



Research article

Exploring the Interconnections between Rice and Wheat Production, Consumption, and Import in Bangladesh

Shaikh Mostak Ahammad*, Md. Fazlay Rabbi and Ahsan Habib

Department of Accounting, Hajee Mohammad Danesh Science and Technology University, Dianjpur-5200, Bangladesh

ABSTRACT

This study examines the interconnections between two primary food crops of Bangladesh those are rice and wheat (production, consumption, and import). Three methods use to examine. Those methods are unit root test, Granger causality test and Johansen cointegration test. Yearly data (collected from the website <https://www.indexmundi.com> from 1972 to 2022) are used to investigate the relationship between rice and wheat in Bangladesh. In the unit root test results, Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) show that rice and wheat (production, consumption, and import) are the initial difference, stationary. By applying the Granger causality test it is founded that consume rice, consume wheat, wheat import, rice production is unidirectional and consumption rice, rice production, rice import is bidirectional relationship. There are a long-run integrating relationship between rice and wheat (production, consumption and import) that's founded by Johansen cointegration test. As a result, rice and wheat are depended on each other and having strong relationship.

ARTICLE INFO

Article timeline:

Date of Submission:

28 January, 2024

Date of Acceptance:

20 August, 2024

Article available online:

25 August, 2024

Keywords:

Granger Causality test

Johansen Cointegration test

Rice

Wheat

Introduction

Bangladesh is a country located in south-central Asia, southeast of the Indian subcontinent. along the Jamuna and Padma River. Bangladesh ("Land of the Bengals"), a riverine nation, has one of the densest populations in the entire world. The statistics show that 16.51 corer people live in Bangladesh. (Source: <http://www.bbs.gov.bd/>) The fundamental activity of the Bangladeshi people is agriculture. The majority of Bangladeshis rely on agricultural operations, both directly and indirectly. Agriculture is one of the longest-producing sectors of the economy and comprises 13.31% of GDP. In Bangladesh, 43% of the labor force is employed in the agricultural sector. (Source: <http://www.bbs.gov.bd/>) In Bangladesh, the main foods are like that (rice, wheat, maize, potato, vegetables, pulses, fruits, etc.). But here, the main foods are considered to be rice and wheat. So every year, huge amounts of food crops were produced. But all production is consumed but not fulfillment the need of food. So, every year we need to import rice and wheat.

Bangladeshi people consume mainly rice, which is derived from paddy. Paddy is grown on over 80% of the arable land in Bangladesh by farmers. Conditions that are excellent for paddy farming are 16°C to 30°C temperatures and 100 cm to 350 cm of rainfall. The

river gathers muddy, fertile soil, which helps paddy fields grow more quickly. Paddy is grown practically everywhere in Bangladesh, specifically in the districts of Dinajpur, Rajshahi, Barishal, Patuakhali, Sylhet, Cumilla, and Mymensing, where it is grown in greater quantities. In the 2018–19 fiscal year, paddy was grown on 284.55 million acres of land, with a total production of 363.89 million metric tons during the aus, amon, and boro seasons. During that period, Bangladesh imported rice worth \$124 million. (Source: <https://oikosmist.com/crops-of-bangladesh/>) Wheat is the second-most popular edible food in Bangladesh. Wheat is the source of flour. Temperatures between 16 and 22 degrees Celsius, a water extraction system, and an average rainfall of 40 to 100 centimeters are requirements for growing wheat. The most rapidly developing districts are Dinajpur, Rangpur, Thakurgaon, Tangail, Jessore, Pabna, Rajshahi, and Bogra. Bangladeshi people eat a lot of wheat, but there is a lack of wheat being produced there. Wheat is harvested on 8.16 lakh acres of land in 2018–19, and 10.16 lakh metric tons are produced. This country was importing wheat worth \$1148 million at the time. (Source: <https://oikosmist.com/crops-of-bangladesh/>)

Several key strategies could be used to make rice and wheat more central in addressing food security issues of Bangladesh. High-yield, climate-resilient

*Corresponding author: mostak@hstu.ac.bdDOI: <https://doi.org/10.53808/KUS.2024.21.02.1143-mb>

varieties of rice and wheat can help to increase production substantially. Improved varieties of seeds from agricultural research institutes can aid farmers to increase their yield. This can be improving yield by adopting advanced and scientific agricultural practices like precision farming, Integrated Pest Management (IPM), improved irrigation methods etc. These techniques are going need training and support so you can make them into reality on the farm. Effective crop rotation strategies and replacement of a rice-wheat system by other crops ameliorate the soil health problem as well reduce pest-disease cycles. The sort of habitual practice that boosts total farm productivity and sustainability. Growing a multi-grain economy that includes rice as well as wheat can play an important role in preventing famine from the failure of single crops. The greater the diversification of crops and diets, the more food different people are able to producer sing and consuming a small related set. Efficient water management systems, like drip or sprinkler irrigation as well as rainwater harvesting techniques can maximize the use of available in-situ and ex situ resources for rice-wheat farming in areas facing salinity and scarcity of water. Use of Organic Fertilizers, Crop Residues and Green Manure: Popularizing organic fertilizers prevents soil fertility degradation which could help reduce the interference on nature imposed by chemical-based or inorganic fertilizers for longer agricultural productivity. In light of this, it is possible to maintain stable food production amidst a changing climate by devising and implementing resilient agricultural practices through the development of new technologies that allow rice and maize varieties resistant/tolerant to prolonged dry conditions. Implementation of early warning systems for extreme weather events is crucial to enable farmers take preemptive action, securing agricultural yields and avoiding food supply disruptions. Improved infrastructure in the form of roads and storage facilities bring rice to consumers more quickly, reducing post-harvest losses that significantly reduce the potential impact for most crops. They can even offer Subsidies or some form of support mechanism to rice and wheat farmers so that these producers are assured fair price for their produce; in this way, they would keep producing. Developing and enforcing broad-based agricultural policies targeting rice/wheat sustainability, which can create an enabling environment for farmers. Land tenure, research and development along with credit facilities should be critically included in policy formulation. Improving agricultural extension services to offer farmers the most current information, technologies and support can help this expansion of capacity in rice-wheat systems.

