World Applied Sciences Journal 9 (11): 1244-1249, 2010
ISSN 1818-4952

Price Volatility and Beef Supply Response: AN Iranian Experience

Forooz jezghani and Reza Moghaddasi

Department of Agricultural Economics Science and Research Branch,
Islamic Azad University, Tehran, Iran

Abstract: This paper examines the supply response of the Iran beef market. A GARCH process is used to estimate expected price and price volatility, while price and supply equations are estimated jointly. In addition to the standard GARCH model, several different symmetric, asymmetric and nonlinear GARCH models are estimated. The empirical results indicate that among the estimated GARCH models, the quadratic NAGARCH model seems to better describe producers' price volatility, which was found to be an important risk factor of the supply response function of the Iranian beef market. Furthermore, the empirical findings show that feed price is an important cost factor of the supply response function and that high uncertainty restricts the expansion of the Iran beef sector. Finally, the model provides forecasts for quantity supplied, producers' price and price volatility.

Key words: Price volatility · GARCH · Beef supply · Asymmetry · Forecasts

INTRODUCTION

Beef is one of the major items in consumption basket for Iranian households, so for the purpose of policy making knowing which variables affect the beef product and what is the rate of price volatilities (uncertainties) is of great importance.

The objective of this paper is to explore the supply response of the Iranian beef industry. Several parameters such as expected beef producer price, price volatility, milk price and cost factors are used to specify the appropriate supply response model and describe producers' risk. An important aspect of the meat supply response, e.g. pork, sheep and beef, is a possible observation of a negative short-run producer price elasticity of supply. That is because cattle is both a capital and consumption good [1]. If the price of beef increases and producers expect that this increase is sufficiently permanent, then they may decide to retain a larger than average number of females to increase the future herd size instead of slaughtering them at present [2]. When specifying a beef supply response model the price of milk should also be taken into account. In Iran, cattle are usually used for both meat and milk production and in that case milk and meat behave like competitive products. A high milk price can have a negative effect on beef supplied quantity mainly because producers decide to market milk rather than to use it as a feed for the young calves. Therefore, a high milk price induces producers to slaughter faster young calves in lower weight. Also, if producers believe that milk price will continue to stay high in the future they will probably decide not to slaughter some young females. Instead they will use them to increase the size of the breeding stock increasing thus future milk production.

Beside the common factors used in a beef supply response equation such as beef price and feed cost, this paper highlights price volatility by entering expected beef price volatility in the supply equation. Uncertainty and risk aversion play an important role in agricultural production and many studies have attempted to specify the role of risk in agricultural supply [3-6]. Price volatility represents an important risk factor of supply especially in agricultural products. A variety of empirical researches support that increases in price risk reduces supply *ceteris paribus*. This implies that omitting price risk from the model has the consequence of having a biased price coefficient downwards underestimating the effect of price on supply. 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.

In this paper, the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) process is adopted to characterize the time varying attributes of

Corresponding Author: Forooz jezghani, Department of Agricultural Economics Science and Research Branch, Islamic Azad University, Tehran, Iran. E-mail: fjezghani@gmail.com.

expected price and price volatility of the beef market. Also a full information maximum likelihood (FIML) estimator is used to estimate the parameters of the supply equation simultaneously with the parameters of the GARCH model [5].

In this paper, a focus is given on estimating and testing different types of symmetric, asymmetric and nonlinear GARCH models in order to specify beef expected price and volatility. An emphasis is given on asymmetric GARCH models in order to investigate the existence of possible asymmetry in the behavior of price volatility in the beef market, which is so far unknown. Asymmetric price volatility is observed when different volatility is recorded between an increase and a decrease of price of the same amount. In the case of the beef market, the existence of price asymmetry can provide useful information about possible market power. For example, the presence of positive asymmetric price volatility suggests that producers react faster to price increases due to ''good news'' than in case of ''bad news,'' when the price decreases.

