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Rice producers' behavior towards unpredictable price and ambient temperature changes: Analysis with ARCH and SUR for the major agricultural regions in the Philippines

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Abstract

The study has investigated the behavior of rice prices and mean temperature levels in Central Luzon, CALABARZON, Cagayan Valley, Ilocos Region, Western Visayas and Northern Mindanao, which are the major rice producing areas in the Philippines. ARCH is used to analyze the changes of these variables to determine whether these changes can pose risks through their volatilities to the rice producers. SUR is used to determine through supply response estimations the influence of which on rice production in the said areas of the country. Results of the study indicate that rice prices and mean temperature levels in the concerned areas have volatile changes, which can augment the risks faced by rice producers in the country. But the volatile changes and risks posed by these variables are found not to affect rice production in the said areas. This finding may be attributed to the programs of the Philippine government for the improvement of the rice industry for increased efficiency. Sustained efforts of the government and other entities for the development of rice industry in the country may enable it to gain competitiveness particularly in the global market.

Keywords: ARC; SUR; volatility; supply response and risks

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1. Introduction

Rice is a staple commodity and a pivotal political commodity since the Commonwealth period in the Philippines (Intal and Garcia, 2005). The Asian Development Bank (ADB) has quoted it as a critical item since it constitutes 34% of the food expenditure of the bottom 20% of households in the country. Daily, rice is consumed in quantities reported to be more than 30 thousand metric tons. An increase in the price of rice is said to result to workers demanding wage increases throughout the nation. Essentially, this has merited the importance of stabilizing rice market conditions, particularly its prices, supply and demand to avoid unfavorable disruptions, comprising of street protests that could affect the conduct of business in the major commercial districts of the Philippines (Senate Economic Planning Office, 2010).

However, volatile conditions could not warrant the certainty of insulating rice markets in the Philippines by merely increasing production to remain stable. Commodity prices fluctuate naturally and weather conditions are beyond human control, thus, rice markets have to deal with volatile elements as efficiently as possible. Particularly, fluctuating prices are considered crucial in market analysis because they affect the decisions made by producers and consumers (Bernard et al., 2006). Price volatility translates to significant price risks that complicate established agribusiness practices (Rezitis and Stavropoulos, 2009 and Mark et al., 2008 as cited by Karali and Power, 2009). Nam Tran et al. (2012) has reported price volatility and increased variability in crop yields as among the effects to watch out under climate variability, which can be detrimental to market welfare since volatile consequences could disrupt commodity markets on a considerable scale by confounding the bases for decision-making (Spargoli and Zagaglia, 2007; Kargbo, 2009; Du et al., 2009).

In this study, the prices of rice are evaluated to detect the presence of volatile behavior through an autoregressive conditionally heteroscedastic approach (ARCH). ARCH is originally a popular technique for monitoring the volatilities of financial variables for highly speculative transactions in financial markets, but it has found its way into agricultural market analysis in recent years for cases involving risk estimations in time series. Similar approach has been applied as well in determining the behavior of ambient temperature changes over time, because it can generate values of expected variance (volatility estimates) that could be analyzed later with the response of rice production in the country. The use of the said approach for this study has been based on the research works of Rezitis and Stavropoulos (2009) and Jordaan et al. (2007), which had estimated the pattern of fluctuations in agricultural markets and had analyzed the responses of agricultural markets to such pattern for policy actions.

The same framework is used in this study, but the analysis has been extended to cover the effects of temperature changes as basis for climate-change-related policies. The inclusion of ambient temperature in the study may serve as a proxy variable to the effect of climate change in rice production. Its incorporation in the supply response model for rice could tell the producers' general response to its changes, which is vital in defining the courses of action for increased resilience and adaptation to climate change among the rice producers in the country. Nam Tran et al. (2012) has recently formulated a model that has combined the estimation of the effects of price volatility and climate change to production, which could estimate losses through simulations when volatility in prices and climate change are heightened. The interest of this study is on producer's response when risks due to the changing prices and temperature are being confronted. Thus, this research focuses on analyzing the behavior of the rice producers towards changes in temperature and prices in the major agricultural areas in the Philippines to determine the policies relevant to building the resilience and efficiency of the rice industry in the country, besides sustaining efforts towards global competitiveness.

2. Review of related literature

Interests on volatile factors are given by the fact that it can influence subsequent actions and that agricultural economists have started to notice the importance of investigating risk aversion in commodity markets (Rezitis and Stavropoulos, 2009).The literatures related to the said topic have been reviewed herein. The analysis of Oktaviani et al. (2011) has produced results that have inferences on rice production in Indonesia. IMPACT model has been used in the analysis, which is a partial equilibrium model of the agricultural sector, representing a competitive agricultural market for crops and livestock. The model has shown that with food price shocks, negative impacts from climate change would heighten. Climate change scenario formulation is carried out in technical simulations utilizing the global circulation model (GCM) datasets, consisting of precipitation, maximum daily temperature and minimum air temperature. The inclusion of temperature data in the model is due to the fact that these data are sufficiently and publicly available.

