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DOES COBWEB PHENOMENON EXIST IN RICE MARKET OF PAKISTAN? A TIME SERIES ANALYSIS

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ABSTRACT

This study investigates the rice price dynamics and their impacts on demand and supply over the time in agricultural markets of Pakistan. Time series data on production and prices for the period 1984-2018 were used to study the cobweb phenomenon in local rice markets. Linear demand and supply models were used to examine the unstable rice-market. Price dynamics were examined through identifying the time path of difference equation derived from demand and supply functions. The results inferred that market prices of rice have remained unstable in agricultural markets of Pakistan over the history. Furthermore, rice prices exhibited damped oscillations towards stable market equilibrium over last three decades in Pakistan. It is suggested that the government may respond promptly to the instability of rice markets by formulating the appropriate agricultural policies, developing state-of-the-art storage facilities and ensuring the steady transmission of market information across the national as well as international rice markets. The study provides deep insights into understanding the on-going and future trends of price fluctuations with respect to demand and supply shocks in rice market of Pakistan. It would greatly help the stakeholders and policy makers in forecasting and stabilizing the rice markets, and alleviating the food insecurity.

Keywords: cobweb model; rice; demand; supply; price fluctuations

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INTRODUCTION

Rice is an important cereal crop which supports a large population of the world as a staple food (Greenland, 1997; Maclean *et al.,* 2002). The geographical, ecological and climatic conditions of many countries support the rice production. Particularly in Asian region, nutrients-rich and fertile lands in addition to the high monsoon rainfalls produce favourable environment for rice crop (Khan *et al.,* 2019). Rice is extensively grown in certain areas of Pakistan which include the fertile lands of Punjab, Sindh and Baluchistan, where large number of famers rely on rice cultivation for their livelihoods.

According to Food and Agricultural Organization (FAO), the global paddy production and yield per hectare have significantly increased over the past decade. The total rice area over the world has also increased but it experienced large fluctuations over the years as shown in Fig. 1. According to the estimates of FAO, China, India, Indonesia, Bangladesh and Vietnam collectively contribute more than 70% to the global rice production of about 755 million tons (Table 1). In 2019, Pakistan produced about 11.1 million tonnes of paddy and secured 9th position in top ten rice producing countries (Anonymous, 2019; FAO, 2019).

Huong *et al.* (2017) and Khan *et al.* (2019) reported that the unstable market conditions pose a number of challenges to the agricultural markets, especially of small producers. Therefore, it is imperative for Pakistan – a predominantly agrarian economy – to respond promptly to the unstable market conditions by devising and adjusting its agricultural policies (Khan *et al.,* 2019). At present, the policy reaction has become more crucial in the wake of global price hikes due to the outbreak and prevalence of Covid-19.

In developing countries, price instability has significant impact on the human development indicators such as health (Jensen, 2000), economic growth (Myers, 2006), food security (Mitra and Boussard, 2012) and welfare of people (Chaudhry and Miranda, 2017). However, controlling the price fluctuations has been a matter of great concern over the time for policy makers. Understanding the mechanism and causes of price instability is quite imperative for market stabilization.

The dynamics of price instability have been divided in two major categories: the exogenous factors which may include the weather shocks and any other causal agent outside the economic settings (Williams, 1936; Gustafson, 1958; Scheinkman and Schechtman, 1983; Deaton and Laroque, 1992, 1996); and the endogenous factors which are the erroneous expectations of the suppliers regarding the future prices which perturb the supply (Ezekiel, 1938; Finkenstädt and Kuhbier, 1992; Boussard, 1996; Hommes, 1998; Athanasiou *et al.*, 2008). Particularly, Scheinkman and Schechtman (1983) have comprehensively discussed the exogenous factors disturbing the supply.

