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Modeling sheep supply response under asymmetric price volatility and cap reforms

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Abstract

This paper investigates the supply response of the Greek sheepmeat market and examines the effects of the Common Agricultural Policy (CAP) reforms in the Greek sheepmeat industry during the period 1993-2005. The nonlinear asymmetric GARCH (NAGARCH) process is used to estimate expected price and price volatility, while supply and price equations are estimated simultaneously. Producers'' price volatility, was found to be an important risk factor of the supply response function of the Greek sheepmeat market while the negative asymmetric price volatility which was detected implies that producers have a weak market position. Furthermore, the empirical findings confirm the positive effect of the annual premium paid by EU to sheepmeat producers and indicate that the recent CAP reform will have a negative effect in the Greek sheepmeat production.

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1. Introduction

The goal of this study is to estimate supply response for the Greek sheep industry taking into consideration recent Common Agricultural Policy (CAP) reforms and thus providing useful information to policy makers and producers. Several parameters such as sheepmeat price and feed cost are used to specify the appropriate supply response model and describe producers' risk. It should be stated, however, that the nature of sheep is that they are simultaneously consumption goods and capital goods (Rosen 1987). Thus, in the short run, it is possible to observe a negative price elasticity of supply. Beside common used risk factors such as sheepmeat price and feed cost, a focus is given on entering expected sheepmeat price volatility in the supply equation. Price volatility represents an important risk factor of supply especially in agricultural products. Agricultural prices tend to be more volatile due to inelastic demand and production uncertainties (Just 1974, Holt and Aradhyula 1990, 1998) and also because many agricultural products and especially fresh meat products are perishable lacking storage ability. An increase in price volatility implies higher uncertainty about future prices, a fact that can affect producers' welfare especially in the absence of a hedging mechanism. Figure 1 indicates the presence of price volatility in the Greek sheepmeat market during the period 1993-2005.

The statistical technique of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) process Bollerslev (1986) is adopted to characterize the time varying attributes of expected price and price volatility in sheep market and a full information maximum likelihood estimator is used to estimate the parameters of the supply equation simultaneously with the parameters of the GARCH model (Holt and Aradhyula 1990). Since first introduced in 1986, the family of GARCH models is continuously expanding including more specified models. In this paper, the Nonlinear Asymmetric GARCH (NAGARCH) (Engle and Ng 1993) model is estimated, tested and evaluated in order to investigate possible existence of asymmetric price volatility. The studies by Rezitis and Stavropoulos (2007a, b) showed that the NAGARCH model is the most appropriate GARCH model to describe asymmetric price volatility for the Greek beef and pork markets respectively. The existence of possible asymmetry in the behavior of price volatility in the sheepmeat market is so far unknown. Asymmetry means that different volatility is recorded in case of a fall in prices than an increase in prices by the same amount and potential asymmetry in producers' price volatility can give useful information about market structure and possible market power.

In the specification of the supply response model, the CAP impact is taken into consideration with the inclusion of the annual premium rate paid to sheep breeders into the model. In addition, recent CAP reforms are taken into account such as the change from a volatile to a flat rate ewe premium decided in the year of 2002 and the established decouple between premium and production decided the year 2003 to take place from the year 2006 to 2013. It is worth stating that CAP was first established in 1962 and has undergone several changes over the years. In particular, during the period 1993-2001, an annual basic price was set and the difference between this basic price and the actual average EU market price formed the basis for the calculation of the annual premium paid to producers with a limit on the number of eligible animals in each member state. During the period 2002-2005, a flat rate annual premium per eligible animal was introduced. The last CAP reform in 2003 introduced the Single Farm Payment (SFP), a system of annual payments to producers irrespective of production, i.e. decoupling. This payment is not linked to farmers' production and it is calculated based on the direct subsidy farmers received during the period 2000-2002. There was also the possibility of partial decoupling but Greece chose full decoupling. The SFP came into effect in the period 2005-2006 and the purpose of this policy is to support market liberalization and rural development rather than farmers' production and incomes.

In Mediterranean countries[1] sheep are usually used for meat and milk production, a fact that should be taken into consideration when specifying sheepmeat supply response models. A high sheep milk price can have a negative effect in sheepmeat supply quantity mainly because producers may decide to slaughter young lambs faster and in lower weight in order to collect and sell the milk produced by the females. Another reason for a possible decrease in sheepmeat quantity supplied is that if producers believe that milk price will continue to stay high in the future they probably decide not to slaughter some young females and use them to increase the size of the breeding stock and thus increase future milk production.

