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Oil and Food Prices in Bangladesh: A Linear and Non-Linear ARDL Analysis

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Fluctuations in the oil price profoundly impact many other prices in the economy, as oil is used to produce numerous goods and services. While literature is ample regarding the linear relationship between crude oil prices and food prices, academic discussion on the presence of non-linear relationships is relatively evolving. This paper strives to explore the existence of both linear and non-linear relationships between crude oil price and food price in Bangladesh by employing the autoregressive distributed lag (ARDL) model and the non-linear autoregressive distributed lag (NARDL) model, respectively. The ARDL model indicates that the crude oil price has a linear and positive impact on food price inflation in Bangladesh. The NARDL model finds no asymmetric relationship between the two variables in the long run. As a result, in the long run, the response of food price inflation in Bangladesh is the same whether oil prices increase or decrease. However, the NARDL model reveals that the change in oil prices asymmetrically impacts food price inflation only in the short run. These findings are essential for further study, and the results can be used for policymaking to ensure food security in Bangladesh.

Keywords: Food, Price Inflation, Crude Oil Price, ARDL, Asymmetric ARDL

JEL Classification: C22, E31

I. INTRODUCTION

The general international consensus regarding shocks in oil prices is that it has an inflationary and recessionary impact on overall macroeconomic aggregates

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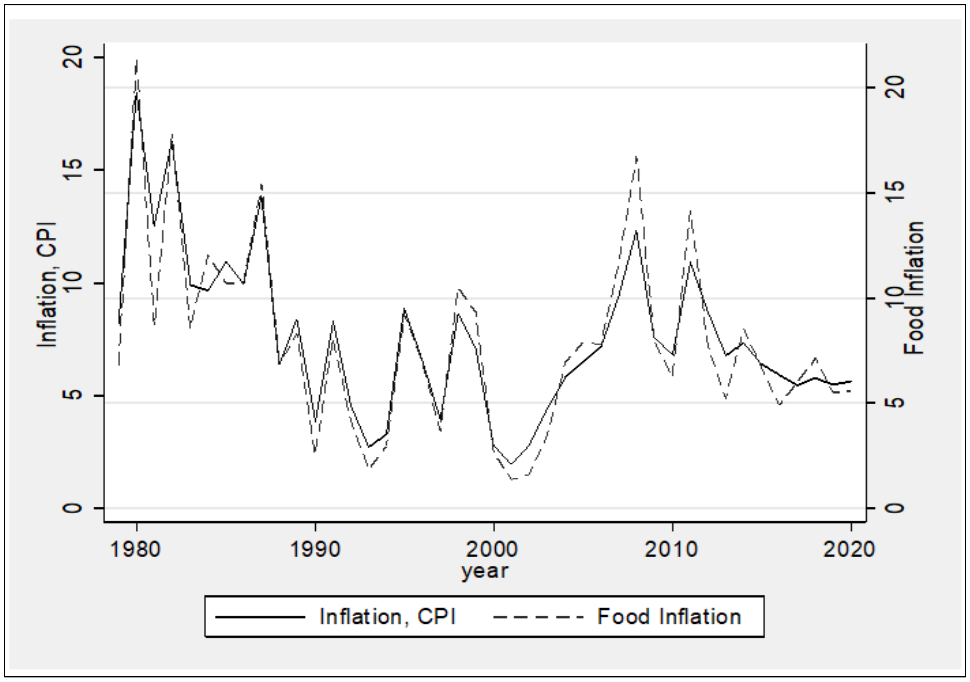
(Darby, 1982). The oil price escalation in 1973 spurred interest among researchers in studying the causal relationship between oil prices and macroeconomic variables (Gokmenoglu, Azin, & Taspinar, 2015). Theoretically, shocks in oil prices led to a substantial increase in wages and prices and a decrease in real output (Bruno, 1982; Bruno & Sachs, 1982). But, empirical studies reveal that the effect of oil price shock is not uniform and identical in every aspect. The level and magnitude of the impact of oil price movements varied from country to country (developing or developed and oil-exporting to oil-importing). Oil price shocks could be transmitted to the economy in different ways (Kilian, 2014), including symmetrically (linear) and asymmetrically (non-linear). In most cases, oil price is a potential factor for the economic recession in developed and developing countries (Sill, 2007). Therefore, policymakers should always be aware of different channels by which the impact of oil shocks is transmitted to the economy.

Bangladesh Petroleum Corporation (BPC), a state-owned enterprise, imports oil and oil products in Bangladesh. BPC imports crude oil mainly from Saudi Arabia and the United Arab Emirates (UAE) and refined oil from Kuwait, Malaysia, UAE, China, Indonesia, Thailand, and India. It then sells those products to public and private agencies. The government of Bangladesh monopolistically fixes energy prices, which are fixed and set by an executive order from the government. However, prices of fuel oil are adjusted less frequently in Bangladesh. For example, according to the Energy and Mineral Resources Division, the Government of Bangladesh adjusted oil prices 17 times in the last 20 years (Azad, 2021). Therefore, changes in global oil prices must directly impact Bangladesh's economy on the one hand. When no direct impact is seemingly observed (because the government of Bangladesh administered a fixed price method of fuel) on food price inflation in Bangladesh, there might be some indirect impact on the other hand. It is because Bangladesh relies heavily on foreign nations to import several food products, so the pass-through effect of oil price increases eventually reaches Bangladesh's economy. Many countries that trade with Bangladesh frequently adjust oil prices consistent with the changes in oil prices in the international market. Therefore, fluctuations in oil prices in the domestic market of trading partners in response to shocks in oil prices in the international market might increase the production costs in these countries, which later can be transmitted to Bangladesh's economy. As global prices rise, the import cost of Bangladesh also increases. So, an increase in crude oil prices may indirectly affect Bangladesh's food price inflation scenario. The connection between the rise in import costs and food price inflation is evident in Majumder's study (2006), where he finds that the import price index is significantly associated with food inflation in both rural and urban areas.