Literature review

A review of the literature is a crucial component of every research project. We have conducted a thorough literature review in this section that is focused on the current research issue. To give a thorough picture of the literature on the research theme and other related concerns, we investigated a wide range of academic journals, conference proceedings, government reports, and books for this purpose. Studies from Bangladesh

and even other countries are included in this sections review.

Morris et al. (1996) this paper presented the outcomes of a research undertaken to analyze the economics of wheat cultivation in Bangladesh. In irrigated places, boro (winter) rice is the most lucrative crop. Whereas in non-irrigated areas, wheat often yields the highest returns and in areas where boro rice production is not possible. In the majority of zone without irrigation and one zone with irrigation, growing wheat is the most cost-effective for determining inputs and outputs, use domestic resources are priced economically. Wheat cultivation would become even more tempting if current trends persisted and Bangladesh achieved rice independence. Given these findings, earlier calls to discontinue activities to promote wheat and reduce funding for wheat research must be reviewed. Mottaleb et al. (2018) examined this study, it is determined whether Bangladesh will boost its wheat production. Bangladesh has excellent prospects to boost wheat production and fulfill the rising local demand thanks to the rice-wheat production system. In light of the findings, the study recommended growing wheat on land that is sometimes fallow, especially in southern Bangladesh. This report also recommended for additional funding for wheat development and research in order to assist ecological growth, comparative advantage, and local adaptation. Mottaleb and Mishra (2016) looked at the factors that affected households' preferences for different types of rice grains. We utilize economic analysis to show that fine-grain (long-and-slender-grain) rice is replacing ordinary-grain (short-and-bold-grain) rice in urban, wealthy, and educated households in Bangladesh. Alam et al. (2012) investigated how, in light of agricultural trade liberalization, the price of rice in Bangladesh's domestic market is dynamically related to the global market. An error correction model was applied after the Johansen multivariate cointegration test. The findings indicated that a long-term unidirectional equilibrium relationship does exist, which means that domestic prices respond to global prices but not the other way around. They found that the Bangladeshi rice market is dependent on the world rice market, highlighting the need for suitable policy that especially address the problem of food security during periods of high global pricing. Such policies have to aim to tame or lessen domestic pricing volatility brought on by the global market. Hossain and Silva (2013) examined main economic sector is agriculture, but global warming is predicted to significantly lower crop yields, notably those of wheat and rice, directly hurting the food security of 165 million people. Although Bangladesh has made considerable strides in agriculture, particularly with regard to rice output and production, but the country is still a net importer of rice because global demand for the grain still exceeds domestic supply. Planning for future cereal production and demand is essential to addressing Bangladesh's concerns with regard to food security given the country's growing population. Projections of future grain supply and demand are essential for facilitating this planning. This study is an attempted to make such estimates for the future in

order to determine the expected supply-demand gap. This information will also aid in the development of a global perspective strategy for rice and wheat research in Bangladesh to address the long-term food needs of a growing population.

Rahman and Hasan (2014) investigated the productivity and cost effectiveness of wheat production in Bangladesh while taking production-related environmental limits into consideration, they employed a stochastic production frontier technique. Environmental challenges such a constrained amount of land, weed and pest invasion, poor weather, planting delay, and unsuitable soils severely limit energy efficiency and wheat production. Tama et al. (2018) examined were to identify the variables influencing aromatic rice production's gross return and to evaluate the aromatic rice's export potential in Bangladesh. A stratified selection technique was employed to choose from among the five villages in the Dinajpur region, 45 aromatic rice farms were selected for the study. Combining mathematical, statistical, and descriptive techniques were employed to evaluate the data. The primary determinant were cost of education, power tiller, and fertilizer. From the viewpoints of export and import substitution, producing aromatic rice is a competitive advantage for Bangladesh, with the Domestic Resource Cost (DRC) being 0.51 for import duties costs and 0.64 for the same export parity pricing. The research indicated maintaining the cost of marketing, seeds, and other inputs constant. Baffes and Gautam (2001) investigated the sources of rice production growth in Bangladesh from 1973 to 1999. The transformation of rice-growing regions from traditional to contemporary types was discovered to be the primary factor. Based on simulations, the most significant finding is that the amount of productivity per person at the moment can only be maintained by increasing yields of modern rice types. Population management has been shown to offer considerable long-term advantages, while speedier conversion of remaining land to modern kinds provides significant short-run benefits. However, the latter two acts can only supplement, not replace, attempts to boost the yields of contemporary types. Alam and Islam (2013) By this research, Bangladesh has made excellent gains in food production during the past 35 years, despite the country's massive population pressure on the country's limited amount of land and other natural resources. Another hurdle facing the economy is the tendency for agriculture production land to become less available. Between 1990 and 2005, there was a very substantial decline in the amount of cultivable land. Despite the population doubling, cereal food production increased by between 100 and 25 percent throughout this time. Production and distribution of modern high-yielding wheat and rice varieties, supported by advantageous government policies, have resulted in progress. The rice industry has seen enormous technological progress. Following the country's independence in 1972, the Bangladesh Rice Research Institute (BRRI) significantly contributed to the recent development of 59 contemporary, HYVs, or high yielding rice varieties, are appropriate for different agricultural ecologies. This study attempts to evaluate the links

