Asymmetric Effects of Cereals Crops on Agricultural Economic Growth: A Case Study of India

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Abstract

The study explores the asymmetric effects of cereals crops, namely wheat, rice, and maize production on agricultural economic growth in India during 1960–2019. The asymmetric ARDL method is used in this study to analyze the asymmetric relationship between the independent and dependent variables. The findings reveal a link between cereal crop growth and agricultural economic growth. The NARDL findings indicate that positive maize and rice shocks have a considerable short- and long-term influence on agricultural economic growth. In contrast, the positive shock of wheat production is not significant. While the negative shocks of maize, rice and wheat production significantly impact agricultural economic growth. In a nutshell, the study reveals that agriculture growth has an asymmetric relationship with maize, wheat and rice production. The study's findings imply that policymakers should develop long- and short-term plans to boost agricultural growth and productivity in order to help farmers.

Keywords: India, NARDL, Rice, Maize, Wheat

1. Introduction

In the low and middle-income group of countries, agriculture is a source of livelihood as food and raw materials. It provides raw materials for industrial use for hastening up industrialization. Agriculture involves crops production, forestry, livestock husbandry, fishery, man's use and consumption, and processing and marketing of its products (Nesheim et al., 2015; Kanianska, 2016). Moreover, it creates ample employment opportunities for unskilled or rural landless workers, which help poverty alleviation and improve the overall social well-being of the people (Pingali et al., 2019). Likewise, in most countries, earnings from foreign exportation of agricultural materials have played a vital role in dropping the pressure on the balance of payment (Izuchukwu, 2011). Hence, Indian agriculture is considered the base of poverty eradication, economic growth and development of a country.

Agriculture has long been regarded as India's economic backbone. The different agroecological conditions in India have blessed and enriched the country, ensuring food and nutritional security for the majority of the Indian population. India is the world's second-most populated country after China, with a population of 1.36 billion people contributing around 16% of the national gross domestic product (GDP). More crucially, around two-fifths of the country's population is entirely or heavily reliant on agriculture and related activities for a living (World Bank, 2020). The agriculture sector's contribution to GDP has been declining over time,

while other sectors, particularly services, have grown. Agriculture contributed 41.31 percent of total GDP in 1960, but by 1990 and 2019 it had dropped to 26.89 percent and 16.01 percent, respectively (World Bank, 2020). Nonetheless, agriculture and related industries continue to be the most important source of income. In 2019, they accounted for 28.63 percent of GDP and 42.6 percent of the country's total employment (World Bank, 2020). India is the world's fifth-largest economy by nominal GDP and third-largest by purchasing power parity, according to World Bank data (2020). (PPP). India is the world's greatest producer of milk, pulses, and jute, as well as wheat, rice, cotton, groundnut, sugarcane, and horticultural crops (FAOSTAT, 2019).

In India, suitable weather conditions and well-arranged irrigation facilities are the reason for the high yield production of cereal crops, i.e., maize, rice, wheat, etc. However, maize is measured as a miracle cereal crop due to its high energy potential and is known as the queen of cereals. Maize is used for a variety of uses in India, including food security, chicken feed, pasture, and industrial raw materials. The production of maize is likely to increase from 10.76 million tonnes to 27.71 million tonnes in the year 1996-97 to 2019-20, respectively (World Bank, 2020). Rice plays a significant role in the agriculture sector. According to World Bank 2020, India is the second-largest rice-producing country in the world after China. The rice output is increased to 177.64 million tonnes from 174.71 million tonnes in the year 2019-20 to 2018-19. In India, rice is considered a staple food crop and grown in the Kharif season. While wheat production is estimated to increase to a record 103.59 million tonnes in 2019-20 from 99.86 million tonnes in the previous year. (World Bank, 2020).

