Nonlinearities in Regional Rice Prices in the Philippines: Evidence from a Smooth Transition Autoregressive (STAR) Approach

Valerien O. Pede[1], Harold Glenn A. Valera[1,4], Mohammad J. Alam[2] and Andrew M. McKenzie[3]

[1]Social Sciences Division International Rice Research Institute (IRRI)
[2]Department of Agribusiness and Marketing, Bangladesh Agricultural University (BAU)
[3]Agricultural Economics and Agribusiness, university of Arkansas (UofA)
[4]Department of Economics, University of Waikato

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting, Washington, DC, August 4-6, 2013

(Preliminary draft; please do not cite.)

Abstract: This paper investigates nonlinear dynamics in monthly rice prices of 16 regions in the Philippines at three levels: farm gate, wholesale and retail, over the period of January 1990 to December 2012. We used a series of tests to investigate whether the regional prices are characterized by linear processes or non-linear smooth transition autoregressive (STAR)-type dynamics. Results indicate that STAR-type nonlinearity exists in several regions, and particularly for farm gate prices. The most common process is a logistic STAR dynamic characterizing an asymmetric price behavior determined by two regimes and a smooth switching process.

Key words: nonlinearity, rice price, smooth transition

1. Introduction

Commodity prices are often subject to government actions through the implementation of domestic and trade measures such as stockpiling and export bans. Government actions such as these could be the major sources of the nonlinearity in food price dynamics, especially for rice to which food policy is mostly prioritized in many countries. This food policy-focused orientation has historically been pervasive in the Philippine rice sector, where price stabilization program is implemented by National Food Authority (NFA). The NFA generally offers to buy rice from farmers when prices are low during peak harvest seasons, and sell the stored grain to consumers through licensed outlets when prices are high during the dry season (Yao et al., 2005). This is consistent with government intervention functions, where there is a stronger price intervention when it is farther from the market determined price. Due to high budgetary costs associated with NFA actions to influence both the farmgate and retail prices, the agency may not respond strongly when the market price is close to the set price. Hence, the market determined price may follow a random walk close to NFA intervention price. Moreover, the higher and more volatile the price of rice in the global market, the greater the probability that the NFA will respond strongly as evident in the stockpiling in 2007.

Besides the government intervention in terms of NFA stocks, rice, like many agricultural crops is also subject to the influence of weather condition and climate variability. Rice price dynamic is therefore also dependent on climate variability. Evidence of a relationship between commodity price dynamic and climate variability has already been stressed in the literature. Rainfall and temperature are among the two main factors that determine crop productivity. Also, more and more there are claims that changes in weather patterns – climate change - have an impact on crop productivity and also on prices. Variability and change in the climatic conditions may be a source of nonlinearity in price movement (see for instance Ubilava and Holt, 2013 for a recent example of climatic induced nonlinearity with respect to vegetable oil prices).

In the economics literature, the term "nonlinear price movement" implies that stabilizing food supply and demand protects producers and consumers against extreme short-term spikes and low-frequency price volatility (Braun and Tadesse, 2012). Similar with prices of other staple food, movement in rice prices can be characterized by nonlinearities and there are at least three reasons to believe a priori that such features might occur. First, the theory of commodity storage recognizes that an inherent nonlinearity in commodity prices can arise due to the inability of the market to carry negative inventories (Shively, 1996). Moreover, inter-temporal price transmission can arise due to storage behavior and induced changes in rice production, which is unpredictable to begin with because of its dependence on weather conditions. Second, policy responses such as stockpiling, price controls and trade restrictions used by several countries during the global price spikes in 2007 and 2008 have been shown to create tensions and market disruptions, which cause inter-temporal and spatial nonlinearity in price transmission across countries and regions (Braun and Tadesse, 2012). And third, transmission of market shocks along the supply chain (vertical price transmission) is capable of giving rise to nonlinear price adjustments due to the presence of fixed costs through various stages of the food chain.

The purpose of this paper is to investigate nonlinearities in regional rice prices dynamics in the Philippines. In particular, the paper examines whether regional rice prices at farm, wholesale, and retail levels exhibit nonlinearities. This study has important implications for research attempting to model impacts of NFA price intervention, and the degrees of market integration and price transmission in Philippine rice markets. Previous research in these areas has used linear modeling assumptions. However, there are a number of factors (e.g. government policy intervention, unstable international markets, and weather) that could generate nonlinear price behavior, and if the true data-generating process of Philippine rice prices is inherently nonlinear, policy implications drawn from linear models are questionable.

2. Literature

There is an extensive literature on price dynamics of agricultural commodities which considers the issue of whether prices exhibit potential nonlinearities. Evidence on nonlinear dynamics has been considered as support for the strong form of the degree of adjustment from one price regime to another, which can be useful for policy-making purposes in recovering information on structural change in prices. Holt and Craig (2006) examine the potential nonlinear dynamics in the hog–corn cycle in the U.S. by using a STAR model of monthly prices of hogs relative to corn, and find evidence of nonlinearity and regime-dependent behavior. Following the same econometric approach, Ubilava (2012) offers a more recent investigation of nonlinearities in the U.S. soybean-to-corn price ratio. Ubilava (2012) reveals evidence of asymmetries in the co-movement of corn and soybean prices, and find structural stability in the price ratio dynamics of these crop pairs over the study period. In the case of single commodity price dynamics analysis, Reitz and Westerhoff (2007) examine nonlinearities in monthly prices of cotton, soybeans, lead, sugar, rice and zinc for the period 1973–2003 using a STAR-GARCH model. Their model suggests that heterogeneous agents and their nonlinear trading impact may be responsible for pronounced swings in commodity prices. Employing annual data for 24 US commodities for the period 1900–2003, Balagtas and Holt (2009) find evidence of nonlinearities in the prices of sixteen commodities using STAR-type models.