The contribution of the present paper in the existing literature is threefold: First, it estimates a supply response model of the Greek sheepmeat sector and introduces price volatility as a risk factor. Second, it tests for the presence of asymmetric price volatility, which is important because it provides some useful indications about the presence of market power in the industry and third, it introduces the impact of recent CAP reforms in the specification of the supply response model and offers quantitative knowledge of the economic impacts resulting from the aforementioned policy action.

2. Methodology

Based on the approach proposed by Nelson and Spreen (1978) and Marsh (1994) it is assumed that producers' utility depends on maximizing profits subject to output price and input prices. Thus, the short run profit function for the jth sheepmeat producer can be specified as:

$$\Pi_j = PPL \times QLP_J - C_J(PLF, VMED, QLP_J) \tag{1}$$

where PPL is the real producer price of sheepmeat, QLP_J is sheepmeat production of the jth producer, PLF is the real price of feed and $VMED$ is the real price of veterinarian medicines. Taking the partial derivatives of (1) with respect to QLP_J, the producer maximizes profit. Thus the short runs supply function is given as:

$$QLP_j^S = \phi_j(PPL, PLF, VMED) \tag{2}$$

For an individual producer, supply curve is assumed to be infinitely elastic which precludes monopoly and monopsony power in output and input markets. Equation (2) is also assumed to be homogenous of degree zero in output and input prices. Market supply function is obtained by summing individual supply functions of all producers.

However, in order to achieve a good specification of the market supply function for sheepmeat some more variables are added:

$$QLP^S = f(PPL, PLF, VMED, PML, PCV, D_i, PR, SD) \tag{3}$$

where PML is the real producer price of sheep milk, PCV , is the expected price volatility, D_i is a monthly dummy variable (i= 1, 2, …, 12), PR is the premium paid to producers and SD is a dummy variable which represents CAP changes.

An empirical econometric specification of the above supply equation model can be described as

$$y_t = a_0 + a_1 P_t^e + a_2 h_t + a_3 x_{1t}' + \varepsilon_{1t} \tag{4}$$

[1] In Greece the sheep industry is one of the most important and traditional industries of the livestock sector. The sheep industry is of particular importance especially to less favored areas of the country and it is characterized mainly by small size localized farms without significant market power. Greece is the forth biggest sheepmeat producer in the European Union (EU) and the domestic production in 2006 satisfied about 85% of the domestic demand, while EU is the second largest producer internationally with a self-sufficiency of about 79% in 2005. The development of the sheep industry in EU countries is affected in many ways by the Common Agricultural Policy (CAP), which sets out a common regime for sheepmeat production.

where y_t is the sheepmeat production, P_t^e is the expected price, h_t is the expected price variance which measures volatility, x'_{1t} is a vector of independent variables and ε_{1t} is a mean zero normally distributed error term with variance σ_{11}.

Then the GARCH (p, q) process is used to generate the variables P_t^e and h_t and it is given as

$$P_t \mid \Omega_{t-1} = c_0 + \sum_{i=1}^{n} c_i P_{t-i} + \varepsilon_{2t} \tag{5}$$

$$h_t = b_0 + \sum_{i=1}^{q} b_{1i}\varepsilon_{2t-i}^2 + \sum_{i=1}^{p} b_{2i} h_{t-i} \tag{6}$$

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

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

Engle (1982) introduced the Autoregressive Conditional Heteroskedasticity (ARCH) model allowing 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, $\sigma_{\varepsilon_2}^2$. Thus, in equation (5), ε_{2t} is a discrete time stochastic error, Ω_{t-1} is the information set of all past states up to the time $t-i$ and c_i is a vector of parameters to be estimated. Following the Generalized ARCH (p, q) [GARCH (p, q)] specification developed by Bollerslev (1986), h_t is defined as in equation (6), which is called GARCH conditional variance equation. According to equation (6) the conditional variance h_t is specified as a linear function of lagged q squared residuals and its own lagged p conditional variances. As the variance is expected to be positive, the coefficients b_0, b_{1i} and b_{2i} are always positive. Also the stationarity of the variance is preserved by the restriction $\sum b_{1i} + \sum b_{2i} < 1$.