between rice and wheat (production, import, and consumption) in Bangladesh by analyzing the facts, aided by the literature, and relative features of the primary food crops of Bangladesh. The above literature reveals that the productivity of rice and wheat contributes to the economic sector but doesn't build up the relationship between rice and wheat (production, consumption, and import). This study seeks to determine how closely related rice and wheat. So, in this study, the Johansen cointegration test and Granger causality tests are applied.

Materials and Method

Econometric methods are utilized in this research to assess the data collection. In this report, unit root tests (such as ADF and PP) are used to find out if the information is steady or not. Second, the Johansen cointegration used to ascertain whether a long-term relationship exists. The Granger causality test is then used to determine which variable is causing the other. To obtain the results, the econometric software E-Views 12 was applied.

Unit root tests

A data-generating procedure whose primary distinction is stationary is known as a unit root method. When ϵ the initial variation of y is stationary.

$$y_t - y_{t-1} = (1 - L)y_t = \epsilon_t \dots\dots\dots (1)$$

here, ϵ is a phrase for random disturbance that is stationary. The prediction value for the series y is constant, dependent on t , and the variance rises over time.

An easy AR (1) procedure is as follows:

$$y_t = \rho y_{t-1} + x_t' \delta + \epsilon_t \dots\dots\dots (2)$$

where x_t are potential external regressors, ρ and δ are estimated parameters, and ϵ_t is assumed to be white noise, x_t may be constant or a constant and trend. If $|\rho| \geq 1$, A non-stationary series is y , and its variance of y grows with time until it reaches infinity.

If $|\rho| < 1$, y is a (trend-) stationary series. As a result, the (trend-) stationary hypothesis can be tested to determine if the absolute value of ρ is strictly smaller than one. The unit root tests offered by EViews usually compare the one-sided alternative $H_0: \rho = 1$ against the null hypothesis $H_1: \rho < 1$. In some situations, a point alternative is checked against the null. In contrast, the KPSS Lagrange Multiplier test evaluates the null of $H_0: \rho < 1$ against the alternative $H_1: \rho = 1$.

Rationale and relevance to selection this method: Unit roots tests are important for time series analysis to ascertain whether data is stationary or non-stationary; Stationarity in time series analysis is an important property as it indicates the means, variances and auto-correlations of a series are constant over time. This Work Characterizes whether the unit root present in as rice, and wheat production, consumption, import data from 1972 to 2022 units was strongly stationary or not the issue of stationarity is relevant for annual observation series on trans-logarithm long-run elasticities. Even though there are examples of situations in which nonstationary data

can be an advantage for making accurate predictions, when it comes to econometric analyses they often result on spurious relationships. With the help of unit root tests like Augmented Dickey-Fuller (ADF) test or Phillips-Perron (PP) test, we can check if differencing is required to make a time-series stationary before proceeding with analysis.

Granger Causality

In any meaningful understanding of the word, causality does not always follow from correlation. There are many magnificent associations in the econometric cemetery that are either false or useless. There is a strong positive association between the UK's mortality rate and the percentage of marriages performed in the Church of England, for instance, as well as a positive correlation between teachers' wages and alcohol usage. Correlations that are less obviously nonsensical are debated by economists.

The Granger (1969) method for determining if x causes y that entails first determining how much of the present y can be described by previous values of y, followed by determining whether inserting lag values of x can enhance the interpretation. If x aids in the prediction of y, or more precisely, if the coefficients on the lagged x's are statistically meaningful, then x is said to be Granger-caused by y. Take note that two-way causality frequently occurs; Granger causes x to happen, and y to happen.

It is crucial to understand that the term "x Granger causes y" does not indicate that y is x's impact or outcome. Granger causality examines information content and precedence, although it does not by itself imply causality in the sense that the word is most commonly used.

E-Views executes the following bivariate regressions: E-Views executes the following bivariate regressions:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \dots + \alpha_l y_{t-l} + \beta_1 x_{t-1} + \dots + \beta_l x_{t-l} + \epsilon_t$$

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \dots + \alpha_l x_{t-l} + \beta_1 y_{t-1} + \dots + \beta_l y_{t-l} + u_t \dots \dots \dots (3)$$

for all potential pairs of (x,y) groups of series. The Wald statistics for the joint hypothesis are the F-statistics that are presented:

$$\beta_1 = \beta_2 = \dots = \beta_l = 0 \dots \dots \dots (4)$$

The null hypothesis is that in the first regression, x does not Granger-cause y, and in the second regression, y does not Granger-cause x

Rationale and relevance to selection this method: Granger causality tests to see can one times series predict another time series. It is useful in identifying the directional relationships between variables. Therefore, knowing rice and wheat production-consumption-imported linkage is essential in the context of this research. For instance, we may want to test if changes in wheat production Granger-cause changes in rice production, or vice versa. These results can be of more insightful for policymakers and the agricultural planners where to focus on their decision-

making actions in an agriculture sector related problem in Bangladesh.