In the current study, 10 different GARCH models are used. These models are tested and evaluated in order to investigate possible existence of asymmetry in volatility, choosing the appropriate model to describe the expected price and price volatility for estimating the beef supply response equation.

MATERIALS AND METHOD

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

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

Where y is the beef production, P^e_t is the expected price, h 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^e_t and h_t and it is given as

$$P_t \mid \Omega_{t-1} = c_0 + \sum_{i=1}^{n} c_i P_{t-i} + \varepsilon_{2t} \qquad \varepsilon_{2t} \mid \Omega_{t-1} \sim N(0, h_t) \tag{2}$$

$$h_t = b_0 + \sum_{i=1}^{q} b_{1i} \varepsilon_{2t-i}^2 + \sum_{i=1}^{p} b_{2i} h_{t-i} \tag{3}$$

Where:

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

The predictions of p_t^e and h_t generated by the GARCH model could be used directly to estimate supply equation (1). But using regressor generated by a stochastic model, e.g. GARCH, as factors in the estimation of equation (1) can cause biased estimates of the parameters. This problem can be avoided by estimating the GARCH model of equations (2) and (3) and the supply equation (1) jointly using the full information maximum likelihood method [7]. More specifically, let ε_{1t} of equation (1) and ε_{2t} of equation (2) 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}, σ_{21} 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

$$L_T(\Theta) = -\log|\Sigma_t| - \varepsilon_t' \Sigma_t^{-1} \varepsilon_t \tag{4}$$

Where: $\quad |\Sigma_t| = \sigma_{11} h_t - \sigma_{12}^2 = \phi$

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

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 [8] proposed the use of quasi-maximum likelihood estimation. 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 case of a fall in price than in case of an increase (i.e. bad and good news). A characteristic asymmetric GARCH model is the Nonlinear Asymmetric GARCH developed by Engle and Ng [9].

Except NAGARCH model equations (2) and (3) of the system described above have been modified appropriately for specifying nine more different symmetric and asymmetric GARCH models in order to detect which GARCH model fits better in the estimation of the system. In particular, the ten GARCH models used in this study are: Linear symmetric GARCH developed by Bollerslev [10], nonlinear symmetric GARCH (NGARCH) developed by Engle and Bollerslev [11], GARCH in mean (MGARCH) developed by Engle *et al.* [12], asymmetric GARCH (AGARCH) developed by Engle [13], nonlinear asymmetric GARCH (NAGARCH), quadratic asymmetric

GARCH model (QGARCH) developed by Sentana [14], TS-GARCH symmetric model proposed by Taylor [15] and Schwert [16], threshold Asymmetric GARCH (GJR-GARCH) proposed by Glosten *et al.* [17], nonlinear asymmetric VGARCH developed by Engle and Ng [9] and exponential asymmetric GARCH model (EGARCH) developed by Nelson [18].

The BFGS algorithm is used to obtain maximum likelihood estimates of the system constructed by the supply response equation (5) and the price model which is described by equations (6) and (7). Note that equation (7) is modified according to each one of the ten different GARCH models. All the estimated models achieve convergence but in AGARCH model the coefficient b_2 has the wrong sign and as a result, the supply-price system based on this specification is not considered. Residual diagnostic tests are performed in order to check the explanatory power of the nine alternative supply-price systems. Ljung- Box *Q(m)* statistic for 6, 12 and 18 lags is performed for the standardized residuals and squared standardized residuals in order to check upon serial correlation and heteroskedasticity respectively.

Data and Model Specification: Data used in this study are monthly time series for the period of April 1998 to March 2007. All variables are transformed in logarithms and all prices are deflated by the consumer price index (1997=100).