The predictions of P_t^e and h_t generated by the GARCH model could be used directly to estimate supply equation (4). But using regressors generated by a stochastic model, e.g. GARCH, as factors in the estimation of equation (4) can cause biased estimates of the parameters. This problem can be avoided by estimating the GARCH model of equations (5) and (6) and the supply equation (4) jointly using the full information maximum likelihood method (Pagan and Aman 1988). More specifically, let ε_{1t} of equation (4) and ε_{2t} of equation (5) be distributed jointly as

$$\varepsilon_t = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \sim N\left[\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{11}\sigma_{12} \\ \sigma_{12} h_t \end{bmatrix}\right]$$

where σ_{11} and σ_{12} are constants. Assuming conditional normality and setting as Σ_t the variance-covariance matrix then the log likelihood function of the above system is given as

$$L_T(\Theta) = -\log|\Sigma_t| - \varepsilon_t' \Sigma_t^{-1} \varepsilon_t \tag{7}$$

where $|\Sigma_t| = \sigma_{11} h_t - \sigma_{12}^2 = \phi$

and $\varepsilon_t' \Sigma_t^{-1} \varepsilon_t = [\varepsilon_{1t}^2 h_t - 2\varepsilon_{1t}\varepsilon_{2t}\sigma_{12} + \varepsilon_{2t}^2 \sigma_{11}]\phi^{-1}$.

GARCH model implies that ε_t is normal and follows the Gaussian distribution but in practice the residuals are often described by excess kurtosis. In order to handle this problem, Bollerslev and Wooldridge (1992) proposed the use of quasimaximum likelihood estimation. The Broyden, Fletcher, Goldfarb and Shanno (BFGS) algorithm is then used to find the maximum likelihood parameter estimates of equation (7).

Although the simple GARCH model has been found to provide a good representation of volatility process, the literature offers many alternative specifications. A very important specification has to do with asymmetry. The asymmetric effect is observed when a different volatility is recorded in the case of a fall in price than in the case of an increase (i.e. bad and good news). The standard GARCH model used above cannot capture the asymmetry as far as the error term, ε_{2t}, which represents the unexpected price shock, enters the conditional variance equation as a square, so there is no difference if the price shock is positive or negative. Asymmetric GARCH model take account of skewed distributions in which good news and bad news have a different effect on volatility.

A characteristic asymmetric GARCH model is the Nonlinear Asymmetric GARCH (NAGARCH) developed by Engle and Ng (1993). In that model equation (5) and (6) of the system presented above are described as:

$$P_t = c_0 + \sum_{i=1}^{n} c_i P_{t-i} + \varepsilon_t \quad , \quad \varepsilon_t \mid \Omega_{t-1} \sim N(0, h_t) \tag{8}$$

$$h_t = b_0 + \sum_{i=1}^{q} b_{1i} (\varepsilon_{t-i} + b_3 \sqrt{h_{t-i}})^2 + \sum_{i=1}^{p} b_{2i} h_{t-i} \tag{9}$$

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

This model defines volatility as a nonlinear asymmetric function of past period's shocks and volatility and if $b_3 \neq 0$ then asymmetry is present. Note that b_3 is the asymmetry parameter and if b_3 is positive then a positive shock causes more volatility than a negative shock of the same size.

3. Data and Model Specification

Data used in this study are monthly time series for the period of January 1993 to December 2005. In particular, sheepmeat quantities and sheepmeat premiums paid to Greek producers are obtained from the Hellenic Ministry of Rural Development and Food (HMRDF) and are transformed into a sheepmeat quantity index and a premium index respectively. Sheepmeat producer price index, sheep milk producer price index, sheep feed price index and veterinarian medicines price index obtained from the National Statistical Service of Greece (NSSG). All variables are transformed in logarithms and all prices are deflated by the consumer price index (1993=100).

The sheepmeat supply response equation (1) is specified as

$$\begin{aligned} QLP_t = \sum_{i=1}^{12} a_i D_{it} + a_{13} TR + a_{14} PPL_t^e + a_{15} PCV_t + a_{16} PLF_{t-7} + a_{17} VMED_{t-7} + a_{18} PLM_t \\ + a_{19} QLP_{t-1} + a_{20} QLP_{t-12} + a_{21} PR_{t-12} + a_{22} SD + a_{23} (SD \times PR_{t-12}) + \varepsilon_{1t} \end{aligned} \tag{10}$$

QLP_t is the sheepmeat production in period *t*. The monthly dummy variable (D_{it}) is used to capture the monthly seasonality effect of the production. The production of sheepmeat in Greece is always high in spring due to the custom of sheepmeat consumption during the Greek-orthodox Easter. A trend component (*TR*) is used to capture technological change in the lamb production process. Expected sheepmeat price, PPL_t^e, and the price volatility term, PCV_t, are considered to be important risk factors and thus they are included.

