Investigating the Co-movement of Cocoa and Coffee Prices in International Markets: Evidence from Non-linear Autoregressive Distributed Lag Model and Rolling Window Methods

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Abstract
The focus of this study is to empirically investigate the co-movement of Cocoa, Arabica, and Robusta coffee prices for 1960-2018. An essential contribution of the present study is using the non-linear autoregressive distributed lagged co-integration technique and rolling window-based methods for empirical analysis and to check the co-integration among variables. At the same time, the Auto Regressive Distributed Lagged (ARDL) bound test and Gregory-Hansen co-integration techniques are employed for robust analysis. The empirical estimations indicate that the positive shocks in Cocoa prices have affected Arabica and Robusta coffee prices in the short and long run. For Cocoa and Arabica coffee estimations, the one unit of positive change of cocoa price tends to increase the Arabica price with 0.1445 and 0.806 for the short run and long run, respectively. These findings suggest that the increase in cocoa price causes an increase in the demand for Arabica coffee from importing countries. Similar results are confirmed in the case of Cocoa and Arabica. At the same time, the adverse shocks in Robusta coffee prices have affected Cocoa prices with greater magnitude in the long run. Thus, our outcomes also confirm the co-movement of the coffee and cocoa prices.
Keywords*:* Cocoa; Arabica; Robusta; Co-movement; Prices; Coffee.

Introduction

During the previous decade, the fluctuations in commodity prices after supply-demand balances and speculative movements attracted the attention of market actors, public authorities and researchers. Commodity means the collection of goods such as materials like gold, copper and oil; food products such as wheat, barley and corn; and also, metals and minerals. Commodities are food products, precious metals, minerals and energy goods. Moreover, commodity prices mainly consist of food products, agricultural raw materials, energy raw materials, and industrial input prices such as minerals, ore, and metals. Since commodity prices and price dynamics are among the risk factors affecting inflation outlook and growth, they are essential for the economy (Li et al., 2024; Mu et al., 2022; Gereffi, 1999).

The intersection of the supply and demand of goods and services determines the commodity prices. Considering the supply and demand, the cost of the relevant commodity is determined by the market (Gondal et al., 2023; Kamran et al., 2023; Ullah et al., 2023; Yousaf et al., 2023). Supply and demand are not always enough to determine the price of a commodity alone. Factors such as inflation, interest rate, economic conjuncture and natural conditions may affect

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commodity prices (Amin and Dogan, 2021; Amin et al., 2021). In particular, development in the world economy after 2000 has caused sudden changes in commodity prices. For example, developing countries have tried to recover their economies after the 2008 global economic crisis and turned their contractionary monetary policies into expansionary ones (Amin et al., 2023; Li et al., 2023; Yua et al., 2023). For this reason, the increasing energy requirement in developing countries and the external dependency on energy after 2008 have caused increasing commodity prices. In recent years, uncertainties regarding the global economy and the extraordinary monetary expansion in developed countries such as the United States (USA), Japan and the Eurozone indicated the possibility of continued volatility in commodity prices (Farooq et al., 2023; Bulut et al., 2023; Isik et al., 2023; Ji et al., 2023; Ongan et., 2023; Sadiq et al., 2022; Ullah et al., 2022; Ai et al., 2006).

The excess or unexplained volatility in commodity prices is likely attributed to Pindyck and Rotemberg (1990). The hypothesis tested in the prior study shows that products' price has moved together at a constant tendency, and the investigation has established the co-movement among prices of a category of products, including timber, gold, Cocoa, cotton, copper, wheat and crude oil. Furthermore, the effects of this range are unrelated and macroeconomic variables highly affect and explain the co-movement of these products, such as demand, inflation, and variability in exchange and interest rates.

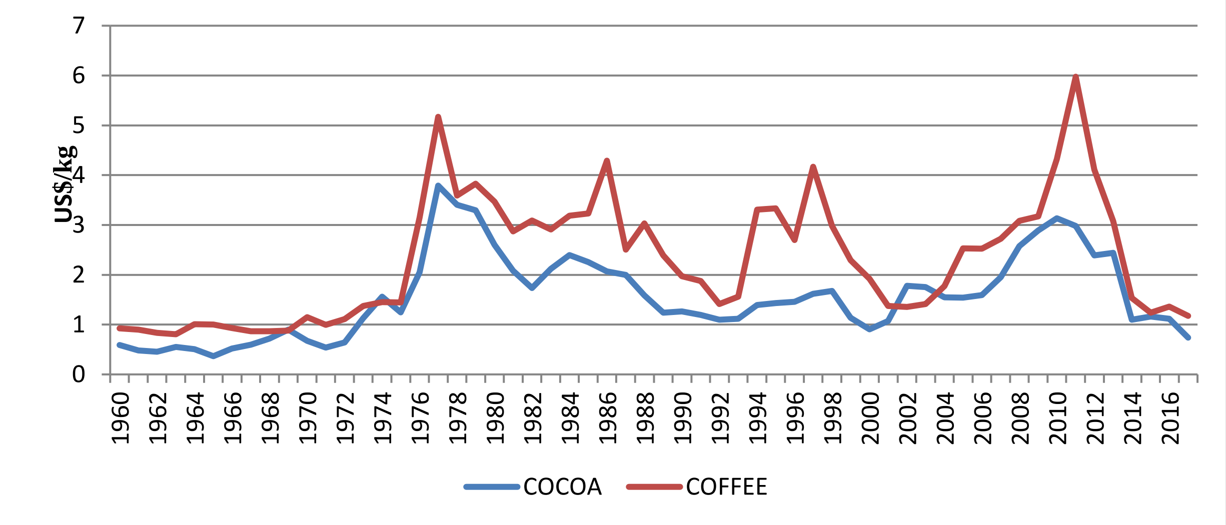
It is essential to understand that commodity prices are generally firmly co-related and tend to move positively or negatively. Similarly, agricultural products, which are also highly co-related, have a substantial impact on the importers and exporters (Amin et al., 2022; Ameer et al., 2022a; Ameer et al., 2022b; Halwan et al., 2022). In addition, Borensztein and Reinhart (1994) have investigated how coordinated commodities prices put significant inflationary pressure on economies highly dependent on imports of those commodities. However, if substitution effects explain the expected change, they support export intensity in commodity-producing countries. Ai et al. (2006) re-examined the co-movement of farming products (Mu et al., 2022; Yousaf et al., 2022). They developed a fundamental model and used five commodities, namely Oats, Soybeans, Corn, wheat, and barley, to describe a significant part of the co-movements of the product prices. They found that their models explained the correlation between the correlated goods but did not indicate the co-movements in commodity prices for non-related goods (Amin & Dogan, 2021; Amin et al., 2021; Shah et al., 2021; Yousaf et al., 2021).

In the early 20th century, the rise in multi-commodity prices in the international markets created a particular interest in the foundation of moving commodities in the same direction, positively or negatively. Even the prices of commodities like Cocoa increased by two hundred per cent, while the prices of coffee and cotton increased from three hundred to four hundred per cent (Amin et al., 2020a; Amin et al., 2020b). Over time, the increase in these commodities' prices suggests three types of hypotheses in this regard. Firstly, the rise in commodity prices is very much related to the natural growth in economies like India and China, which show an increase in demand. (See, e.g., Amin et al., 2020c; Caballero et al. 2008). Secondly, the hypothesis related to the rise in commodity prices is that these commodities are now traded on financial stock exchanges in contracts like futures and forwards and the physical form (Amin et al., 2020d; Kilian & Murphy, 2014). Lastly, the third hypothesis is based on the co-movement of commodities in the market, which are collectively affected and are perfect substitutes for each other, such as Coffee and Cocoa (Amin et al., 2020e).

Traoré and Badolo (2016) have tested the movement between cocoa and coffee prices. The empirical finding reveals that the coffee price is estimated to be 0.88 for long-term flexibility compared to the cocoa price. According to the causality result, it was also determined that the cost of Cocoa caused coffee prices to rise.