The issue of nonlinearities in commodity prices has also been studied in relation to the price transmission along the food chain. In this vein, considerable attention within the price transmission literature put particular importance to regime-switching models which have been employed in many empirical analyses in investigating the presence of nonlinear price transmission in food markets (Hassouneh *et al.*, 2009). Goodwin and Holt (1999) examine price interrelationships and transmission among farm, wholesale, and retail beef markets in the US using a threshold error correction model. Their results suggest that the transmission of shocks appears to be largely unidirectional with information flowing up the marketing channel from farm to wholesale to retail markets but not in the opposite direction. Mainardi (2001) applies the threshold and smooth transition cointegration models to quarterly prices of three major wheat producing countries over the period 1973–1999 and finds evidence that non-linear cointegration models have substantial explanatory power for international wheat prices. Serra *et al.* (2008) test the existence of a long-run relationship between ethanol, corn and oil prices using a smooth transition vector error correction model (STVECM). They find the existence of an equilibrium relationship between ethanol, corn and oil prices, with non-linear adjustment of ethanol prices to deviations from its long-run parity. Moreover, Ubiliva and Holt (2009) estimate the effect of El Niño Southern Oscillation (ENSO) over time on market dynamics for eight major vegetable oil prices using STVECM, and present evidence of strong cointegration between the vegetable oil prices, which exhibit nonlinear behavior conditional on the state of nature and the direction of shocks of the ENSO anomaly. The long-run relationship between vegetable oil prices and conventional diesel prices in the EU for the period 2005–2007 is also explored by Peri and Baldi (2010) who apply threshold cointegration approach. Their results suggest a two-regime threshold cointegration model for rapeseed oil-diesel price relationship.

While a number of studies have provided reviews of the causes and estimation of asymmetric price transmission (Ward, 1982; Kinnucan and Forker, 1987; Boyd and Brorsen, 1988; Griffith and Piggot, 1994; Zhang *et al.*, 1995; Bernard and Willet, 1996; von Cramon-Taubadel, 1998;; Worth, 2000; Parrot *et al.*, 2001; Romain *et al.*, 2002; Girapunthong *et al.*, 2004; Frey and Manera, 2005; Vavra and Goodwin, 2005), little research has been done with respect to vertical price transmission in Philippine rice markets. The existence of asymmetric price transmission across markets in the Philippine rice industry was examined by Reeder (2000) and Matriz (2008). Reeder (2000) employs a symmetry model in estimating the changes in rice prices at different market levels and finds no evidence of the presence of market power among Filipino traders. On the other hand, Matriz (2008) estimates the Wolffram-Houck and the VAR models and finds that price symmetry exists at all levels of the rice market with or without heavy government intervention.

Methodology

This paper utilizes rice price series at farmgate, retail and wholesale levels for 16 regions in the Philippines, a total of 48 price series from January 1990 to December 2012.[1] We examine nonlinearity in all 48 prices following a smooth transition auto-regressive approach. The price series are for the following regions: Cordillera Administrative Region (CAR), Ilocos, Cagayan Valley, Central Luzon, CALABARZON, MIMAROPA, Bicol, Western Visayas, Central Visasyas, Eastern Visasyas, Zamboanga Peninsula, Northern Mindanao, Davao, SOCCSKSARGEN, CARAGA, and the Autonomous Region of Muslim Mindanao (ARMM).

[1] No distinction is made on the variety and type of rice.

We start our analysis with the determination of the optimal lag length for each series. Starting with the maximum lag length of 12, the optimal lag is chosen on the basis of the AIC and SC criterion.[2] Next we proceed to test for stationarity of all series at the farm gate, retail and wholesale levels. Several tests are available to investigate stationarity in time series. Some of the common tests of stationarity are the Augmented Dikey-Fuller (ADF), KPSS, Schmidt Phillips and Phillips-Perron. In the presence of nonlinearity or structural breaks in data series, usual unit root tests such as ADF may not be appropriate. We first consider the ADF unit root test, but investigated further by implementing some unit root tests which accounts for the presence of structural breaks. For the latter, we follow the specification and shift functions outlined in Lutkepolhl (2004).

Considering an AR(p) of a time series x_t written as:

$$\Delta x_t = \phi x_{t-1} + \sum_{j=1}^{p-1} \alpha_j \Delta x_{t-j} + \varepsilon_t, \qquad (1)$$

where ϕ and α are parameters to be estimated and ε is the error term, the Augmented Dikey-Fuller (ADF) consists in testing the null hypothesis $H_0 : \phi = 0$ against the alternative $H_0 : \phi < 0$.