Johansen Cointegration

Utilizing a Group object or a projected Var object, EViews allows Johansen (1991, 1995) methodology-based VAR-based cointegration testing.

Think about a VAR of order p:

$$y_t = A_1 y_{t-1} + \dots + A_p y_{t-p} + Bx_t + \epsilon_t \dots \dots \dots (5)$$

Where x_t is a d -vector of deterministic variables, ϵ_t is a vector of innovations, and y_t is a k -vector of non-stationary I (1) variables. This VAR might be rewritten as,

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + Bx_t + \epsilon_t \dots \dots \dots (6)$$

where,

$$\Pi = \sum_{i=1}^p A_i - I, \Gamma_i = - \sum_{j=i+1}^p A_j \dots \dots \dots (7)$$

According to Granger's representation theorem, Assuming the coefficient matrix Π has decreased rank $r < k$, then there appear $k \times r$ matrices α and β each with rank r such that $\Pi = \alpha\beta'$ and $\beta'y_t$ is I (0). Each column in β is a cointegrating vector, and r is the total number of cointegrating relations (the cointegrating rank). In the VEC model, the components of α are referred to as the adjustment parameters. According to Johansen's methodology, we can evaluate whether we can reject the limits implied by the lower rank of Π by estimating the Π matrix from an unrestricted VAR.

Rationale and relevance to selection this method: Johansen cointegration test is a method for determining an equilibrium relationship between multiple time series. It is incredibly powerful in that it can deal with multiple cointegrating relationships at once. Considering the long dimension of the data set (1972-2022) and possible feedback effects between domestic rice production, consumption, and imported wheat in Iran it is important to analyze whether these variables are cointegrated or not. Cointegration analysis has to detect stable long-run relationship which is very vital for proposed study of food security dynamics in Bangladesh. The Johansen methodology allows us to do so in a more correct way giving the possibility of investigating equilibrium long term interactions among these fundamental agrarian variables.

Data

In this study, we used data consisting of annual observations from 1972 to 2022. The data were acquired from the website (<https://www.indexmundi.com>) on December 21, 2022, for Bangladesh, where the primary food crops were rice and wheat (production,

consumption, and import). Other crops (like maize, potatoes, pulses, fruits, vegetables, spices, oilseeds, etc.) were passed up because of unattainable data for all variables from 1972 to 2022. For this study, data includes natural log wheat import (lnWI), consumption wheat (lnCW), wheat production (lnIW), rice production (lnRP), rice import (lnRI), and consumption rice (lnCR) in metric tons.

The decision to use data from IndexMundi for this study was driven by the need for comprehensive, consistent, and easily accessible data covering a long historical period. While other sources like the World Bank or FAO provide valuable data, they might not provide the same level of detail and specificity required for an in-depth analysis of the interrelationships between rice and wheat in the context of our research. IndexMundi's specialization in agricultural statistics and

its ability to provide detailed, continuous data for rice and wheat production, consumption, and import in Bangladesh made it the most suitable choice for our research objectives. This ensures that our analysis is based on robust and reliable data, leading to meaningful and accurate insights into the relationships between these crucial food crops and their impact on food security in Bangladesh.

Results

Unit root test: Table below presents unit root tests results which check stationary of time series data in levels and first differences for various variables. It is important that the data in a time series be stationary for accurate and robust analysis, as non-stationary data can give misleading or spurious results.

Table 1: Unit root tests of variables at first difference

Variables	Test	Level (P-value)	First difference (P-value)	Details
<i>lncr</i>	ADF	0.70	0.00	SIC, Int
<i>lncr</i>	ADF	0.92	0.00	SIC, Int, Tr
<i>lncr</i>	PP	0.68	0.00	NW,B, Int
<i>lncr</i>	PP	0.71	0.00	NW,B, Int, Tr
<i>lncw</i>	ADF	0.33	0.00	SIC, Int
<i>lncw</i>	ADF	0.02	0.00	SIC, Int, Tr
<i>lncw</i>	PP	0.42	0.00	NW, B, Tr
<i>lncw</i>	PP	0.01	0.00	NW, B, Tr, Int
<i>lnri</i>	ADF	0.00	0.00	SIC, Int
<i>lnri</i>	ADF	0.00	0.00	SIC, Int, Tr
<i>lnri</i>	PP	0.00	0.01	NW, B, Tr
<i>lnri</i>	PP	0.00	0.00	NW, B, Tr, Int
<i>lnrp</i>	ADF	0.66	0.00	SIC, Int
<i>lnrp</i>	ADF	0.17	0.00	SIC, Int, Tr
<i>lnrp</i>	PP	0.66	0.00	NW, B, Int
<i>lnrp</i>	PP	0.16	0.00	NW, B, Int, Tr
<i>lnwp</i>	ADF	0.01	0.00	SIC, Int
<i>lnwp</i>	ADF	0.46	0.00	SIC, Int, Tr
<i>lnwp</i>	PP	0.02	0.00	NW, B, Int
<i>lnwp</i>	PP	0.46	0.00	NW, B, Int, Tr
<i>lnwi</i>	ADF	0.99	0.00	SIC, Int
<i>lnwi</i>	ADF	0.87	0.00	SIC, Int, Tr
<i>lnwi</i>	PP	0.22	0.00	NW, B, Int
<i>lnwi</i>	PP	0.06	0.00	NW, B, Int, Tr

The following tests are run to determine if the data is stationary among them Augmented Dickey-Full (ADF) testBooker and May 2009, Phillips-Perron (PP) testChan & Tran for both with intercept (Int), without drift or trend in PP terminology and Drift terminology in ADF namely detrended from a linear line ((det)) aka Stochastic Trending(ST).