Additionally, Substitute commodities like Cocoa and coffee, which are agricultural products, have a good market for those living in developing countries. It is also a solid commodity export need for supplier countries (Aqdas et al., 2020; Aziz et al., 2020). For instance, Cote d'Ivoire's 25% exports are mainly based on coffee and Cocoa, which provide a livelihood to the people of this area. Similarly, Ethiopia and Burundi's primary sources of exports are coffee and Cocoa, which are 79% and 64% of the country's exports, respectively (Amin et al., 2018; Azim & Amin, 2017; FAO, 2006). Coffee is also known to be used chiefly seasonally and is one of the most traded products. Since the seasons vary from country to country, most of the supply becomes uncertain. For many developing countries and the private sector, coffee production, trade, and consumption significantly contribute to socio-economic development (Amin et al., 2015; Javed et al., 2015). In contrast, It is also seen that Cocoa is different from coffee in production; it is mainly produced in developing countries in small volumes, while Cocoa is also dependent on the weather conditions because of its harvesting and productivity (Amin et al., 2014).
Figure 1 below shows coffee and cocoa prices' robust co-movements and significant volatility during the previous 30 years. Indeed, the two commodity prices are close to each other, and they move together. Price volatility is provided by the monthly data obtained from the World Bank from 1985 to 2018, with a coefficient of variation of 0.39 for Cocoa and 0.44 for coffee. While price volatility is a significant concern for coffee and Cocoa exporting countries, it is a relatively minor concern for most importing countries. The significant fluctuations in prices in the world can significantly impact both national and producer levels because excessive price volatility prevents producers from investing more in productivity and production. It is observed that Cocoa and coffee are substitute commodities and will have lesser effect or changes in consumption patterns despite the differences in prices to the importing countries of these commodities.

Figure 1 Evolution of world coffee and cocoa prices Cocoa: International Cocoa Organization daily price, average. Coffee: International Coffee Organization indicator price.



Source: World bank.

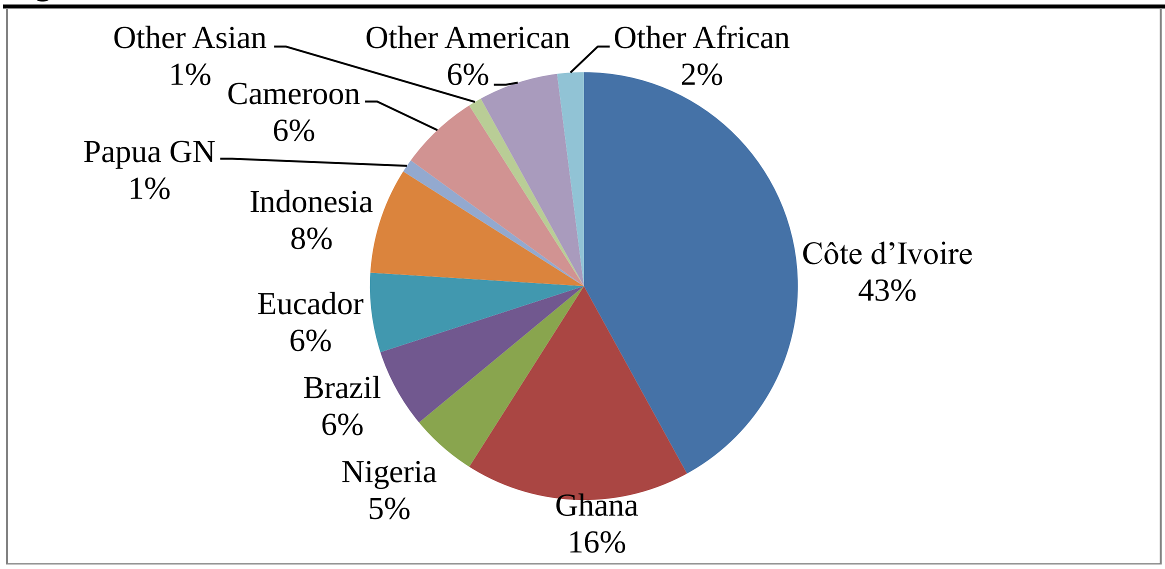
Although, as we know, Cocoa and Coffee are substitutes, there are some other uses for these commodities. As far as these commodities are concerned, the preference or choice of consumers also depends on some other income factors. The demand for cocoa and Coffee depends upon the consumer's income, the product's price, the consumer's preference, taste and its substitute. (Gardner, 1956; Nerlove, 1958).

Additionally, Coffee and cocoa commodities are harvested, produced in developing countries, and traded in the same over-the-counter markets through forwards and futures. Thus, it is understood that both commodities will covariate similarly in prices on the supply end.

Therefore, this study enriches the understanding of the mutual dependency of coffee and cocoa prices and finds out whether these prices are interrelated and affect each other. As shown in Figure 1, the prices of both commodities are also strongly correlated. As highlighted in Figure 1, the two prices are highly correlated; they move interconnected and display similar rise and fall sequences.

Cocoa and Coffee are produced chiefly in developing and less developed countries in tropical and humid places such as South Asia, South America and Africa. *Cocoa* is a vital money source and a critical export product for producer countries. It is also a vital import product for consumer countries, which generally need suitable climates for its production. Indeed, growing cocoa requires a warm, rainy and tropical climate and abundant vegetation to shade cocoa trees. Thus, the central growing regions are Africa, Asia and Latin America. The largest producing country in the world is Cote d'Ivoire, which produces 43% of the global supply (Figure 2).

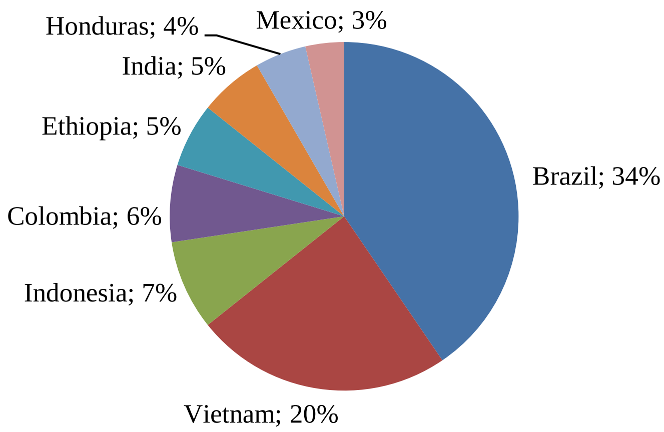
Figure 2 Production of cocoa 2016 estimates



Source: International cocoa organization (ICCO).

Coffee is a perennial agricultural product that can be produced from the same root structure for 2 years or more. In 2016, 8.2 million metric tons of coffee was produced in more than 50 countries on 0.2% of the world's agricultural land. The top producers were Brazil (34%), Vietnam (20%), Indonesia (7%), Colombia (6%), Ethiopia (5%), India (5%), Honduras (4%) and Mexico (3%) and they own 67% of global production (Figure 3).

Figure 3 Production of coffee 2016 estimates



Source: International coffee organization (ICCO)

In order to carry out our empirical analysis, we have evaluated the information about the prices of coffee and cocoa obtained from the World Bank between 1960 and 2018.