For the unit root test with structural breaks, we consider three shift functions described in Lutkepolhl (2004). These are: the shift dummy function, the exponential shift function and the rational shift function. Considering a general form of time series given as:

$$x_t = \alpha_0 + \alpha_1 t + f_t(\theta)' \gamma + \varepsilon_t, \qquad (2)$$

where, α and γ are unknown parameters, ε_t is the error term, and f_t is the shift function. The shift dummy is similar to a dummy variable which defines two regimes based on a shift date T. It can be expressed as follow:

$$f_t(\theta) = \begin{cases} 0 & t < T \\ 1 & t \geq T \end{cases}, \qquad (3)$$

where, T is the endogenously determined shift date.

[2] In case where there are differences in the orders suggested by the AIC and SC, we consider the lag order suggested by the SC, as suggested in Lutkepohl (2004).

The exponential shift function allows a nonlinear gradual shift between the regimes defined by the shift date. It is expressed as:

$$f_t(\theta)=\begin{cases}0, & t<T\\ 1-\exp\{-\theta(t-T+1)\}, & t\geq T\end{cases} \quad , \tag{4}$$

The rational shift which is expressed as:

$$f_t(\theta)=\left[\frac{d_{1,t}}{1-\theta L}:\frac{d_{1,t-1}}{1-\theta L}\right] \quad , \tag{5}$$

After the test of stationarity, we now proceed to the investigation of nonlinearity in the individual series for all three levels. This consists in testing between a linear AR specification against a Smooth Transition Autoregressive (STAR)-type non-linearity. Following, Terasvirta (2004), a STAR model of order p can be written as:

$$\Delta x_t=\varphi_1'\mathrm{z}_t+\varphi_2'\mathrm{z}_t G(s_t;\gamma,c)+\varepsilon_t, \tag{6}$$

where, x_t is a dependent variable; $\mathrm{z}_t=(1,\Delta x_{t-1},.....,\Delta x_{t-p,}x_{t-1},E_t)'$ is a matrix of explanatory variables (including lagged dependent variables), and a vector of exogenous variables E_t. The terms φ_1' and φ_2' represent parameter vectors to be estimated. In this equation, $G(s_t;\gamma,c)$ represents the transition function where s_t is a transition variable, γ represents a slope parameter, and $c=(c_1,......,c_l)$ is a vector of location parameters.

The general functional form of the transition function considered in this paper is a general logistic function:

$$G(s_t;c,s_t)=\left(1+\exp\left\{-\gamma\prod_{l=1}^{K}(s_t-c_l)\right\}\right)^{-1}, \quad \gamma>0 \tag{7}$$

where, all parameters are defined as previously. Based on values of *l* we consider two functional forms as defined in Terasvirta (2004). The simplest form of the logistic function in equation (7) is obtained with *l* = 1, defining a smooth transition between two regimes at a unique location c_1. This form of STAR model (denoted LSTR1), can be used to characterize asymmetric behavior, particularly dynamic process that exhibits period of expansion (peak) and recession (trough). The second functional form is obtained with *l* = 2, and denoted LSTR2. Dynamic processes characterized by an LSTR2 type nonlinearity exhibits similar behavior at large and small values of the transition variable s_t. Another functional form commonly used in this type of study (but not considered in this paper) is the exponential STAR function (ESTAR). It has a similar shape as LSTR2, except that its minimum value is zero. The exponential STAR model is written as:

$$G(s_t;\gamma,c,) = 1 - \exp\left\{-\gamma(s_t - c)^2\right\}, \quad \gamma > 0 \tag{8}$$

where, all parameters are defined as previously, and c is the unique location parameter that defines two regimes. The ESTAR model could be considered as an approximation of the LSTR2 model but not in the case of large values of gamma.

There are several candidates for the transition variable s_t. It could be an exogenous variable or a linear combination of exogenous variables. Two common forms of the transition variable are also: $s_t = x_{t-d}$ and $s_t = \Delta x_{t-d}$ where $d > 0$ represents the delay parameter. The special case $s_t = t$ represents the Time-varying Smooth Transition Autoregressive or TV-STAR (See Tereasvirta et Anderson, 1992; Holt and Craig, 2006; Van Dijk et al. 2002). The TV-STAR model is considered in this paper.[3]

Results

The nominal regional prices used in the study are obtained from the Bureau of Agricultural Statistics of the Philippines. We deflated all price series based on 2005 prices using consumer price index (CPI) obtained from International Financial Statistics. All real prices are expressed in pesos per kilogram[4]. The logarithmic values of all series are considered. Starting with the maximum lag length of 12, the optimal lag is chosen on the basis of the AIC and SC criterion. Table 1 shows the optimum lag length on farm gate, retail and wholesale price series for all 16 regions. For almost all regions, the optimal lag length is 1 month for all farm gate series. For retail and wholesale price series the optimal lag length is 2 months in most of the regions.

[Table 1 about here]

After the determination of optimal lag length, we proceed to test for stationarity on series at the farm gate, retail and wholesale. Table 2a shows results for stationarity test using

[3] All estimations are performed with JMulti. It is an interactive software for time series analysis. More information about can be obtained at http://www.jmulti.de/

[4] Peso is the currency used in the Philippines. 1 USD = 40 PhP.

ADF test. For the farm gate prices, the majority of regional series were found to be stationary in levels. This is consistent with pricing theory which would suggest that nominal cash commodity prices should be stationary around long-run production costs (Wang and Tomek, 2007). In contrast all retail and wholesale price series were found to be I(1). Results of unit root tests with structural breaks are presented in table 2b. First of all, one or two structural breaks were indentified in several instances. Second, results seem to show similar patterns as the ADF results. The majority of farm gate price series are I(0), while most of the series for retail and wholesale prices are I(1).