Oil price fluctuations have varied impacts on output and other macroeconomic indicators. However, the asymmetric effect of oil price shocks on the real output has not been much explored (Sill, 2007). Due to the interaction of market mechanisms (supply and demand) and the reallocation effects, the relationship can be asymmetric. In other words, asymmetric price transmission results from market power and economic structure (McCorriston, Morgan, & Rayner, 2001). Moreover, magnitude, speed, nature, and direction are the elements that make the transmission of price in the market asymmetric (Vavra & Goodwin, 2005). While the international oil market structure is oligopolistic, Bangladesh's domestic market structure is monopolistic. It is because OPEC member countries control the supply of oil in the international market, and in Bangladesh, BPC maintains supply in the domestic market. Also, the government of Bangladesh (GoB) subsidises fuel prices. Such a non-competitive market structure may thus lead to a dissimilar adjustment in food price inflation in response to an increase or decrease in the oil price (Meyer & von Cramon-Taubadel, 2004). In this context, it would be interesting to explore the existence of asymmetric adjustment in food prices due to changes in oil prices in Bangladesh.

Oil prices can immensely impact production and distribution costs in an economy. Hence, the oil price is regarded as an essential source of price stability. Price level stability is reflected in the movement of inflation. The most conventional way of measuring the intensity of inflation in an economy is the consumer price index (CPI). It typically measures the cost incurred for a basket of food and non-food commodities, which a country determines according to its local consumption pattern. Since CPI aggregates both food and non-food stuff, a separate index that reflects only food prices might be more apprehensive to know the fluctuation in food price inflation. To this end, we use the food price index to monitor changes in food price movement. Although many factors affect food prices, oil prices significantly influence food inflation. This is because oil is used as a primary input in agricultural production. Also, transportation and preservation of agricultural commodities require fuel oil. Hence, it is reasonable to think that oil and food prices move together.

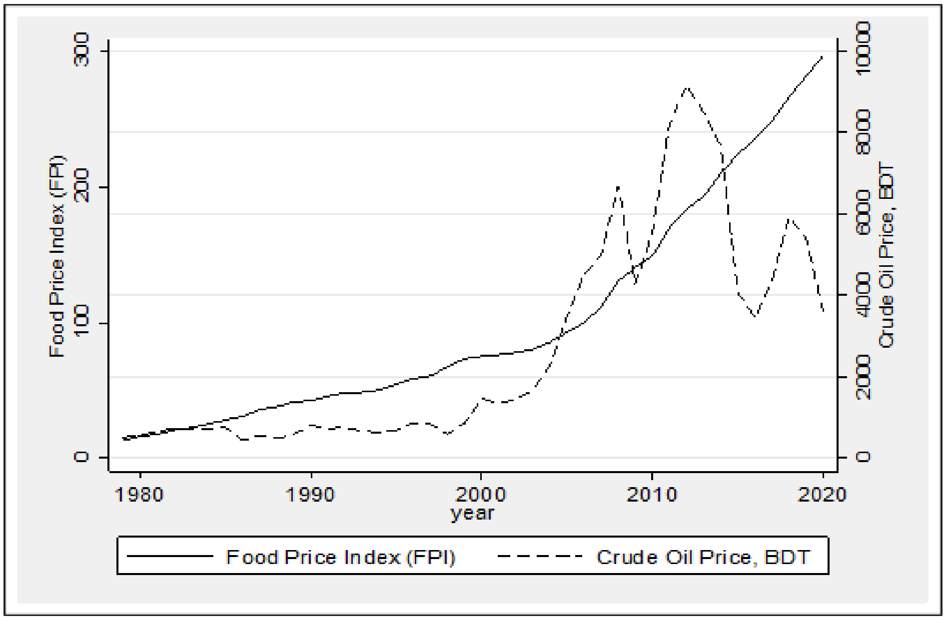
FIGURE 1: Inflation and Food inflation in Bangladesh (1979-2020)



Source: Bangladesh Bureau of Statistics (BBS).

Bangladesh has experienced inflationary pressure in the last four decades. Figure 1 shows the nexus between the consumer price index (CPI) and food inflation (FI) of Bangladesh. As can be seen from Figure 1, the CPI and FI have exhibited the same movement pattern, but FI has more intense movement than the CPI. In many cases, the food inflation movement surpasses the movement in the consumer price index. Except for 1981-82, 1989-1990, 1993-1995, and 2001-2004, when the fluctuations in CPI are much more pronounced than the FI, movement in FI generally exceeds movement in CPI for the rest of the period considered in this analysis. Between 1979 and 2020, the CPI peaked at 18.5 per cent; the maximum FI reached 21.4 per cent in 1980. In that particular time frame, the average value of FI is 7.9 per cent, which is greater than the CPI; the average value of CPI accounts for 7.6 per cent. In Bangladesh, the crude oil price is one of the influential factors responsible for price level stability. Several other elements, such as input price, transportation cost, and crop tax, also influence food price inflation. Figure 2 depicts the inflationary trend in the Food Price Index (FPI) and the crude oil price.

FIGURE 2: Trend of Crude Oil Price and Food Price Index of Bangladesh (1979-2020)



Source: FPI-BBS; Crude Oil Price-*Commodity Markets Outlook*, World Bank.

From Figure 2, we get some economically exciting findings. As can be seen, the link between the FPI and the price of crude oil is not synchronous throughout time. The price fluctuation of oil and FPI follows a linear trend only from 1979 to 1984, and the relationship is non-linear beyond 1989. However, the average value of crude oil price is 43.12 US dollars per barrel, whereas the average FPI is 101.71 points. The maximum amount of crude oil price is 111.97 US dollars per barrel; for the food price index, it is 296.96 points. The non-linear relationship between oil price and food price inflation, as evident in Figure 2, beyond 1984, has an intensive appeal for academic discussion and policymaking. When the association between FPI and oil price is asymmetric, the effect of a rise in oil price on FPI is not similar to the effect of a decrease in oil price. This asymmetric impact has significant implications for policymaking. The policy implication will be different if there is an asymmetric relation among the variables compared to the situation where variables are linearly related.