Thus, the beef supply response equation (1) is specified as:

$$QBP_t = \sum_{i=1}^{12} a_i D_{it} + a_{13} TR_t + a_{14} PPB_t^e + a_{15} PCV_t + a_{16} PBF_{t-26} + a_{17} VMED_{t-26} + a_{18} PML_t + a_{19} QBP_{t-1} + a_{20} QBP_{t-12} + \varepsilon_{1t} \quad (5)$$

Where QBP_t is beef production in period t. The monthly dummy variable (D_{1l}) is used to capture the possible monthly seasonality effect on the production. A trend component (TR_t) is used to capture technological change in the beef production process. Expected beef price, PPB_t^e and the price volatility term, PCV_t, are considered to be important risk factors and thus they are included. Note that domestic producer beef price differ from the imported beef price and specifically during the examined period, domestic beef price was usually higher than imported beef price. The correlation between these two variables is very high, 88%, which indicates that domestic producer beef price reflects almost all changes occurred in the international beef market. Thus, the domestic producer beef price is used in the specification of the model. Prices of two senior cost factors are used. Firstly, the price of feed, PBF_{t-26}, which is the most important cost factor because beef production in Iran is mainly cereal-based production due to the lack of natural pastures and secondly, the price of veterinarian medicines, $VMED^{t-26}$, which is a significant cost factor because producers try to avoid production loss due to diseases. A twenty six lag period for input prices, i.e. an PBF_{t-26}, and $VMED^{t-26}$, used because the biological cycle of Iranian beef is about 26 months. Furthermore, the price of bovine milk, PLM_t, is regarded as an important variable of the supply equation because it represents a kind of opportunity cost for beef as it was discussed in section 1. In addition, 1 and 12 lags of beef 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.

The specification of the real producer beef price is given as:

$$PPB_t = c_0 + \sum_{i=1}^{11} c_i PPB_{t-i} + c_{12} PPB_{t-26} + c_{13} TR_t + \varepsilon_{2t} \quad (6)$$

Where TR is a trend component and PPB^{t-i} is the real producer price of beef in time $t - i$ where I = 1,2,...,11 and PPB^{t-26} is the real producer price of beef in time t - 26. All the alternative GARCH models were tested for several orders such as GARCH (1, 2), GARCH (2, 1) and GARCH (2, 2) but in all cases the simple GARCH (1, 1) process fits better. Thus the variance equation of the GARCH (1, 1) model is used and it is given by

$$h_t = b_0 + b_1 \varepsilon_{2t-1}^2 + b_2 h_{t-1} \quad (7)$$

RESULTS AND DISCUSSION

The tests for the supply response equation for each of the nine models are presented in Table 1 and indicate that all models except TSGARCH, QGARCH and EGARCH present neither heteroskedasticity nor autocorrelation at the 5% level of significance. Furthermore, residual tests for the price equation are also presented in Table 1 and in this case all models do not present any heteroskedasticity and autocorrelation at the 5% level of significance. Finally, a comparison of the Schwarz Information Criterion[1] (SIC) values, presented in Table 1 indicates that the NAGARCH model is the most appropriate one to describe the supply-price equation system for the Iranian beef production.

[1]The Schwarz information criterion is given by SIC=L-0.5p*log (T), where L is the maximized value of the likelihood function, p is the number of the estimated parameters and T is the number of the observations.