[Table 2a about here]

[Table 2b about here]

Following the procedure described in the methodology the null hypothesis of linear model versus non-linear TV-STAR model was tested for all series at the different levels. In cases where a non-linear STAR model is detected, the procedure also allows estimation of the model with the appropriate functional form for the transition function. In all cases the transition variable is assumed to be *t*, (as in Lin and Terasvirta, 1994) and the function *G* allows a smooth transition across the endogenously defined regimes. Results are presented in Table 3. It is interesting to notice that in all regions a non-linear STAR-type dynamic is observed either for farm gate price, retail price, and wholesale price or at all 3 levels. The majority of series exhibiting TV-STAR-types nonlinearity have a logistic functional form (LSTAR1). The LSTAR1 type of nonlinearity characterizes asymmetric price dynamic with regime of low and high values separated by a smooth transition band.

For the regions for which a STAR-type non-linearity was detected, we proceed to the estimation of parameters as described in equation (6). Results are presented in Tables 4, 5 and 6. After estimation of these models, we also proceeded to their evaluation by testing for the presence of additive nonlinearity and for parameter constancy. In almost all cases no remaining nonlinearity was detected. Also, the null hypothesis of parameter constancy was rejected in almost all cases with few exceptions. However in some instances, the computed Gamma parameter appears to be quite high with large standard errors. This was observed for example in the farm gate prices of central Luzon, the retail price of Davao and SOCCSKSARGEN, the wholesale prices of Davao, CARAGA and ARMM. For the price series where LSTR1 is found to be appropriate, the large value of gamma indicates that the two regimes identified have equal variance. However, for LSTR2, the large value of gamma indicates that there are 3 regimes (2 identical outer regimes and a mid-regime).

It is interesting to observe that the LSTAR1 form of nonlinearity has been predominant at the farm gate level. This could be due to the seasonal and cyclical nature of rice production or weather influence. The regular intervention of the government in the form of NFA stock could also be the source of the observed nonlinearity. The sources of the observed nonlinearity warrant further investigation.

[Table 4 about here]

[Table 5 about here]

[Table 6 about here]

Conclusion

This paper investigates nonlinear dynamics in rice prices in 16 regions in the Philippines at three levels: farm gate, wholesale and retail using A Smooth Transition Autoregressive time series approach. Results show strong evidence of nonlinearity in the price dynamics, in particular farm gate price dynamics are best characterized by a logistic STAR process with two distinct regimes. This study is a work in progress and our results, although important, represent only the preliminary step of our overall research goal – namely to examine the sources of nonlinearity in Philippine rice price dynamics. We have alluded to possible causes of rice price nonlinearities (e.g. government intervention, periodic shocks in international rice market, and episodic weather effects), and the natural extension to this paper is to investigate the specific potential sources of nonlinearity.

References

Bernard, J. C., & Willett, L. S. (1996). Asymmetric price relationships in the U.S. broiler industry. *Journal of Agricultural and Applied Economics, 28*(2), 279-289.

Boyd, M. S., and Brorsen, B. W. (1988). Price asymmetry in the US pork marketing channel. *North Central Journal of Agricultural Economics, 10*, 103-109.

Frey, G., & Manera, M. (2007). Econometric models of asymmetric price transmission. *Journal of Economic Surveys, 21*(2), 349-415.

Girapunthong , N., VanSickle, J. J., & Renwick A. (2004). Price Asymmetry in the United States fresh tomato market. *Journal of Food Distribution, 34,* 51-59.

Goodwin, B. K., & Holt, M. T. (1999). Price transmission and asymmetric adjustment in the U.S. beef sector. *American Journal of Agricultural Economics, 81*(3), 630-637.

Griffith, G. R., & Piggott, N. E. (1994). Asymmetry in beef, lamb and pork farm-retail price transmission in Australia. *Agricultural Economics, 10*(3), 307-316.

Hassouneh, I., Serra, T., & Gil, J. M. (2010). Price transmission in the Spanish bovine sector: the BSE effect. *Agricultural Economics, 41*(1), 33-33.

Hassouneh, I. von Cramon-Taubadel, S. & Gil, J.M. (2012). Recent developments in the econometric analysis of price transmission. Working Paper No. 2, Transparency of Food Pricing.

Holt, M., & Balagtas, J. (2009). Estimating structural change with smooth transition regressions: an application to meat demand. *American Journal of Agricultural Economics, 91*(5), 1424-1424.

Holt, M. T., & Craig, L. A. (2006). Nonlinear dynamics and structural change in the U.S. hog-corn cycle: a time-varying STAR approach. *American Journal of Agricultural Economics, 88*(1), 215-233.

Kinnucan, H. W., & Forker, O. D. (1987). Asymmetry in farm-retail price rransmission for major dairy products. *American Journal of Agricultural Economics, 69*(2), 285-292.

Lin, C. F. J., & Teräsvirta, T. (1994). Testing the constancy of regression parameters against continuous structural change. *Journal of Econometrics*,*62*(2), 211-228.

Lutkepohl, H. (2004). "Univariate Time Series Analysis" in H. Lütkepohl, and M. Krätzig, (eds) *Applied time series econometrics*. Cambridge, UK: Cambridge University Press.