Literature Review

The following past literature supports this study. Traoré and Badolo (2016) identified the co-movement between the prices of two substitute commodities, cocoa and coffee, using the ARDL technique. The empirical outcomes confirmed the co-movement of the prices of both commodities with the existence of co-integration and the estimated elasticity of the price of coffee concerning cocoa's price, which is 0.88. The study found that the price of coca is a source of more significant cause for the coffee price and not vice versa by using the lag augmented VAR approach presented by Toda and Yamamoto (1995), and this approach is valid irrespective of order for data integration. The study's outcomes implied that the confirmation of the co-movement of coffee and cocoa prices had given suitable policy measures for policymakers in the production phase. Chatrath and Song (2006) also worked out the co-movement of coffee and cocoa prices, which were produced in less developed and developing countries of Africa, South America and South Asia. They also verified the co-integration between these two commodities' prices. This study reported an overview of these commodities' production and price variations. Cocoa was included in those crops, which was a source of earning cash, helped share exports of a country, and had a significant share in imports of a country for the consumption purpose of those countries. The trees of these two commodities were produced in the regions of Africa, Asia, and Latin America, and the highest production of these trees is in the country of Cote d'Ivoire, with the production of 42 % of the world's supply. A vital increase in the production of these trees by 13 % was seen, from 4.3 million metric tons in 2008 to 4.8 million metric tons in 2012. This increase showed a 3.1 % more production annually. When cocoa beans were harvested and supplied to different places, and after processing in different components, these beans were used for commercial use. Edwards (2013) also discussed that the European Union dominated the production of Cocoa trade, contributing to half of the imports. Europe and the U.S. were vital importers of post-processing cocoa products as they were the significant manufacturers of chocolate. China had increased its imports of cocoa, and there was an increase in imports from 12th position to ninth position for cocoa paste. It was ranked 15th to 9th for the most giant cocoa powder and cake importer. The upcoming cocoa contracts were considered a benchmark for the international quote price. Each contract had ten metric tons, and prices were quoted in US dollars for each metric ton. Coffee is a lasting crop with an agricultural commodity produced by a similar root structure for two or more years. From the .2

agricultural sites worldwide, 8.2 million metric tons of coffee were produced in 50 countries in 2012. Brazil produced 32 %, Vietnam produced 18 %, Indonesia produced 6%, Colombia produced 6%, and Ethiopia produced 5% of the total 67 % globally. The total export is US $ 23.4 billion, with 80 % of total production globally, with Brazil producing 24%, Vietnam producing 22%, Indonesia producing 9%, Colombia producing 6%, and Honduras producing 5%. There has been a vital increase in the consumption of coffee by 22.3 % during the last ten seasons, and the European Union has a dominance level of 31 %.

Latin America and Asia were the significant consumers in the list of producer countries in 2012. Except for Traoré and Badolo (2016) and Chatrath and Song (2006), none worked out for the co-movement of two substitute products in the literature. The literature mainly concerns the statistical description of these two commodities' domestic production, consumption and trade in the past data. This study is quite different from the above studies, with a discussion on the co-movement of cocoa and two types of coffee's prices and the co-integration of these prices worldwide, not for the specific region as the earlier studies did. This has used NARDL estimation to measure the non-linear association between the variables of interest given in the concerned model.

Data and Materials

Data Overview

To empirically examine the co-movement of cocoa and coffee, we used the data from the international organizations governing the commodities, and data was accessed from World Bank[6], (2019). The paper used the annual data of cocoa, coffee Arabica and coffee Robusta prices for the period 1960 to 2018. The cocoa prices are governed by International Cocoa Organization, and cocoa prices are presented as the annual average of daily price average of three positions on the terminal markets of London and New York. However, the coffee Arabic and coffee Robusta commodities are governed by the International Coffee Organization and prices correspond to the different factors such as; mild Arabicas, average New York, Hamburg markets and organization indicator prices. For all three commodity prices, we employed annual data to examine the short-run and long-run fluctuations by using asymmetric co-integration technique. Table 1 shows the descriptive statistics of cocoa, arabica coffee and robust coffee. The descriptive analysis shows strong evidence for positive correlation among cocoa to Arabica coffee and cocoa to Robusta coffee. In addition, we find no outliers in the data of all studied variables.

Table 1 Descriptive Statistics and correlation analysis

	Descriptive statistics			Correlation		
	Mean	SD	Jarque-Bera	Cocoa	Arabica coffee	Robusta coffee
Cocoa	0.3623	0.6037	3.755		0.8977*	0.8168*
Arabica coffee	0.7640	0.5620	4.470	0.8977*		
Robusta coffee	0.3961	0.5543	3.314	0.8168*	0.9005*	0.9005*
*denote statistical significance at the 5% level.						

Co-integration Analysis

In the present study, we employed non-linear ARDL technique to examine the non-linear relationship and to check the cointegration of variables. Shin et al. (2014) extended the ARDL framework of Pesaran et al. (2001) with an assymetric cointegration approach or non-linear

[6] *Commodity markets data can be accessed from: http://www.worldbank.org/en/research/commodity-markets.*

autoregressive distributed lag (NARDL). This technique is capable to capture short term and long term volatalities and structural breaks (assyemtric). In addition, the non-linear ARDL can be utilized irrespective of the behavior of variables, i.e., I(0), I(I) or mixuture of both. In consistent with Shin, et al., (2014) the NARDL model is presented in linear form following assymetric long run relationships;

$$Y_t = \beta^+ X^+{}_t + \beta^- X^-{}_t + \varepsilon_t \quad \ldots\ldots (1)$$

ε_t presents the stationary zero mean process that denotes that long run equilibrium β^+ and β^- explains the linkages of asymmetric long run parameters while, X_t presents the vector of regressors and it is decomposed as;

$$X_t = X_0 + X^+{}_t + X^-{}_t \quad \ldots\ldots (2)$$

Whereas, X factors denotes an arbitrary initial value and adjustment of positive and negative changes in regressor variables. We investigate the assymetric effect of cocoa to arabica coffee and cocoa to robusta coffee. The specific assymetric long run equation is presented as;

$$\Delta w_t = \alpha_0 + \alpha_1 \Delta x_t^+ + \alpha_2 \Delta x_t^- + \varepsilon_t \quad \ldots\ldots (3)$$

Whereas, w_t presents the coffee Arabic and coffee Robusta, while α shows the cointegrating factor to be estimated for cocoa prices and x presents the partial sum of positive and negative changes in cocoa prices for coffee. Following the equation 3 the assymetric ARDL framework is further presented as;

$$\Delta w_t = \beta_0 + \beta_1 w_{t-1} + \beta_2 x^+{}_{t-1} + \beta_3 x^-{}_{t-1} + \sum_{i=1}^{m} \delta_{1i} \Delta w_{t-i} + \sum_{i=0}^{n} \delta_{2i} \Delta x^+{}_{t-i} + \sum_{i=0}^{p} \delta_{3i} \Delta x^-{}_{t-i} + \mu_i \quad \ldots\ldots (4)$$

This study has used the NARDL estimation method to diagnose the non-linear association between the variables of interest.

Rolling-window Approach

By extending our empirical analysis, we further employed the recently developed technique, rolling window method introduced by Hurn, et al., (2016). The rolling window technique ensures that empirical estimations are not spurious. The rolling analysis helps to construct new observations by using the sample of consecutive observations. In addition, the impact of rolling analysis on auto covariance can be observed in figures, and it is easy to examine that the auto covariance is absolutely summable. For example, if a series of prices of one commodity, $\{p(t)\}_{t=1}^{T}$ from which the objective is to examine the aggregate price for ΔT, then we can either take the samples and divide it with T/ΔT as equally sized non-over lapping sub-samples, from which the statistical measures can be estimated mean, medium variance etc. However, in such a case the preferable approach is rolling window analysis, in which the aggregated price is estimated by moving the window forward one observation at a time. In this approach, the number of aggregated ΔT -prices becomes T-ΔT+1 which is greater than T/ΔT for ΔT<T. By assuming that $\{p(t)\}$ is a stationary time series with mean μ_p having auto covariance function $\lambda_p(.)$ then the rolling prices ṗ(t) is defined as;

$$\tilde{p}(\Delta T)_{(n)} := \sum_{t=n}^{n+\Delta T-1} p(t) \quad \ldots\ldots (5)$$

If $n = 1, \ldots,$ T-ΔT+1, the above equation can be rewritten as

$$\tilde{p}(\Delta T)_{(n)} = \mu_{\bar{p}} + \sum_{t=n}^{n+\Delta T-1} (p(t) - \mu_p) \quad \ldots\ldots (6)$$