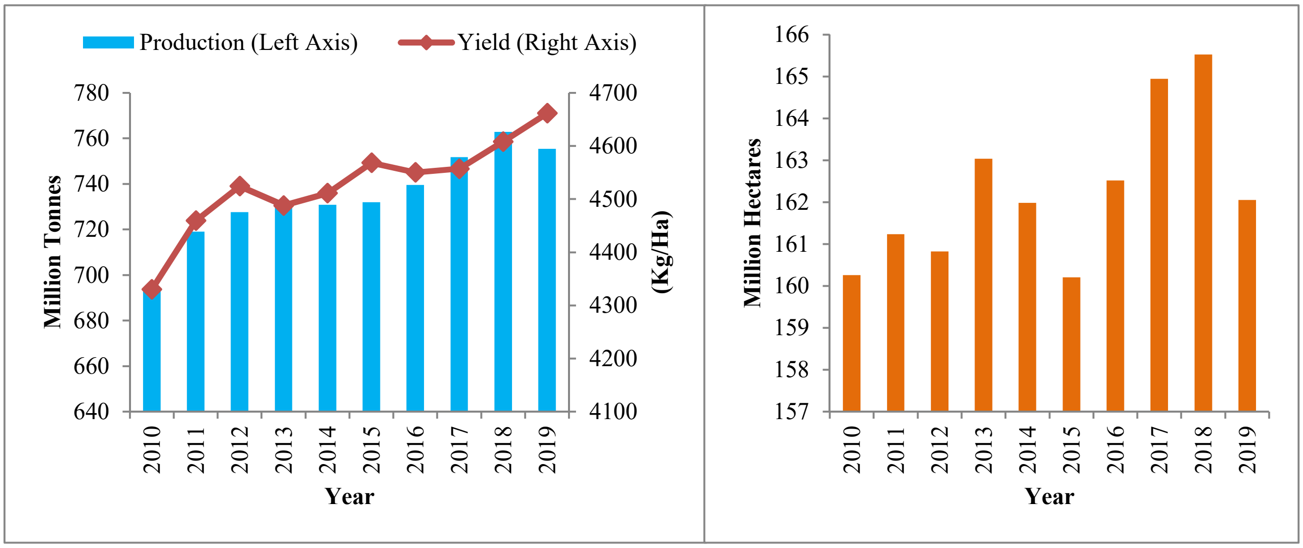

Fig. 1. Global paddy production, average yield (left panel) and area harvested (right panel)
***Source: Food and Agricultural Organization Statistics* (FAO, 2019)**

Table 1. Paddy area, production and price in major world producers for the year 2019

Country	Area (Million Ha)	Production (Million Tonnes)	Productivity (Kg/Ha)	Producer Price Index (2014-2016 = 100)
China	29.96	211.41	7056.2	100.3
India	43.78	177.65	4057.7	109.8
Indonesia	10.68	54.60	5113.7	58.0
Bangladesh	11.52	54.59	4739.8	101.2
Viet Nam	7.47	43.45	5816.5	102.6
Thailand	9.72	28.36	2918.8	119.0
Myanmar	6.92	26.27	3795.7	92.0
Philippines	4.65	18.81	4044.9	111.6
Pakistan	3.03	11.12	3663.7	60.4
Cambodia	3.00	10.89	3627.1	-
Japan	1.54	10.53	6826.8	122.9
Brazil	1.71	10.37	6063.3	122.9

Source: Food and Agricultural Organization Statistics (FAO, 2019)

An inelastic or steeper demand augments the price instability in a market (Chaudhry and Miranda, 2017). Under the exogenous explanation, a number of policy measures including insurance schemes, stockpiling and widening the markets are effective tools to mitigate price volatility. In the endogenous case, in contrast, government intervenes through production quotas and supply management to stabilize the prices. In agriculture sector, the supply decisions of the farmers depend on the expected future prices of the produce (Anokye *et al.*, 2014). Therefore, the knowledge of price dynamics of rice will enable the farmers to take informed decisions for sowing the crop in the coming season (White and Dawson, 2005).

To illustrate the price dynamics in the sense of endogenity, Ezekiel (1938) presented cobweb model which explains that the fluctuations primarily arise due to the erroneous expectations of the farmers which cause the under- or over-supply. The cobweb model (Ezekiel, 1938; Nerlove, 1958) is an economic model which explains why prices might be subject to periodic fluctuations in certain types of markets. It explains recurrent demand and supply in a market where the quantity to be produced must be chosen before prices are observed.