Prices of two senior cost factors are used. Firstly, the price of feed, PLF_{t-7}, which is the most important cost factor (even though Greek small size sheep breeders use also natural pasture) and secondly, the price of veterinarian medicines, $VMED_{t-7}$, which is a significant cost factor because producers try to avoid production loss due to sheep diseases. A seven lag period for input prices, i.e. PLF_{t-7} and $VMED_{t-7}$, is used because of the biological cycle of the sheep production which in Greece is about 200 days. Furthermore, the price of sheep milk, PLM_t, regarded as an important variable of the supply equation and it represents a kind of opportunity cost for sheepmeat as analyzed in section 1. In addition, 1 and 12 lags of sheepmeat production, i.e. QBP_{t-i} where i = 1 and 12, are included to the supply function because production needs time to adjust to the desirable level.

Finally three variables are used to capture the effect of the CAP on the sheepmeat market. Firstly, a twelve lag period of the annual premium paid to sheepmeat producers (PR_{t-12}) is included because producers become aware of the annual premium level paid at the end of each year. Thus, they form their expectations about the premium paid this year based on the premium paid in the previous year. Secondly, a dummy variable (SD) for the period from 1/2003 to 12/2005 is used to evaluate the effect of CAP reform related to decouple between premium and production which was decided in 2003 to take place from 2006 to 2013. The dummy variable SD is used to evaluate whether the knowledge of this oncoming change by sheep breeders affects sheepmeat supply or not. Thirdly, the interaction variable $PR_{t-12} \times SD$ is constructed by multiplying the premium rate (PR_{t-12}) with the dummy variable (SD) and it is used to evaluate the effect of the change from a volatile to a flat premium rate during the period 1/2003 to 12/2005.

The specification of the real producer price of sheepmeat is given as

$$PPL_t = c_0 + \sum_{i=1}^{12} c_i PPL_{t-i} + c_{13} TR + \varepsilon_{2t} \tag{11}$$

where PPL_t is the real producer price of sheepmeat in time t, TR is a trend component and PPL_{t-i} is the real producer price of sheepmeat in time $t-i$ where $i = 1, 2, \ldots\ldots, 12$.

The NAGARCH model was tested for several orders such as NAGARCH (1, 2), NAGARCH (2, 1) and NAGARCH (2, 2) but in all cases the simple NAGARCH (1, 1) process fits better. Thus the variance equation of the NAGARCH (1, 1) model is used and it is given by

$$h_t = b_0 + b_1(\varepsilon_{t-1} + b_3\sqrt{h_{t-1}})^2 + b_2 h_{t-1} \tag{12}$$

4. Empirical Results

Table I provides the results of unit root tests on the data. Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests are evaluated. The sheepmeat production variable, QLP, and the real producer price of sheepmeat, PPL, remained stationary in all cases. The real producer price of milk PML is no stationary and the results for real feed price, PLF, and veterinarian medicines real price, $VMED$, are mixed.

The BFGS algorithm is used to obtain maximum likelihood estimates of the system and the model achieve convergence. Residual diagnostic tests are performed in order to check the explanatory power of the supply-price system. In particular, Ljung- Box Q(m) statistics for 6 and 12 lags is performed for the standardized residuals and squared standardized residuals in order to check upon serial correlation and heteroskedasticity respectively. The residual tests for the supply response equation and price equation are presented in Table II. In supply response equation the model present no heteroskedasticity for all the examined lags at the 5% level of significance, no autocorrelation at 6 lags at the 5% level of significance and no autocorrelation at 12 lags at the 1% level of significance. With regard to the price equation, model present no heteroskedasticity for all the examined lags at the 5% level of significance, no autocorrelation at 6 lags at the 5% level of significance and no autocorrelation at 12 lags at the 1% level of significance.