Variables: *lncr*: Log of rice consumption, *lncw*: Log of wheat consumption, *lnri*: Log of rice imports, *lnrp*: Log of rice production, *lnwp*: Log of wheat production, *lnwi*: Log of wheat imports

Tests and Results: 1. Augmented Dickey-Fuller (ADF) Test: Level(P-value): It is denoted as the P value of

applying test when called on original data (without further differencing). First difference (P value): P-value when the test is applied to first differenced data - this shows how different these numbers are from previous

period's term. 2. Phillips-Perron (PP) Test: Level (P-value): This is a similar test to the ADF but uses an alternative approach to take care of serial correlation and heteroskedasticity in the errors. First difference (P-value): the same idea as ADF test.

Interpretation: Stationary at Level: Reject the null hypothesis of a unit root in case the p-value is less than some significance level (usually 0.05), so time series should be stationary at level. **Stationary at First Difference:** If the series is non-stationary at level (p-value > 0.05) but stationary after differencing once #(p < 0.05), this means it will be one order less integrated (I(1)).

Summary of Results

lncr (Log of Rice Consumption): ADF Test: ADF Test: Level- not stationary at level (p-values : 0.70, 0.92); first difference - the series is stochastic but no significant trend (p-value =); PP Test: Same results

(Non- stationary at level:p-values : 0.68, 0.71 but stationary at first difference: 0.00, 0.00

lnw (Log of Wheat Consumption): ADF Test: Mixed results at level (one case not stationary: p-value 0.33, another case stationary: p-value 0.02) but stationary at first difference (p-values: 0.00, 0.00). **PP Test:** Similar mixed results at level (not stationary: p-value 0.42, stationary: p-value 0.01), but stationary at first difference (p-values: 0.00, 0.00).

lnri (Log of Rice Imports): ADF Test: Stationary at level (p-values: 0.00, 0.00) and stationary at first difference (p-values: 0.00, 0.00). **PP Test:** Mostly stationary at level (p-values: 0.00, 0.00), and stationary at first difference (p-values: 0.01, 0.00).

lnrp (Log of Rice Production): ADF Test: Not stationary at level (p-values: 0.66, 0.17) but stationary at first difference (p-values: 0.00, 0.00). **PP Test:** Similar results (not stationary at level: p-values: 0.66, 0.16, but stationary at first difference: 0.00, 0.00).

lnwp (Log of Wheat Production): ADF Test: Mixed results at level (one case stationary: p-value 0.01, another not stationary: p-value 0.46) but stationary at

first difference (p-values: 0.00, 0.00). **PP Test:** Similar mixed results at level (stationary: p-value 0.02, not stationary: p-value 0.46), but stationary at first difference (p-values: 0.00, 0.00).

lnwi (Log of Wheat Imports): ADF Test: Not stationary at level (p-values: 0.99, 0.87) but stationary at first difference (p-values: 0.00, 0.00). **PP Test:** Similar results (not stationary at level: p-values: 0.22, 0.06, but stationary at first difference: 0.00, 0.00).

As can be seen from the table, most of the variables are non-stationary at levels but stationary in first differences (unit root tests). It means that the data series are integrated of order one, I (1). This is an important step for downstream analysis like Granger causality and Johansen cointegration tests, it proves that the data needs to be differenced in order to become stationary making your choices made later on with econometric modeling valid.

Johansen cointegration test

Johansen cointegration test it is a practice whereby the aim of determining how many distinctive (cointegrated) horizons that contains more than one time series. We interpret the results from this table as follows

Table 2: Johansen cointegration estimation results of variables Rank Test (trace)

Number of cointegration	Eigenvalue	Trace	5% Critical value	Probability Value
None *	0.640489	137.7483	95.75366	0.00
At most 1 *	0.533390	87.62076	69.81889	0.00
At most 2 *	0.362345	50.26996	47.85613	0.02
At most 3	0.259093	28.22204	29.79707	0.07
At most 4	0.205762	13.52793	15.49471	0.09
At most 5	0.044680	2.239714	3.841465	0.13

None (r = 0): Since the trace statistic (137.7483) is greater than the 5% critical value (95.75366) and the p-value is 0.00, we reject the null hypothesis of no cointegration. There is at least one cointegrating relationship among the variables.

At most 1 (r ≤ 1): Since the trace statistic (87.62076) is greater than the 5% critical value (69.81889) and the p-value is 0.00, we reject the null hypothesis of at most one cointegrating relationship. There are at least two cointegrating relationships.

At most 2 (r ≤ 2): Since the trace statistic (50.26996) is greater than the 5% critical value (47.85613) and the p-value is 0.02, we reject the null hypothesis of at most two cointegrating relationships. There are at least three cointegrating relationships.

At most 3 (r ≤ 3): Since the trace statistic (28.22204) is less than the 5% critical value (29.79707) and the p-value is 0.07, we fail to reject the null hypothesis of at most three cointegrating relationships. This suggests that there are at most three cointegrating relationships.

At most 4 (r ≤ 4): Since the trace statistic (13.52793) is less than the 5% critical value (15.49471) and the p-value is 0.09, we fail to reject the null hypothesis of at most four cointegrating relationships. This suggests that there are at most three cointegrating relationships.