Table 1: Residuals tests for supply response equation and price equation

	GARCH(1,1)	NGARCH(1,1)	GARCH-M(1,1)	TS-GARCH(1,1)	EGARCH(1,1)	NAGARCH(1,1)	QGARCH(1,1)	VGARCH(1,1)	GJR-GARCH(1,1)
supply response equation									
$Q(6)$	8.944(0.418)	5.633 (0.493)	7.762 (0.4395)	13.143 (0.042)	17.365 (0.013)	4.220 (0.648)	15.684(0.007)	5.195(0.521)	2.460(0.872)
$Q(12)$	18.519(0.275)	13.705 (0.403)	16.749 (0.306)	20.300 (0.055)	25.7325 (0.038)	13.563 (0.404)	31.597(0.002)	14.125 (0.356)	19.549 (0.3595)
$Q(18)$	28.422 (0.159)	27.146 (0.089)	25.734 (0.244)	29.174 (0.349)	36.538 (0.014)	27.353 (0.098)	40.871 (0.001)	29.409 (0.048)	29.130 (0.178)
$Q^2(6)$	16.696 (0.499)	9.539(0.470)	15.100 (0.499)	12.524 (0.408)	23.139 (0.325)	6.249 (0.524)	19.076 (0.302)	7.676 (0.482)	19.454 (0.496)
$Q^2(12)$	18.615 (0.499)	10.982 (0.537)	16.696 (0.501)	14.513(0.495)	25.842(0.451)	7.635(0.673)	21.4095(0.463)	9.1685(0.599)	20.834(0.499)
$Q^2(18)$	19.981 (0.501)	12.429 (0.621)	17.876 (0.504)	15.445(0.556)	27.33(0.493)	9.7505(0.753)	23.378(0.747)	11.360(0.681)	24.022(0.499)
price equation									
$Q(6)$	4.004 (0.675)	1.280 (0.970)	2.004 (0.889)	3.687 (0.690)	4.097 (0.663)	2.582 (0.856)	2.081 (0.910)	2.983 (0.810)	2.280 (0.885)
$Q(12)$	11.221 (0.509)	7.756 (0.795)	10.320 (0.582)	12.633 (0.467)	13.870 (0.331)	11.892 (0.457)	12.526 (0.470)	14.147 (0.291)	8.146 (0.767)
$Q(18)$	18.458 (0.407)	17.237 (0.512)	16.735 (0.545)	19.141 (0.411)	21.190 (0.277)	20.865 (0.293)	20.329 (0.389)	24.907 (0.127)	17.531 (0.492)
$Q^2(6)$	2.617 (0.85)	1.754 (0.920)	2.684 (0.835)	2.230 (0.897)	2.783 (0.835)	2.118 (0.889)	1.929 (0.898)	2.520 (0.866)	2.797 (0.794)
$Q^2(12)$	3.658 (0.984)	2.805 (0.988)	4.364 (0.968)	3.740 (0.983)	3.965 (0.983)	3.067 (0.988)	3.738 (0.987)	3.752 (0.987)	5.011 (0.874)
$Q^2(18)$	9.393 (0.886)	10.516 (0.827)	11.141 (0.751)	14.553 (0.841)	8.795 (0.902)	9.195 (0.895)	12.665 (0.7955)	12.189 (0.837)	14.905 (0.557)
SIC	1441.99	1446.93	1448.995	1443.52	1438.15	1591.81	1202.49	1446.48	1427.75

Figures in brackets are p-values

Source: Authors findings

Table 2: 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}	a_{14}	a_{15}	a_{16}	a_{17}	a_{18}	a_{19}	a_{20}
1.624	1.700	1.652	1.735	1.765	1.772	1.803	1.774	1.673	1.710	1.732	2.124	0.103	-0.154	-0.280	-0.065	-0.047	0.508	0.125
(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(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}	c_{12}
0.781	0.983	-0.087	0.106	-0.112	0.083	0.150	-0.189	-0.081	0.142	-0.174	0.094	-0.109
(0.000)	(0.000)	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)	-(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

GARCH factors

b_0	b_1	b_2	b_3
0.001	0.263	0.586	-0.030
(0.000)	(0.000)	(0.000)	(0.000)

Figures in brackets are p-values

Source: Authors findings

Analyzing the parameters of NAGARCH model, presented in Table 2, it can be noticed that the magnitude of b_1 is 0.263 and that of b_2 is 0.586. The size of b_1 and b_2 parameters determine 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. -0.030, indicating a negative asymmetric effect. The existence of negative asymmetric price volatility means that a negative shock in price causes more volatility than a positive shock of the same size. In other words, producers respond more intensely in the case of a negative shock than in the case of a positive one. This behavior suggests that producers' position in the market chain is weak and they cannot benefit by "good news" 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 structure of the Iranian beef industry.

