, and shocks in the prices of fuel has been experienced in the world thereby impacting the world economy. Therefore, on top of causing greenhouse effect to the world, fossil fuels are finite resources that can be depleted thereby causing volatility in the inter-market (Becker & Fischer, 2013). Thus, we ascertain that there are many disadvantages of relying on using fossil fuels, rather nations should adopt the renewable energy use which is more advantageous as compared to fossil fuels.

It is crucial to ascertain the relationship of renewable energy use and economic indicators for better policy making and implementation. Various researches have been done in the past to ascertain the association of the use of renewable energy and economic variables such as economic growth, Smolovic, et al., (2020); Shahbaz, et al., (2020); Chen, et al., (2020); Ivanovski, et al., (2020). The study on the relationship of renewable energy and employment has been partially analyzed (see, Ge & Zhi, 2016). The researches on the determinants of renewable energy consumption have been widely done (see, for example, Li, et al., 2020; Silva, et al., 2018; Bourcet, 2020; Lin & Zhu, 2019; Akintande, et al., 2020; Zhao, et al., 2020) and different findings have been found. However, the causal association of the use of renewable energy, rate of currency exchange and rate of inflation has not been fully studied, Deka and Dube (2021). Deka and Dube (2021) gives a strong significant positive link on the use of renewable energy and the rate of currency exchange. Promoting the use of renewable energy in Mexico is observed to appreciates the Mexican Peso and thereby stabilizing inflation levels in the country (Deka & Dube, 2021). Therefore, there is still a gap in the literature on the association of exchange rate and renewable energy; inflation rate and renewable energy since only a single study has been done.

This research is aimed at analyzing the causal link of the use of renewable energy, rate of currency exchange and the rate of inflation of Brazil. ARDL model by Pesaran, Shin and Smith (1997; 1999; 2001) which is capable of ascertaining the causal link between variables irrespective of them being integrated of different orders is used in this paper. This study is different from past studies in that it seeks to examine the association of the use of renewable energy and rate of currency exchange; use of renewable energy and the rate of inflation, which has been partially studied in the past. This study will help nations in understanding how the use of renewable energy can affect the rate of currency exchange, how the rate of currency exchange impacts the use of renewable energy, how the use of renewable energy affects rate of inflation and how inflation rate affects the use of renewable energy in both short-run and long-run. The results are very useful to nations that seek to stabilize inflation rate by ensuring currency appreciation or increasing exports by devaluing the currency.

2. Literature Review

Examining the causal link of renewable energy and economic factors is of paramount importance considering that nations are shifting from the use of fossil fuels to renewable energy use as the source of power. Knowledge on the causal relationship of renewable energy and economic variables is vital to governments and market players as this will enhance proper policy making and implementation. Various studies have been examined to ascertain the determinants of renewable energy consumption (Akintande, et al., 2020; Omri, et al., 2014; Lin & Zhu, 2019; Papiez, et al., 2020; Bourcet, 2020), some studies have been widely done to ascertain the causal link between renewable energy and economic growth (Wang & Wang, 2020; Rahman & Velayutham, 2020; Eren, et al., 2020; Chen, et al., 2020; Ivanovski, et al., 2020; Chica-Olmo, et al., 2020; Smolovic, et al., 2020), while some researches have been done to analyze the link between employment and the use of renewable energy (Ge & Zhi, 2016). However, only a single study has been done to examine the relationship between the use of renewable energy and the rate of currency exchange; and the relationship between the rate of currency exchange and rate of inflation (Deka & Dube, 2021). The rate of currency exchange and the rate of inflation are very crucial economic indicators. When exchange rate of a nation appreciates, inflation rate is lowered since prices of goods stabilizes because the currency has gained value, Fisher (1930). Inflation rate is not good for a nation because it erodes the buying power of the currency. On the other hand, some nations devalue their currency to promote exports, since their products will become relatively cheap in the international market.