The monitoring and utilization of temperature in productivity studies has been also noted in the case of managing and sharing the risk of drought in Australia. Hertzler et al. (2006, p. 5) have reported that "most climate models forecast warmer conditions across Australia with the implication that dairy and beef cattle will experience even greater heat stress, causing greater mortality and limitations on productivity."Their report has also pointed out that agricultural decision-making in the same country is done under a situation of high uncertainty because of risks associated with increased temperature. Since farm resources are usually allocated and determined prior to having known yields and product prices, farmers have to allocate these resources every season based on their expectations on yields and prices (Anderson, 2003 as cited by Hertzler, Kingwell, Crean and Carter, 2006). As such, the accuracy of forming expectations has bearing on how the said resources would be used efficiently, which has repercussions on the amount of farm income to be generated (Hertzler et al., 2006).

Studies using temperature changes in relation to agricultural productivity have been increasing through the years due to the impacts of climate change and these can be found in the works of Thurlow et al. (2011), Dono et al. (2012), Cunha et al. (2012), Ringler et al. (2010), Hertel and Rosch (2010) and Deressa (2008) for the recent period, where the analysis through temperature changes are intertwined with the concept of evapotranspiration. FAO (2013) has stated that "evapotranspiration (ET) is a concept that refers to the combination of evaporation and transpiration processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration." Air temperature is among the principal weather parameters that affect evapotranspiration, according to FAO (2013). Thus, in this study, the volatility of ambient temperature would have to be understood as referring to the degree at which changes of temperature can become difficult to predict. As stated in the report of Krechowicz et al. (2010), the most financially material impacts of climate change and water scarcity are increased agricultural input prices and increased processing costs. Food commodity prices are particularly sensitive to the shocks induced by unpredictable extreme weather conditions, while animal yields are put at risk when water temperature is increased and access to clean water supplies becomes limited, according to Krechowicz et al. (2010).

On the other hand, studies on price volatility have likewise spiraled, because of the importance of forming price expectations in agricultural commodity markets (Rezitis and Stavropoulos, 2009). The ability to forecast accurately the prices of commodities greatly matters in policy and business circles (Bernard et al., 2006). Volatile movements in prices are associated with risks and uncertainties (Rezitis and Stavropoulos, 2009; Jordaan et al., 2007 and Rezitis, 2003 as cited by Balanay, 2011). As reported by Kargbo (2005), highly volatile prices are a deterrent to agricultural productivity, which tend to intensify inflationary pressures. Such prices can increase the uncertainty faced by farmers and agribusiness firms, which affect farmer's investment decisions and have serious ramifications on the growing farm debt, decreasing farm income and productivity. Volatile movements have been captured for analysis in several models in several studies already. Examples of which is the use of threshold autoregressive (TAR) models in the study of Ramirez (2009) where the model specification has allowed two different autocorrelation regimes depending on the value of the error terms; partial equilibrium and time series WEMAC 2.0 model in the study of Benjamin et al. (2009), and stochastic volatility models and Bayesian Markov Chain Monte Carlo methods in the study of Du et al. (2009).

However, for researches which deal with expectations in the empirical analysis of risks in commodity markets, autoregressive conditionally heteroscedastic (ARCH) has been preferred as in the studies of Aradhyula and Holt (as cited by Rezitis and Stavropoulos, 2009), Rezitis (2003), Rezitis and Stavropoulos (2009) and Bekkerman and Pelletier (2009). These studies have generated the evidence of price volatility as an important risk factor in supply response functions. Particularly, ARCH or generalized ARCH (GARCH) is used to estimate price uncertainty in the Greek broiler market, and quadratic NAGARCH model to capture better the producer's price volatility in the Greek pork sector in the study of Rezitis and Stavropoulos (2009). In view of the aforementioned studies, this research is founded on the estimation procedures and analytical procedures used by Rezitis and Stavropoulos (2009) with double expected variances (volatilities of prices and temperature levels) to determine the behavior of rice producers toward the changes in rice prices and temperature levels in the major rice-producing areas of the Philippines.

3. Data and model specification

The data used in this study are comprised of the monthly retail prices of rice, quarterly supply of rice in the major rice-producing regions or areas in the Philippines, monthly retail prices of corn and climate data consisting of monthly mean temperature and rainfall amount in similar areas. The time period covered in these data is 1994 to 2011. The major rice-producing regions or areas are identified from the supply data by region. Except for the climate data, all these data are taken from the Bureau of Agricultural Statistics (BAS) of the Department of Agriculture (DA) through its online information service at Countrystat website. The data on mean temperature and rainfall amount are obtained from the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) of the Department of Science and Technology (DOST). However, for the price data, monthly consumer price indices (CPI) have been used to deflate these prices before using them in the analysis. These CPI values are taken from the online information facility of the National Statistical Coordination Board (NSCB). The major rice-producing areas of the Philippines whose supply responses are analyzed in this study are Central Luzon, CALABARZON, Cagayan Valley, Ilocos Region, Western Visayas and Northern Mindanao (BAS, 2012).