Table 2 also presents the empirical results of the supply response equation estimated with the NAGARCH model. Short-run supply price elasticity given by the estimated coefficient a_{14} is positive, i.e. 0.103, indicating that an expected beef price increase induces Iranian beef producers to slaughter steers at present instead of holding them in the breeding flock. The calculated long-run supply price elasticity of the present study is nearly inelastic, i.e. 0.909. This result is similar the one obtained by Rezitis and Stavropoulos [19] and differ than the one obtained by Lianos and Katranidis [20] who estimated a negative short-run and a positive long-run supply elasticity for the Greek beef industry. One possible explanations of the positive short-run price elasticity obtained in the present study is that producers in most cases believe that increases in price are transitory and these kinds of increases are not signal stock accumulation and an additional explanation is that producers are able to increase their herb by imported live animals and at the same time they increase slaughtering.

The estimated beef price volatility, i.e.a_{15}=-0.154, indicates that volatility is an important risk factor for the beef industry. The magnitude of feed cost coefficient, i.e.a_{16}=-0.280, indicates that feed cost is a significant cost factor in beef production, while the veterinarian medicine

Table 3: Forecasted Produced Quantity, Beef Price and Price Volatility

	Produced Quantity		Beef Price		Price Volatility	
	Actual	Forecast	Actual	Forecast	Actual	Forecast
1/2008	4.5515	4.5647	4.3448	4.5387	0.0225	0.0257
2/2008	4.4377	4.4506	4.3268	4.554	0.0247	0.0252
3/2008	4.3851	4.3956	4.3208	4.557	0.0246	0.0266
4/2008	4.3814	4.3977	4.3184	4.5587	0.0239	0.0254
5/2008	4.3900	4.4153	4.3607	4.5499	0.0210	0.0227
6/2008	4.4176	4.4655	4.3777	4.5561	0.0158	0.0165
7/2008	4.4375	4.4835	4.3849	4.5481	0.0148	0.0181
8/2008	4.4703	4.5476	4.4121	4.5670	0.0178	0.0162
9/2008	4.4411	4.4791	4.4110	4.5680	0.0165	0.0189
10/2008	4.4584	4.5281	4.4063	4.5554	0.0131	0.0157
11/2008	4.5222	4.5632	4.4233	4.5629	0.0120	0.0145
12/2008	4.8596	4.9609	4.4233	4.5381	0.0129	0.0142
RMSE(1/08-12/08)	0.0343		0.0441		0.0039	

Source: Authors findings

cost estimated coefficient, i.e. a_{17}=-0.065, is smaller. This is consistent with the production process of the Iranian beef industry which is cereal-based and as a result the share of cereals in the cost of production is very high. Moreover, the estimates obtained for lagged production are high implying that production is adjusting slowly to the desirable level. Furthermore, the magnitude of the bovine milk price coefficient is negative and significant, i.e.a_{18}=-0.047, indicating that a high milk price causes a decrease in beef supply quantity.

Trend component coefficients i.e. c_{13} and a_{13} are not statistically different from zero.

Furthermore, the estimated supply response model provides out of sample forecasting of produced quantity (*QBP*), expected producer price (*PPB*) and price volatility (*PCV*) for the period 1/2008 to 12/2008. Actual and forecasted values are presented in Table 3 and the root mean square error (RMSE) for produced quantity and expected producer price is also presented in Table 3. Result shows a good forecasting ability of the model.

CONCLUTIONS

This paper examined the beef supply response in Iran. GARCH process used to model producers' expectations about expected price and expected price volatility and the supply response equation estimated jointly with the price equation. Several different symmetric and asymmetric GARCH models were tested and the NAGARCH model appeared to be particularly appropriate to describe the beef supply response.