According to Akintande, et al., (2020), there is a significant positive impact of human capital, population growth and urban population on renewable energy use. The results of the research indicates that an increase in population growth, urban population and human capital of a nation has the tendency of promoting renewable energy use. This implies that nations with high population and high human capital have high chances of increasing renewable energy use. Bourcet (2020) concur with Akintande, et al., (2020) that demographic factors are the major determinants of renewable energy. In addition to demographic factors, Bourcet, et al., (2020) adds regulatory and political factors as major determinants of renewable energy. This implies that the regulatory system of a nation significantly affects renewable energy consumption. Other studies like Omri, et al., (2020) alludes that carbon-dioxide emissions and trade openness significantly impact renewable energy use. This follows that carbon-dioxide emissions by fossil fuels have paved way to the shift to using renewable energy.

In the OECD, renewable energy consumption was found to cause economic growth positively (see, for example, Wang & Wang, 2020; Chen, et al., 2020). Therefore, renewable energy should be promoted in the OECD countries since it helps improving economic growth in these nations. In Europe, renewable energy is also observed to improve economic growth (Chica-Olmo, et al., 2020; Smolovic, et al., 2020). Thus, on top of reducing global warming effects,

renewable energy significantly improves economic growth of nations. As a result, if nations shift from fossil fuels to renewable energy sources, they will create carbon free environment as well as improving the nation's economic growth.

The association of the rate of currency exchange and rate of inflation is traced from the Relative Purchasing Power Parity by Fisher (1930). The Relative Purchasing Power Parity is an extension of the Purchasing Power Parity by Fisher (1930) which alludes that a positive association of inflation rate and exchange rate exists. Thus, high rate of inflation in a nation has the effect of increasing the exchange rate (currency depreciation). Thus, high inflation rate is not good for the economy because it reduces the currency value of the nation thereby reducing its buying power. For this reason, any factors that raises inflation and depreciates the currency in a nation are always shunned and thus this research seek to check if renewable energy stabilizes inflation of nations as well as promotes currency value.

At this juncture, we have found out that renewable energy affects various economic factors such as economic growth and employment just to mention a few, while renewable energy is determined by various factors ranging from economic, political, demographic to regulatory factors. However, few researches have been carried out to directly ascertain the causal association of use of renewable energy and exchange rate on one hand and the causal association of use of renewable energy and the rate of inflation on the other. However, it is crystal clear from the literature discussed above that a causal relationship exists between these variables since economic factors significantly determine renewable energy use and this will be ascertained in this study.

3. Method And Data

In this study we make use of three variables of Brazil, that is, rate of currency exchange, the use of renewable energy, as well as the rate of inflation for a period 1990 to 2019. Use of renewable energy refers to the power sources which are not harmful and hazardous to the environment. They are environment friendly and have the capability of being used over and over again, hence cannot be depleted, unlike fossil fuels sources of energy that are hazardous to the environment and can be depleted. Sources of renewable energy include those sources such as; water, wind, tidal, waves and solar among many others. Rate of exchange is the price at which one currency is sold against another currency in the foreign exchange market. In this study the exchange rate employed is expressed as Brazilian Real per one United States dollar (Real/Dollar) and a rise in the rate of currency exchange indicates a depreciation in the Brazilian Real whereas a drop in the currency shows an appreciation. Inflation rate is referred to as a general rise in the price of goods and services and the Consumer Price Indicator (CPI) of Brazil, in this study is used to proxy inflation rate.