Using both the linear autoregressive distributed lag (ARDL) model and the non-linear autoregressive distributed lag (NARDL) model, this paper attempts to reveal the symmetric and asymmetric impact of crude oil prices on food price inflation in Bangladesh, respectively. Using the bounds testing approach, we try to determine the symmetric impact of oil price shocks on Bangladesh's food price inflation. The NARDL model uses the partial sum of the decomposition of the regressors to detect the short-run and long-run non-linearity (Shin, Yu, & Greenwood-Nimmo, 2014). This paper is structured as follows: Section II provides an in-depth and brief literature review. Section III describes the methodology, and section IV explains the description of the data and its sources. Section V analyses the findings. Finally, section VI concludes the paper with policy recommendations.

II. LITERATURE REVIEW

It is observed that oil price shocks induced several economic effects (Du, Yanan, & Wei, 2010) in the whole world. For example, oil price volatility negatively affects the macroeconomic aggregates in OECD member countries (Katircioglu, Sertoglu, Candemir, & Mercan, 2015), retards economic performance, and reduces the values of real variables by escalating inflationary pressure in G-7 countries (Cologni & Manera, 2008). Like other effects, inflationary pressure on food or commodity prices is not rare. Previous studies overwhelmingly confirm the inflationary effects of oil prices on food prices either in the short or long run or in both time periods.

Prices of primary commodities, particularly agricultural commodities, are more sensitive to oil price changes. For the period 1960 to 2005, prices of 35 international tradeable primary commodities responded positively to crude oil prices; if the crude oil price remains high for some periods, the current commodity price hikes are likely to last more than the previous price hikes (Baffes, 2007). Crude oil price shocks from 2005 to 2008 positively changed the prices of grains during that period (Chen, Kuo, & Chen, 2010). Oil prices significantly influence the prices of agricultural commodities in the short run and long run (Baffes & Dennis, 2013). Nwoko, Aye, & Asogwa (2016) reported a significant positive effect of oil prices on the food price changes of selected agricultural commodities in the short run.

As developing countries heavily depend on agricultural production, food price volatility is more awkward in these countries (Gilbert & Morgan, 2010). Besides shocks in agricultural production, the increased demand for grains (biofuel feedstock), with the increased oil price, leads to increased food prices. Cunado and De Gracia (2005) reported an asymmetric impact of crude oil prices on the inflation level (CPI) and other macroeconomic variables in six Asian countries.

For some Asia and Pacific countries, Alom, Ward, & Hu (2011) estimated that oil prices positively influence food prices only in the short run. They found that a 1 per cent increase in shocks oil prices leads to a rise in food price volatility of 0.396 per cent in Taiwan, 0.283 per cent in Australia, 0.269 per cent in Korea, 0.114 per cent in New Zealand, 0.126 per cent in Thailand, 0.084 per cent in Singapore, 0.11 per cent in Hong Kong and 0.0520 per cent in India. Comparatively, a lower impact is observed in India.

Using data for the period 2000 to 2014 for 31 oil-exporting developing countries, the majority of which are net food-importing countries such as Indonesia, Malaysia, and Thailand, Meyer, Sanusi, and Hassan (2018) found that although an increase in food prices is associated with an increase in oil price, the opposite is not true- an asymmetric relationship holds only in the long run. The study also used CPI and trade openness as control variables and found that trade openness reduces food prices in the long run, but inflation (CPI) increases food prices both in the short run and long run. Conducting a panel study with a Panel-VAR model for eight Asian economies, including Bangladesh, Taghizadeh-Hesary, Rasoulinezhad, and Yoshino (2019) found that oil price significantly impacts food prices, and food price volatility rises over time if there are fluctuations in oil price.

Besides reviewing studies dealing with a group of countries, crucial findings could be observed from some country-level analyses. In Thailand, oil prices are found to significantly influence the aggregate consumer price index (CPI) in the long run by Ibrahim and Chancharoenchai (2014). At the disaggregate level, they find a long-run relationship between oil price and non-food and beverage price index, housing and furnishing price index, energy price index, non-raw food and energy price index, and transportation and communication price index. But, no cointegrating relationship is found between the food and beverage price index and the raw food price index. Real GDP and exchange rate are used as control variables.

For Malaysia, a net food importing country, Ibrahim and Said (2012) confirmed the inflationary effects of oil prices in the long run. Later, applying the non-linear ARDL method, Ibrahim (2015) found an asymmetric effect of oil prices on the food price index in the short run and long run. The increases in oil prices are associated with increases in food prices both in the short-run and long-run, but decreases in oil prices are not related to food prices. It is found that a 10 per cent increase in oil price leads to 0.6 per cent to 0.8 per cent increases in food price, on average, holding other things constant in the long run, showing an incomplete pass-through effect like other studies as explained by Jongwanich and Park (2011). Regarding the effects of real income, the study found that around 0.50 per cent inflation in food prices occurred due to a 1 per cent increase in oil prices.

Like Malaysia, evidence of a strong positive association between crude oil price increases and food prices in domestic currency has also been found in Indonesia in the short run and long run (Abdlaziz, Rahim, & Adamu, 2016). Using the non-linear autoregressive distributed lag (NARDL) method, they found that in Indonesia, more than a 3.6 per cent increase in food prices is due to a 10 per cent increase in crude oil prices. It is much larger than the estimated effects of crude oil prices on food prices in Malaysia by Ibrahim (2015) and other studies. Indonesia's local commodity prices are found to be affected by global crude oil prices and global commodity prices, while the global crude oil price effect occurs due to the existence of the high shipping cost of importing (Ayu, 2020).

Increases in oil prices lead to an increase in inflation in South Asian countries, but oil price reductions cannot influence inflation in South Asian countries (Zakaria, Khiam, & Mahmood, 2021). By applying the SVAR approach, Khan and Ahmed (2011) identified the inflationary effects of oil price shocks in Pakistan, confirmed by Ansar and Asghar (2013). Sarwar, Hussain, and Maqbool (2020) used a non-linear ARDL model for a quarterly dataset spanning from 1990 to 2019 and found that crude oil prices asymmetrically affected both food and non-food CPI in Pakistan. They asserted that the presence of market power in Pakistan led prices to adjust in response to an increase in crude oil prices. However, an adjustment in price does not occur when there is a decrease in the oil price. The Reserve Bank of India (2011) estimated that, in India, every 10 per cent increase in global crude oil price directly increases the Wholesale Price Index (WPI) by one percentage point, and the total impact could be about two percentage points if transmission of input cost across sectors is taken into consideration. These findings are in the same line with the Bhattacharya and Bhattacharyya (2001), and Bhattacharya and Batra (2009), while the magnitude of impacts varies slightly.