The demand and supply curves are non-linear in more realistic economic models. Nonlinearities are generated endogenously due to the trade-off among various expectation regimes in the conventional cobweb model, which leads to chaos (Chaudhry and Miranda, 2017). The literature on chaotic cobweb models primarily focused on the effect of nonlinearity on cobweb model because nonlinearity is necessary but not a sufficient condition for chaos. Jensen and Urban (1984) and Chiarella (1988) studied chaotic dynamics in a cobweb model with nonlinear supply and linear demand functions. Finkenstädt (1995) penned a book on nonlinear dynamics in economics with respect to agricultural markets and discussed demand and supply functions. Hommes (1991) studied linear demand and nonlinear supply models. Ma and Mu (2007) framed a cobweb theory based on real estate nonlinear model, where the demand and supply are quadratic functions.

This paper examines the price dynamics of rice in the Pakistan using cobweb model. It investigates whether the rice market of Pakistan exhibits the cobweb phenomenon. This study will be worthwhile to the stakeholders and policy makers in stabilizing the market prices and ensuring the food security.

MATERIALS AND METHODS

Study Area: The study was conducted in Pakistan, the 5th most populous country of the world with more than 215 million population. The area of Pakistan is 796096 square-km which is bordered by India to the east, Afghanistan to the west, Iran to the southeast and China to the northeast. Rice is an important staple food as well as cash crop of Pakistan, which largely contributes to the exports volume of the country. According to the recent estimates, rice has been grown on an area of 3335 thousand hectares in Pakistan which accounts for more than 14% of total cultivated area (Anonymous, 2021).

Data: To achieve the research objectives, time series data were used which included historical average prices and production of rice in Pakistan. The required data for a period of 35 years (1984-2018) were retrieved from the statistical supplements issued by the Ministry of Finance, Pakistan, various issues of Pakistan Economic Surveys and the official website of Agricultural Marketing Information Services (AMIS) Pakistan. In addition, the data on global rice production, prices and average yield was also collected from FAO (2019). The nature and properties of data were carefully examined prior to the analysis. The data on rice production was found stationary at level, whereas, price series was stationary at first difference. So, the price series was used in transformed form i.e., as the first differenced series to avoid the unit root problem.

Methods

Cobweb Model: Cobweb model explains that the price fluctuations primarily arise due to the erroneous expectations of the farmers which cause the under- or over-supply (Ezekiel, 1938; Nerlove, 1958). It explains recurrent demand and supply in a market where the quantity to be produced must be chosen before prices are observed. The cobweb model has been constructed under the naïve expectations hypothesis to derive time-delay difference equation characterized by the price fluctuations in rice market (Chaudhry and Miranda, 2017). It is assumed that there is an economic system with a single commodity. The cobweb model employs the supply and demand functions of price curves to determine the change in price P_k at time k from the price P_{k-1} at time k-1. This study follows the methods of Anokye and Oduro (2013), Anokye *et al.* (2014) and Khan *et al.* (2019) to develop the cobweb model. The Market Clearing Equation (MCE) is the first order non-homogeneous difference equation which describes this process (Nicholson, 1972). Given an initial price P_{k-1}, the market responds at time k with a quantity D_k determined by the supply curve S_k. Therefore, market demand determines the current price P_k. Linear demand and supply curves are given as:

$$D_k = \alpha - \beta P_k \quad \dots\dots\dots\dots (1)$$

$$S_k = \delta + \gamma P_{k-1} \quad \dots\dots\dots\dots (2)$$

where α represents intercept while β represents the slope for the demand function, and also δ and γ respectively represent the intercept and slope of the supply function.

At the MCE, $D_k = S_k$ which implies that,

$$P_k = -\frac{\gamma}{\beta} P_{k-1} + \frac{\alpha - \delta}{\beta} \quad \dots\dots\dots\dots (3)$$

Assuming $A = -\frac{\gamma}{\beta}$ and $B = \frac{\alpha-\delta}{\beta}$, the equation (3) can be written as:

$$P_k = AP_{k-1} + B \quad \dots\dots\dots\dots (4)$$

Solving the of difference equation (4), we get:

$$P_k = A^k P_0 + B\left(\frac{1 - A^k}{1 - A}\right) \quad \dots\dots\dots\dots (5)$$

where, $A \neq 1$ and k = 0,1,2, … …

Equation (5) can be transformed by putting the values of A & B as:

$$P_k = \frac{\alpha - \delta}{\beta + \gamma} + \left\{P_0 - \left(\frac{\alpha - \delta}{\beta + \gamma}\right)\right\}\left(-\frac{\gamma}{\beta}\right)^k \quad \dots\dots (6)$$