Mainardi, S. (2001). Limited arbitrage in international wheat markets: threshold and smooth transition cointegration. *The Australian Journal of Agricultural and Resource Economics, 45*(3), 335-335.

Matriz, M.J. (2008). Price transmission mechanism in the Philippine rice industry. Unpublished thesis. Master of Science in Agricultural and Resource Economics. University of Delaware

Parrott, S. D., Estwood, D. B., & Brooker, J. R. (2001). Testing for symmetry in price transmission: an extension of the Shiller lag structure with an application to fresh tomatoes. *Journal of Agribusiness, 19*, 35- 49.

Peri, M., & Baldi, L. (2010). Vegetable oil market and biofuel policy: An asymmetric cointegration approach. *Energy Economics, 32*(3), 687-693.

Reeder, M. M. (2000). Asymmetric prices: implications on trader's market power in the Philippine rice. *Journal of Philippine Development, 49*, 49-69.

Reitz, S., & Westerhoff, F. (2007). Commodity price cycles and heterogeneous speculators: a STAR–GARCH model. *Empirical Economics, 33*(2), 231-244.

Romain, R., Doyon, M., & Frigon, M. (2002). Effects of state regulations on marketing margins and price transmission asymmetry: Evidence from the New York City and upstate New York fluid milk markets. *Agribusiness, 18*(3), 301-315.

Serra, T., & Goodwin, B. K. (2003). Price transmission and asymmetric adjustment in the Spanish dairy sector. *Applied Economics, 35*(18), 1889-1899.

Shively, G. E. (1996). Food Price Variability and Economic Reform: An ARCH Approach for Ghana. *American Journal of Agricultural Economics, 78*(1), 126-136.

Terasvirta, T. (2004). "Smooth Transition Regression Modelling" in H. Lütkepohl, and M. Krätzig, (eds) *Applied time series econometrics*. Cambridge, UK: Cambridge University Press.

Terasvirta, T. and Anderson, H.M. (1992). "Characterizing Nonlinearities in Business Cycles Using Smooth Transition Autoregressive Models" Journal of Applied Econometrics 7:119–136.

Ubilava, D. (2012). Modeling nonlinearities in the U.S. soybean-to-corn price ratio: a smooth transition autoregression approach. *Agribusiness, 28*(1), 29-41.

Ubilava, D., & Holt, M. (2013). El Niño southern oscillation and its effects on world vegetable oil prices: assessing asymmetries using smooth transition models. *Australian Journal of Agricultural and Resource Economics, 57*(2), 273-297.

Van Dijk, D., Terasvirta, T and Franses, P.H. (2002). "Smooth Transition Autoregressive Models: A Survey of Recent Developments" Econometrics Review 21:1–47.

Vavra, P., & Goodwin, B. K. (2005). Analysis of price transmission along the food chain. OECD Directorate for Food, Agriculture and Fisheries, OECD Food, Agriculture and Fisheries Working Papers: 3.

Von Cramon-Taubadel, S. (1998). Estimating Asymmetric Price Transmission with the Error Correction Representation: An application to the German Pork Market. *European Review of Agricultural Economics, 25*(1), 1-18.

Von Braun, J. & Tadesse, G. (2012). Global Food Price Volatility and Spikes: An Overview of Costs, Causes, and Solutions. Policy No. 161, ZEF-Discussion Papers on Development. University of Bonn

Wang, D., & Tomek, W. G. (2007). Commodity prices and unit root tests.*American Journal of Agricultural Economics*, *89*(4), 873-889.

Ward, R. W. (1982). Asymmetry in retail, wholesale, and shipping point pricing for fresh vegetables. *American Journal of Agricultural Economics, 64*(2), 205-212.

Worth, T. (2000). The FOB-retail price relationship for selected fresh vegetables.

Zhang, P., Fletcher, S. M., & Carley, D. H. (1995). Peanut price transmission asymmetry in peanut butter. *Agribusiness, 11*(1), 13-20.

Table 1. Lag length selection results using Akaike Information Criterion and Schwarz Criterion.†

	Farmgate		Wholesale		Retail	
Regions	AIC	SC	AIC	SC	AIC	SC
CAR	5	1	2	2	6	2
Ilocos Region	1	1	2	2	2	2
Cagayan Valley	1	1	2	2	2	2
Central Luzon	3	1	4	2	4	2
CALABARZON	5	1	5	2	5	2
MIMAROPA	1	1	2	2	2	2
Bicol Region	4	1	6	2	7	5
Western Visayas	2	1	1	1	1	1
Central Visayas	1	1	5	2	3	2
Eastern Visasyas	2	2	2	2	2	2
Zamboanga Peninsula	3	1	5	3	9	2
Northern Mindanao	4	1	4	2	6	4
Davao Region	7	1	4	1	4	1
SOCCSKSARGEN	1	1	10	2	10	2
CARAGA	1	1	5	4	4	2
ARMM	4	1	2	2	5	2

† AIC= Akaike Information Criterion, SC= Schwarz Criterion.

Table 2a. Results Unit Root testing with ADF.