Several studies have been conducted to understand whether agriculture is a viable engine and panacea of the economic prosperity of a country. In response to this, most studies used a time series approach to study the nexus of agricultural production and gross domestic product. (Awokuse and Xie, 2015; Oyakhilomen and Zibah, 2014; Anwer et al., 2015; Awoyemi et al., 2017; Mohammed et al., 2020). Some paper used different cereals crops, namely maize, wheat, rice, cotton by employing the ADRL model to examine the linear association between the independent and dependent variable (Mapfumo, 2013; Rehman and Jingdong, 2017; Rehman et al., 2017; Rauf et al., 2017; Ullah et al., 2018). Lastly, Ali et al. (2020) exhibited a different perspective by employing a non-linear autoregressive distributed lag model to examine the long run and short-run shock between cereals crops and Pakistan's agricultural gross domestic product. The result depicts that wheat, rice, and maize crop positively impacted agricultural growth. Hence, to the author's knowledge, no work had been conducted yet to employ the non-linear autoregressive distributed lag model technique to check positive and negative shock of cereal crop namely wheat, rice and maize on agricultural growth in India.

Literature review is presented in Section 2. Section 3 discusses the data and econometrics methods used in the paper. Results and Discussion are presented in Section 4. Lastly, Section 5 reports the Conclusion and Policy Implications of the paper.

2. Literature Review

This section provides the crux of previous studies that directly and indirectly related to understanding the influence of agricultural crop production on the growth of a country's economy.

Insert [Table 1]

In the context of developing nation, particularly India agriculture growth has been lagging behind as compare to other sector such as manufacturing sector and service. To understand what contributes in the agriculture growth there has been copious studies happened in cross countries to find out the plausible determinant of agriculture growth. Rice output have positive impact on agriculture growth in Pakistan (Rehman et al., 2017; Ali et al., 2020) however, Rehman and Jingdong (2017) conclude that rice production is negatively related with agriculture growth. The wheat and maize production are other important determinant for agriculture growth (Ali et al., 2020). The continuous falling of agriculture share in GDP has compelled policy maker to prioritize this issue as soon as possible and formulate national agriculture policy for increasing share of agriculture in GDP. There is no consensus among determinant of agriculture growth. Against this backdrop, this study has taken all preconceived notion of agriculture growth to into consideration. This study is a novel contribution to see asymmetric relationship among rice production, wheat production maize production and agriculture growth.

3. Data and Methods

The study uses the data set contains long annual time series data ranging from 1960 to 2019. The study uses the agricultural gross domestic product (AGDP) as a proxy for agricultural economic growth. To measure the cereal crop, we have taken rice, wheat and maize production. Rice, wheat, and maize are the main cereals crops in India. Trends of the production rice, wheat and maize crops is demonstrated in Figure 1–3. The summary of variables is exhibited in Table 2.

Insert [Figure 1]

Insert [Figure 2]

Insert [Figure 3]

Insert [Table 2]

Nonlinear Autoregressive Distributed Lag Model

Traditional time series models, such as Johansen-Juselius cointegration and the ARDL model are unable to provide enough information about the non-linear relationship. These models presume that the variables have a linear and systematic connection. Shin et al. (2014) developed the nonlinear ARDL (NARDL) methodology, which is an expanded version of the linear ARDL methodology. Nonlinear ARDL model is used to investigate the asymmetric non-linearity association among the study variables; it helps to check the probability of the asymmetric impact of explanatory variables' positive and negative shocks on the dependent variable both in the long run and in the short run. Therefore, the NARDL model has been used in this study.

To ensure the asymmetric long-run association between AGDP on cereals crop in India, the NARDL model is written in the following equations:

$$AGDP_t = \beta_0 + \beta_1 MP_t + \beta_2 RP_t + \beta_3 WP_t + u_t \quad (1)$$

Where AGDP, MP, RP, and WP indicate India's agricultural gross domestic product (AGDP), maize, rice, and wheat crop production, respectively, throughout a time period t . The long run coefficients are denoted by β_i , while the error term is denoted by μ_t . This method was also used in related works by Khan et al. (2019), Ahmad et al. (2020), Ullah et al. (2020), Liao and Baek (2020). Rewrite of equation (1) to express the positive and negative change in maize, wheat and rice production as follows:

$$AGDP = \delta_0 + \delta_1 MP_t^+ + \delta_2 MP_t^- + \delta_3 RP_t^+ + \delta_4 RP_t^- + \delta_5 WP_t^+ + \delta_6 WP_t^- + \mu_t \quad (2)$$