In order to analyze the causal link of use of renewable energy, rate of inflation and rate of currency exchange of Brazil, dynamic Autoregressive Distributive Lag (ARDL) model is employed. The ARDL approach was pioneered by Pesaran, Shin and Smith (1997; 1999; 2001). Before, it was not possible to run levels relationship with variables that are integrated of different orders, rather variables were supposed to be stationary to be specified in the traditional Ordinary Least Square (OLS) model or to be integrated of the same order one, $I(1)$, in order to be specified in cointegration regressions such as Fully Modified Ordinary Least Square (FMOLS) or Dynamic Ordinary Least Square (DOLS) or in a Vector Error Correction Mechanism (VECM) (Pesaran, et al., 2001; Keele and DeBoef, 2008). However, the ARDL approach allows for variables that are integrated of different orders, $I(0)$ and $I(1)$ or that are not mutually cointegrated to be specified in a levels' relationship, Pesaran, et al. (2001); Keele and DeBoef (2008). It follows that, inasmuch as $I(0)$ and $I(1)$ variables can be specified by employing the ARDL method, $I(2)$ variables cannot be specified; hence unit root test should be employed to check if all variables are $I(0)$ and $I(1)$ (Pesaran, et al., 2001; Smolovic, et al., 2020; Salim & Rafiq, 2020). Thus, in this paper we test for stationarity by employing Augmented

Dickey Fuller (ADF) test, that was pioneered by Dickey and Fuller (1979) and Phillips Peron (PP) test, that was pioneered by Phillips and Peron (1988). Various studies have recommended the ADF and PP tests of unit root as the best and appropriate methods (see, Granger, 1986).

The ARDL model is a univariate method that is based on F-statistics and t-statistics to test for the existence of levels relationship of variables irregardless of them being I (0), I (1), Pesaran, et al., (2001). The null hypothesis of the model is that there is no levels relationship irregardless of the fact that the regressions are I (0), I (1), Pesaran, et al., (2001). When the F-statistics and t-statistics values of the ARDL bounds test, approach is greater than the I (0) and I (1) bounds, then levels relationship exists and we can specify the short-run ARDL model and the Equilibrium Correction Mechanism (ECM), Pesaran, et al., (2001). The ECM examines the long-run association and equilibrium among variables and the rate of adjustment to longrun equilibrium (see, for example, Granger, 1986; Engle & Granger, 1987; Pesaran, et al., 2001). When the F-statics and t-statistics values is less than the I(1) and I(0) then we can only specify the short-run ARDL model, Pesaran, et al., (2001). However, when the F-statistics and t-statistics lies in between the I (0) and I (1) bounds then inference is inconclusive and the dilemma can be overcome by examining the integration order and cointegration of variables, Pesaran, et al., (2001).

Equations 1 and 2 below are the statistical representation of the short-run and long-run ARDL model respectively (see, for example, Pesaran, et al., 1999; Pesaran, et al., 1997; Pesaran, et al., 2001). The long-run ARDL model contains the error correction term (ECT) of the ECM model plus short-run coefficients of the regressors. The ARDL model in this study is employed in such a way that all variables are employed as dependent variables, in turns, to examine how each variable is impacted by other variables, Pesaran, et al., (2001). ER_t represents the rate of exchange value of Brazil currency; $\ln RE_t$ is the log value of use of renewable energy sources of Brazil; INF_t is the rate of inflation of Brazil; ECT_{t-1} stands for the ECM's error correction term; Δ represents the operator of the first difference; $\beta_0; \beta_{1i}; \beta_{2i}; \beta_{3i}$ are the coefficients of the short- and long-run ARDL model, and β_{4i} is the ECT's coefficient whereas e_t is the error term.

$$\Delta ER_t = \beta_0 + \sum_{i=1}^p \beta_{1i} ER_{t-i} + \sum_{i=1}^q \beta_{2i} \ln RE_{t-i} + \sum_{i=1}^q \beta_{3i} INF_{t-i} + e_t \quad (1)$$

$$\Delta ER_t = \beta_0 + \sum_{i=1}^p \beta_{1i} \Delta ER_{t-i} + \sum_{i=1}^q \beta_{2i} \Delta \ln RE_{t-i} + \sum_{i=1}^q \beta_{3i} \Delta INF_{t-i} + \beta_4 \text{varvec{E}} \text{varvec{C}} \text{varvec{T}}_{\text{varvec{t}-1}} + e_t \quad (2)$$

To test the robustness, validity and reliability of the results of this model, Breusch-Godfrey test of serial correlation, Jarque-Bera normality test, and Breusch-Pagan-Godfrey test of heteroskedasticity is employed. If the null hypothesis is not rejected, then we conclude that the residuals of the models are free from serial correlation, are homogeneous and normally distributed. Moreover, CUSUM stability test is also employed to test model stability.