	ADF Test Statistic†					
	Farmgate		Wholesale		Retail	
Regions	L	FD	L	FD	L	FD
CAR	-4.375*		-2.856	-9.902*	-2.814	-9.675*
Ilocos Region	-3.371	-11.755*	-3.019	-8.576*	-3.097	-8.992*
Cagayan Valley	-4.547*		-2.877	-9.426*	-2.76	-9.601*
Central Luzon	-3.894	-14.102*	-2.909	-9.648*	-3.443	-9.768*
CALABARZON	-4.209*		-2.622	-8.899*	-2.535	-8.879*
MIMAROPA	-3.957	-13.481*	-2.91	-9.199*	-2.584	-8.064*
Bicol Region	-4.145*		-2.982	-8.272*	-2.6	-7.260*
Western Visayas	-3.748	-12.688*	-2.769	-12.223*	-2.521	-12.459*
Central Visasyas	-5.203*		-3.132	-8.834*	-2.948	-8.632*
Eastern Visasyas	-4.445*		-2.71	-8.972*	-2.816	-9.678*
Zamboanga Peninsula	-4.482*		-3.955	-12.604*	-2.474	-10.480*
Northern Mindanao	-4.305*		-3.299	-10.560*	-2.393	-7.636*
Davao Region	-4.399*		-3.469	-11.275*	-3.437	-10.794*
SOCCSKSARGEN	-3.813	-13.584*	-3.545	-13.584*	-3.771	-10.725*
CARAGA	-4.741*		-2.781	-9.102*	-3.468	-9.963*
ARMM	-6.034*		-2.469	-9.007*	-2.656	-8.409*

* Indicates rejection of null hypothesis of non-stationarity or unit roots at 1% level.

† L indicates series in level, FD first differenced series

Table 2b. Unit Root Results using Structural Dummy.

Regions	Price Level	Structural Dummy† Impulse dummy L	Impulse dummy FD	Shift dummy L	Shift dummy FD	Exponential shift L	Exponential shift FD	Rational shift L	Rational shift FD
CAR	Farmgate	-4.478*		-4.498*		-4.516*		-4.513*	
	Wholesale	-2.421	-9.606*	-2.458	-9.832*	-2.571	-7.921*	-2.682	-6.588*
	Retail	-2.69	-9.830*	-2.704	-9.419*	-2.632	-8.558*	-2.83	-7.671*
Ilocos Region	Farmgate	-3.475	-11.784*	-3.492	-11.530*	-3.349	-9.760*	-3.659	-8.900*
	Wholesale	-2.838	-8.624*	-2.85	-8.357*	-2.777	-8.302*	-2.983	-8.118*
	Retail	-3.076	-9.105*	-3.084	-9.239*	-3.007	-9.243*	-3.268	-9.200*
Cagayan Valley	Farmgate	-4.485*		-4.465*		-4.221*		-4.490*	
	Wholesale	-2.712	-9.615*	-2.763	-9.226*	-2.777	-9.258*	-2.858	-9.674*
	Retail	-2.527	-9.919*	-2.552	-9.957*	-2.725	-9.855*	-2.75	-9.759*
Central Luzon	Farmgate	-3.899	-14.405*	-3.703	-10.002*	-3.525	-9.924*	-3.415	-14.852*
	Wholesale	-2.934	-9.914*	-2.937	-9.945*	-2.892	-9.676*	-2.923	-9.487*
	Retail	-3.387	-9.926*	-3.188	-9.765*	-3.089	-10.077*	-3.702*	-9.847*
CALABARZON	Farmgate	-4.398*		-4.584*		-4.592*		-4.177*	
	Wholesale	-2.668	-8.699*	-2.671	-8.606*	-2.685	-8.891*	-2.681	-9.080*
	Retail	-2.576	-8.932*	-2.577	-9.081*	-2.577	-9.001*	-2.566	-8.670*
MIMAROPA	Farmgate	-3.879	-13.030*	-3.842	-8.817*	-3.469	-8.114*	-3.1	-7.598*
	Wholesale	-2.896	-9.293*	-2.945	-7.946*	-2.735	-8.019*	-2.992	-9.350*
	Retail	-2.618	-8.148*	-2.633	-6.449*	-2.431	-6.498*	-2.651	-7.954*
Bicol Region	Farmgate	-3.41	-12.373*	-3.505	-12.753*	-4.065*	-12.723*	-3.347	-11.872*
	Wholesale	-2.767	-8.403*	-2.726	-8.061*	-2.684	-7.028*	-2.958	-6.626*
	Retail	-2.62	-7.511*	-2.619	-7.249*	-2.517	-6.398*	-2.781	-5.944*
Western Visayas	Farmgate	-3.364	-12.925*	-3.593*		-3.621*		-3.766	-12.878*
	Wholesale	-2.528	-12.249*	-2.549	-11.394*	-2.723	-11.547*	-2.733	-12.150*