Where δ_i indicates coefficients vector for long run parameters to be estimated and MP_t^+ , MP_t^- , RP_t^+ , RP_t^- , WP_t^+ and WP_t^- denote the partial sum of positive (negative) changes in MP, RP and WP, respectively. Following the value of MP_t^+ , MP_t^- , RP_t^+ , RP_t^- , WP_t^+ and WP_t^- can be framed through the following Equations.

$$MP^+ = \sum_{i=1}^t \Delta MP_i^+ = \sum_{i=1}^t \max(\Delta MP_i, 0)$$

$$MP^- = \sum_{i=1}^t \Delta MP_i^- = \sum_{i=1}^t \min(\Delta MP_i, 0)$$

$$RP^+ = \sum_{i=1}^t \Delta RP_i^+ = \sum_{i=1}^t \max(\Delta RP_i, 0)$$

$$RP^- = \sum_{i=1}^t \Delta RP_i^- = \sum_{i=1}^t \min(\Delta RP_i, 0)$$

$$WP^+ = \sum_{i=1}^t \Delta WP_i^+ = \sum_{i=1}^t \max(\Delta WP_i, 0)$$

$$WP^- = \sum_{i=1}^t \Delta WP_i^- = \sum_{i=1}^t \min(\Delta WP_i, 0)$$

As set out in Shin et al. (2014) and Pesaran et al. (2001), we substitute equation 2 into equation 1 for estimating the asymmetric long-run and short-run relationship among study variables, we specify the equation as follow:

$$\begin{aligned} \Delta AGDP_t = & \vartheta_0 + \vartheta_1 AGDP_{t-1} + \vartheta_2^+ MP_{t-1}^+ + \vartheta_3^- MP_{t-1}^- + \vartheta_4^+ RP_{t-1}^+ + \vartheta_5^- RP_{t-1}^- + \\ & \vartheta_6^+ WP_{t-1}^+ + \vartheta_7^- WP_{t-1}^- + \sum_{i=1}^k \omega_i \Delta AGDP_{t-1} + \sum_{i=1}^p \varphi_{2i}^+ \Delta MP_{t-1}^+ + \\ & \sum_{i=1}^q \varphi_{3i}^- \Delta MP_{t-1}^- + \sum_{i=1}^r \varphi_{4i}^+ \Delta RP_{t-1}^+ + \sum_{i=1}^s \varphi_{5i}^- \Delta RP_{t-1}^- + \sum_{i=1}^a \varphi_{6i}^+ \Delta WP_{t-1}^+ + \\ & \sum_{i=1}^b \varphi_{7i}^- \Delta WP_{t-1}^- + \mu_t \end{aligned} \quad (3)$$

We extend the single equation asymmetric model specified in equation (3) with the introduction of an error correction model (ECM).

$$\begin{aligned} \Delta AGDP_t = & \vartheta_0 + \vartheta_1 AGDP_{t-1} + \vartheta_2^+ MP_{t-1}^+ + \vartheta_3^- MP_{t-1}^- + \vartheta_4^+ RP_{t-1}^+ + \vartheta_5^- RP_{t-1}^- + \\ & \vartheta_6^+ WP_{t-1}^+ + \vartheta_7^- WP_{t-1}^- + \sum_{i=1}^k \omega_i \Delta AGDP_{t-1} + \sum_{i=1}^p \varphi_{2i}^+ \Delta MP_{t-1}^+ + \\ & \sum_{i=1}^q \varphi_{3i}^- \Delta MP_{t-1}^- + \sum_{i=1}^r \varphi_{4i}^+ \Delta RP_{t-1}^+ + \sum_{i=1}^s \varphi_{5i}^- \Delta RP_{t-1}^- + \sum_{i=1}^a \varphi_{6i}^+ \Delta WP_{t-1}^+ + \\ & \sum_{i=1}^b \varphi_{7i}^- \Delta WP_{t-1}^- + \omega ECM_{t-1} + \mu_t \end{aligned} \quad (4)$$