In equation (6), the term $(-\gamma/\beta)^k$ is very important as it explains the time path of difference equation. There are three conditional explanations for absolute value of the term $(-\gamma/\beta)$ regarding price dynamics:

i) If $\left|-\frac{\gamma}{\beta}\right| < 1$, there are damped or convergent oscillations in prices towards stable equilibrium (Fig**. 2**).

ii) If $\left|-\frac{\gamma}{\beta}\right| = 1$, there are continuous price fluctuations i.e., price oscillates in period-2 cycle, also called "hog cycle".

iii) If $\left|-\frac{\gamma}{\beta}\right| > 1$, there are exploding or divergent oscillations and the prices will move away from the equilibrium level (Fig**. 2**).

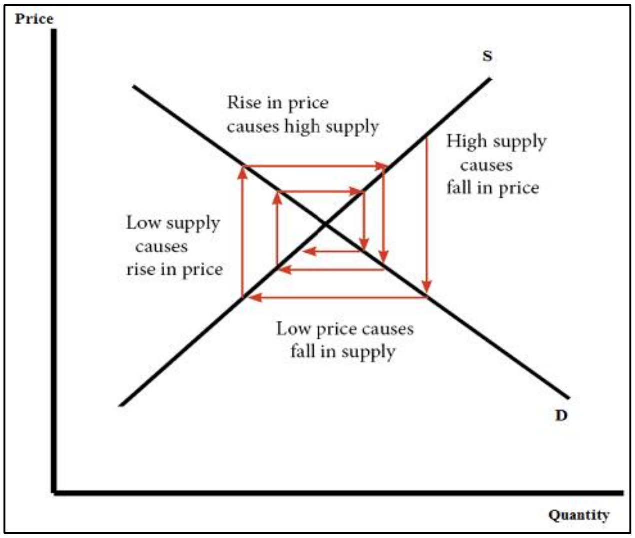

Fig. 2. Convergent Oscillations

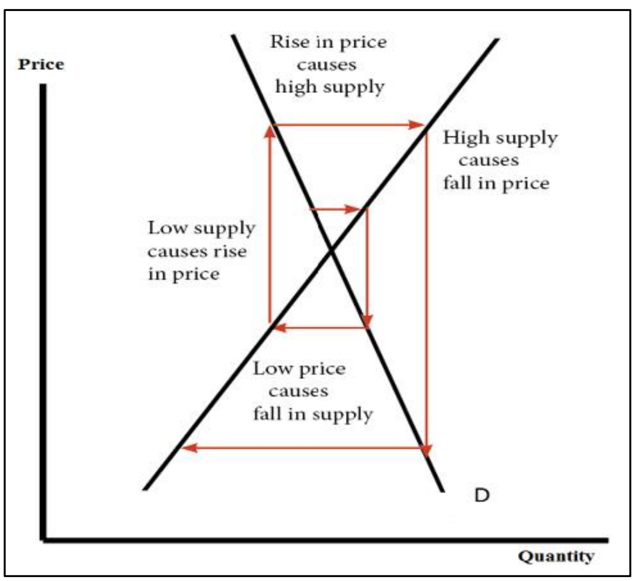

Fig. 3. Divergent Oscillations

Time series data may encounter number of problems including small sample size, non-stationarity (or unit root), autocorrelation and endogeniety etc. The stationarity was checked through Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests. In the primitive demand and supply functions as given in Equation 1 & 2, the Durbin Watson (DW) statistic was about 1.23 which showed the existence of endogenity problem. Lagged dependent variable has been included in models to redress the endogenity and autocorrelation problems. The demand and supply functions with lagged dependent variables are given as:

$$D_k = \alpha - \beta P_k + \vartheta \ {}_{k-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$S_k = \delta + \gamma P_{k-1} + \rho S_{k-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

where ϑ and ρ are the parameters of lagged dependent variables.