	Retail	-2.296	-12.427*	-2.323	-10.576*	-2.302	-8.861*	-2.498	-8.1400*
Central Visasyas	Farmgate	-4.718*		-4.483*		-4.175*		-4.177*	
	Wholesale	-3.097	-8.900*	-3.121	-8.810*	-3.16	-8.816*	-3.242	-9.003*
	Retail	-2.926	-8.706*	-2.924	-8.879*	-3.002	-7.566*	-3.053	-6.860*
Eastern Visasyas	Farmgate	-3.940*		-4.335*		-4.365*		-4.284*	
	Wholesale	-2.375	-9.057*	-2.416	-9.056*	-2.75	-8.987*	-2.879	-9.362*
	Retail	-2.572	-8.218*	-2.659	-8.168*	-2.706	-9.623*	-2.735	-9.792*
Zamboanga Peninsula	Farmgate	-4.079*		-4.581*		-4.610*		-4.496*	
	Wholesale	-3.759*		-3.911*		-3.989*		-4.016*	
	Retail	-2.379	-9.448*	-2.412	-8.854*	-2.49	-10.391*	-2.516	-10.288*
Northern Mindanao	Farmgate	-3.549	-13.542*	-3.305	-13.562*	-4.253*		-4.388*	
	Wholesale	-3.309	-9.755*	-3.283	-10.718*	-3.213	-10.702*	-3.26	-9.330*
	Retail	-2.235	-7.421*	-2.294	-7.489*	-2.249	-6.114*	-2.456	-5.845*
Davao Region	Farmgate	-4.154*		-4.028*		-4.398*		-4.363*	
	Wholesale	-3.31	-11.082*	-3.346	-11.569*	-3.357	-10.517*	-3.486	-9.996*
	Retail	-3.393	-10.968*	-3.446	-10.987*	-3.235	-10.884*	-3.481	-10.358*
SOCCSKSARGEN	Farmgate	-3.746*		-3.895*		-3.078	-7.456*	-3.154	-13.278*
	Wholesale	-3.183*		-3.300*		-3.493	-10.871*	-3.578*	
	Retail	-3.393	-10.941*	-3.446	-10.976*	-3.235	-10.872*	-3.481	-10.216*
CARAGA	Farmgate	-4.120*		-4.308*		-4.770*		-4.894*	
	Wholesale	-2.457	-8.793*	-2.436	-9.292*	-2.566	-6.857*	-2.688	-6.405*
	Retail	-3.114	-10.169*	-3.021	-9.986*	-3.007	-10.219*	-3.47	-9.930*
ARMM	Farmgate	-5.131*		-5.688*		-6.863*		-6.583*	
	Wholesale	-2.623	-8.327*	-2.609	-7.574*	-2.413	-7.733*	-2.718	-9.057*
	Retail	-2.763	-8.295*	-2.729	-8.692*	-2.729	-8.508*	-2.838	-8.397*

* Indicates rejection of null hypothesis of unit roots at 1%. † L indicates series in level, FD first differenced series

Table 3. Test Results between Linear and STAR-type Nonlinearity

Regions	Farm	Wholesale	Retail
CAR	LSTAR2	Linear	Linear
Ilocos Region	LSTAR2	Linear	Linear
Cagayan Valley	LSTAR1	Linear	Linear
Central Luzon	LSTAR1	Linear	Linear
CALABARZON	Linear	Linear	Linear
MIMAROPA	Linear	Linear	Linear
Bicol Region	LSTAR2	Linear	Linear
Western Visayas	LSTAR1	LSTAR1	LSTAR1
Central Visayas	LSTAR1	Linear	Linear
Eastern Visayas	LSTAR1	Linear	Linear
Zamboanga Peninsula	Linear	LSTAR1	Linear
Northern Mindanao	LSTAR1	Linear	LSTAR1
Davao Region	LSTAR1	LSTAR1	LSTAR1
SOCCSKSARGEN	LSTAR1	LSTAR1	LSTAR1
CARAGA	LSTAR2	LSTAR1	Linear
ARMM	Linear	Linear	LSTAR1

Table 4a: Smooth Transition Autoregressive (STAR) estimation for farmgate prices

	CAR		Cagayan Valley		Central Luzon		MIMAROPA		Bicol Region	
Variable	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Constant	4.218*	-3.920*	-10.888	11.238	0.292***	0.710***	0.205**	0.233	0.276***	0.145
	(2.164)	(2.171)	(0.000)	(0.000)	(0.079)	(0.258)	(0.090)	(0.200)	(0.070)	(0.172)
farm_log_d1(t-1)	-0.690	1.560*	5.488	-4.626	0.884	-0.276***	0.917***	-0.090	0.892***	-0.029
	(0.905)	(0.908)	(0.000)	(0.000)	(0.033)	(0.104)	(0.038)	(0.083)	(0.031)	(0.077)
Gamma	164.911*		55.242		1713.954		3.526*		4.601	
	(176.382)		(33.518)		(782634.809)		(2.001)		(3.445)	
C1	44.030***		10.370		213.967***		174.219		47.247***	
	(3.864)		(0.000)		(15.127)		(14.854)		(5.991)	
C2	24.329***								280.349***	
	(3.527)								(14.195)	
AIC	-5.428		-5.666		-5.799		-5.647		-5.717	
SC	-5.060		-5.298		-5.431		-5.279		-5.335	
R^2	0.790		0.815		0.833		0.838		0.838	
$\hat{\sigma}_{\varepsilon}$	0.063		0.056		0.053		0.057		0.055	

Table 4b: Smooth Transition Autoregressive (STAR) estimation for farmgate prices (cont'd)