In equation 4, where Δ 's exhibits the differenced variables in time period k, p, q, r, s, a, and b symbolize the respective lags orders. $\vartheta = \vartheta_1, \vartheta_2^+, \vartheta_3^-, \vartheta_4^+, \vartheta_5^-, \vartheta_6^+, \vartheta_7^-$ specify the coefficients of the long-term positive and negative variations of maize, rice and wheat on AGDP. While $\sum_{i=1}^p \varphi_{2i}^+ \Delta MP_{t-1}^+ + \sum_{i=1}^q \varphi_{3i}^- \Delta MP_{t-1}^-$, $\sum_{i=1}^r \varphi_{4i}^+ \Delta RP_{t-1}^+ + \sum_{i=1}^s \varphi_{5i}^- \Delta RP_{t-1}^-$,

$\sum_{i=1}^a \varphi_{6i}^+ \Delta WP_{t-1}^+ + \sum_{i=1}^b \varphi_{7i}^- \Delta WP_{t-1}^-$ and express short term positive and negative effects of maize, rice as well as wheat crop production on AGDP, respectively. Additionally, the long-term consequence of positive and negative variations on the AGDP can be scrutinized as $\gamma_1 = -\frac{\vartheta_2}{\vartheta_1}$, $\gamma_2 = -\frac{\vartheta_3}{\vartheta_1}$, $\gamma_3 = -\frac{\vartheta_4}{\vartheta_1}$, $\gamma_4 = -\frac{\vartheta_5}{\vartheta_1}$, $\gamma_5 = -\frac{\vartheta_6}{\vartheta_1}$, $\gamma_6 = -\frac{\vartheta_7}{\vartheta_1}$, respectively.

As discussed earlier, NARDL model involves numerous steps, i.e., it is vital step to check to stationarity of study variables that none of variable integrated beyond of second order. So, it is compulsory to scrutinize the unit root properties of the variables used in the study. According

to Ouattara (2004), consisting a variable with more than 1 order of integrated yield spurious results. Thus, before applying the NARDL model, we employ Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests to inspect the order integration of variables.

After that, we examine the presence of long-term asymmetric among dependent and independent variables with the testing of following hypothesis

$$H_0 = \vartheta_1 = \vartheta_2^+ = \vartheta_3^- = \vartheta_4^+ = \vartheta_5^- = \vartheta_6^+ = \vartheta_7^-$$

$$H_1 = \vartheta_1 \neq \vartheta_2^+ \neq \vartheta_3^- \neq \vartheta_4^+ \neq \vartheta_5^- \neq \vartheta_6^+ \neq \vartheta_7^-$$

We use many diagnostic tests to assess the robustness of our results after determining the presence of long- and short-term asymmetric effects on research variables. To assess parameter constancy, we use the Breusch-Godfrey LM test for serial correlation, the Breusch-Pagan-Godfrey test for heteroscedasticity, and the CUSUM and CUSUMQ tests suggested by Brown et al (1975).

4. Results and Discussion

Before interpreting the results, it is important to describe the descriptive statistics of the variable that was utilised in the study. We have shown the results of descriptive statistics in Table-3. Agriculture growth mean is 183.236 billion while its maximum and the minimum value are 393.724 and 77.454 respectively standard value is 89.044. Wheat production's mean and standard deviation value in a million tonnes is 52.265 and 27.934, whereas maize production's standard deviation and mean value are 6.973 and 11.472 million tonnes. Rice production has got a mean value of 105.269. The Jarque-Bera test confirms the normality of residuals

Insert [Table 3]

Table 4 shows the results of the unit root tests, namely ADF and PP. It is necessary to assess the order of integration among variables using the proper unit root test before predicting the elasticities. It is also pertinent to confirm the stationary properties since the cointegration technique and causality estimation depends upon integration among variables. The ADF test results indicate that agriculture growth and rice production are stationary at a level while maize production and wheat production are non-stationary at a level. However, all the variables become stationary at first difference. Hence a common order of integration is confirmed from the ADF test. However, we have applied another test of stationary. The t-test statistics are corrected non-parametrically using the Phillips-Perron (PP) test. This test is unaffected by

nonspecific autocorrelation and heteroscedasticity in the test equation's disturbance process. Except for wheat production, the findings of the PP test show that all variables are stationary at a certain level. At first difference, however, they all become immobile. At the second difference, it has also been assured that none of the variables are stationary.