Table III presents the estimated parameters of the supply response and price equation. Analyzing the estimated parameters, it can be noticed that the magnitude of b_1 is smaller than the magnitude of b_2, i.e. 0.284 and 0.455 respectively. The size of b_1 and b_2 parameters determines the short-run dynamics of price volatility. Since b_2 has a larger value, this indicates that volatility is persistent and shocks to conditional variance take a long time to die out. The asymmetry factor b_3 is significant and negative, i.e. -0.101, indicating a negative asymmetric effect. This means that a negative shock causes more volatility than a positive shock of the same size. Sheepmeat producers seem to react more intensely in the case of a negative shock which push them to decrease prices than in the case of a positive shock when they increase prices. The fact that producers respond less to unexpected price increases suggests that their position in the market chain is very weak and so they can not benefit by "good news" about price and increase their price immediately while in the case of "bad news" they are immediately forced to a price cut. This result is consistent with the situation existing in the sheepmeat market structure in Greece, which is characterized by a large number of small size sheep breeding farms with a weak influence in the market and a number of wholesalers and retailers (among them big supermarkets) with a strong influence in the market. Unfortunately, there are not any other studies examining the existence of asymmetric price volatility in the behavior of sheepmeat prices in order to cross check the results of the present study. However, the asymmetric price volatility result of the present study can be compared to those obtained by Rezitis and Stavropoulos (2007a, b), which estimate a negative asymmetric effect, i.e. -0.005, for the Greek beef industry and no asymmetry for the Greek pork industry, respectively. These findings can be justified because the Greek beef market is characterized by a large number of small size breeding farms with a weak influence in the market, while in pork market producers have a balance position in the market chain.

Examining the coefficients of the supply response equation of the NAGARCH model, presented in Table III, it can be remarked that almost all the estimated coefficients have the theoretically expected signs and they are statistically significant at all levels. Short-run supply price elasticity given by the estimated coefficient a_{14} is positive, i.e. 0.214, indicating that an expected sheepmeat price increase induces producers to slaughter lambs at present instead of holding them in the breeding flock in order to increase future production. This result is similar to that obtained by SAC and INRA (2000) with a magnitude of about 0.210 and quite smaller from that obtained by Fotopoulos (1988) with a magnitude between 0.30-0.55, with both of these studies referring to the Greek sheep industry. The calculated long-run price supply elasticity of the present study is about 1.797 which is elastic, and higher than the one obtained by SAC and INRA (2000) of about 0.84 and by Fotopoulos (1988) of about 0.9. The sign of the estimated coefficient for the expected price volatility is negative, i.e. $a_{15} = -0.151$, as expected, indicating the importance of price volatility as a risk factor in the Greek sheepmeat production.

The magnitude of the sheep milk price coefficient, i.e. $a_{18} = -0.046$, confirms that a high milk price causes a decrease in sheepmeat supply quantity. The magnitude of this parameter is smaller than the one obtained by Fotopoulos (1988) which is between -0.51 and -0.62. The magnitude of sheep feed cost coefficient, i.e. $a_{16} = -0.203$, indicates that feed cost is a significant cost factor in sheepmeat production, while the veterinarian medicine cost estimated coefficient, i.e. $a_{17} = -0.018$, is smaller indicating that this production cost is less important. Almost all seasonal components are statistically significant indicating the presence of seasonal effects. Traditionally Greek sheepmeat production is higher around April and December due to higher demand, i.e. during Orthodox Easter and Christmas respectively. Moreover, the estimates obtained for lagged production are high implying that production is adjusting slowly to the desirable level.

The estimates of the parameters used to capture CAP effects provide useful information. Firstly, the positive coefficient of the premium parameter, i.e. $a_{21} = 0.076$, confirms that the annual premium rate paid to producers has a positive effect to sheepmeat production. Secondly, the dummy variable for the period from 1/1/2003 to 1/12/2005 is negative, i.e. $a_{22} = -0.130$, indicating that the effect of the CAP reform related to decouple between premium and production which was decided the year 2003 to take place from the year 2006 to 2013 has a negative effect on sheepmeat production. This indicates that even though the new CAP was decided to take place from the year 2006, the sheepmeat production was affected much earlier and especially when the CAP reform was decided, i.e. the year 2003. This empirical result is consistent with a rational behavior because although the new CAP came into effect in 2006, farmers started adjusting their production to lower levels since 2003 because they knew about this oncoming event since then. This policy may lead many sheep breeders to withdraw from production and especially those in the most disadvantageous areas of Greece causing serious socio-economic problems since in these areas there are not any alternative production activities. Canali and Consortium (2006) raise similar concerns about the CAP reform. Finally, the coefficient of the interaction variable ($PR_{t-12} \times SD$) is positive, i.e. $a_{23} = 0.020$, indicating that the change from a volatile to a flat annual premium per ewe during the period 2003-2005 has a positive impact on sheepmeat production which is an expected outcome since this policy instrument reduces uncertainty. In particularly, while the effect of the volatile annual premium of the period 1993-2002 is $a_{21} = 0.076$, the effect of the flat annual premium of the period 2003-2005 is higher, i.e. $a_{21} + a_{23} = 0.096$.