Being a prime oil importer country, the economy of Bangladesh is also affected by oil price volatility. In Bangladesh, increases in oil prices persistently increase the interest rate and inflation and depreciate local currency by increasing production costs and inflation (Das & Dutta, 2020). Also, Oil price shocks negatively affect growth and food security simultaneously (Saha, Sayem, Al-Amin, & Majumder, 2018). Moreover, the inflation rate in Bangladesh's food sector is currently higher than in the non-food sector (Abdullah, Shamsher, & Chowdhury, 2012). Although some studies have been conducted to identify the effects of crude oil prices on the country's overall inflation level, identifying the effects of crude oil prices on food prices is yet to be examined.

III. METHODOLOGY

This study first looks at the linear relationship between food price inflation and crude oil prices in Bangladesh using the autoregressive distributed lag (ARDL) model developed by Pesaran, Shin, and Smith (2001). For three reasons, the ARDL method of examining cointegration outperforms other traditional time series cointegration techniques (Adeleye, Osabuohien, Bowale, Matthew, & Oduntan, 2017). To begin with, ARDL provides flexibility in the order in which the underlying variables are integrated up to I (1). As a result, rather than requiring all variables to be integrated in the same order, the ARDL model allows variables to be integrated into either order zero and one or a composite of zero and one. Second, the ARDL method is more powerful and effective for data with small and finite sample sizes. Finally, the ARDL model offers unbiased long-run model estimates (Harris & Sollis, 2003; Kripfganz & Schneider, 2016).

In accordance with Zmami & Ben-Salha (2019), the functional structure of the ARDL (n, m) can be rendered as:

$$\Delta y_t = \alpha + \delta y_{t-1} + \theta x_{t-1} + \sum_{i=1}^{n-1} \varphi_i \, \Delta y_{t-i} + \sum_{i=0}^{m-1} \rho_i \Delta x_{t-i} + \varepsilon_t \qquad (1)$$

where Δ is the first difference operator. On the other hand, the parameters of the estimated model are represented by $\alpha, \delta, \theta, \varphi_i, \ \rho_i$. Also, we denote the optimal lag length of the variables by n, m. The ARDL cointegration method compares the null hypothesis of no cointegration $(\delta = \theta = 0)$ to the alternative hypothesis of cointegration $(\delta \neq \theta \neq 0)$. Pesaran et al. (2001) have a set of lower bound critical values assuming all variables are *I (0)* and a set of upper bound critical values assuming all variables *I (1)*. When the projected value of the test statistics (F_{PSS}) exceeds the critical value for the upper bound, rejection of the null hypothesis, which implies the existence of long-run cointegration, is confirmed.

However, ARDL modelling presumes a symmetric impact of *x* on *y*. In other words, it assumes a linear relationship among the underlying variables considered in the model as such: the impact on *y* will always be the same whether there is an increase or decrease in *x*. Empirically, this might not be the case. For example, food price inflation may not respond in the same way to an increase (positive change) in oil price as it does to a fall (negative change) in oil price in our situation.

Furthermore, the interplay of market power and government policies might lead to an adjustment in the food price inflation in a dissimilar fashion due to the rise or fall in the price of oil (Ibrahim, 2015). As a result, the linear ARDL model is insufficient to account for such an asymmetrical link between food price inflation and crude oil price.

In addition to using the linear ARDL model, we also use the non-linear ARDL approach in our analysis, as developed by Shin et al. (2014), to capture potential asymmetric effects among the variables. The explanatory variable x_t, as suggested by the authors, is decomposed as follows:

$$x_t = x_0 + x_t^+ + x_t^- \tag{2}$$

where x_t^+ and x_t^- are partial sums of positive and negative changes in x_t, respectively, as calculated:

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j, 0) \tag{3}$$

$$x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \min(\Delta x_j, 0) \tag{4}$$

Then we specify the asymmetric long-run equation as follows:

$$y_t = \beta^+ x_t^+ + \beta^- x_t^- + u_t \tag{5}$$

where $\beta^+ \, and \, \beta^-$ are the asymmetric long-run parameters for positive and negative changes in the independent variable x_t, respectively. Following Shin et al. (2014), in an ARDL scenario, we can evaluate equation (5) and present the non-linear ARDL (n, m) model as follows:

$$\Delta y_t = \alpha + \delta y_{t-1} + \theta^+ x_{t-1}^+ + \theta^- x_{t-1}^- + \sum_{i=1}^{n-1} \varphi_i \Delta y_{t-i} + \sum_{i=0}^{m-1} (\rho_i^+ \Delta x_{t-i}^+ + \rho_i^- \Delta x_{t-i}^-) + \varepsilon_t \tag{6}$$

where $\theta^+ \, and \, \theta^-$ denote the asymmetric distributed-lag parameters. On the other hand, $\beta^+ = -\frac{\theta^+}{\delta}$ and $\beta^- = -\frac{\theta^-}{\delta}$ represent long-run impacts of an increase in oil prices and a decrease in oil prices on food price inflation, respectively. Also, $\sum_{i=0}^{m-1} \rho_i^+$ measures the influence of the rise in oil price on food price inflation in the short-run and $\sum_{i=0}^{m-1} \rho_i^-$ measures the influence of the fall in oil price on food price inflation in the short run.