4. Data Analysis And Results

4.1. Descriptive statistics

The descriptive statistics results in this study are provided in Table 1 below and we ascertain that this study uses 30 observations for each and every variable (use of renewable energy, rate of currency exchange, rate of inflation). For the rate of currency exchange the mean value is 1.9224 Brazilian Real per dollar for the period between 1990 to 2019, while the standard deviation is 1.1249. The mean value of rate of inflation and use of renewable energy are 59.57%

and 3.7489 respectively and their standard deviations are 196.45 and 0.0594 respectively. We show that inflation rate of Brazil is deviating much from the mean value, thus it is not stable.

Table 1
Results of descriptive statistics

Variable	<i>ER</i>	<i>INF</i>	<i>lnRE</i>
Mean	1.9224	59.574	3.7489
Median	1.9501	6.6	3.7541
Maximum	3.9445	952	3.8439
Minimum	0.00003	3.2	3.6187
Std. Dev.	1.1249	196.45	0.0594
Sum	57.674	1608.5	112.47
Obs	30	30	30

4.2. Unit root test

We provide the unit root test of the variables under study in Table 2 below. Pre-testing of variables is not compulsory, Pesaran, et al., (2001), since we employ ARDL approach which can be employed irrespective of whether the variables are I (0), I (1) or are not cointegrated. However, since I (2) variables cannot be specified in an ARDL model we conduct unit root test to check if no variable is I (2). By employing ADF and PP unit root test, we ascertain in this study that the variables rate of currency exchange, the rate of inflation as well as the use of renewable energy are all integrated of order one, I (1).

Table 2
Unit root test results

ADF test			PP test			
Variable	t-Statistic	P-value	Integration	t-Statistic	P-value	Integration
ER	-3.8525	0.0284**	I (1)	-3.8154	0.0307**	I (1)
lnRE	-3.3224	0.0234**	I (1)	-3.3224	0.0234**	I (1)
INF	-14.2717	0.0000***	I (1)	-37.6856	0.0000***	I (1)
Note: ***, ** represents 1%; 5% level of significant.						

4.3. ARDL test results

The F- and t-statistics results of the ARDL bounds test in Table 3 shows that when the rate of currency exchange, the rate of inflation and the use of renewable energy are specified in an ARDL model as the explained variables, in turns, there is significant levels relationship among the variables irrespective of whether they are I (1), I (0) or are not mutually cointegrated, Pesaran, et al., (2001). Therefore, we ascertain that we can specify both the ECM and the short-term ARDL model, Pesaran, et al., (2001).

We also provide the ECM findings in Table 3 below. If the rate of currency exchange and the use of renewable energy are specified as explained variables respectively, the error correction term (ECT) is negative and significant at 1%

level, implying that a long-run effect running from the rate of inflation and use of renewable energy to rate of currency exchange exists and also that a long-run effect running from rate of inflation and rate of currency exchange to use of renewable energy exists (Pesaran, et al., 2001; Pesaran, et al., 1999; Granger, 1986; Engle and Granger, 1987). Therefore, in the long-term use of renewable energy and rate of inflation significantly impact the rate of currency exchange and also the rate of currency exchange and rare if inflation significantly impact the use of renewable energy. Thus, a bidirectional causal effect on the rate of currency exchange and use of renewable energy in the long-run is ascertained. If the rate of inflation is given as the explained variable in the ECM, its ECT is found to be positive, see Table 3 below, indicating that for convergence to occur with the rate of currency exchange and the rate of inflation in the long run, inflation rate should rise, Enders (1995). The ECT also gives the adjustment rate to equilibrium, Granger (1986), and the ECT when the rate of currency exchange is the explained variable is 34.79% while that when use of renewable energy is explained variable is 1.63%. The ECT values are very low, below 50%, showing that the adjustment rate to long-run equilibrium is very low, Granger (1986). The R-squared and adjusted R² values are very high, hence robust results.