Insert [Table 4]

After confirming the order of integration, it is pertinent to evaluate the cointegrating properties among variables. To check the presence of cointegration among variables, we have applied the Bounds cointegration test. The results of this test indicate that there is cointegration among variables. The F- statistics value is above the upper bound value, ensuring a long-run association among variables (Table 5).

Insert [Table 5]

Insert [Table 6]

In Table 6, we discuss the long-run asymmetric between a dependent variable and independent variables. The occurrence of positive and negative shocks of maize production, wheat production, and rice production on agriculture growth are captured through the NARDL econometric model. The positive shock of maize production has significantly influenced agriculture growth in the long run and short run, with the coefficient value 0.330 and 0.150, respectively, at a 1% level of significance. The positive shock of maize production implies that a rise in maize production will significantly contribute to agriculture growth positively. The maize negative shock coefficient value is 0.342. It implies that agricultural economic growth falls by 0.342% with a 1% fall in MP^{*} in India. We observed that agriculture growth responds more rapidly to a decrease in maize production than an increase in maize production. Therefore, it indicates that a reduction of maize production automatically leads to a decline in agriculture growth. Hence, it gives an important message to the policymaker to make a policy for the negative shock it can combat whenever there is a decrease in the production of maize.

At a 1% significance level, the positive and negative shock coefficient values for rice production are 0.771 and 0.933, respectively. The negative shock of rice production is more dominant than the positive shock of the same. The negative shock's coefficient sign is positive, saying that rice production decreases will reduce agriculture growth. In a nutshell, the intrinsic non-linearity between positive and negative shocks of rice production and agriculture is indispensable for policy formulation. The positive and negative shocks in the short run are also significant at a 1% significance level.

The wheat production's positive shock value has a neutral impact on agriculture growth, while its negative shock significantly impacts agriculture growth. The value of wheat production

coefficient for negative shocks are 0.558 while the positive shocks are 0.095 but it is statistically insignificant. This implies that production of wheat has negative linkage with AGDP in the long run. The decrease in the quantity of wheat production is because of certain agricultural practices often lead to decreasing production from crops, these include irrigation facility, seed, machinery, and fertilizers. Moreover, for optimum wheat growth, it requires mild winters but it get impacted due to intense heat.

Insert [Table 7]

Table 7 shows the presence of asymmetry in the long run among dependent and independent variables. The results indicate that there is a presence of asymmetry among maize production, wheat production, rice production, and agriculture growth, while in the short run, maize production and rice production shows no asymmetry with agricultural growth.

Insert [Table 8]

Insert [Figure 4]

Insert [Figure 5]

The diagnostic test results are presented in Table-8. The LM and Breusch-Pagan–Godfrey tests have p-values of 0.312 and 0.302, showing that the model is free of severe serial correlation issues and heteroscedasticity. Any statistical study must be checked for robustness in order to ensure parameter stability in the model. As a result, the CUSUM and CUSUMSQ parameter stability tests were used. After estimating the long-run and short-run, we may check the model's stability. In contrast to the break-point, the statistics of CUSUM and CUSUMSQ are updated recursively. If the CUSUM and CUSUMSQ lines stay inside the upper and lower bounds of the CUSUM and CUSUMSQ graph, the predicted parameter is stable. The CUSUM and CUSUMSQ graph shows that the blue line remains inside the red line of the upper and lower bound, which confirmed the stability of the model.

Insert [Table 9]

The asymmetric causality between dependent and independent variables can be seen in Table 9. In this section, we interpreted the results of asymmetric causal linkages between dependent and independent variables. The Granger causality test is being applied for causality analysis. It is concluded that the positive shock of maize production has a significant impact on agriculture growth. However, agriculture growth does not Granger cause maize production. The negative shock in maize production did not negatively impact or a neutral effect on agriculture growth. Moreover, agriculture growth does not Granger causes a negative shock of maize production. There is a unidirectional causal relationship that exists between maize production and agriculture growth. Therefore, policy implication needs to increase maize's production for

boosting agriculture growth by providing input subsidies on seeds and fertilizer. The positive shock of wheat production does not Granger cause agriculture growth. We have rejected the null hypothesis, which states that wheat production does not granger cause agriculture growth.