The estimation of non-linear ARDL is performed in five steps. To begin, we check for stationarity to guarantee that no variable is *I (2)*. This is because the presence of an *I (2)* variable may provide invalid computed F-statistics while testing for cointegration. Second, using the linear ARDL model, as given in equation (1), the long-run relationship between the underlying variables is investigated. Short-run and long-run coefficients are estimated if such a link is discovered. Third, we apply the non-linear ARDL model to the equation to see if there is an asymmetric cointegrating relationship among the underlying variables in the model (6). If we uncover any cointegrating link between the two variables after step three, we can estimate the asymmetric responsiveness of food price inflation to crude oil price variations in step four. Following Katrakilidis & Trachanas (2012), the final specification of the NARDL is determined by trimming the insignificant lags. Finally, we use the Wald test to see if there are any short-run and long-run asymmetries.

IV. DATA AND SOURCES

The data used in this study is annual, with a sample period spanning 1979 to 2020. We collect data on the food price index (FPI) from the Bangladesh Bureau of Statistics (BBS), which has been converted to a uniform base year (2005-06) using the data splicing technique. On the other hand, Brent crude oil price (COP) data have been collected from the Commodity Markets Outlook report published by the World Bank. Brent is one of the most important global oil price benchmarks. Since Bangladesh imports crude oil mainly from members of the Organization of the Petroleum Exporting Countries (OPEC), and OPEC uses Brent as their pricing benchmark, we choose to use Brent crude oil price for our analysis. Brent oil prices are then multiplied by the exchange rate to convert into Bangladeshi Taka (BDT). We choose to use gross domestic product (GDP) data series to capture aggregate demand or business cycle effect. In addition, we incorporate broad money supply (BM) to assess the impact of money supply on the food prices inflation scenario; precipitation (PR) in a country is considered essential for agricultural production. Hence, the changes in precipitation rate might indirectly impact food prices by causing variations in the production level. Data series on the exchange rate, GDP, and broad money (BM) as a percentage of GDP are collected from *World Development Indicators*, and the precipitation rate (PR) series is from the Climate Change Knowledge Portal of the World Bank. However, all variables in the study are transformed using the log transformation.

Table I provides the descriptive statistics of the variables used in our analysis before the log transformation. Over the 42 years, the minimum FPI was 13.404 points, while the maximum FPI was 296.960, with an average of 101.710 per cent. Crude oil prices, on the other hand, range from 449.135 BDT to 9165.798 BDT for the same period, with a mean of 2677.565 BDT. The standard deviation for FPI is 82.137, whereas the standard deviation for COP is 2625.315.

TABLE I

DESCRIPTIVE STATISTICS

	FPI	COP	GDP	BM	PR
Mean	101.710	2677.565	5.87×10^{12}	38.409	2282.917
Maximum	296.960	9165.798	2.74×10^{13}	66.854	2923.74
Minimum	13.404	449.1353	2.37×10^{11}	13.906	1740.18
Std. Dev.	82.137	2625.315	7.33×10^{12}	18.460	298.729
Observations	42	42	42	42	42

Source: Authors' computations.

To recognise the existence of a contemporaneous correlation between crude oil price (COP) and the food price index (FPI), we employ the Pearson correlation coefficient. From Table II, we see a significant positive contemporaneous correlation between COP and FPI; the mean of the Pearson correlation is 0.873 in Bangladesh. This result corroborates theoretical findings that an increase in crude oil prices may contribute to the increase in food price inflation in a country. It is, however, purely a correlation analysis and does not establish a causative relationship. Moreover, since a simple correlation analysis only explores the correlation between two variables, it potentially disregards the influence of other important variables in the analysis. In this context, we need to consider regression analysis to verify the existence of the relationship between crude oil prices and food price inflation in Bangladesh.

TABLE II

PEARSON CORRELATION RESULTS

	*ln*FPI	*ln*COP	*ln*GDPPC	*ln*BM	*ln*PR
*ln*FPI	1.000				
*ln*COP	0.873**	1.000			
*ln*GDP	0.846**	0.730**	1.000		
*ln*BM	0.963**	0.938**	0.850**	1.000	
*ln*PR	-0.332**	-0.416**	-0.224	-0.356**	1.000

Notes: N=42. ** corresponds to a 5% significance level.

V. RESULTS AND DISCUSSION/ EMPIRICAL RESULTS

5.1 Unit Root Tests

ARDL bounds testing procedure requires that no variable is integrated at the second or higher order. This is because the appearance of a variable (s) with an integrated order greater than one invalidates the computed F-statistics. We subject each time series to Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests to confirm that no variable in our study is I (2). Table III summarises the findings. The level and differenced series in our unit root tests include both constant and trend terms. The Schwarz Information Criterion (SIC) is used to determine the best lag order for the ADF test. On the other hand, the PP test uses the number of Newey-West lags to account for serial correlation.

TABLE III

ADF AND PP UNIT ROOT TESTS

	ADF		PP	
Variable	Level	First Difference	Level	First Difference
lnFPI	-2.151	-5.079***	-3.137	-5.113***
lnCOP	-1.567	-4.592***	-1.675	-5.240***
$lnGDP$	-1.849	-4.428***	-2.152	-4.388***
$lnBM$	-2.701	-5.031***	-2.102	-4.949***
$lnPR$	-8.203***	-	-8.210***	-

Note: ***denotes significance at 1% level.

For the food price index (FPI), both the ADF test and PP tests suggest that the series is non-stationary at level but stationary after first differencing. Both tests also indicate that crude oil price is non-stationary at levels but stationary in first differences. All other variables except precipitation rate are found stationary in first-difference. The precipitation rate is stationary at level. As none of the variables is integrated of order two or above (Table III), we can proceed to the ARDL bound testing approach to determine cointegration.

5.2 ARDL Results: Linear Model

Since we have variables integrated of order one or zero, we can use the ARDL bounds test procedure (Pesaran et al., 2001) for our analysis. To determine whether the variables are cointegrated, we specify the linear ARDL model as follows:

$$\Delta lnFPI_t = \alpha + \delta_1 lnFPI_{t-1} + \delta_2 lnCOP_{t-1} + \delta_3 lnGDP_{t-1} + \delta_4 lnBM_{t-1} + \delta_5 lnPR_{t-1} + \sum_{i=1}^{n-1} \varphi_i \, \Delta lnFPI_{t-i} + \sum_{i=0}^{m-1} \rho_i \, \Delta lnCOP_{t-i} + \sum_{i=0}^{p-1} \theta_i \Delta lnGDP_{t-i} + \sum_{i=0}^{q-1} \gamma_i \Delta lnBM_{t-i} + \sum_{i=0}^{r-1} \phi_i \Delta PR_{t-i} + \varepsilon_t \quad (7)$$

where *FPI, COP, GDP, BM, and PR* represent the food price index and crude oil price, gross domestic product, broad money supply as a percentage of GDP, and precipitation rate, respectively.