The analytical foundation of this research is adopted from the work of Rezitis and Stavropoulos (2009) where the Greek meat market has been evaluated for its response to volatility. For this study, a simple autoregressive conditionally heteroscedastic (ARCH) approach is applied whose basic functional form is as follows:

$$P_t \mid \Omega_{t-1} = c_0 + \sum_{i=1}^{n} c_i P_{t-i} + \varepsilon_{2t} \quad (1)$$

$$h_t = b_0 + \sum_{i=1}^{q} b_{1i}\varepsilon_{2t-i}^2 + \sum_{i=1}^{p} b_{2i}h_{t-i} \quad (2)$$

$$\varepsilon_{2t}|\Omega_{t-1} \sim N(0,h_t)$$

where $b_0 > 0, b_{1i} \geq 0\ i = 1,\dots,q, b_{2i} \geq 0\ i = 1,\dots,p, \sum b_{1i} + \sum b_{2i} < 1$.

The ARCH (Engle, 1982) makes the conditional variance h_t to depend on past volatility measured as a linear function of past errors, ε_{2t} while leaving unconditional variance constant. In Equation 1, ε_{2t} is a discrete time stochastic error, and Ω_{t-1} is the information set of all past states up to the time t−1. In Equation 2 (GARCH conditional variance equation), h_t is the conditional variance specified as a linear function of p lagged squared residuals and its own q lagged conditional variances. The variance is expected to be positive, and so are the coefficients b_0, b_{1i} and b_{2i}. The stationarity also of the variance is preserved by the restriction $\sum b_{1i} + \sum b_{2i} < 1$. The predictions of $P_t^e$and h_t are to be generated by the ARCH/GARCH model, which could be used in estimating the supply response function (Rezitis and Stavropoulos, 2009). The deflated retail prices of rice by region would be evaluated with Equation 1 and the generated errors from Equation 1 would be auto regressively analyzed with Equation 2. The same process is used in analyzing the behavior of the mean temperature and the predictability of its changes over the period of 1994 to 2011.

Estimates of Equations 1 and 2 are integrated in the supply response functions of the major rice-producing areas of the country, which have been analyzed through a seemingly-unrelated regression (SUR) due to the simultaneous analysis of these supply functions. The specification of the supply response for each area is as follows:

$$QP_r = \Sigma\, a_i D_{it} + a_B TR_t + \beta_1 R_t + \beta_2 TV_t + \beta_3 RP^e + \beta_4 RPV_t + \beta_5 CP_t + \delta e_t + e_t$$

where QP_r is the production of rice in metric tons at time period t;D_{it} is quarterly dummy variable (i = 1, 2, 3 and 4); TR_t is the trend component; R_t is the amount of rainfall as water input to rice production in time t; TV_t is the expected variance and volatility of mean temperature in time t; $RP_t^e$is the expected real retail price of rice in time t; RPV_t is the expected variance of the real retail price of rice in time t; CP_t is the real price of corn as rice substitute in time t; e_t is the error term; and a_i,$a_{B,}$$\beta_{1,}$$\beta_2$,$\beta_3$,$\beta_4$,$\beta_5$,$\delta$ are the regression coefficients in the model.

Prior to ARCH, stationarity of data is important to be established. To do this, the study has applied the Augmented Dickey Fuller (ADF) test to test for stationarity of data in level form and at first difference. Stationary data are used in ARCH and these are characterized to have no unit roots. Following the selection of the form at which the data to be analyzed are stationary is the ARCH-LM test, which determines the presence of ARCH effects or unpredictable behavior in the pattern. ARCH can be used only when ARCH effects are significant. The absence of which in the series would mean the use of autoregressive integrated moving average (ARIMA) approach as the appropriate tool for estimation. The use of ARIMA implies that the data series has predictable fluctuations. The lag length of the series is determined through Akaike Information Criterion (AIC). However, in the SUR estimation, an error correction factor is integrated because of the significance of spatial cointegration where the test is performed with the use of Johansen test for cointegration.

4. Results and Discussion

4.1. Stationarity of prices and climate variables

The ADF test result has indicated that not all data at level form are stationary. Non-stationary data at level form are found in the real retail prices of rice and the mean temperature readings in Cagayan Valley, Central Luzon and CALABARZON. These data have unit roots and must be stationarized by means of differencing. At first difference, all variables in the study areas as shown in Table 1 have exhibited stationarity with the rejection of null hypothesis (presence of unit roots) at 5% to 1% level of significance (Table 1).