Whereas, it is observed that ṗ (ΔT) presents a moving average process of order ΔT with mean and variance presented as;

$$E\left(\bar{p}(\Delta T)_{(n)}\right) = E\left(\sum_{t=n}^{n+\Delta T-1}(p(t)\right) = \sum_{t=n}^{n+\Delta T-1} E(p(t)) = \mu_{p} \quad \text{......................................(7)}$$

Results and Discussion

Stationarity Testing

In order to examine the stationarity properties of data, we employed the Augmented Dickeye Fuller (ADF) test (Dickey & Fuller, 1979), Phillipse Perron (P-P) tests (Phillips & Perron, 1988) unit root test and Zivot Andrews test with one stage structural break (Zivot & Andrews, 1992). Although the traditional unit root tests provide specific outcomes for the variables but the potential weakness of traditional unit root tests is that these do not undertake the possibility of shocks and structural breaks in data which makes the results biased. However, the structural break tests account for any possible breaks, shocks and does not provide biased outcomes (Baum, 2006). Table 2 provides the estimations for unit root tests at the first difference while the estimations at level are reported in table 1A. In empirical findings of unit root testing, we find that all three variables are integrated at the first difference in all employed tests. We find no evidence of stationarity of any variable at level in all employed tests. In line with these results, we employed asymmetric cointegration and granger causality tests. However, to check the linear relationship, we further applied autoregressive distributed lag (ARDL) bound test and Gregory-Hansen Cointegration technique as robust analysis.

Table 2 Unit Root Tests (at first difference)

Variables	ADF and P-P test Statistics		Zivot–Andrews Structural break test	
	ADF statistics	P-P statistics	t-Statistic	Time break
Cocoa	-6.69***	-5.72***	-7.85***	1980
Arabica coffee	-7.56***	-7.55***	-7.93***	1978
Robusta coffee	-6.10***	-6.11***	-6.65***	1978

Superscripts ***, **, *denote statistical significance at the 1 and 5% and 10% levels, respectively.

Findings for NARDL Cointegration

The findings of short run and long run relationship is presented in table 3 where panel A presents the short run relationship, panel B is about long run association and panel C discusses the diagnostic of the model. Focusing to the panel A, the coefficient of increase in cocoa price have a significant effect on Arabica prices, in short run estimations. Similarly, the Arabica prices are affected by the decrease in the price of cocoa, mentioning that there exists a short run relationship from cocoa to Arabica. The lags of Arabica coffee are significant in three out of eleven cases; significant and positive at lag 1, lag 2 and lag 9. Where, the lag 1 have higher coefficient value and significant at the 1% level, indicating that the price of Arabica is affected by its first lag price. In the estimation of price increase of cocoa, the coefficient of cocoa has reported significant and positive relationship with Arabica coffee, in the same period. This result confirms that the increase in the cocoa price tends to increase the Arabica price. Emphasizing to the lags of cocoa, most of the lags have confirmed insignificant coefficient, except lag 3 and lag 8. For a price decrease of cocoa, the coefficients are insignificant at level, as well as on lags, which mentioning that the decrease in cocoa price have no impact on Arabica coffee. To concise the findings of cocoa and Arabica, in the short run, the price of Arabica coffee depends on its previous price and the current price of cocoa.

In long run analysis, the increase in cocoa price has significant and positive coefficient, reporting that the high price of cocoa leads to increase the price of Arabica. Interestingly, in the long run, the coefficient of decrease in cocoa price is statistically significant and negative at 1% level. However, the long run estimations have confirmed the presence of asymmetric effect of cocoa on Arabica.

Considering the association of cocoa to Robusta, the results produce the significant coefficient of lagged Robusta which represents that current Robusta price depends on the lagged price of Robusta. In the short run, lag 1 and lag 9 of Robusta are significant at the 1% level, while the magnitude is higher at lag 1. The finding confirms that current Robusta price depends on previous Robusta price. For positive change in the price of cocoa, the coefficient of current cocoa is positive and significant with a coefficient value of 0.1345, revealing that the increase in cocoa price tends to increase the Robusta price. In case of negative change in the cocoa price, the coefficient shows significant and positive which indicates that the decrease in cocoa price tends to decrease the Robusta price. Lagged positive and lagged negative cocoa price have testified insignificant coefficient. However, there exists an asymmetric association between cocoa and Robusta in the short run. In long run estimations, both the positive and negative change in cocoa price have significant coefficient which confirms the asymmetric association in the long run.

Table 3 NARDL Cointegration

Cocoa to Arabica		**Cocoa to Robusta**	
Panel A: Short run	Coefficient	**Panel A: Short run**	Coefficient
Arabica $^{(t-1)}$	-0.057***	Robusta $_{(t-1)}$	-0.039***
Cocoa $_{(t-1)}$ POS	0.459***	Cocoa $_{(t-1)}$ POS	0.037***
Cocoa $_{(t-1)}$ NEG	0.045***	Cocoa $_{(t-1)}$ NEG	0.039***
Δ Arabica $_{(t-1)}$	0.249***	Δ Robusta $_{(t-1)}$	0.282***
Δ Arabica $_{(t-2)}$	0.100**	Δ Robusta $_{(t-2)}$	-0.007
Δ Arabica $_{(t-3)}$	0.044	Δ Robusta $_{(t-3)}$	0.038
Δ Arabica $_{(t-4)}$	-0.016	Δ Robusta $_{(t-4)}$	0.045
Δ Arabica $_{(t-5)}$	-0.053	Δ Robusta $_{(t-5)}$	-0.078
Δ Arabica $_{(t-6)}$	0.023	Δ Robusta $_{(t-6)}$	0.036
Δ Arabica $_{(t-7)}$	0.052	Δ Robusta $_{(t-7)}$	-0.050
Δ Arabica $_{(t-8)}$	-0.003	Δ Robusta $_{(t-8)}$	0.067
Δ Arabica $_{(t-9)}$	0.085**	Δ Robusta $_{(t-9)}$	0.117***
Δ Arabica $_{(t-10)}$	0.047	Δ Robusta $_{(t-10)}$	0.049
Δ Arabica $_{(t-11)}$	0.020	Δ Robusta $_{(t-11)}$	0.017
Δ Cocoa $_{(t)}$ POS	0.145**	Δ Cocoa $_{(t)}$ POS	0.134**
Δ Cocoa $_{(t-1)}$ POS	0.011	Δ Cocoa $_{(t-1)}$ POS	0.007
Δ Cocoa $_{(t-2)}$ POS	-0.024	Δ Cocoa $_{(t-2)}$ POS	0.035
Δ Cocoa $_{(t-3)}$ POS	-0.159**	Δ Cocoa $_{(t-3)}$ POS	-0.047
Δ Cocoa $_{(t-4)}$ POS	0.077	Δ Cocoa $_{(t-4)}$ POS	0.018
Δ Cocoa $_{(t-5)}$ POS	-0.011	Δ Cocoa $_{(t-5)}$ POS	-0.096
Δ Cocoa $_{(t-6)}$ POS	-0.060	Δ Cocoa $_{(t-6)}$ POS	0.003
Δ Cocoa $_{(t-7)}$ POS	-0.070	Δ Cocoa $_{(t-7)}$ POS	-0.004
Δ Cocoa $_{(t-8)}$ POS	-0.141**	Δ Cocoa $_{(t-8)}$ POS	-0.067
Δ Cocoa $_{(t-9)}$ POS	-0.045	Δ Cocoa $_{(t-9)}$ POS	-0.062
Δ Cocoa $_{(t-10)}$ POS	0.108	Δ Cocoa $_{(t-10)}$ POS	0.023