	Western Visayas		Central Visasyas		Eastern Visasyas		Northern Mindanao		Davao Region		SOCCSKSARGEN	
Variable	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Constant	0.241	0.067	0.410**	-0.019	0.379***	0.222	0.334***	0.014	0.289	0.060	- 17227.647	17227.999
	(0.324)	(0.385)	(0.197)	(0.229)	(0.113)	(0.253)	(0.090)	(0.159)	(1.107)	(1.181)	(0.000)	(0.000)
farm_log_d1(t-1)	0.951***	-0.082	0.821***	0.012	0.525***	0.015	0.859***	0.001	0.854*	0.001	6603.183	0.456
	(0.194)	(0.216)	(0.081)	(0.094)	(0.072)	(0.138)	(0.040)	(0.068)	(0.493)	(0.524)	(0.000)	(0.405)
farm_log_d1(t-2)					0.307***	-0.105						
					(0.071)	(0.136)						
Gamma	1.474		7.482		28.007		26.662		1.112		0.456	
	(1.412)		(4.972)		(29.116)		(29.709)		(0.000)		(0.405)	
C1	12.326		43.707***		199.054***		155.674***		-75.535		-1974.857	
	(175.155)		(9.645)		(4.441)		(6.604)		(0.000)		(1543.607)	
AIC	-5.959		-5.314		-5.246		-5.873		-5.613		-6.008	
SC	-5.590		-4.945		-4.850		-5.504		-5.244		-5.640	
R^2	0.874		0.740		0.655		0.838		0.730		0.873	
$\hat{\sigma}_\varepsilon$	0.048		0.067		0.069		0.051		0.058		0.047	

Table 5: Smooth Transition Autoregressive (STAR) Estimation results for retail prices

Variable	Western Visayas		Zamboanga Peninsula		Northern Mindanao		Davao Region		SOCCSKSARGEN		ARMM	
	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Constant	-2.553	2.670	-1.532	1.622	0.006	-0.008	0.173**	0.972***	0.185**	1.387***	-0.017***	0.033***
	(3.413)	(3.423)	(2.973)	(2.976)	(0.012)	(0.016)	(0.084)	(0.248)	(0.078)	(0.230)	(0.006)	(0.011)
retail_log_d1(t-1)	1.813*	-0.849	3.620	-2.373	0.164	0.013	0.945***	-0.295***	1.128***	-0.207*	-0.004	0.715***
	(1.083)	(1.086)	(3.396)	(3.398)	(0.115)	(0.165)	(0.027)	(0.076)	(0.086)	(0.121)	(0.077)	(0.146)
retail_log_d1(t-2)			-2.137	1.860	-0.011	0.267			-0.187**	-0.224*	0.094	-0.380
			(3.583)	(3.583)	(0.123)	(0.174)			(0.085)	(0.117)	(0.077)	(0.142)
retail_log_d1(t-3)					-0.135	-0.084						
					(0.116)	(0.164)						
retail_log_d1(t-4)					0.092	-0.397**						
					(0.132)	(0.188)						
Gamma	30.027		116.640		2.254		1327.400		1477.199		14.131	
	(0.117)		(232.936)		(1.153)		(159.211)		(193194.050)		(9.954)	
C1	13.169**		13.955***		116.985***		217.947***		216.945***		195.382***	
	(5.740)		(2.751)		(22.910)		(6.311)		(7.144)		(6.181)	
AIC	-7.119		-7.540		-7.437		-6.857		-7.149		-7.417	
SC	-6.751		-7.144		-6.985		-6.488		-6.753		-7.020	
R^2	0.947		0.961		0.419		0.916		0.922		0.295	
$\hat{\sigma}_\varepsilon$	0.027		0.022		0.023		0.031		0.027		0.023	

Table 6: Smooth Transition Autoregressive (STAR) estimation results for wholesale prices.

	Northern Mindanao		Davao Region		SOCCSKSARGEN		CARAGA		ARMM	
Variable	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2	Regime 1	Regime 2
Constant	0.007	0.189	0.174**	1.355***	0.248	0.030	0.206**	1.944***	-0.068	0.181
	(0.107)	(0.131)	(0.078)	(0.265)	(0.201)	(0.221)	(0.082)	(0.322)	(0.114)	(0.125)
wholesale_log_d1(t-1)	0.886***	0.309**	0.946***	- 0.428***	0.828***	0.314	0.957***	-0.235*	1.022***	0.197
	(0.106)	(0.131)	(0.026)	(0.084)	(0.230)	(0.243)	(0.079)	(0.135)	(0.106)	(0.132)
wholesale_log_d1(t-2)	0.111	-0.369***			0.083	-0.312	0.085	0.047	-0.014	-0.242*
	(0.110)	(0.135)			(0.221)	(0.235)	(0.110)	(0.166)	(0.111)	(0.135)
wholesale_log_d1(t-3)							-0.049	-0.415**		
							(0.109)	(0.165)		
wholesale_log_d1(t-4)							-0.059	0.020		
							(0.078)	(0.129)		
Gamma	99.517		2087.260		8.958		1805.112		1551.767	
	(216.624)		(11653925.32)		(0.000)		(2315592.94)		(867004.82)	
C1	74.757***		218.009***		48.208***		215.035***		72.976***	
	(2.117)		(50.970)		(10.240)		(45.355)		(13.495)	
AIC	-7.130		-6.843		-6.515		-7.198		-7.240	
SC	-6.735		-6.475		-6.119		-6.747		-6.845	
R^2	0.928		0.926		0.898		0.939		0.950	
$\hat{\sigma}_{\varepsilon}$	0.027		0.031		0.037		0.026		0.025	