Both, short and long-run supply price elasticity is positive, short-run supply price elasticity is inelastic and long-run is nearly inelastic indicating that even in the short-run a higher price has a positive effect in supplied quantity. Furthermore, price volatility has a significant negative effect in the production level denoting that producers are risk averse, while negative asymmetric effect was detected on price volatility indicating that Iranian beef producers have weak market position. Feed cost found to be a major cost factor for production, due to the lack of natural pastures, while milk was found to have a negative effect on beef production confirming that milk and beef are competitive products.

The results of the present study should be taken into consideration by the Iranian beef industry participants. The challenge of the industry participants is to reduce uncertainty by using various hedging mechanisms(e.g. contracts to vertically coordinate the production process) in order to diversify away a portion of the risk and to improve product quality. Finally, policy makers should design production strategies which take into consideration the risk structure and also assist Iranian beef producers to participate in specialized investment programs, financed jointly by the Iran government, in order to modernize production, improve their performance in the level of providing standardized packing products and be more competitive.

REFERENCES

1. Jarvis, L., 1974. Cattle as capital goods and ranchers as portfolio managers: an application to Argentine Cattle sector. J. Political Economy, 82: 486-520.

2. Aadland, D. and D. Bailey, 2001. Short run supply response in the US beef-cattle industry. American J. Agricultural Econom., 83(4): 826-839.
3. Antonovitz, F. and R. Green, 1990. Alternative Estimates of Fed Beef Supply Response to Risk. American J. Agricultural Econom., 72 (2): 475-487.
4. Holt, M.T., 1993. Risk response in the beef marketing channel: A multivariate generalized ARCH-M approach. American J. Agric. Econom., 75: 559-571.
5. Holt, M.T. and S.V. Aradhyula, 1990. Price risk in supply equations: An application of GARCH time-series models to the U.S. broiler market. Southern Economic J., 57: 230-242.
6. Holt, M.T. and S.V. Aradhyula, 1998. Endogenous risk in rational expectations commodity models: A multivariate generalized ARCH-M approach. J. Empirical Finance, 5: 99-129.
7. Pagan, A. and A. Ullah, 1988. The econometric analysis of models with risk terms. J. Applied Econometrics, 3: 87-105.
8. Bollerslev, T. and J. Wooldridge, 1992. Quasi-maximum likelihood estimation and inference in dynamic models with time-varying covariances. Econometric Rev., 11: 143-72.
9. Engle, R.F. and V. Ng, 1993. Measuring and testing the impact of news in volatility. J. Finance, 48: 1749-1778.
10. Bollerslev, T., 1986. Generalized autoregressive conditional heteroskedasticity. J. Econometrics, 31: 307-327.
11. Engle, R.F. and T. Bollerslev, 1986. Modeling the persistence of conditional variances. Econometric Rev., 5: 1-50.
12. Engle, R.F., D.M. Lilien and R.P. Robins, 1987. Estimating time varying risk premium in the term structure: The ARCH-M model. Econometrica, 55: 391-407.
13. Engle, R.F., 1990. Discussion: Stock market volatility and the crash of 87. Review of Financial Studies, 3: 103-106.
14. Sentana, E., 1995. Quadratic ARCH models. Review of Economic Studies, 62: 639-661.
15. Taylor, S., 1986. Modeling Financial Time Series. New York, NY: Wiley.
16. Schwert, G.W., 1989. Why Does Stock Market Volatility Change Over Time? The J. Finance 44: 1115-1153.
17. Glosten, L., R. Jarannathan and D. Runkle, 1993. Relationship between the expected value and volatility of the nominal excess return on stocks. J. Finance, 48: 1779-1802.
18. Nelson, D., 1991. Conditional Heteroskedasticity in Asset Returns: A New Approach. Econometrica, 59: 347-370.
19. Rezitis, A. and K.S. Stavropoulos, 2007. Modeling Beef Supply Response under Rational Expectations and CAP Reforms: Application to the Greek Sheep Industry. Working Paper, University of Ioannina, Agrinio, Greece.
20. Lianos, T.P. and S. Katranidis, 1993. Modelling the beef market of the Greek economy. European Review of Agricultural Economics, 20: 49-63.