RESULTS AND DISCUSSION

Autocorrelation and Stationarity Diagnosis: Autocorrelation was tested through DW test with and without incorporating the lagged dependent variable as predictor. In former case, DW-test statistic was 2.66 (with p-value 0.97) & 2.61 (with p-value 0.96) for demand and supply functions, respectively, which implies that the problems of autocorrelation and endogeniety were resolved by use of lagged dependent variable in both demand and supply models.

Time series data often contains the problem of non-stationarity. So, we employed the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests to detect the stationarity in data. The data of production was found to be stationary at level, whereas price series was stationary at first difference. The results of unit root test are presented in

Table **2**.

The graphical presentation of production and price data is given in Fig. 3. Production and price both series are clearly showing an upward trend. The variance of price series has increased with the passage of time, so

it is found non-stationary at level. There are significant fluctuations in production and prices of rice in Pakistan over the time.

Descriptive Summary: Table 3 presents the descriptive statistics of the variables used in cobweb model of rice. From 1984 to 2018, the minimum, average and maximum production of rice in Pakistan was 2919, 4873 and 7202 metric tonnes, respectively. Similarly, minimum, average and maximum prices per kilogram of rice were Rs. 5.88, Rs. 42.91 and Rs. 124.22, respectively.

Demand and Supply Functions: The cobweb model has been constructed under the naïve expectations hypothesis to derive time-delay difference equation characterized by the price fluctuations in rice market. The results of demand and supply functions are presented in

Table **4**. The signs of parameters are according to the expectations. In both models, the coefficients of price are insignificant, whereas those of lagged dependent variable are significant. The later reveals the existence of endogenity in model. The signs of estimated parameters are consistent with literature (Anokye and Oduro*,* 2013; Anokye *et al.,* 2014; Khan *et al.,* 2019).

Table 2. ADF and PP Unit Root Test Results.

Time Series	ADF Test Statistic	p-value	PP Test Statistic	p-value	Result
Production	-3.743	0.036	-26.995	0.010	Stationary
Price	-1.186	0.889	-4.629	0.8384	Non-Stationary
Diff(Price,1)	-4.088	0.018	-41.857	0.01	Stationary

Note: Alternative hypothesis: Stationary. *Source: Author's own calculations*

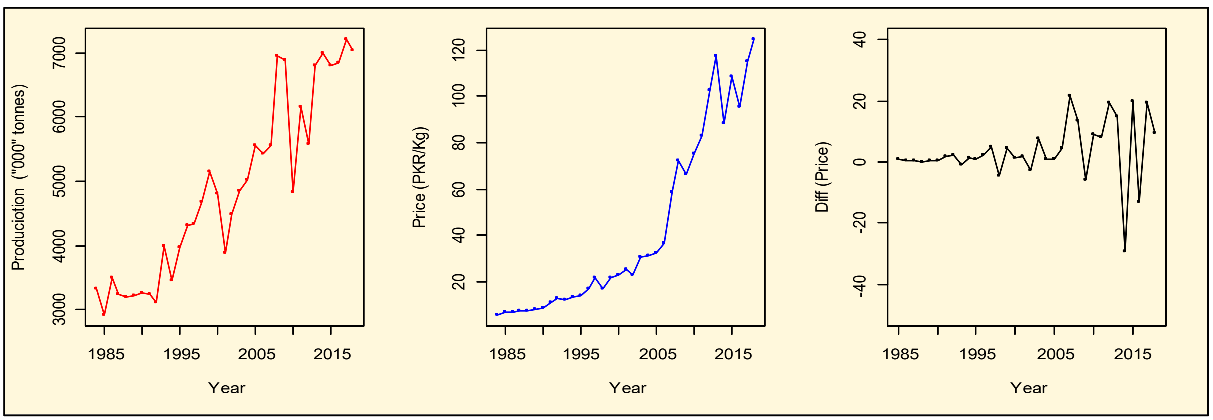

Fig. 3. Graphical illustration of production and prices of rice in Pakistan (1984-2018)

Table 3. Descriptive Statistics of Rice Data in Pakistan (1984-2018).

Variable	Minimum	Mean	Maximum	Std. Deviation
Production ('000' Tonnes)	2919	4873	7202	38.861
Price (PKR Per Kg)	5.88	42.91	124.22	1414.527

Source: Pakistan Economic Survey: Various issues

Table 4. Results of Demand & Supply Functions for Agricultural Markets of Pakistan.