4.2. Cointegration and ARCH effects in the price and temperature series

Cointegration implies that deviations from equilibrium are stationary with finite variance, even though the series themselves are non-stationary and have infinite variance (Engle and Granger, 1987). Thus, a significant level of which yields dubious results in estimations, which entails model adjustment to ensure robust estimates. In this study, Johansen test is used to detect cointegrating relationships that have obscured the true long-run relationships of the factors under study, particularly those involved in the consequent supply response analysis. Models having to deal with cointegrating data series are usually rectified with error correction factor, indicated by a weighted error term in the analytical/regression model. The results of the Johansen test for cointegration are shown in Table 2, where the presence of which is noted to be significant–thus, a model adjustment would have to incorporate an error correction factor.

In the test for ARCH effects, ARCH-LM test is used, where its results are depicted in Table 3. ARCH effects indicate the presence of unpredictable tendencies of the data series and thus warrant the use of ARCH in the succeeding analysis of price and mean temperature changes. The results in Table 3 show that the retail prices of rice and mean temperature have significant ARCH effects in all major rice producing areas in the country, namely: Central Luzon, CALABARZON, Cagayan Valley, Ilocos Region, Western Visayas and Northern Mindanao. This means that ARCH is valid for the analysis of changes in rice prices and in mean temperature.

Table 1. Augmented Dickey Fuller Test Results for Rice Prices and Mean Temperature

ADF Test Statistics												
Variable	Ilocos Region		Cagayan Valley		Central Luzon		CALABARZON		Western Visayas		Northern Mindanao	
	L	*FD*	*L*	*FD*	*L*	*FD*	*L*	*FD*	*L*	*FD*	*L*	*FD*
Real retail price of rice	-2.8***	-8.0***	-2.5	-10.2***	-2.2	-11.0***	-1.9	-7.3***	-2.7**	-4.1***	-2.7**	-4.1***
Mean temperature	-5.4***	-8.7***	-2.5	-9.1***	-2.7	-14.9***	-2.4	-6.6***	-3.0**	-12.1***	-2.9**	-6.3***

*Note: *** and ** are significant at the 1% level and 5% level, respectively.*

Table 2. Cointegration Test (Johansen) Results for the Commodities in the Supply Response Analysis

Commodity	**Region/Lag length**	**Hypothesized No. of CE(s)**								
		k = 0	k ≤ 1	k ≤ 2	k ≤ 3	k ≤ 4	k ≤ 5	k ≤ 6	k ≤ 7	k ≤ 8
Rice production	Ilocos Region (3)	360.18***	261.57***	192.30***	137.51***	103.52***	71.17***	49.10***	29.42***	13.03***
	Cagayan Valley (1)	523.13***	380.12***	271.22***	207.20***	152.17***	104.04***	61.22***	32.17***	11.61***
	Central Luzon (1)	524.26***	392.02***	292.82***	207.24***	138.99***	96.74***	57.70***	31.51***	13.66***
	CALABARZON (1)	738.04***	484.64***	376.42***	285.25***	197.91***	136.50***	87.26***	50.14***	19.82***
	Western Visayas (1)	546.61***	383.1***	285.7***	191.80***	133.34***	93.78***	57.94***	29.40***	7.44***
	Northern Mindanao (1)	470.52***	372.66***	292.74***	219.24***	168.42***	124.03***	80.86***	46.68***	21.30***

The Trace test was used to test the null hypothesis that the number of cointegrating vectors is less than or equal to k, where k is equal to 0 to 6.
****, ** and * indicates that the null hypothesis is rejected at the 1%, 5% and 10% levels, respectively.*
The lag length chosen by the AIC criteria is shown in parentheses after relevant poultry product.

4.3. Volatility of rice prices in the major rice-producing regions in the Philippines

The analysis of the changes of rice prices intends to capture the volatile movements in the price series, which are associated with price risks in the rice markets. Volatile price movements increase market uncertainties because of the difficulty of forming price and/or market expectations. This is usually linked with the inability of commodity markets to develop and compete sustainably. In the analysis of rice price volatility with ARCH, the results are presented in two categories: expected price levels as exhibited in the results under the mean equation and the expected price variances (ARCH/GARCH parameters) as shown under the variance equation. The expected price levels could reveal the formation of price expectations among commodity producers as possibly practiced when found significant in supply response analysis. The expected variances by its significance indicate price volatility that are associated with price risks, because the range within which price can vary is widened (Rezitis, 2003).

As shown in Tables 4 and 5, the results of price analysis through ARCH for Ilocos Region, Cagayan Valley, Central Luzon, CALABARZON, Western Visayas and Northern Mindanao indicate the presence of price volatility, wherein changes in rice prices in the said regions are expected to be unpredictable. Thus, rice producers and consumers in the said regions are confronted with market risks, which would make them face the difficulty of forming market expectations and decisions. The indicators of price volatility are indicated by the highly significant coefficients of ARCH/GARCH parameters under the variance equations of Tables 4 and 5. On the other hand, the parameters under the mean equations of the same tables show the bases of forming price expectations among the rice producers and consumers in the aforementioned regions or areas.