Our investigation for cointegration starts with bounds testing for the joint F-statistics under the null hypothesis: there is no cointegration. The alternative hypothesis, on the other hand, states that there is cointegration. The bounds test considers the model with both I (0) and I (1) variables and corresponding critical values are thus calculated accordingly. In this process, the first critical values are calculated, assuming that all the variables the ARDL model includes are *I (0)*. On the other hand, second critical values are calculated based on the assumption that all the variables are *I (1)*. Bound test rejects the null hypothesis that there is a non-existence of the cointegrating relationship if the value of F-statistics exceeds the critical value at I (1); it fails to reject the null if the value of the F-statistics is less than the critical value at I (0). The result is inconclusive if the value of the F-statistics falls between the two critical values. In our analysis, we have used the critical values provided by Pesaran et al. (2001).

TABLE IV

BOUNDS TEST FOR LINEAR COINTEGRATION

	F-Statistics	95% lower bound	95% upper bound	Decision
Cointegration Test	11.472	3.202	4.544	Cointegrated

Notes: The critical values for the F-statistics are from Pesaran et al. (2001). EViews was used to generate the results.

Table IV shows the Bounds test's result. As the F-statistics (11.472) is greater than the upper bound critical value at the 5% significance level, we can reject the null hypothesis of no cointegration among the variables in the model. It, therefore, implies the presence of a cointegrating relationship among the variables in the model. In other words, the bounds test result indicates that the variables, including crude oil price and food price index, move together in the long run. Since cointegration among variables in our model is obtained, we can now explore the short-run and long-run dynamics of the relationship. Based on our specification of the model in equation (7), error correction results are presented in Table V.

TABLE V

THE LINEAR AUTOREGRESSIVE DISTRIBUTED LAG (ARDL) ESTIMATION RESULTS

Variable	Coefficient
Dependent variable: ΔlnFPI	
Constant	-3.330 (0.000)
Long-run estimates	
lnCOP	0.199** (0.045)
$lnGDP$	0.424*** (0.000)
$lnBM$	0.095 (0.715)
$lnPR$	0.603 (0.105)
Adjustment	
ECT_{t-1}	-0.239***(0.000)
Short-run estimates	
ΔlnCOP	0.023 (0.119)
$\Delta lnCOP_{t-1}$	-0.030* (0.054)
$\Delta lnBM$	-0.157** (0.011)
$\Delta lnBM_{t-1}$	-0.111* (0.069)
$\Delta lnBM_{t-2}$	-0.152**(0.015)
$\Delta lnPR$	0.060*** (0.007)
Adj. R^2	0.638

Notes: Numbers in parentheses are p-values. The symbols ***, **, and * denote a significance level of 1%, 5%, and 10%, respectively. EViews selects the optimal lag length for the variables in the ARDL model (1 2 0 3 1). Δ represents the difference operator.

As the estimation result suggests, there is a positive and highly significant connection between crude oil prices and food price inflation in Bangladesh. In the long run, a 1 per cent increase in crude oil price results in a 0.199 per cent increase in food price inflation and vice-versa. This finding corroborates the estimate for the oil price pass-through to the global food price, which is 0.18, as noted by Baffes (2007) and 0.25 by Gilbert (1989). Moreover, the finding that a higher crude oil price increases food price (and vice versa) is in line with the findings of Chen et al. (2010), Baffes & Dennis (2013), Saha et al. (2018), and Taghizadeh-Hesary et al. (2019). On the other hand, short-run estimates also indicate a positive association between crude oil price and food price inflation, although statistically insignificant. In summary, the linear ARDL bounds testing approach demonstrates that an increase (decrease) in oil prices results in an increase (decrease) in food price inflation in Bangladesh's domestic economy.

Looking at other variables in our analysis, we find that the coefficient of *GDP* is 0.424, which is significant at 1 per cent level. A higher income level increases the demand for all consumer products, including foods. Hence, food prices shift upward if there is an increase in *GDP*. Other variables- broad money (BM) and precipitation rate (PR)- are found to influence the food price index positively, but they are statistically insignificant.

We find the adjustment coefficient is negative and statistically significant (-0.239). If there is a shock in the long-term equilibrium relationship, the adjustment coefficient explains how fast the equilibrium is restored following that shock. The adjustment coefficient implies that, in the current year, 23.9 per cent of the disequilibrium caused by the previous year's shocks is corrected back to long-run equilibrium. The speed of adjustment is most often measured by the half-life, that is, the time (here years) needed for half of the shocks to dissipate. This is calculated as follows $HL = \frac{\ln(0.5)}{\tau} \approx \frac{-0.69}{\tau}$; where τ is the error correction coefficient. The half-life for our case is 2.9 years.