Δ Cocoa $_{(t-11)}$ POS	-0.065	Δ Cocoa $_{(t-11)}$ POS	-0.046
Δ Cocoa $_{(t)}$ NEG	0.037	Δ Cocoa $_{(t)}$ NEG	0.158**
Δ Cocoa $_{(t-1)}$ NEG	0.059	Δ Cocoa $_{(t-1)}$ NEG	0.012
Δ Cocoa $_{(t-2)}$ NEG	0.072	Δ Cocoa $_{(t-2)}$ NEG	0.122
Δ Cocoa $_{(t-3)}$ NEG	0.049	Δ Cocoa $_{(t-3)}$ NEG	-0.002
Δ Cocoa $_{(t-4)}$ NEG	-0.080	Δ Cocoa $_{(t-4)}$ NEG	-0.051
Δ Cocoa $_{(t-5)}$ NEG	-0.015	Δ Cocoa $_{(t-5)}$ NEG	-0.007
Δ Cocoa $_{(t-6)}$ NEG	-0.018	Δ Cocoa $_{(t-6)}$ NEG	-0.100
Δ Cocoa $_{(t-7)}$ NEG	-0.070	Δ Cocoa $_{(t-7)}$ NEG	-0.018
Δ Cocoa $_{(t-8)}$ NEG	0.058	Δ Cocoa $_{(t-8)}$ NEG	0.029
Δ Cocoa $_{(t-9)}$ NEG	0.005	Δ Cocoa $_{(t-9)}$ NEG	0.061
Δ Cocoa $_{(t-10)}$ NEG	0.055	Δ Cocoa $_{(t-10)}$ NEG	0.017
Δ Cocoa $_{(t-11)}$ NEG	0.118	Δ Cocoa $_{(t-11)}$ NEG	0.136
Constant	0.136	constant	0.010
Panel B: Long run		**Panel B: Long run**	
POS	0.806***	POS	0.947***
NEG	-0.793***	NEG	-0.993***
Panel C: Diagnostic		**Panel C: Diagnostic**	
Cointegration		Cointegration	
Banerjee, Dolado, Mestre (t-test)	-5.017	Banerjee, Dolado, Mestre (t-test)	-4.292
Bounds (F-test)	8.394	Bounds (F-test)	6.166
Asymmetric	F-statistics	*Asymmetric*	F-statistics
Long-run	0.780	Long-run	5.968**
Short-run	2.723*	Short-run	2.483
Portmanteau (Chi2)	37.920	Portmanteau (Chi2)	42.210
B/P heteroskedasticity	33.4***	B/P heteroskedasticity	11.11***
Ramsey RESET (F)	0.617	Ramsey RESET (F)	3.838***
J-B normality	267***	J-B normality	208***

Note: ***,**,* represents the significance at 1%, 5% and 10% respectively.

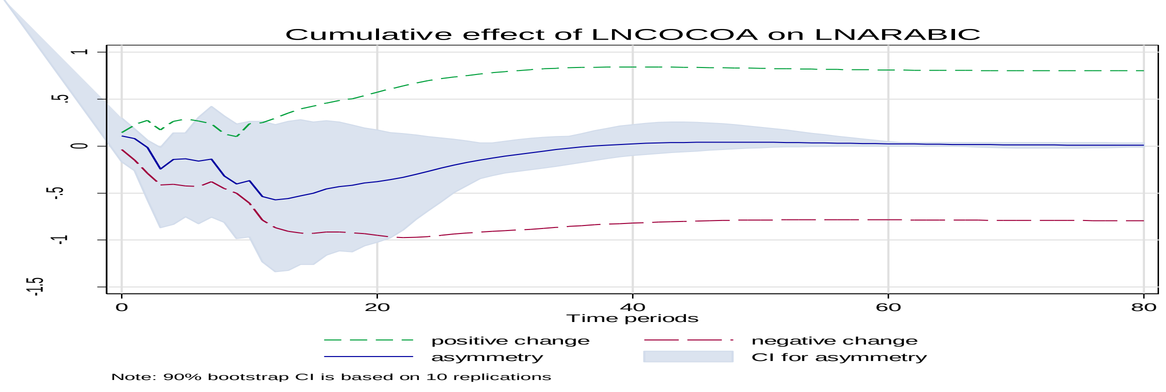
However, the volatility in the price of cocoa, Arabica and Robusta coffee is a crucial concern for exporting countries, as these agricultural products are substitute products, implying that the price change of one good affect the demand for other goods. The change in the demand for the product due to the change in substitute prices directly disrupts the trade balance. On the contrary, importing countries are not severely affected, as the rise in the price of one commodity leads to a decrease in demand and the country imports substitute commodities with lower prices. However, the importing countries have to change their tastes and consumption behaviors slightly. For cocoa and Arabica coffee estimations, the one unit of positive change of cocoa price tends to increase the Arabica price with 0.1445 and 0.806 for the short and long run, respectively. These findings suggest that the increase in cocoa price causes an increase in the demand for Arabica coffee from importing countries. Similar results are confirmed in the case of cocoa and Arabica.

Panel C presents the diagnostics of models; according to F-statistics of bound PSS co-integration exists between Arabica and cocoa and between Robusta and cocoa. In the account of the Wald test asymmetric association, there is no evidence of the long run. In contrast, the short-run asymmetric association has been confirmed at a 10% level in Arabica and cocoa. Accounting for the Robusta and cocoa, a strong asymmetric association exists in the long run. Figure 4 represents this asymmetric association of cocoa on Arabica and cocoa on Robusta. Positive 1% shocks calculate the cumulative dynamic multiplier for positive components.

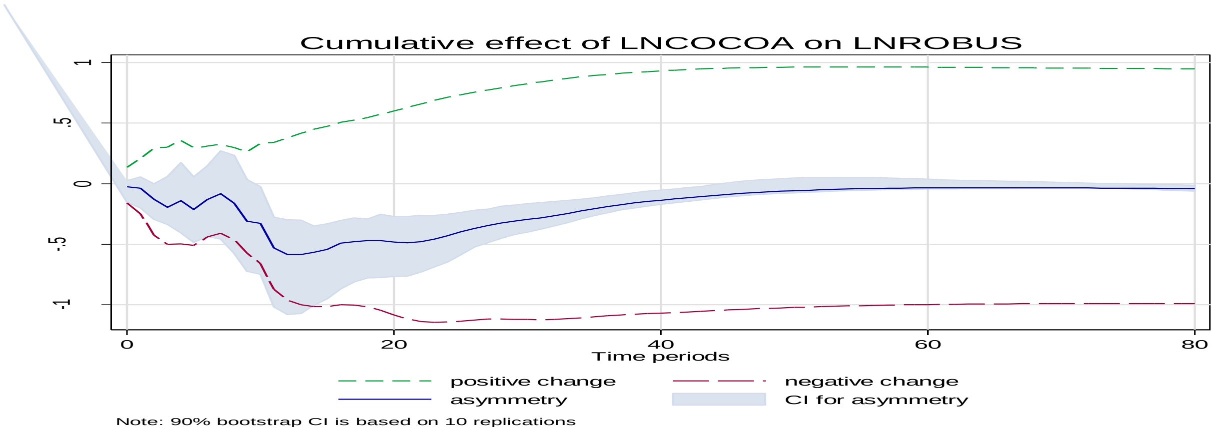
Similarly, the cumulative dynamic multiplier for negative values is estimated by adverse 1% shocks. Additionally, the asymmetric line denotes the sum of positive/negative shocks for positive/negative components. Figure 4 (a) reports that in the start (around 30 years), adverse shocks in cocoa have a higher impact on the price of Arabica coffee in the short run. In the case of cocoa to Robusta, in Figure 4 (b), the adverse shocks of cocoa prices substantially affect Robusta prices in the long run. Hence, Arabica coffee prices are more sensitive to cocoa price shocks in the short run. In the long run, robusta prices are susceptible to cocoa price shocks. The coefficient of Breusch-Pagan heteroskedasticity and normality is also significant at the 1% level. The null hypothesis of Breusch-Pagan heteroskedasticity is rejected, proposing that the model is homoscedastic in both cases.

Figure 4 Dynamic multiplier of positive and negative components of cocoa and Arabica in (a); cocoa and Robusta in (b). Asymmetric line between the confidence interval for asymmetric.