Agricultural expansion has also had a favourable and considerable impact on wheat production. Agriculture growth has created bad shocks in wheat output, and agriculture growth has generated adverse shocks in wheat output. The positive Agricultural expansion has also had a favourable and considerable impact on wheat production. Agriculture growth has created bad shocks in wheat output, and agriculture growth has generated adverse shocks in wheat output. shock of rice production does not granger cause agriculture growth, while its negative shock significantly impacts agriculture growth. There is no bidirectional causality exist between rice production and agriculture growth. Moreover, we can say that causality runs from rice production to agriculture growth. There is a presence of unidirectional causality between maize production and wheat production. We have found bidirectional causality between wheat's negative shock and maize positive shock.

5. Conclusion and Policy Implications

During the period 1960–2019 in India, this study looked at the relationship between agricultural economic growth and cereal crop production, specifically maize, rice, and wheat. We look into the potential of asymmetric effects of positive and negative wheat, rice, and maize production shocks on India's agricultural economic growth. The variables are stationary at either the level or first difference, according to the ADF and PP unit root tests. Bounds cointegration establish the long-run relationship between cereals crops and agricultural economic growth. Detrimental shocks in wheat output have a negative impact on agricultural economic growth, according to the NARDL model. While the increase in wheat production is beneficial in the short term, it has little long-term impact on agricultural economic growth. It might be due to declining the total factor productivity over the years due to stagnant productivity with overuse of chemical fertilizers. Input scarcity, inconsistent power supply, temperature fluctuations during growth, high input costs, and limited access to seed of freshly released varieties are among the issues. The effects of positive and negative shocks in rice production have a significant impact on agricultural economic growth in the short and long term. Since the government provides subsidies in inputs, high demand at the domestic level and high consumption. At the same time, India stands second for the production of rice after China. Conversely, regarding maize production, it plays an important role in attaining long-run agricultural economic growth. So

the government should focus on expand the production of maize crop by providing more subsidies for its production.

The result of the NARDL model recommended that crop production have a robust both in short- and long-term relationship with the agricultural economic growth of India. Thus this study suggested that to boost the export of agricultural products by launch new rural development projects. Improve crop productivity with the introduction of new agriculture technologies and the provision of good seeds and other agriculture inputs. Government should also focus on proper training to farmers about the usage of fertilizers and chemical sprays on food crops, adequate storing marketing, insurance, irrigation facilities, subsidies on farm machinery etc. Since there exist a long run relationship between GDP and agriculture, more investments from both the private and public sector should be undertaken to enhance agricultural productivity towards economic growth.

Declaration

Availability of data and materials: Data will be made available upon request

Competing interests: We do not have any conflict of interest

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Table 1. Summary of Review of Literature

Author(s)	Time	Countries	Econometric Model	Results
Rehman and Jingdong (2017)	1980-2015	China	Johansen Cointegration model	Output of Wheat, cotton ,sugarcane, corn and tubers = +AGDP Output of Rice = - AGDP
Rehman et al (2017)	1970-2015	Pakistan	Johansen cointegration test	Rice output and cultivated area =+ AGDP
Ali et al (2020)	1970-2017	Pakistan	NARDL	Rice, maize, wheat=+AGDP Rice, maize=> AGDP
Mohammed et al (2020)	1960-2016	Ghana	Johannsen cointegration	Agricultural output =+Economic growth
Anwer et al (2015)	1975-2012	Pakistan	OLS	Agriculture sector =+GDP
Awokuse and Xie (2015)	1980-2011	3 Sub-Saharan Africa, 3 Asia and 3 Latin America	ARDL	agriculture could be an engine of economic growth, the impact varies across countries
Hussain and Ajmair (2016)	1980-2010	Pakistan	OLS	Maize, wheat, rice and cotton = + GDP Sugarcane= - GDP
Raza et al(2012)	1980-2010	Pakistan	OLS	Rice, wheat, cotton=+economic growth
Awoyemi et al (2017)	1981-2015	Nigeria	Johansen cointegration	Agricultural productivity =+ economic growth
Kulshrestha and Agrawal (2019)	1961-2017	India	Johansen cointegration	Rice and pulses =+GDP Wheat and cotton lint=-GDP
Pattanayak and Mallick (2017)	1991-2012	India	Johansen cointegration	Tea, cereals and tobacco =+ GDP growth Coffee and sugarcane production=-GDP growth
Oyakhilomen and Zibah (2014)	1970-2011	Nigeria	ARDL	Agricultural Production=+Economic growth
Mapfumo (2013)	1980-2010	Zimbabwe	Johansen cointegration	Tobacco and cotton=+ Real GDP Coffee =- Real GDP
Rauf et al (2017)	1981 to 2015	Pakistan	ARDL	Wheat crop area =+ agril GDP