5. Conclusions

The objective of this study is to investigate the sheepmeat supply response in Greece and examine the impact of CAP reforms on Greek sheepmeat production. The empirical analysis used a FIML approach to estimate simultaneously the supply response equation with the price equation and the NAGARCH process used to model producers' expectations about expected price and expected price volatility. The results indicate that producers are risk averse because sheepmeat price volatility is negative. In addition, negative asymmetric effect was detected on price volatility indicating that Greek sheepmeat producers have a weak market position. Both, short and long-run supply price elasticities are positive with the long-run elasticity to be elastic. Sheep milk was found to have a negative effect on sheepmeat production indicating that sheep milk and sheepmeat are competitive products. Feed price has a stronger impact on sheepmeat production than veterinarian medicine indicating that feed is more important cost factor of sheepmeat production than veterinarian medicine. Finally, the empirical results indicate a negative impact of the CAP reform, i.e. decouple between premium and production, on the Greek sheepmeat production. Thus, EU and Greek policy makers should take this effect into consideration because it will cause intense socio-economic problems especially to less favored areas of the country where sheep breeding is the main production activity and where there is an absence of alternative production opportunities.

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Table I. Results of Unit Roots Tests				
	Augmented Dickey Fuller (ADF)	**Augmented Dickey Fuller (ADF) (with intercept & trend)**	**Phillips Perron (PP)**	**Phillips Perron (PP) (with intercept & trend)**
QLP	**-6.378***	**-6.499***	**-6.095***	**-6.7816***
PPL	**-4.578***	**-4.665***	**-5.884***	**-6.053***
PLF	**-2.459**	**-3.768***	**-1.168**	**-3.3101***
PML	**-2.060**	**-2.390**	**-1.853**	**-2.195**
PR	**0.128**	**0.255**	**0.112**	**0.203**
$VMED$	**-2.166****	**-3.239****	**-1.869**	**-2.778****

* = Significant at 5%
** = Significant at 10%

Table II. Residuals tests for supply response equation and price equation under NAGARCH model		
supply response equation		
	Supply response equation	**Price equation**
$Q(6)$	**10.205 (0.117)**	**2.073 (0.913)**
$Q(12)$	**26.433 (0.010)**	**8.197 (0.769)**
$Q(18)$	**38.495 (0.003)**	**32.226 (0.021)**
$Q^2(6)$	**4.167 (0.654)**	**7.645 (0.265)**
$Q^2(12)$	**4.835 (0.963)**	**11.291 (0.504)**
$Q^2(18)$	**5.202 (0.998)**	**28.319 (0.057)**

Figures in brackets are p-values

Table III. **Results of supply response equation and price equation under NAGARCH model**

supply response equation											
a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9	a_{10}	a_{11}	a_{12}
-0.220 (0.000)	**-0.025 (0.048)**	**0.088 (0.000)**	**0.780 (0.000)**	**-0.748 (0.000)**	**-0.438 (0.000)**	**-0.122 (0.000)**	**-0.039 (0.001)**	**-0.200 (0.000)**	**-0.002 (0.904)**	**0.106 (0.000)**	**0.438 (0.000)**
a_{13}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}	a_{19}	a_{20}	a_{21}	a_{22}	a_{23}	
0.000 (0.979)	**0.214 (0.000)**	**-0.151 (0.000)**	**-0.203 (0.000)**	**-0.018 (0.000)**	**-0.046 (0.000)**	**0.829 (0.000)**	**0.107 (0.000)**	**0.076 (0.000)**	**-0.130 (0.000)**	**0.020 (0.000)**	
price equation											
c_0	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	c_9	c_{10}	c_{11}
1.367 (0.000)	**0.536 (0.000)**	**0.126 (0.000)**	**0.047 (0.000)**	**0.027 (0.000)**	**-0.139 (0.000)**	**-0.187 (0.000)**	**0.055 (0.000)**	**0.174 (0.000)**	**-0.017 (0.000)**	**-0.050 (0.000)**	**-0.093 (0.000)**
							GARCH factors				
c_{12}	c_{13}						b_0	b_1	b_2	b_3	
0.219 (0.000)	**0.000 (0.000)**						**0.002 (0.000)**	**0.284 (0.000)**	**0.455 (0.000)**	**-0.101 (0.000)**	
Figures in brackets are p-values