(a) Cocoa and Arabica



(b) Cocoa and Robusta



Granger Causality and Rolling Window

Extending our empirical analysis, we utilized the Granger causality analysis and rolling window technique introduced by Hurn et al. (2016). Moreover, we use time-varying Wald test statistics to examine the causal relationship between cocoa and Arabica coffee prices cocoa and Robusta coffee prices. Figure 5 mentions the time-varying causal relationship from cocoa to Arabica, where (a) the Wald test statistics are used to calculate the forward recursive-based estimation. The graph encompasses the period from 1960 to 2018. From 1960 to 1972, the test statistics sequence line for the slop of cocoa to Arabica is below the critical value sequence line, representing that the null hypothesis of no Granger causality cannot be rejected. On the contrary, from 1972 to 2018, the test statistics line is above the critical line, which rejects the null hypothesis of Granger causality and reports that cocoa has a significant effect on Arabica. Moreover, this magnitude of dependence is increasing after 1998.

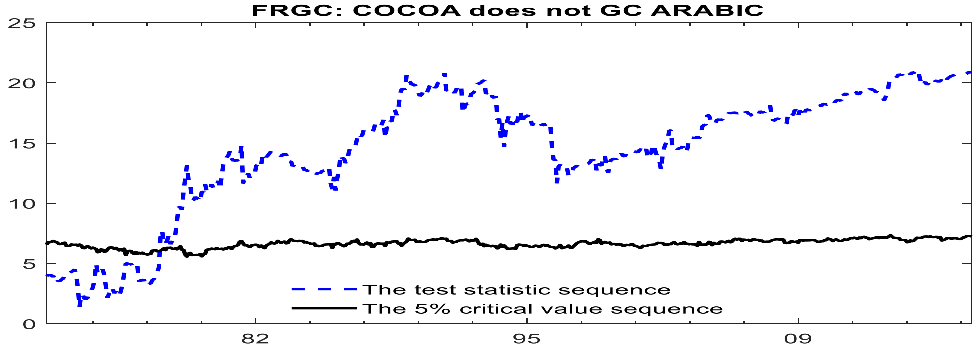
Figure 5 (b) reports the relationship using a rolling window; the results differ from the forward recursive-based estimations. Arabica's dependence has been dependent on cocoa for only three periods: 1972-1985, 1990-1993, and a short time in 2011. The null hypothesis of no Granger causality is not rejected during the remaining period. Focusing on the recursive rolling estimation, figure 5 (c) validates the forward recursive findings that cocoa has had a significant impact from 172 to 2018. The dependence's magnitude varies across the period: higher dependence during 1990 and weak dependence during 1998-2003.

Additionally, figure 6 presents the impact of Arabica on cocoa, where (a), (b) and (c) show the estimated graphs of the forward recursive, rolling window and recursive rolling-based estimations. During the complete period, except around 1965, the test statistics sequence line in Figure 6 (a) is below the critical value line. This mentions that Arabica does not granger cause the cocoa from 1960 to 2018. In Figure 6 (a) and (b), the rolling window and recursive rolling window procedure findings confirm the forward recursive estimation. However, recursive and rolling recursive show a dependence of cocoa on Arabica for a short time, from 1997 to 2001, indicating the rejection of the null hypothesis of no Granger causality. The findings from Figure 7 mention the causal relationship between cocoa and Robusta. Panel (a) of Figure 7 estimates the forward recursive Wald test statistics-based slop of cocoa to Robusta, which confirms that cocoa does not granger cause the Robusta from 1996 to 1980 and 2001 to 2005. Conversely, the null hypothesis of Granger Causality was rejected from 1980 to 2000 and 2005-2018, indicating that cocoa significantly affects Robusta.

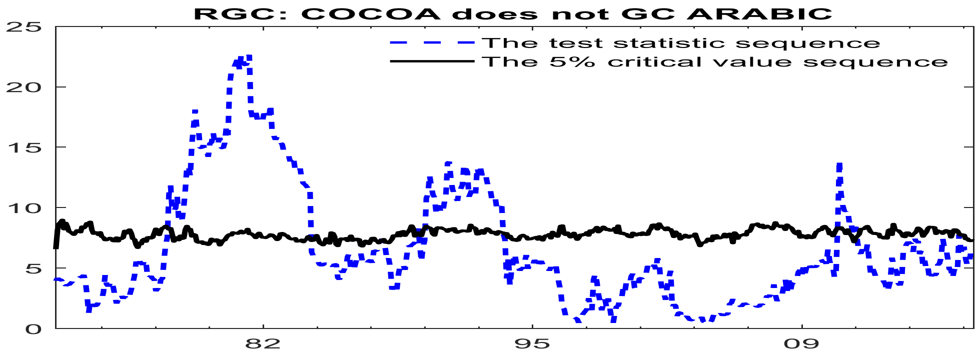
In the case of a rolling window, the findings differ from the forward recursive estimation. The three intervals, 1979-1983. 1987-1993 and 2005-2008 reject the null hypothesis of no Granger causality, suggesting that cocoa has predictive power towards Robusta. Conversely, no granger causality exists in the remaining period, as the test statistics of cocoa for Robusta are below the critical value line. For rolling recursive estimations, the findings contradict the forward and rolling window-based results. Figure 7 (c) portrays that cocoa does not granger cause the Robusta, except from 1983 to 1993. A comprehensive analysis of Figure 6 depicts that cocoa has no predictive power to affect Robusta except in 1983-1993, which is significant in forward, rolling, and recursive rolling-based estimations.

Figure 5 Granger causality test running from Cocoa to Arabica

(a) Forward recursive



(b) Rolling window



(c) Recursive Rolling

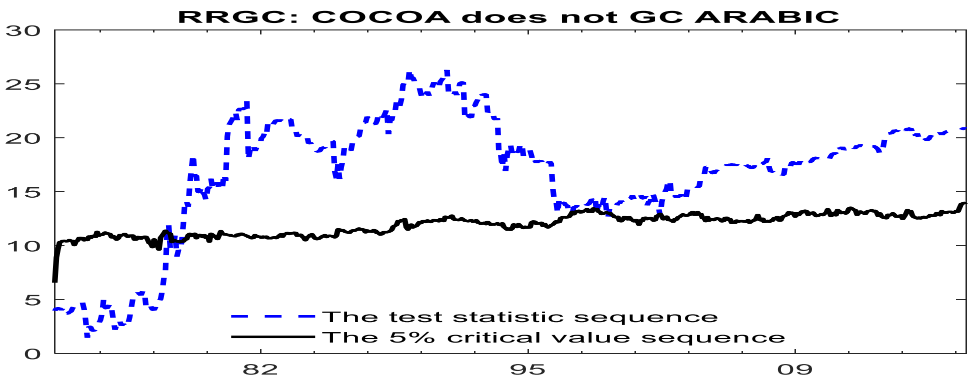
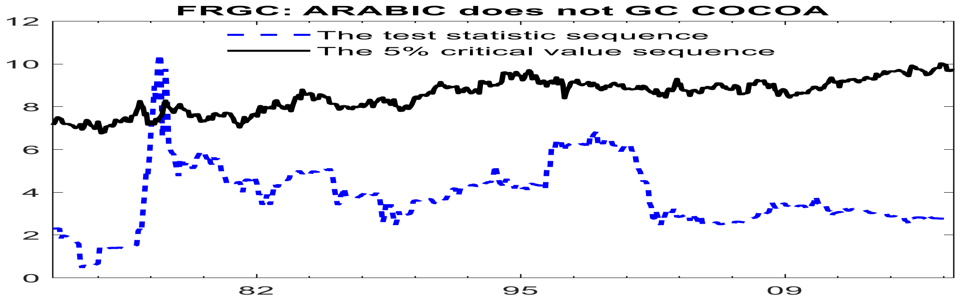
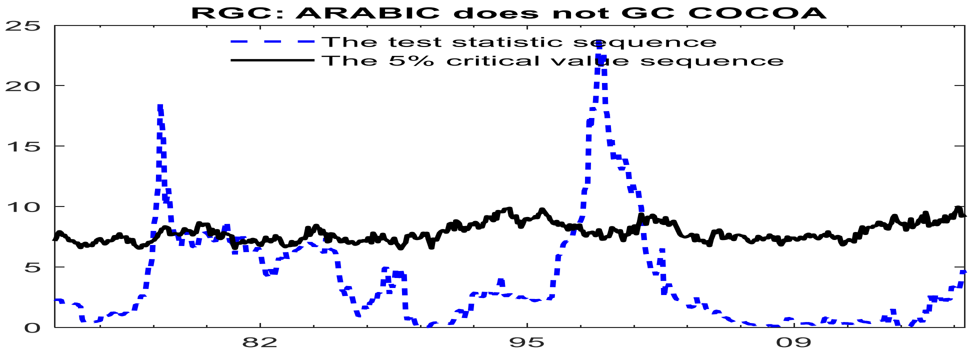