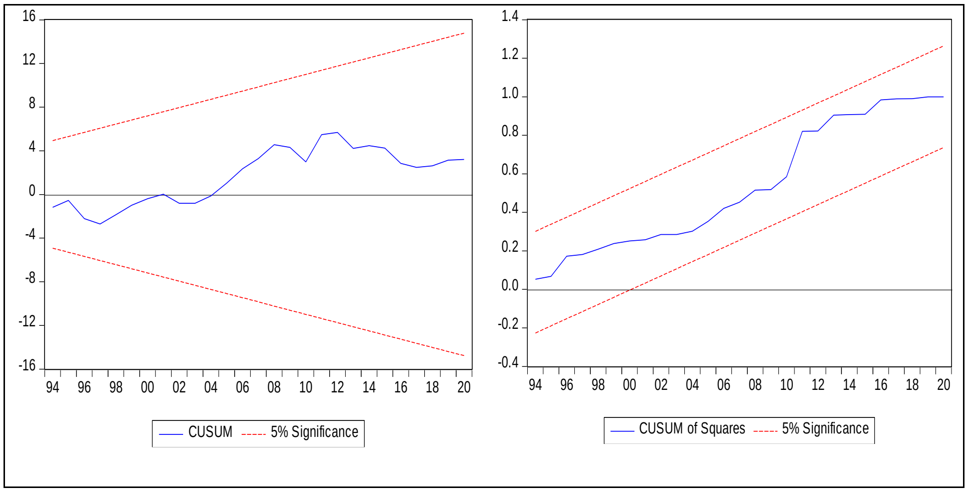
TABLE VI

RESULTS OF DIAGNOSTIC TESTS

Tests	Statistics/P-values	Decision
Ramsey RESET test	0.332 (0.743)	No omitted variables
Breusch-Godfrey test	2.278 (0.123)	No higher-order autocorrelation
ARCH LM test	0.950 (0.336)	No conditional heteroscedasticity
Breusch-Pagan-Godfrey test	0.519 (0.873)	No heteroscedasticity
Jerque-Bera test	5.799 (0.055)	Evidence of normality

Diagnostic test findings are also analysed. The adjusted R^2 value is a measure of the goodness of fit of the model, and it indicates that the variation in crude oil price explains 63.8 per cent of the variations in food price inflation in Bangladesh. We perform several diagnostic tests such as serial correlation, heteroscedasticity, conditional heteroscedasticity, Ramsey's RESET test, and normality test to assess the adequacy of the dynamic specification of our model. Results of the tests are reported in Table VI, suggesting that our model passes all diagnostic tests. In addition, we employ CUSUM and CUSUM^2 to ascertain the stability of the short-run and long-run coefficient estimates. The plot of the CUSUM and CUSUM^2 (Figure 3) indicates that the model is stable within the 5% confidence band.

FIGURE 3: CUSUM and CUSUMQ for the Linear ARDL Model



Source: Authors' compilation from EViews 10.

5.3 ARDL Results: Non-linear Model

Since the ARDL model may incorrectly assume a symmetrical relationship among the variables considered in the model, we use the NARDL model to ascertain the presence of an asymmetrical relationship. To this end, oil price changes are split into two components: a partial sum of positive changes and a partial sum of negative changes. Consequently, while constructing the NARDL model, the variable COP will be replaced by COP^+ and COP^-. We can represent the non-linear ARDL model as follows:

$$\Delta lnFPI_t = \alpha + \delta_1 lnFPI_{t-1} + \delta_2^+ lnCOP_{t-1}^+ + \delta_3^- lnCOP_{t-1}^- + \delta_4 lnGDP_{t-1} + \delta_5 lnBM_{t-1} + \delta_6 lnPR_{t-1} + \sum_{i=1}^{n-1} \varphi_i \Delta lnFPI_{t-i} + \sum_{i=0}^{m-1}(\rho_i^+ \Delta lnCOP_{t-i}^+ + \rho_i^- \Delta lnCOP_{t-i}^-) + \sum_{i=0}^{p-1} \theta_i \Delta lnGDP_{t-i} + \sum_{i=0}^{q-1} \gamma_i \Delta lnBM_{t-i} + \sum_{i=0}^{r-1} \phi_i \Delta lnPR_{t-i} + \varepsilon_t \quad (8)$$

We determine optimal lag lengths for our non-linear model *(n, m, p, q, r)* based on the Akaike Information Criterion (AIC). The maximum lag order considered for both the dependent and independent variables is 4. Consequently, the number of optimal lags determined for *FPI*, *COP*$^+$, *COP*$^-$, *GDPPC*, *BM*, and *PR* are (1, 2, 4, 2, 0, 4), respectively. Table VII shows the results of the non-linear ARDL (NARDL) model.

TABLE VII

THE NON-LINEAR ARDL ESTIMATION RESULTS

Variable	Coefficient
$Constant$	-4.074** (0.019)
$lnFPI_{t-1}$	-0.255** (0.005)
$lnCOP^{+}_{t-1}$	0.049***(0.008)
$lnCOP^{-}_{t}$	0.091***(0.006)
$lnGDP_{t-1}$	0.188**(0.010)
$lnBM$	-0.120***(0.009)
$lnPR_{t-1}$	0.037(0.319)
$\Delta lnCOP^{+}$	0.074**(0.020)
$\Delta lnCOP^{-}_{t-1}$	-0.082**(0.013)
Cointegration test statistics	
F_{PSS}	6.366***
t_{BDM}	-4.531**
Long-run coefficients	
$lnLR^{+}_{COP}$	0.190* (0.069)
$lnLR^{-}_{COP}$	0.358** (0.036)
$lnGDP$	0.737*** (0.000)
$lnBM$	-0.471* (0.058)
$lnPR$	0.143 (0.351)
Long -run & Short-run asymmetry tests	
$W_{LR,lnCOP}$	1.100 (0.294)
$W_{SR,lnCOP}$	12.832*** (0.000)
$Adj. R^2$	0.508

Notes: F_{PSS} and t_{BDM} represent the F-statistic proposed by Pesaran et al. (2001) and the t-statistic proposed by Banerjee, Dolado & Mestre (1998), respectively. *,**, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Similar to the ARDL model, we first need to examine the cointegrating relationship among the variables. In our analysis, the F_{PSS} statistic is above the upper bound value given by Pesaran et al. (2001), suggesting an asymmetric long-run relationship between the crude oil price and the food price index. On the other hand, the t_{BDM} statistic also surpasses the upper bounds value. Based on our F_{PSS} statistic and t_{BDM} statistic result, we can assert that there is an asymmetric impact of crude oil price on food price inflation in the long run in Bangladesh. However, the long-run Wald test, conducted to capture the asymmetry of the impact of oil prices in the long run, is found insignificant. It, therefore, suggests that regardless of whether the price of crude oil increases or decreases, the food price index in Bangladesh responds symmetrically in the long run. In other words, the impact of oil price changes on food price inflation is symmetric in the long run.

Consequently, based on our findings of symmetrical relationships among the variables, it is evident that the ARDL model can alone explain the nature of the long-run relationship between crude oil price and food price inflation in Bangladesh.