				Wheat crop yield and fertilizer =-Agril GDP
Ullah et al (2018)	1961-2015	Pakistan	ARDL	Mango, apple, peach production =+ AGDP

Note => Unidirectional relationship, + positive impact, - negative impact, the Kwiatkowski-Phillips- Schmidt-Shin (KPSS) test, ADF Augmented Dickey Fuller test, PP Phillips-Perron, ARDL Autoregressive Distributed lag model, NARDL Nonlinear Autoregressive Distributed lag model,

Table 2. Description of Variables

Variable	Symbol	Unit	Source
Agricultural Growth	lnAGDP	Constant billion 2010 US \$	World Bank
Wheat Production	lnWP	million tonnes	FAO
Rice Production	lnRP	million tonnes	FAO
Maize Production	lnMP	million tonnes	FAO

Table 3. Descriptive Statistics

	AGDP	MP	RP	WP
Mean	183.236	11.472	105.269	52.265
Median	160.790	8.884	109.001	54.110
Maximum	393.724	28.753	177.645	103.596
Minimum	77.454	4.312	45.657	9.853
Std. Dev.	89.044	6.973	38.846	27.934
Skewness	0.707	1.066	0.110	0.070
Kurtosis	2.423	2.871	1.738	1.833
Jarque-Bera	5.739	11.210	4.036	3.397
Probability	0.087	0.42	0.133	0.183
Observations	59	59	59	59

Table 4. Unit Root Test Results

Variables	ADF Test		PP Test	
	I (0)	I (1)	I (0)	I (1)
lnAGDP	-5.610***	-11.752***	-5.559***	-23.737***
lnMP	-1.432	-9.879***	-4.458***	-21.890***
lnRP	-3.491*	-9.127***	-5.890***	-27.918***
lnWP	-1.831	-8.878***	-1.685	-8.894***

Note: *** < 0.01, ** < 0.05, and * < 0.1

Table 5. Bounds Cointegration Test

Test Statistic	Value	Significance level	LB	UB
F-statistic	16.508	1%	1.990	2.940
		5%	2.270	3.280
		10%	2.880	3.990

Table 6. NARDL Model Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
$\ln MP^+$	0.330	0.056	5.896	0.000
$\ln MP^-$	0.342	0.079	4.316	0.000
$\ln RP^+$	0.771	0.147	5.228	0.000
$\ln RP^-$	0.933	0.165	5.636	0.000
$\ln WP^+$	0.095	0.063	-1.513	0.137
$\ln WP^-$	0.558	0.197	-2.835	0.007
Constant	25.102	0.044	575.125	0.000
ECM	-0.413	0.034	-12.335	0.000
$\Delta \ln MP^+$	0.150	0.041	3.627	0.001
$\Delta \ln MP^-$	-0.017	0.059	-0.292	0.772
$\Delta \ln RP^+$	0.523	0.083	6.333	0.000
$\Delta \ln RP^-$	0.387	0.057	6.811	0.000
$\Delta \ln WP^+$	-0.228	0.082	-2.764	0.009
$\Delta \ln WP^-$	0.016	0.121	0.131	0.897
R-squared	0.879			
Adjusted R-squared	0.872			
Durbin-Watson Statistics	1.865			

Table 7. Testing the Presence of Asymmetries

Variable		F-statistics	P-value	Presence of Asymmetry
Long run Asymmetry				
$\ln MP$		19.984	0.000	Yes
$\ln WP$		3.748	0.063	Yes
$\ln RP$		3.953	0.053	Yes
Short run Asymmetry				
$\ln MP$		0.131	0.720	No
$\ln WP$		18.127	0.000	Yes
$\ln RP$		0.009	0.924	No