Variable	Units	Demand of Rice	Supply of Rice
Intercept	('000' Tonnes)	316.69 (423.39)	503.52 (406.253)
Diff(1)_$Price_k$	PKR per Kg	-17.512 (11.923)	-
Diff(1)_$Price_{k-1}$	PKR per Kg	-	2.652 (11.717)
$Production_{k-1}$	('000' Tonnes)	0.923^{***} (0.084)	0.873^{***} (0.081)
Adjusted R^2		0.7922	0.7849
F-Statistic		61.98^{***}	61.19^{***}
No of observations		34 [1984-2018]	34 [1984-2018]
DW-Statistic		2.66	2.61

Note: S.E reported after the coefficients in parenthesis. Significance Codes: '***' = 0.01 '**' = 0.05 '*' = 0.1

The resultant demand and supply functions are given in equation 9 and 10, respectively.

$D_k = 316.69 - 17.512\, P_k + 0.923\, D_{k-1}$ (9)

$S_k = 503.52 + 2.652\, P_{k-1} + 0.873\, S_{k-1}$ (10)

From Equations 9 and 10, we have $\beta = 17.512$ whereas $\gamma = 2.652$. Hence, we have the ratio $\left|-\frac{\gamma}{\beta}\right| = 0.151$ that is less than one.

The slope of supply function is smaller than that of demand function. The time path analysis of difference equation suggests the existence of cobweb phenomenon in the rice market of Pakistan. The resultant ratio $\left|-\frac{\gamma}{\beta}\right| < 1$ detects the damped or convergent oscillations in rice prices towards the stable equilibrium level. The presence of convergent price oscillations in Pakistan's rice market is in contrast to the divergent oscillations in Ghana's tomato market (Anokye and Oduro*,* 2013) and maize market (Anokye *et al.,* 2014). The possible reasons of contradictory results are the distinct characteristics of agricultural markets in terms of difference among the countries, crops, marketing structures and systems.

Pakistan's rice market has been improved to an extent over the time in terms of facilities, structure, information transmission system and equilibrium attainment. However, a number of shortcomings still exist in rice market which need attention of the concerned government bodies and policy makers. The peculiar characteristics of agricultural markets such as bulkiness, varietal differences, dispersed production, processing requirements and seasonality lead to the complicated marketing system and ultimately the market prices of farm commodities remain unstable. In general, farmers dispose-off their farm commodities in raw form immediately after harvesting without processing and therefore, many intermediaries are involved between the producer and the end consumer.

It is crucial to take certain measures to mitigate the fluctuations in rice prices and supply shocks in Pakistan's agricultural markets. Anokye and Oduro (2013) analysed Ghana's tomato market and found that the appropriate storage facilities can help stabilizing the prices. Promoting the private sector trade of agricultural products can also increase the price stability (Dorosh and Salam*,* 2008). Swift price transmission and efficient market integration – both horizontal and vertical – can increase the speed of price adjustments in agricultural markets (Zafar *et al.,* 2020). The price and supply shocks may be buffered by adopting suitable policies, promoting trade facilities, developing appropriate market structure especially storage facilities and improving the market information system in rice market of Pakistan.

Conclusion and Policy Suggestions: Rice is an important cereal crop of Pakistan. Unstable market conditions raise many challenges for small growers. This paper attempted to study the price dynamics of rice in Pakistan using the cobweb model. The official estimates revealed that rice price have fluctuated between a minimum level of Rs. 5.88 per kg and a maximum level of Rs. 124.22 per kg during the period 1984-2018. The study concludes that cobweb phenomenon exists in local rice market of Pakistan. However, price fluctuations are convergent towards stable equilibrium in rice market of Pakistan over the past three decades. To minimize the price and supply shocks, it is suggested as policy measures that the government may respond promptly to the instability of rice markets through formulating the appropriate agricultural policies, developing advanced storage facilities and improving the market information system for steady transmission of market information across the national as well as international rice markets. This study provides useful insights into understanding the dynamics and performance of local rice markets which will be worthwhile to the stakeholders and policy makers in respect of forecasting and stabilizing the market prices, and alleviating the food insecurity.

Conflicts of Interest: The authors declare no conflict of interest.

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