Figure 6 Granger causality test running from Arabica to Cocoa

(a) Forward recursive



(b) Rolling window



(c) Recursive Rolling

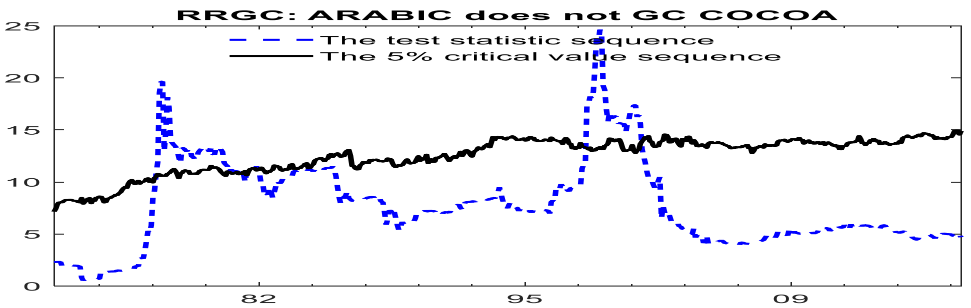
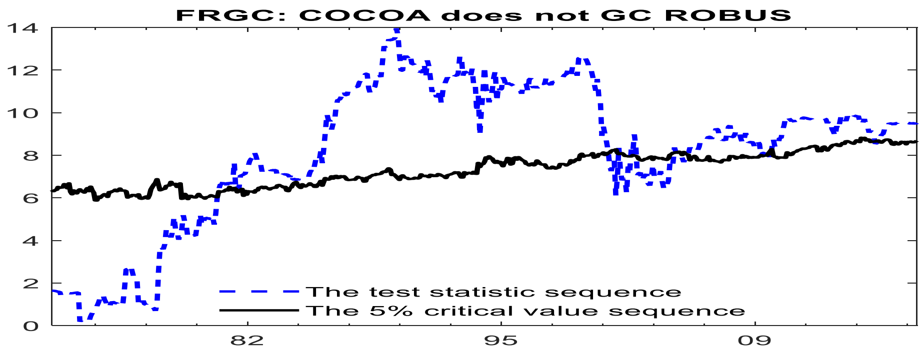
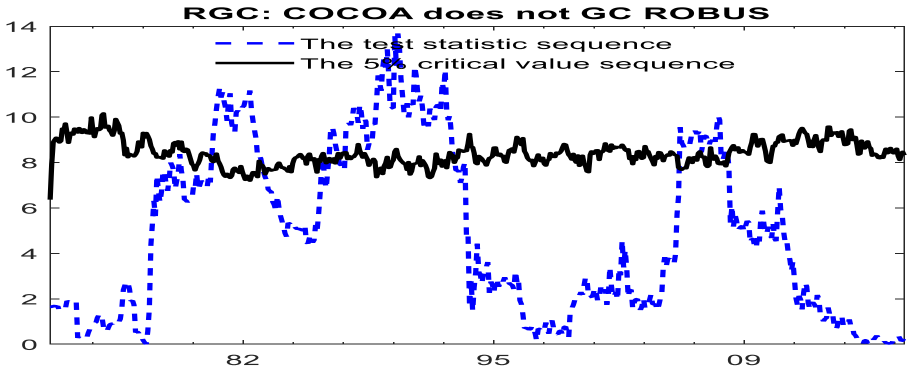


Figure 7 Granger causality test running from Cocoa to Robusta

(a) Forward recursive



(b) Rolling window



(c) Recursive Rolling

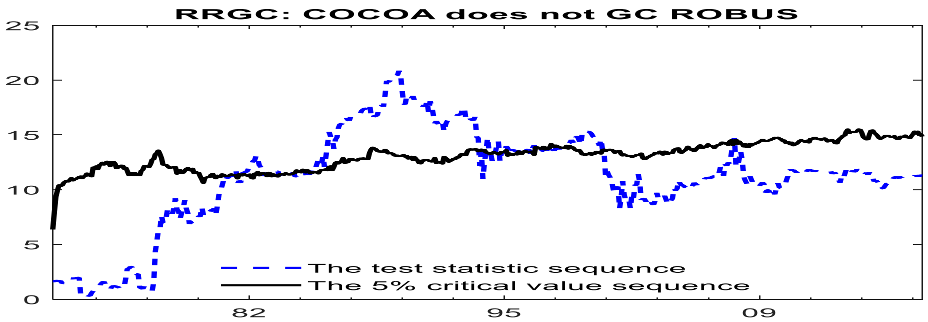
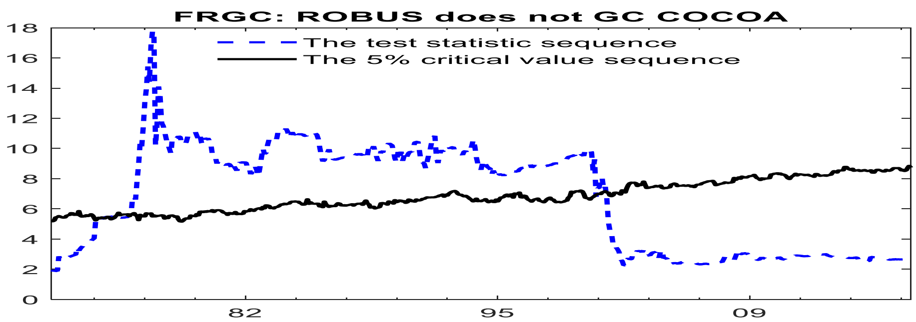
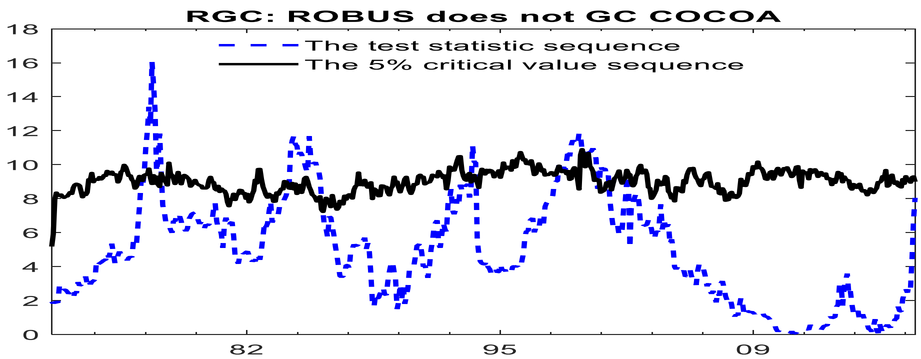