At most 5 (r ≤ 5): Since the trace statistic (2.239714) is less than the 5% critical value (3.841465) and the p-value is 0.13, we fail to reject the null hypothesis of at

most five cointegrating relationships. This confirms that there are at most three cointegrating relationships.

Based on the Johansen cointegration test results, there are three cointegrating relationships among the variables. The presence of cointegration indicates that despite being non-stationary individually, the variables move together in the long run, maintaining a stable equilibrium relationship.

Granger causality test: Interpretation of the Granger causality test results is show on Table 3. Dependent Variable (y): Test the variable that you are trying to determine is affected by another variable. The independent variable (x)-the one that is being changed in order to observe the effect on your dependent variable. P-value: The level of significance at which we test whether or not our independent variable causes the dependent variable (Granger-causality). A low p-value (usually less than 0.05) suggests that the independent variable Granger-causes the dependent variable. The sign (denotes the existence and direction of causality, and the sign means does not exists causality. Incr, Incw, lnri, lnrp, lnwp and lnwi are the natural log of consumption rice, consumption wheat, rice import, rice production, wheat production and wheat import. Table 3 shows the Granger causality test results. The null hypothesis is rejected at the 5% level of significance, and the alternative hypothesis is accepted at the 5% level of significance.

Table 3: Granger causality test results of the variables

Dependent variable	Independent variable	Probability value
<i>lncw</i>	<i>lncr</i>	– 0.22
<i>lncr</i>	<i>lncw</i>	← 0.02
<i>lncr</i>	<i>lnrp</i>	← 0.00
<i>lnrp</i>	<i>lncr</i>	← 0.00
<i>lncr</i>	<i>lnwi</i>	← 0.01
<i>lnwi</i>	<i>lncr</i>	– 0.38
<i>lncw</i>	<i>lnrp</i>	– 0.22
<i>lnrp</i>	<i>lncw</i>	← 0.01
<i>lnri</i>	<i>lnrp</i>	← 0.00
<i>lnrp</i>	<i>lnri</i>	← 0.04
<i>lnrp</i>	<i>lnwi</i>	← 0.01
<i>lnwi</i>	<i>lnrp</i>	← 0.26

The first row shows consumption of rice and consumption of wheat. P-value is greater than 5%, meaning that consumption of rice does not cause consumption of wheat. But the consumption of wheat causes the consumption of rice. Because of P value is more than 5%. They have a unidirectional relationship. The second row represents rice production and rice consumption. Their P value is less than 5%. This row has a bidirectional relationship. The third row showed that rice consumption and wheat import P values were less than 5%. It means that wheat imports cause the consumption of rice. But consumption of rice does not cause wheat import. The fourth row showed that rice production does not cause rice the consumption of wheat. Because of P-value is more than 5%. But consumption of wheat causes rice production because the P value is more than 5%. In the fifth row, rice production and rice import cause each other because the P value is less than 5%. Last row represents that rice production and wheat import. Wheat import causes rice production, but rice production does not cause wheat import.

Discussion

Through application of econometric methods, including unit root tests, Granger causality tests and Johansen cointegration test the study examined short- and long-run relationships among rice-wheat production-consumption-import for Bangladesh. Findings of the research mention in all rice and wheat (production, consumption and import) are difference stationary according to the Augmented Dickey-Fuller ADF test as well Phillips-Perron PP.Test of Granger causality: There is a one-way causal relationship between rice and wheat, wheat importation, and also that with variation in the production of these two crops. Rice consumption, rice production and so on the other are complementary goods because it is a case of bidirectional relationship. Johansen Cointegration Tests: According to the results, these variables are interrelated in long-run and they move together implying that there is a long-run integrating relationships among rice & wheat production (P), consumption(C) and Import. This analysis of findings intensifies us to how these relationships could affect in current or upcoming scenario for agricultural policies or economic decisions making initiatives as a Bangladesh economy.... and the bidirectional relationship between rice consumption and production prescribe policies to

improve ROM. The demand for food should be resourced by high-yield and climate resilient varieties of rice and wheat to make investments worth their while. Modern agricultural practices including smarter farming methods, monitoring and control of pest attacks leading to Integrated Pest Management (IPM) system can help in improving yield. However, farmers need to be trained and supported in implementing these techniques. Promoting rice and wheat production along with other crops can that protect against food shortages connected to the failure of a single crop. Good crop rotation systems can make soil healthier and break the cycle of pests and diseases as part of growing your farm production in general. Implementing best management practices in water for the rice and wheat system, through improved irrigation systems (e.g., drip irrigation or sprinkler) rainwater harvesting will help improve overall water productivity. Using organic fertilizers, crop residues and green manure help maintain soil fertility which can decrease reliance on chemical inputs to improve long-term agricultural productivity. This would allow the continued growth in agriculture that is vital to meet growing needs for food and, increasingly, biofuels, especially considering investments are being made in developing resilient crop varieties such as drought-resistant rice/wheat etc. which can weather extreme temperatures keeping production stable despite climate variability. Construction of better infrastructure such as roads and storage facilities will improve their access to markets, reduce post-harvest losses and distribute rice equitably in India while avoiding wastage. In conclusion, the government can also provide with fair pricing policies and subsidize agripreneurs/speculative companies looking to foray into procurement of rice & wheat directly from Farmers at their doorstep ensuring they are paid well amount helping them continue production without fail. Agricultural extension services must be improved to help farmers grow rice and wheat more effectively by providing them with latest knowledge, techniques & support. Investing in agricultural research to develop high-yield and climate-resilient crop varieties is one of the continued practices required for food security, as well as supporting economic growth. Stable food prices and availability can be managed by designing and implementing trade policies that help in maintaining an uninterrupted supply of rice, wheat domestically as well as through imports. These include the establishment of national depots for