Table 8. Diagnostic Tests

Tests	Statistics	Probability
LM for serial correlation	0.312	0.733
BPG for heteroscedasticity	0.302	0.977
CUSUM	Stable	
CUSUM Square	Stable	

Table 9. Granger Causality Test

Null Hypothesis:	F-Statistic	Prob.
$\ln MP^+ \nRightarrow \ln AGDP$	3.029	0.057
$\ln AGDP \nRightarrow \ln MP^+$	1.321	0.276
$\ln MP^- \nRightarrow \ln AGDP$	1.037	0.362
$\ln AGDP \nRightarrow \ln MP^-$	0.066	0.936
$\ln WP^+ \nRightarrow \ln AGDP$	1.013	0.370
$\ln AGDP \nRightarrow \ln WP^+$	20.113	0.000
$\ln WP^- \nRightarrow \ln AGDP$	4.220	0.020
$\ln AGDP \nRightarrow \ln WP^-$	13.022	0.000
$\ln RP^+ \nRightarrow \ln AGDP$	0.750	0.477
$\ln AGDP \nRightarrow \ln RP^+$	3.500	0.038
$\ln RP^- \nRightarrow \ln AGDP$	2.762	0.073
$\ln AGDP \nRightarrow \ln RP^-$	0.657	0.523
$\ln MP^- \nRightarrow \ln MP^+$	8.052	0.001
$\ln MP^+ \nRightarrow \ln MP^-$	2.302	0.110
$\ln WP^+ \nRightarrow \ln MP^+$	1.936	0.155
$\ln MP^+ \nRightarrow \ln WP^+$	6.248	0.004
$\ln WP^- \nRightarrow \ln MP^+$	3.770	0.030
$\ln MP^+ \nRightarrow \ln WP^-$	5.181	0.009
$\ln RP^+ \nRightarrow \ln MP^+$	1.865	0.165
$\ln MP^+ \nRightarrow \ln RP^+$	0.117	0.890
$\ln RP^- \nRightarrow \ln MP^+$	5.026	0.010
$\ln MP^+ \nRightarrow \ln RP^-$	0.337	0.715
$\ln WP^+ \nRightarrow \ln MP^-$	6.800	0.002
$\ln MP^- \nRightarrow \ln WP^+$	0.354	0.704
$\ln WP^- \nRightarrow \ln MP^-$	1.041	0.361
$\ln MP^- \nRightarrow \ln WP^-$	2.488	0.093
$\ln RP^+ \nRightarrow \ln MP^-$	2.116	0.131
$\ln MP^- \nRightarrow \ln RP^+$	2.367	0.104

$\ln RP^- \nRightarrow \ln MP^-$	0.693	0.505
$\ln MP^- \nRightarrow \ln RP^-$	0.968	0.387
$\ln WP^- \nRightarrow \ln WP^+$	6.930	0.002
$\ln WP^+ \nRightarrow \ln WP^-$	1.633	0.205
$\ln RP^+ \nRightarrow \ln WP^+$	8.467	0.001
$\ln WP^+ \nRightarrow \ln RP^+$	3.293	0.045
$\ln RP^- \nRightarrow \ln WP^+$	5.698	0.006
$\ln WP^+ \nRightarrow \ln RP^-$	1.538	0.225
$\ln RP^+ \nRightarrow \ln WP^-$	3.217	0.048
$\ln WP^- \nRightarrow \ln RP^+$	2.798	0.070
$\ln RP^- \nRightarrow \ln WP^-$	12.652	0.000
$\ln WP^- \nRightarrow \ln RP^-$	0.910	0.409
$\ln RP^- \nRightarrow \ln RP^+$	22.657	0.000
$\ln RP^+ \nRightarrow \ln RP^-$	2.579	0.086

Figure 1. Trends of Wheat Production in India

Figure 2. Trends of Rice Production in India

Figure 3. Trends of Maize Production in India

Figure 4. CUSUM Plot

Figure 5. CUSUM Square Plot

Figures

Figure 1

Trends of Wheat Production in India

Figure 2

Trends of Rice Production in India

Figure 3

Trends of Maize Production in India

Figure 4

CUSUM Plot

Figure 5

CUSUM Square Plot