Table 3. ARCH-LM Test Results for ARCH Effects Among the Prices and Climate Variables by Region, 1990-2011

Variable	Ilocos Region	Cagayan Valley	Central Luzon	CALABARZON	Western Visayas	Northern Mindanao
F-Statistic						
Real retail price of rice	31.6416***	14.4669***	15.1307***	40.9349***	0.5198***	23.3886***
Mean temperature	11.8535***	4.1270**	3.5737**	5.6667**	1019.1760***	12.5530***
Observed Square of Residual						
Real retail price of rice	28.4366***	13.8122***	14.4112***	35.6563***	0.5227	21.6296***
Mean temperature	11.4254***	4.0939**	7.0365**	5.5888**	210.0121***	23.1594***

*Note: *** and ** are significant at the 1% level and 5% level, respectively.*

4.1. Volatility of mean temperature in the major rice-producing regions in the Philippines

Tables 6 and 7 depict the results of analyzing ambient temperature in similar regions with the use of ARCH. These results have to be interpreted in the same way as how the earlier results in Tables 4 and 5 are understood. Temperature changes are noted to be likewise volatile, but a bit less compared to the changes in rice prices. This finding still implies that rice producers are confronted with risks due to changes in ambient temperature, because warming can worsen at any point in time. In terms of expectations about the levels of ambient temperature, most of the regions account the levels of temperature for two months, although in the case of Cagayan Valley, the significant basis is the level of temperature in the previous four months.

Table 4. Price Volatility of Rice in Ilocos Region, Cagayan Valley and Central Luzon, 1990-2011

Region/Variables	Coefficient	Std. Error	z-Statistic	Prob.
Ilocos Region				
		Mean Equation		
Constant	-0.0028	0.0011	-2.6101	0.0091
Lagged real retail price of rice (Δ), t-1	0.3180	0.0836	3.8038	0.0001
Lagged real retail price of rice (Δ), t-2	-0.1347	0.0416	-3.2403	0.0012
		Variance Equation		
Constant	0.0000	0.0000	7.8829	0.0000
ARCH(1)	0.4041	0.0419	9.6333	0.0000
GARCH(1)	1.1206	0.0454	24.6625	0.0000
GARCH(2)	-0.4323	0.0311	-13.8969	0.0000
Log Likelihood		628.3321		
N		261		
Cagayan Valley				
		Mean Equation		
Constant	-0.0034	0.0011	-3.0347	0.0024
Lagged real retail price of rice (Δ), t-1	0.2861	0.0887	3.2256	0.0013
Lagged real retail price of rice (Δ), t-2	-0.1262	0.0716	-1.7625	0.0780
Lagged real retail price of rice (Δ), t-3	-0.1592	0.0860	-1.8502	0.0643
		Variance Equation		
Constant	0.0000	0.0000	4.4405	0.0000
ARCH(1)	0.5934	0.0818	7.2533	0.0000
GARCH(2)				
Log Likelihood		627.9498		
N		260		
Central Luzon				
		Mean Equation		
Constant	-0.0021	0.0004	-4.9268	0.0000
Lagged real retail price of rice (Δ), t-1	0.1500	0.0707	2.1204	0.0340
		Variance Equation		
Constant	0.0001	0.0000	6.6953	0.0000
ARCH(1)	1.0901	0.1175	9.2788	0.0000
Log Likelihood		671.3383		
N		262		

Table 5. Price Volatility of Rice in CALABARZON, Western Visayas and Northern Mindanao, 1990-2011

Region/Variables	Coefficient	Std. Error	z-Statistic	Prob.
CALABARZON				
		Mean Equation		
Constant	-0.0037	0.0011	-3.4869	0.0005
Lagged real retail price of rice (Δ), t-1	0.2682	0.0537	4.9917	0.0000
Lagged real retail price of rice (Δ), t-2	-0.2426	0.0455	-5.3367	0.0000
		Variance Equation		
Constant	0.0002	0.0000	10.2581	0.0000
ARCH(1)	0.6909	0.0779	8.8655	0.0000
GARCH(1)	0.1663	0.0758	2.1951	0.0282
GARCH(2)	-0.0981	0.0409	-2.4003	0.0164
Log Likelihood		676.9008		
N		261		
Western Visayas				
		Mean Equation		
Constant	-0.0015	0.0016	-0.8970	0.3697
Lagged real retail price of rice (Δ), t-1	0.2911	0.0720	4.0456	0.0001
		Variance Equation		
Constant	0.0001	0.0000	4.1693	0.0000
ARCH(1)	0.2295	0.0227	10.1113	0.0000
GARCH(1)	-0.0377	0.0207	-1.8231	0.0683
GARCH(2)	0.7348	0.0283	25.9657	0.0000
Log Likelihood		553.4421		
N		262		
Northern Mindanao				
		Mean Equation		
Constant	-0.0003	0.0018	-0.1821	0.8555
Lagged real retail price of rice (Δ), t-1	0.2235	0.0801	2.7897	0.0053
		Variance Equation		
Constant	0.0002	0.0000	13.4367	0.0000
ARCH(1)	0.1077	0.0294	3.6644	0.0002
GARCH(1)	1.1242	0.0580	19.3752	0.0000
GARCH(2)	-0.5183	0.0509	-10.1808	0.0000
Log Likelihood		599.8958		
N		262		