Table 3
Long-run bounds test and Error Correction Model results

	F-statistic	t-statistic	ECT	R-squared	Adjusted R²
ER	7.8030***	-5.0634***	-0.3479***	0.5521	0.4937
lnRE	7.2268***	-4.8463***	-0.0163***	0.4746	0.4746
INF	124.75***	20.3386***	1.2490***	0.9503	0.9432
Note: *** represents 1%. Schwarz Information Criterion is used to automatically select lag length.					

In Table 4 below, the findings of the short-run ARDL model when rate of currency exchange, rate of inflation and use of renewable energy are the explained variables are given. The findings show that in the short-run, renewable energy has a significant negative impact on exchange rate in Brazil. The results are significant implying that a rise in the use of renewable energy in Brazil has the effect of reducing the foreign exchange rate (currency appreciation), ceteris paribus. Inflation rate in the short-run is found to have no significant effect on the rate of currency exchange in Brazil, ceteris paribus. The lag value of the rate of exchange significantly affects current rate of currency exchange negatively, indicating that if exchange rate is high in the past in Brazil, it will fall in the future and vice versa. Therefore, we provide that on top of reducing global warming effects, the use of renewable energy is vital in ensuring high currency value in a country and thus Brazil should invest in renewable energy. Our findings support the findings by Smolovic, et al., (2020) and Shahbaz, et al., (2020).

The findings also shows that the rate if currency exchange significantly impact the use of renewable energy positively in the short-run. This shows that a rise in foreign exchange rate has the effect of promoting the use of renewable energy, ceteris paribus. In other words, undervaluation of Brazilian Real will improve renewable energy use in the nation. The effect of inflation rate is positive and significant, indicating that high rate of inflation in Brazil will cause the use of renewable energy supply to rise. The lag value of renewable energy significantly impacts current value negatively. The results however show that, use of renewable energy and rate of currency exchange of Brazil does not significantly impact the rate of inflation. It is only the lag value of inflation rate that positively affect inflation rate.

Table 4
Results of short-run ARDL

ER		INF		lnRE	
Lag 0	Lag 1	Lag 0	Lag 1	Lag 0	Lag 1
Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
t-Statistic	t-Statistic	t-Statistic	t-Statistic	t-Statistic	t-Statistic
ER	-0.348	-1.5905		3.7597	-3.6028
	-3.405***	-0.047		1.986*	-3.652***
lnRE	1.9856	6.2705			-0.0163
	4.594***	2.023*			-4.239***
INF	11.708	-16.578	1.249	61.289	-9.2607
	0.6272	-0.9456	15.417***	0.2808	-1.4985
Note: ***; * represents 1%; 10% level of significant. Schwarz Information Criterion is used to automatically select lag length.					

4.4. Residual diagnostic and Stability test results

Breusch-Godfrey serial correlation test is user to test if the residuals in the models are serially correlated or not. Also, Jarque-Bera normality test and the Breusch-Pagan-Godfrey test of heteroskedasticity are employed in this research. We provide that the residuals of the models have no serial correlation problems, and that there are homogeneous. When the rate of currency exchange and use of renewable energy are explained variables the residuals are normally distributed but when the rate of inflation is the explained variable the residuals are not normally distributed. Therefore, we ascertain that the models' residuals have no serial correlation problems, are homogeneous and normally distributed, thus the robustness, reliability and validity of the findings in this study.

Table 5
Residual Diagnostic test results

Breusch-Godfrey Serial Correlation LM Test:			Jarque-Bera Normality Test		Heteroskedasticity Test: Breusch-Pagan-Godfrey	
	F-statistic	P-value	Statistic	P-value	F-statistic	P-value
ER	1.6869	0.2131	0.8617	0.6499	0.6118	0.718
lnRE	0.1928	0.826	1.5776	0.4544	0.7708	0.5222
INF	0.1377	0.8723	207.33	0.0000***	0.6512	0.689
Note: *** represents significant at 1% level.						