emergency food reserves, and distribution systems which together can reduce vulnerabilities so that risks to availability at household levels are retained only in extreme circumstances related specifically to varying degrees of limited physical access. Promoting non-agricultural sectors also helps the economy diversify, reducing economic dependence on agriculture and increasing its resilience to shocks in agriculture. Rice and wheat in Bangladesh form an asymmetric interlocking relationship with far-reaching implications for agricultural policies as well as economic decisions. Bangladesh can improve agricultural productivity, ensure food security and support sustainable economic development through inclusive economic growth if it adopts comprehensive and forward-looking strategies.

Conclusions and Recommendations

The purpose of this study was to look into exploring the interconnections between wheat and rice production, import, and consumption in Bangladesh. The production, import, and consumption of wheat and rice were the main topics of this study over the period extending from 1972 to 2022. By applying various stationary tests (Augmented Dickey-Fuller and Phillips-Perron), the Johansen cointegration test, and the Granger causality test, both attempts were made to identify the interconnections. The empirical results supported the stationary test's conclusion that there is no unit root, demonstrating particular variables that do not hold patterns and that are changed over time. Results of the Granger causality test show both unidirectional and bidirectional links. The consumption of wheat influences the consumption of rice. Rice production and rice consumption influence each other. They have a bidirectional relationship. Bangladesh's main foods are rice and wheat. Every year huge amount of rice is produced but, in our country, population are so high so that need to import other countries. The demands are so high. So, rice production and rice consumption influenced each other. Rice production does not cause wheat imports. But wheat imports cause rice production. Because of every year Bangladesh government need huge amount of wheat import than rice. The Johansen cointegration test results demonstrate the existence of long-run cointegration between the variables wheat and rice (production, import, and consumption). This study's result of the cointegration test evidenced that rice and wheat are correlated because people in Bangladesh are fond of consuming these foods. If one time consume wheat two times like to consume rice. Rice and wheat are related to each other.

Develop and promote effective crop rotation strategies to build soil health, reduce pest and disease cycles- effectively increase overall farm productivity while emphasizing the sustainability of these rotational schemes. Promotion of the use of organic fertilizers, crop residues and green manuring for sustaining soil health to minimize fertilizer application. Water-saving systems using efficient irrigation methods (e.g., drip or sprinkler irrigation) as well as rainwater harvesting, which may come additional handy when sourced in water-scarce regions. Research and development Invest Further in agricultural research to develop high yielding, climate resilient varieties. Would prefer ecological growth, comparative advantage and local adaptation.

Reducing dependence on agriculture to make the economy less vulnerable to shocks in this sector by promoting non-agricultural areas.

The foregoing discussion demonstrates a strong link between rice and wheat (production, import, and consumption). This work focuses almost exclusively on the interconnections between total production, imports, and consumption. Long-term relationships were found between the selected variables.

Policy implications

Soil and water conservation programmed: Integrated Agricultural Policy: Conceive/practice holistic policies related to production of rice, wheat sustainably minimizing wastes. Such policies should entail land tenure, credit facilities and research & development. Enforce fair pricing norms for cereals; it should also allow subsidies or supports for rice and wheat farmers so that they receive the required level of remuneration. This would promote consistent production over time. Invest in infrastructure like roads, storage facilities and effective irrigation systems the construction of better markets and road links would help farmers sell more efficiently, reduce post-harvest losses and increase the efficiency in using water. Appropriate for the development and application of agricultural production practices capable of adapting to adverse climate conditions; This will be done through the promotion of drought-tolerant rice and wheat varieties for stable food production despite climate variability. Develop and upgrade agricultural extension services to provide latest knowledge, new techniques with support on different facets of farming. Provide farmers the best practices and improve their productivity: Better extension services help in dissemination of improved technologies; a knowledge center should be established for this. Develop and enforce trade policies that guarantee the availability of rice and wheat, whether from domestic sources or imports. This would have curbed food inflation and ensured that there was enough supply of food, so the lower income people in rural areas were better off. Establish comprehensive food security programs with a mutually supporting system of emergency food reserves, distribution capabilities and nutrition interventions to mitigate against potential shortfalls in supply chains or improve the general state of food insecurity.

Limitations and Future Research

While the clear limitation of this research is that it only examines such interconnections on rice-wheat nexus and ignores all other variables which might play along these dynamics. Although it is widely accepted, the research heavily depends on historical data and those might not be enough to form clear sustainable trends or sudden market shocks. The study also looks primarily at long-term relationships, and does not focus much on short-term volatility or exogenous variables such as policy modifications, global market trends over time. Climate change issues and advances in technology are recognized but not sufficiently scrutinized to fully understand how they can reshape production, consumption patterns. For a more comprehensive understanding of the dynamics between rice and wheat production, consumption and import in Bangladesh, future research should investigate