On the other hand, the Wald test reveals the presence of short-run asymmetry in the impact of crude oil prices on food price inflation in Bangladesh. The estimated short-run results associated with a positive shock and negative shock on the crude oil prices are 0.074 and -0.082, respectively, and are statistically significant at the 5 per cent level. The estimation result suggests that positive crude oil price changes of 1 per cent increase food prices by 0.074 per cent immediately, while a decrease in the crude oil price of the same size decreases food prices by 0.082 per cent with a lag of one period. This finding is interesting as it indicates that food price inflation adjusts immediately in the short run in response to an increase in crude oil prices. In contrast, a downward adjustment of the food price index takes a long time if there is a decrease in crude oil prices. The short-run asymmetric response to food price inflation is in line with the works' of Sarwar et al. (2020) and Ibrahim (2015).

TABLE VIII

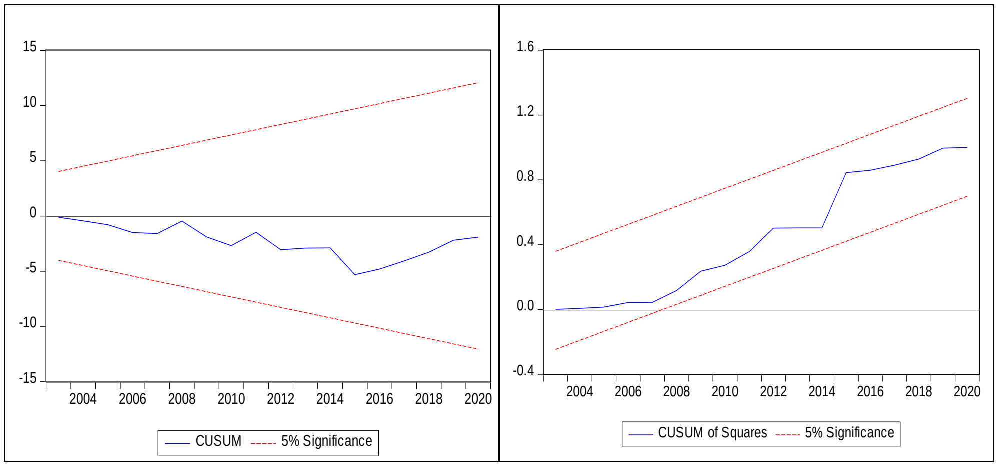
DIAGNOSTIC TEST RESULTS

Tests	Statistics/P-value	Decision
Ramsey RESET test	0.993 (0.327)	No omitted variable
Breusch-Godfrey test	1.349 (0.276)	No higher order autocorrelation
ARCH LM test	1.077 (0.306)	No conditional heteroscedasticity
Breusch-Pagan-Godfrey test	1.109 (0.385)	No heteroscedasticity
Jerque-Bera test	2.879 (0.237)	Evidence of normality

Source: Authors’ computations.

Finally, we subject our non-linear ARDL model to several diagnostic tests: the Ramsey RESET test for correct functional form, Breusch-Godfrey tests for autocorrelation, ARCH LM, Breuch-Pagan-Godfrey tests for heteroscedasticity, and Jerque-Bera tests for normality. The results presented in Table VIII confirm that our model passes all the tests. In addition, the CUSUM and CUSUM^2 tests indicate that our model is stable (Figure 4).

FIGURE 4: CUSUM and CUSUMQ for the Non-linear ARDL Model



Source: Authors' compilation from EViews 10.

VI. POLICY RECOMMENDATIONS AND CONCLUSION

This paper examines the symmetric and asymmetric impact of crude oil prices on Bangladesh's food price inflation. While the autoregressive distributed lag (ARDL) model is used to explore the symmetric relationship, the non-linear autoregressive distributed lag (NARDL) model examines the asymmetric relationship. Using the NARDL model, we find that the food price index is affected by positive and negative changes in crude oil prices in the short run, thereby substantiating the presence of an asymmetric short-run relationship between crude oil prices and food price inflation. However, the NARDL approach shows no significant asymmetric impact of oil prices on food price inflation in Bangladesh in the long run; instead, the relationship is symmetric. We find that the long-run positive shock of crude oil prices (LR^{+}_{COP}) on food inflation is 0.190 (significant at 10% significance level); the long-run negative impact (LR^{-}_{COP}) is 0.358 (significant at 5% significance level). But, the Wald test suggests that these two long-run asymmetric coefficient values are statistically insignificant. In other words, the Wald test does not provide any evidence of the existence of long-run asymmetry since it fails to reject the null hypothesis. Thus, we only observe a linear relationship between crude oil price and food price inflation in the long run in Bangladesh, which we model using the linear ARDL bounds test method. However, the long-run estimated equation of the ARDL approach is:

$$\widehat{lnFPI}_t = -3.330 + 0.199\ lnCOP_t + 0.424\ lnGDP_t + 0.095\ lnBM_t + 0.603\ lnPR_t$$

As we see, the impact of crude oil prices on the food price inflation in Bangladesh is linear and positive. Accordingly, in the long run, an increase in the price of crude oil will positively affect food inflation in Bangladesh and vice versa. Therefore, the relation between the crude oil price and food price inflation in Bangladesh is symmetric in the long run, i.e., whether the oil price increases or decreases, the magnitude of the impact will be the same.

In Bangladesh, a fixed pricing approach is used to adjust fuel oil prices in response to changes in crude oil prices in the international market. An upward adjustment in oil price is more frequent than a downward adjustment, although both are limited. An increase in oil prices passes through to inflation, raising the prices of food and non-food items in urban and rural areas (World Bank, 2006). Some measures such as increasing domestic supply, reducing wastage, lessening the influence of intermediaries in the distribution channel, and improving the food preservation facilities can be adopted primarily to deal with food price inflation in Bangladesh. Additionally, alternative approaches, such as prudent monetary policy and targeted subsidy programs for the poor, can be undertaken. Furthermore, the adoption of energy-efficient technology will help reduce production costs and control the inflationary pressure in the economy of Bangladesh.

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