Table 6. The Volatility of Temperature in Ilocos Region, Cagayan Valley, Central Luzon and CALABARZON, 1990-2011

Variables	Coefficien	Std. Error	z-Statistic	Prob.
Ilocos Region				
		Mean Equation		
Constant	-0.0001	0.0065	-0.0171	0.9864
Lagged mean temperature (Δ), t-1	-0.1588	0.0716	-2.2177	0.0266
		Variance Equation		
Constant	0.0078	0.0010	8.2016	0.0000
ARCH(1)	0.0972	0.0534	1.8216	0.0685
ARCH(2)	-0.1150	0.0265	-4.3392	0.0000
GARCH(1)	0.5350	0.0670	7.9868	0.0000
Log Likelihood		190.8600		
N		262		
Cagayan Valley				
		Mean Equation		
Constant	-0.0018	0.0066	-0.2713	0.7862
Lagged mean temperature (Δ), t-1	-0.0289	0.0998	-0.2899	0.7719
Lagged mean temperature (Δ), t-2	-0.0571	0.0475	-1.2015	0.2296
Lagged mean temperature (Δ), t-3	-0.0519	0.0372	-1.3968	0.1625
Lagged mean temperature (Δ), t-4	-0.1933	0.0343	-5.6365	0.0000
		Variance Equation		
Constant	0.0103	0.0005	20.9727	0.0000
ARCH(1)	0.1374	0.0801	1.7145	0.0864
ARCH(2)	0.0089	0.0152	0.5865	0.5575
ARCH(3)	-0.0565	0.0098	-5.7453	0.0000
Log Likelihood		217.3651		
N		259		
Central Luzon				
		Mean Equation		
Constant	-0.0107	0.0511	-0.2097	0.8339
Lagged mean temperature (Δ), t-1	0.0448	0.0604	0.7423	0.4579
Lagged mean temperature (Δ), t-2	0.1191	0.0519	2.2935	0.0218
		Variance Equation		
Constant	0.7477	0.0740	10.1054	0.0000
ARCH(1)	-0.0497	0.0534	-0.9297	0.3525
ARCH(2)	-0.0966	0.0378	-2.5543	0.0106
Log Likelihood		-312.1517		
N		261		
CALABARZON				
		Mean Equation		
Constant	-0.0020	0.0039	-0.5196	0.6033
Lagged mean temperature (Δ), t-1	0.0458	0.1203	0.3802	0.7038
Lagged mean temperature (Δ), t-2	-0.1247	0.0606	-2.0588	0.0395

Variables	**Coefficien**	**Std. Error**	**z-Statistic**	**Prob.**
		Variance Equation		
Constant	0.0042	0.0002	24.2315	0.0000
ARCH(1)	0.3656	0.0906	4.0356	0.0001
ARCH(2)	0.0548	0.0287	1.9124	0.0558
Log Likelihood		309.2151		
N		261		

Table 7. The Volatility of Temperature in Western Visayas and Northern Mindanao, 1990-2011

Variables	Coefficient	Std. Error	z-Statistic	Prob.
Western Visayas				
		Mean Equation		
Constant	0.0072	0.0041	1.7299	0.0837
Lagged mean temperature (Δ), t-1	0.2783	0.1496	1.8601	0.0629
Lagged mean temperature (Δ), t-2	0.1059	0.0195	5.4300	0.0000
		Variance Equation		
Constant	0.0010	0.0002	5.5176	0.0000
ARCH(1)	1.1161	0.2407	4.6374	0.0000
ARCH(2)	-0.8916	0.1743	-5.1145	0.0000
GARCH(1)	0.7820	0.0415	18.8561	0.0000
Log Likelihood		308.2866		
N		261		
Northern Mindanao				
		Mean Equation		
Constant	-0.0012	0.0012	-1.0288	0.3036
Lagged mean temperature (Δ), t-1	0.1249	0.0615	2.0313	0.0422
Lagged mean temperature (Δ), t-2	-0.1741	0.0569	-3.0605	0.0022
Lagged mean temperature (Δ), t-3	-0.2993	0.0559	-5.3580	0.0000
		Variance Equation		
Constant	0.0009	0.0002	4.5429	0.0000
ARCH(1)	0.2159	0.1134	1.9036	0.0570
ARCH(2)	0.2463	0.1037	2.3758	0.0175
GARCH(1)	-1.2833	0.2130	-6.0253	0.0000
GARCH(2)	-0.3620	0.2135	-1.6954	0.0900
Log Likelihood		656.4120		
N		260		