to explore the impact of climate change on production potential/achievable of rice and wheat. This may result from investigations on the impact of temperature, precipitation and extreme weather events on crop productivity. It also examines adaptation strategies development of climate-resilient crop varieties. How has new technology changed the productivity of rice and wheat agriculture? As part of that it will include anything from the practice precision farming, using drones to monitor crop health and more advanced irrigation practices. It is important to assess the cost-effectiveness and accessibility of these technologies for smallholder farmers. Conduct long-term research on soil health and fertility practices. Future research should address the soil quality for determining organic fertilizers, crop rotation patterns and sustainable land management practices. This could be something like benefits of soil microbiomes for improving crop yield. System-wise attitudes of the production, consumption demand-supply gaps on rice wheat in view with global trade & cost dynamics; Policy analysis needs to consider how current agricultural policy is conveyed and explore different options for farmer support, as it is vital that policies are conducive of farm level stability. Understanding the demand & supply patterns of crops produced, assess production-consumption gap in case of rice & wheat. These may include studies of how the farmers' education, access to credit and land ownership patterns or labor availability affect agricultural productivity. It will also give us good insights on the questions of gender particularly in agriculture, and what challenges female farmers face. Learn about rice, wheat production and its wider implications on food security-nutrition cycle Research need to focus on the nutritional quality of various rice and wheat trading varieties in fulfilling dietary intake of the population. In addition, the paper further noted that it is imperative to evaluate effects of agricultural practices on food safety and prevalence land in what cause diseases.

Food-borne. This session will take a deep dive into the environmental externalities of rice and wheat agriculture, covering water use efficiency practices in terms of crop productivity looking at various case studies around major GM commercialized traits; greenhouse gas emissions due to agricultural input (fertilizer application) use patterns, possible adaptations towards less emission intensive methods without affecting food production; biodiversity loss predictions with land use cover change modelling under sustainable development growth scenarios. Our research should be geared toward producing more sustainable agricultural practices that limit environmental degradation yet provide high productivity. The issues discussed in the present study shall help formulate aspects of future research that further examine the determinants of rice and wheat production (and consumption) for development purposes within Bangladesh. This would be useful in the planning of workable policies and strategies for sustenance, not only to guarantee progress on sustainable agricultural development but also toward food security in Bangladesh.

Acknowledgement

I would like to express my sincere gratitude to my colleagues, whose invaluable insights, support, and collaboration were instrumental in the successful completion of this research. Their dedication and thoughtful contributions greatly enhanced the quality of this work. The co-author Ahsan Habib is grateful to the Institute of Research and Training (IRT) of Hajee Mohammad Danesh Science and Technology University (HSTU) for providing the financial support necessary for this project.

Conflict of Interest

None of the authors present any conflicts of interest.

References

- Alam, M. J., Buysse, J., McKenzie, A. M., Begum, I. A., Wailes, E. J., & Van Huylenbroeck, G. (2012). The dynamic relationships between world and domestic prices of rice under the regime of Agricultural Trade Liberalization in Bangladesh. *Journal of the Asia Pacific Economy*, 17(1), 113–126. <https://doi.org/10.1080/13547860.2012.640010>
- Alam, M. S., & Islam, M. A. (2013). Long-term assessment of rice production scenario in Bangladesh: A Macro Dynamics. *Bangladesh Journal of Agricultural Research*, 38(2), 257–269. <https://doi.org/10.3329/bjar.v38i2.15889>
- Baffes, J., & Gautam, M. (2001). Assessing the sustainability of rice production growth in Bangladesh. *Food Policy*, 26(5), 515–542. [https://doi.org/10.1016/s0306-9192\(01\)00019-7](https://doi.org/10.1016/s0306-9192(01)00019-7)
- Dickey, D. A., & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49(4), 1057. <https://doi.org/10.2307/1912517>
- Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, 37(3), 424. <https://doi.org/10.2307/1912791>
- Hossain, A., & Silva, J. A. (2013). Wheat and rice, the epicenter of food security in Bangladesh, 35(2).
- Johansen, S. (1988). Statistical Analysis of Cointegration vectors. *Journal of Economic Dynamics and Control*, 12(2-3), 231–254. [https://doi.org/10.1016/0165-1889\(88\)90041-3](https://doi.org/10.1016/0165-1889(88)90041-3)
- Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root. *Journal of Econometrics*, 54(1-3), 159–178. [https://doi.org/10.1016/0304-4076\(92\)90104-y](https://doi.org/10.1016/0304-4076(92)90104-y)
- Morris, M., Chowdhury, N., & Meisner, C. (1996). Economics of wheat production in Bangladesh. *Food Policy*, 21(6), 541–560. [https://doi.org/10.1016/0306-9192\(96\)00023-1](https://doi.org/10.1016/0306-9192(96)00023-1)
- Mottaleb, K. A., & Mishra, A. (2016). Rice consumption and grain-type preference by household: A bangladesh case. *Journal of Agricultural and Applied Economics*, 48(3), 298–319. <https://doi.org/10.1017/aae.2016.18>
- Mottaleb, K. A., Rahut, D. B., Kruseman, G., & Erenstein, O. (2018). Wheat production and consumption dynamics in an Asian Rice Economy: The bangladesh case. *The European Journal of Development Research*, 30(2), 252–275. <https://doi.org/10.1057/s41287-017-0096-1>
- Rahman, S., & Hasan, M. K. (2014). Energy productivity and efficiency of wheat farming in Bangladesh. *Energy*, 66, 107–114. <https://doi.org/10.1016/j.energy.2013.12.070>
- Tama, R. A., Dhar, A. R., & Begum, I. A. (2018). An economic perspective of the export potentiality of aromatic rice in Bangladesh. *American Journal of Economics and Business Administration*, 10(1), 22–30. <https://doi.org/10.3844/ajebasp.2018.22.3>