In Fig. 1, Fig. 2 and Fig. 3 below we provide the results of CUSUM stability test results. The CUSUM graph in all the three figures lies within the 5% significant bounds, indicating that the ARDL models employed in this study are stable, hence robust results.

5. Conclusion

In short, the research findings show that when the rate of currency exchange, use of renewable energy and rate of inflation are specified as explained variables respectively in an ECM model, a long-run causal effect running from renewable energy and inflation rate to the rate of currency exchange; running from the rate of currency exchange and rate of inflation to use of renewable energy exists because the ECT is negative and significant (Pesaran, et al., 2001; Granger, 1986; Engle and Granger, 1987). This implies that in the long-run use of renewable energy and the rate of inflation of Brazil significantly impact the nation's rate of currency exchange and that in the long-run the rate of currency exchange and the rate of inflation significantly impact the use of renewable energy, Granger (1986). Therefore, in the long-run a bidirectional causal effect of the rate of currency exchange and the use of renewable energy of Brazil is observed. The ECT when the rate of inflation is the explained variable is positive and significant, indicating that for convergence to occur inflation rate should rise (Enders, 1995). The speed of adjustment to equilibrium of the ECM models are very low, below 50%, showing that it will take long for the rate of currency exchange, use of renewable energy and the rate of inflation of Brazil to adjust to the long-run equilibrium (Granger, 1986; Engle & Granger, 1987).

We also ascertain that renewable energy use significantly affect the rate if currency exchange negatively in the short-run, indicating that a rise in the use of renewable energy in Brazil will reduce the foreign exchange rate of the Brazilian Real (appreciation), *ceteris paribus*. This implies that a rise in the use of renewable energy in Brazil will have the effect of improving the value of the Brazilian Real. The Brazilian real is enhanced to appreciate as the nation increases the use of renewable energy. This is in line with the findings of Deka and Dube (2021). Therefore, on top of reducing the emissions of carbon-dioxide and global warming effects, Smolovic, et al., (2020); Shahbaz, et al., (2020), the use of renewable energy in Brazil improves the value of the nation's currency. Therefore, if Brazil will want to stabilize the rate of inflation by through currency appreciation should encourage the use of renewable energy. Therefore, like in all other nations that have shifted from the use of non-renewable energy sources to the use of renewable energy sources, Brazil should also increase the use of renewable energy sources and this move will help achieve zero carbon in the future. The limitations of the research study are that it only employs three variables and leaves out other determinants of exchange rate and of inflation rate which may tend to produce biased results. However, the model used in this study, ARDL model, includes the lag values of the explained variable and that of the explanatory variables which increases the number of regressors in the model hence robust results. These results can be generalized to other emerging economies that have similar conditions as Brazil, and more studies in the future should be done to examine how the rate of currency exchange is impacted by the use of renewable energy in developing and developed countries.

6. Declarations

Funding

No funding was received from any organization.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The data used in this paper is secondary data and was retrieved from Organization for Economic Co-operation and Development (OECD) website www.oecd.org

Ethical Approval

Not Applicable

Consent to Participate

Not Applicable

Consent to Publish

The authors guarantee that this manuscript has not been previously published in other journals and is not under consideration by other journals. The authors also guarantee that this manuscript is original and is their own work.

Authors Contributions

AD: Conceptualization, Methodology, Writing - original draft, Software. **BC:** Data curation, Writing - review & editing, Supervision. **SD:** Visualization, Investigation.

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Figures

Figure 1

CUSUM stability test (Exchange rate is dependent variable)

Figure 2

CUSUM stability test (Renewable energy is dependent variable)

Figure 3

CUSUM stability test (Inflation rate is dependent variable)