4.2. Supply response of the major rice-producing regions in the Philippines to the unpredictable changes in rice prices and temperature

The results of analyzing rice producers' behavior to the risks posed by the changes of rice prices and ambient temperature are exhibited in Tables 8 to 13. In general, production timing (represented by Quarters 2, 3 and 4 in the tables) and error correction factors are the most significant factors that could affect the supply response of rice in all regions under study. Both volatilities induced by price and temperature changes have not emerged significant in the analysis. Production timing as represented by the quarters in the year implies that rice production during the said quarter is significantly different from that of Quarter 1. Error correction factors as highly significant in all regions in the analysis suggests that market interdependence and feedback mechanisms are strong in such a way that true long-run relationships of the parameters in the supply response models can be obscured through co-integrating patterns of behavior.

Table 8. Supply Response Estimates for Rice in Ilocos Region, Philippines. 1994 - 2011.

Variables	**Coefficient**	**Std. Error**	**t-statistic**	**Prob.**
Constant	-1.4445	0.2447	-5.9027	0.0000
Trend	0.0001	0.0013	0.0638	0.9493
Quarter 2	0.4351	0.0789	5.5166	0.0000
Quarter 3	1.7458	0.1703	10.2543	0.0000
Quarter 4	3.8805	0.1295	29.9557	0.0000
Lagged amount of rainfall (Δ)	0.0145	0.0360	0.4017	0.6893
Mean temperature variability	-0.4871	1.7711	-0.2750	0.7843
Lagged expected real retail price of rice (Δ)	0.0074	0.6347	0.0117	0.9907
Expected price variance of retail price of rice	0.0451	1.3597	0.0332	0.9736
Lagged real retail price of corn (Δ)	0.7262	0.7834	0.9271	0.3577
Error-correction	-1.1968	0.1345	-8.8982	0.0000
R-squared	0.9856			
Durbin-Watson	1.6267			
N	70			

However, the insignificance of the parameters for price volatility (expected price variance of rice) and temperature volatility (mean temperature volatility) means that the rice producers in the major rice-producing regions in the country are risk-takers, because the risks due to these volatile parameters do not affect their rice production. This is probably because of the technologies promoted by the government of the Philippines to sustain, if not improve further, rice production in these areas. The production of rice varieties that can withstand stresses from submergence and drought, farmer field schools (FFS)and organic farming technology are among the technology packages that have been extensively supported for rice farmers to adopt. The risk-taking behavior of the rice producers in the area may have been boosted by these interventions that could work in their areas.

Table 9. Supply Response Estimates for Rice in Cagayan Valley, Philippines. 1994 - 2011.

Variables	Coefficient	Std. Error	t-statistic	Prob.
Constant	-0.2016	0.2901	-0.6949	0.4899
Trend	0.0009	0.0016	0.5578	0.5791
Quarter 2	-0.2561	0.1349	-1.8986	0.0625
Quarter 3	-0.5503	0.1016	-5.4159	0.0000
Quarter 4	0.6636	0.0987	6.7218	0.0000
Lagged amount of rainfall (Δ)	-0.1338	0.0622	-2.1498	0.0357
Mean temperature variability	1.6300	2.6705	0.6104	0.5440
Lagged expected real retail price of rice (Δ)	-0.6340	1.0004	-0.6337	0.5287
Expected price variance of retail price of rice	2.0628	2.1135	0.9760	0.3330
Lagged real retail price of corn (Δ)	0.7591	0.7149	1.0619	0.2926
Error-correction	-0.9395	0.1348	-6.9697	0.0000
R-squared	0.8141			
Durbin-Watson	2.1594			
N	70			

Table 10. Supply Response Estimates for Rice in Central Luzon, Philippines. 1994 - 2011

Variables	Coefficient	Std. Error	t-statistic	Prob.
Constant	-0.8072	0.6719	-1.2015	0.2344
Trend	0.0003	0.0012	0.2074	0.8364
Quarter 2	1.5579	0.0726	21.4715	0.0000
Quarter 3	-0.9753	0.1361	-7.1659	0.0000
Quarter 4	3.1903	0.1037	30.7610	0.0000
Lagged amount of rainfall (Δ)	0.0721	0.0316	2.2847	0.0259
Mean temperature variability	-0.1645	0.7941	-0.2072	0.8366
Lagged expected real retail price of rice (Δ)	0.8312	0.6302	1.3190	0.1923
Expected price variance of retail price of rice	-0.2134	1.2056	-0.1770	0.8601
Lagged real retail price of corn (Δ)	0.2206	0.5546	0.3977	0.6923
Error-correction	-1.1332	0.1447	-7.8328	0.0000
R-squared	0.9867			
Durbin-Watson	1.8705			
N	70			

However, other than production timing and error correction factor, rainfall amount (lagged amount of rainfall) has also emerged significant in the supply response analysis for Cagayan Valley in Table 9 and based on the sign of its coefficient, its increase would reduce rice production. But this is not the case for Central Luzon, because the positive coefficient for rainfall amount in Table 10 suggests that increase in rainfall amount would increase rice production in the area. Similar finding holds true for Western Visayas because of the positively-signed coefficient of rainfall amount as shown in Table 12. On the other hand, the retail price of corn (lagged real retail price of corn) has likewise registered a significant coefficient that is positively signed for CALABARZON (Table 11). This means that increase in the price of corn would increase rice production in the area, which can be brought about the substitutability of rice for corn and vice versa.