Figure 8 Granger causality test running from Robusta to Cocoa

(a) Forward recursive



(b) Rolling window



(c) Recursive Rolling

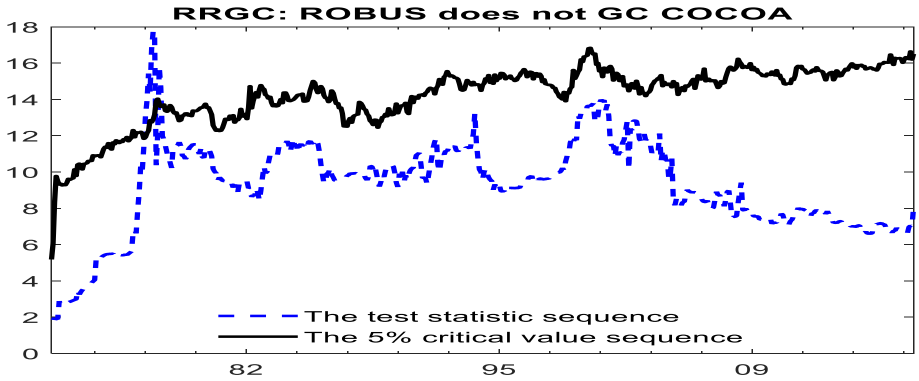


Figure 8 demonstrates the granger causality from robusta to cocoa, where forward recursive based test statistics show that robusta granger cause towards cocoa, from 1971 to 2001, as the panel (a) of figure 8 presents the test statistics of Robusta for cocoa lies below the critical value line. Panel (b) and (c) of figure 8 represents the results of rolling and recursive rolling window estimations, respectively. The findings of rolling and rolling recursive estimations have failed to reject the hypothesis of no granger causality which contradicts the forward recursive estimates. For rolling window, there is only four sharp spikes above the critical value line and one for rolling recursive procedure. In concise, rolling and rolling recursive have suggested that there is no granger causality from Robusta to cocoa, during the study period.

Robustness Check

In order to further check that empirical estimations are not spurious, we further employed the ARDL bound test introduced by Pesaran, et al., (1999, 2001) and Gregory-Hansen Cointegration test as robustness check. The detailed outcome of the ARDL bound testing approach and Gregory-Hansen Cointegration test is reported in Table 4 and table 5. The long-term outcomes of ARDL report a significant positive impact of cocoa prices on Arabic coffee and Robusta coffee, indicating that any significant change in cocoa price affects the price of coffee commodities. This finding is similar with our main findings of asymmetric cointegration, while we find no evidence on cointegration in short run results. Notably, we find insignificant response in short run empirics. Although there is evidence of a relationship with lag of three year of cocoa price to current year prices of coffee in both models. However, this relationship is significantly positive in the period of pre-9/11, implying that terrorist attacks are risen by 3.57% with 1% increment in development assistance. Overall, we find both models as robust and with inconsistent to our basic findings. The calculated F-statistics in both models (cocoa to Arabic and Cocoa to Robusta) are 9.2 and 6.19, respectively and higher than the upper critical value at 5% levels of significance. Our analysis confirms a co-integrating vector which verifies a long run relationship between cocoa and coffee commodity prices.

Table 4 ARDL Bound test

Variables	Cocoa to Arabica	Cocoa to Robusta
Long Run estimates		
Δ Arabica $_{(t-1)}$	-0.521*** (0.123)	
Δ Robusta $_{(t-1)}$		-0.330*** (0.096)
Δ Cocoa $_{(t)}$	0.837*** (0.100)	0.674*** (0.168)
Short Run estimates		
Δ Cocoa $_{(t)}$	0.044 (0.172)	0.244 (0.157)
Δ Cocoa $_{(t-1)}$	-0.040 (0.149)	0.004 (0.170)
Δ Cocoa $_{(t-2)}$	-0.097 (0.150)	-0.089 (0.152)
Δ Cocoa $_{(t-3)}$	0.333** (0.318)	0.344** (0.145)
Constant	0.2471 (0.067)	0.047 (0.038)
Diagnostic		
F-bound test	9.210	6.199

Superscripts ***, **, *denote statistical significance at the 1 and 5% and 10% levels, respectively. Parentheses values show standard error.

To examine the further robustness of long-term cointegration we applied Gregory-Hansen Cointegration technique introduced and developed by Gregory and Hansen, (1996). The Gregory-Hansen cointegration can estimate the cointegration relationship of variables in the presence of structural breaks (such as; shift, shift with trend or regime). The null hypothesis of Gregory-Hansen Cointegration states that no cointegration exists among variables. While, in order to reject the null hypothesis, the ADF and Z_t statistics should be significant at intercept, intercept with shift and at regime (both levels). Concerning the empirical outcome, the study notes a significant response of ADF and Z_t in both empirical models used. Generally speaking, as per empirical estimations, we strongly reject the null hypothesis of no cointegration and support the argument of long-term relationship among cocoa to coffee (Arabic and robusta) prices. Furthermore, the empirical results also certify the main findings of the paper and it direct us to draw innovative conclusions regarding the prices of cocoa and coffee commodities.

Table 5 Gregory-Hansen Cointegration empirics

	Cocoa to Arabica			Cocoa to Robusta		
Gregory-Hansen Models	ADF Statistic	Z_t Statistic	Z_a Statistic	ADF Statistic	Z_t Statistic	Z_a Statistic
Intercept shift	-4.65** (1977)	-5.14** (1977)	-35.78 (1977)	-6.80*** (1998)	-5.02** (1998)	-34.86 (1998)
Intercept shift with trend	-5.31** (1997)	-5.68** (1999)	-41.34 (1999)	-6.75*** (1998)	-5.06** (1998)	-35.23 (1998)

Intercept shift with slope	-4.75* (1973)	-5.24** (2000)	-36.40 (2000)	-6.87*** (1999)	-5.20** (2000)	-36.66 (2000)

Note: ***,**,* represents the significance at 1%, 5% and 10% respectively. Parenthesis shows the structural break point year.

Conclusion

This study examines the relationship between Cocoa, Arabica and Robusta coffee beverage commodities. For econometric estimations, time series data of studied variables were collected throughout 1960-2018. We use non-linear ARDL, rolling window-based technique, and Granger causality test to examine the cointegration and relationship of cocoa and coffee commodities. At the same time, the ARDL bound test and Gregory-Hansen cointegration are utilized as robustness checks to analyze the causal relationship between the prices of cocoa, Arabica, and Robusta coffee. The main contribution of the current study is to investigate whether the change in cocoa price has a symmetric or asymmetric relationship with various coffee prices. Previously, the literature has focused on the symmetric relationship between two types of coffee (Cocoa and Arabica). In addition, the rolling window method is also an essential academic contribution to the present study, as this technique has recently been developed and has several advantages over previous causality methods. This study extended the previous work in two dimensions: (i) we have used three beverage commodities: Cocoa, Arabica coffee and Robusta coffee; (ii) the study examines the presence of an asymmetric relationship between cocoa and coffee prices, whereas previous studies focus previous studies focus on symmetric analysis (Traoré & Badolo, 2016).

The results of asymmetric cointegration have confirmed the cointegration between Cocoa-Arabica and Cocoa-Robusta coffee. In the case of cocoa and Arabica, the price of Arabica coffee is affected by the positive shocks in the price of cocoa, for the short run and long run. Similarly, a positive change in cocoa price directly relates to the price of Robusta coffee. In the short and long-run estimations, the adverse shocks in Robusta price have a significant relationship with cocoa. However, the magnitude of shocks is higher for long-run estimations than short-run estimations. The findings indicate that the shocks of cocoa have a higher effect in the long run.

However, based on empirical results, the price of Arabica and Robusta coffee can be predicted by examining the price shocks in cocoa. However, this discrepancy needs to be clarified for the trade balance of importing and exporting countries for given commodities.

Policy Measures

Given the above concerns, specific policy implications are needed to avoid disturbing the trade balance. Firstly, policymakers should introduce more transparency in physical markets to attain accurate and timely information regarding cocoa and coffee price changes. By using this accurate and timely information, governments can take precautionary measures, such as going for future contracts, replacing the imports of commodities with substitutes, etc. Secondly, the financial investors are attracted by the price change in commodities (e.g. cocoa and coffee); these investors are interested in capital gains instead of physical holding and trading of commodities, which resultantly boosts the prices. Such speculation in price can be adverse for cocoa and coffee trading countries. However, strict laws should prohibit financial investors from speculating on cocoa and coffee prices.

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