Table 11. Supply Response Estimates for Rice in CALABARZON, Philippines. 1994 - 2011

Variables	Coefficient	Std. Error	t-statistic	Prob.
Constant	-0.4673	0.1183	-3.9510	0.0002
Trend	0.0001	0.0010	0.0525	0.9583
Quarter 2	0.7056	0.0840	8.4016	0.0000
Quarter 3	-0.2355	0.0827	-2.8475	0.0061
Quarter 4	1.6889	0.0748	22.5643	0.0000
Lagged amount of rainfall (Δ)	-0.0174	0.0450	-0.3868	0.7003
Mean temperature variability	-0.4427	1.1520	-0.3843	0.7021
Lagged expected real retail price of rice (Δ)	-0.0046	0.4839	-0.0095	0.9925
Expected price variance of retail price of rice	-2.0889	1.9185	-1.0888	0.2807
Lagged real retail price of corn (Δ)	0.7185	0.4242	1.6937	0.0956
Error-correction	-1.0158	0.1357	-7.4857	0.0000
R-squared	0.9634			
Durbin-Watson	2.1189			
N	70			

Table 12. Supply Response Estimates for Rice in Western Visayas, Philippines. 1994 - 2011

Variables	Coefficient	Std. Error	t-statistic	Prob.
Constant	0.2847	0.1272	2.2386	0.0290
Trend	-0.0007	0.0012	-0.6014	0.5499
Quarter 2	-1.3955	0.0879	-15.8761	0.0000
Quarter 3	1.2632	0.1274	9.9124	0.0000
Quarter 4	-0.4963	0.1007	-4.9311	0.0000
Lagged amount of rainfall (Δ)	0.1216	0.0466	2.6087	0.0115

Variables	Coefficient	Std. Error	t-statistic	Prob.
Mean temperature variability	-0.3907	0.6512	-0.5999	0.5509
Lagged expected real retail price of rice (Δ)	0.9702	0.6872	1.4118	0.1633
Expected price variance of retail price of rice	-2.3130	2.1914	-1.0555	0.2955
Lagged real retail price of corn (Δ)	1.0234	0.6264	1.6337	0.1077
Error-correction	-0.7218	0.1333	-5.4156	0.0000
R-squared	0.9783			
Durbin-Watson	2.1089			
N	70			

Table 13. Supply Response Estimates for Rice in Northern Mindanao, Philippines. 1994 - 2011

Variables	Coefficient	Std. Error	t-statistic	Prob.
Constant	-0.6141	0.2145	-2.8624	0.0058
Trend	0.0000	0.0008	-0.0056	0.9956
Quarter 2	0.2723	0.0591	4.6114	0.0000
Quarter 3	0.3779	0.0725	5.2119	0.0000
Quarter 4	0.9174	0.0645	14.2185	0.0000
Lagged amount of rainfall (Δ)	-0.0501	0.0459	-1.0931	0.2788
Mean temperature variability	9.4354	9.4290	1.0007	0.3211
Lagged expected real retail price of rice (Δ)	-0.1115	0.4657	-0.2395	0.8115
Expected price variance of retail price of rice	1.5683	2.8653	0.5474	0.5862
Lagged real retail price of corn (Δ)	-0.0216	0.2730	-0.0790	0.9373
Error-correction	-0.9900	0.1304	-7.5938	0.0000
R-squared	0.8819			
Durbin-Watson	1.9073			
N	70			

5. Conclusion

The study has analyzed price and temperature volatilities and the influence of which on rice production in Central Luzon, CALABARZON, Cagayan Valley, Ilocos Region, Western Visayas and Northern Mindanao, which are the major rice producing regions in the Philippines. Both rice prices and ambient temperature have shown unpredictability in their behavior because of their significant volatilities. ARCH has been a good facility in generating the risk estimates that can be used in response analysis as in the supply response of rice producers in this study, which can imply the general behavior of rice producers towards risks. The study has shown that rice producers in the major rice-producing regions in the Philippines are not affected by the risks induced by the rice price and temperature changes. Government programs may have played a key role in this aspect and supporting further these programs may strengthen the rice industry in the country, which may have later on enhanced capability to be efficient and competitive in the global market.

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