Greek Beef Supply Response and Price Volatility under CAP Reforms

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Abstract: **This study examines the supply response of the Greek beef market and the possible effect of the European Union's Common Agricultural Policy (CAP) on the Greek beef sector during the period 1993-2005. A GARCH process is used to estimate expected price and price volatility while several different symmetric, asymmetric and nonlinear GARCH models are estimated. The empirical results show that price volatility and feed price are important risk factors of the supply repose function, while the negative asymmetric price volatility which was detected implies that producers have a weak market position. Furthermore, the empirical findings confirm that the annual premium paid by EU to beef producers had a positive impact on the production level and that the change of the EU price support regime after 2006 will have negative effects on the beef production level in Greece.**

Keywords: **beef supply, price volatility, CAP**

I. INTRODUCTION

The objective of this paper is to explore the supply response of the Greek beef industry taking into consideration recent CAP reforms.[1] 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 (Jarvis 1974). 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 (Aadland and Bailey 2001). When specifying a beef supply response model the price of milk should also be taken into account. In Greece, 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.

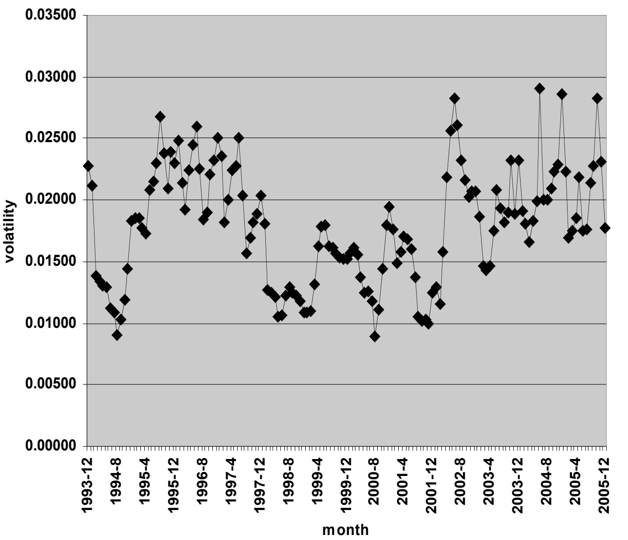
Beside the common factors used in a beef supply response equation such as beef price and feed cost, this paper highlights price volatility by entering expected beef price volatility in the supply equation. Uncertainty and risk aversion play an important role in agricultural production and many studies have attempted to specify the role of risk in agricultural supply (Antonovitz and Green 1990, Holt and Aradhyula 1990, 1993, 1998). Price volatility represents an important risk factor of supply especially in agricultural products. Agricultural prices are usually more variable compare to other products because short-term demand and production elasticities are low and also because many agricultural products and especially fresh meat products are perishable lacking storage ability (Just 1974, Holt and Aradhyula 1990, 1998). A variety of empirical research supports that increase in price risk reduce 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

[1] 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.

especially in the absence of a hedging mechanism. Figure 1 indicates the presence of price volatility in the Greek beef market during the period 1993-2005.

Figure 1

Actual Beef Price Volatility



Furthermore, the evaluation of the impact of CAP in Greek beef production during the period 1993-2005 can provide useful information to policy makers and beef producers. Thus, the specification of the supply response model includes the annual premium rate paid to producers. In addition, recent CAP reforms are taken into account, such as: The change from a volatile to a flat premium rate decided in the year of 2002 and the established decouple between premium and production decided in the year of 2003 to take place from the year of 2006 to 2013. A possible connection between CAP reform and producer price volatility is also investigated. The statistical technique of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) process is adopted to characterize the time varying attributes of expected price and price volatility 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). In this study ten different types of symmetric, asymmetric and nonlinear GARCH models are estimated, tested and evaluated in order to investigate possible existence of asymmetry in volatility choosing thus the appropriate one to describe expected price and price volatility for estimating the beef supply response equation. The existence of possible asymmetry in the behavior of price volatility in the beef 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.

II. METHODOLOGY

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

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

where y_t is the beef 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

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

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

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

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

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 regressors 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 (Pagan and Ullah 1988). More specifically, let ε_{1t} of equation (2) and ε_{2t} of equation (3) 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

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

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

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. 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 (1993). In that model equation (2) and (3) of the system presented above are described as:

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

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

Where $b_0 > 0$, $b_3 > 0$ $b_{1i} \geq 0$ $i = 1,...,q$, $b_{2i} \geq 0$ $i = 1,..., p$ 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.

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 (1986), Nonlinear symmetric GARCH (NGARCH) developed by Engle and Bollerslev (1986), GARCH in mean (MGARCH) developed by Engle, Lilien, and Robins (1987), Asymmetric GARCH (AGARCH) developed by Engle (1990), nonlinear Asymmetric GARCH (NAGARCH), Quadratic Asymmetric GARCH model (QGARCH) developed by Sentana, (1995), TS-GARCH symmetric model proposed by Taylor and Schwert (1989), Threshold asymmetric GARCH (GJR-GARCH), proposed by Glosten, Jagannathan and Runkle (1993), nonlinear asymmetric VGARCH developed by Engle and Ng (1993) and Exponential asymmetric GARCH model (EGARCH) developed by Nelson (1991).

III. DATA AND MODEL SPECIFICATION

Data used in this study are monthly time series for the period of January 1993 to December 2005. In particular, beef quantities and beef premiums paid to Greek producers are obtained from the Hellenic Ministry of Rural Development and Food (HMRDF) and are transformed into a beef quantity index and a premium index respectively. It has to be mentioned that premiums paid to Greek producers are of different types according to animal category (cows, steers, bulls). All the types of premium paid are described according to a premium index constructed by Kitsopanidis (2005). Beef producer price index, bovine milk producer price index, beef feed price index and veterinarian medicines price index are 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).

Thus, the beef supply response equation (3) is specified as:

$$\begin{aligned} QBP_t = {} & \sum_{i=1}^{12} a_i D_{it} + a_{13} TR_t + a_{14} PPB_t^e + a_{15} PCV_t + a_{16} PBF_{t-26} + \\ & + a_{17} VMED_{t-26} + a_{18} PML_t + a_{19} QBP_{t-1} + a_{20} QBP_{t-12} + \\ & + a_{21} PR_{t-12} + a_{22} SD_t + a_{23} (SD_t \times PR_{t-12}) + \varepsilon_{1t} \end{aligned} \qquad (5)$$

where QBP_t is beef production in period *t*.The monthly dummy variable (D_{it}) 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. This difference occurs mainly because Greek consumers tend to prefer domestic meat products. The correlation between theses two variables, i.e. domestic and imported beef prices, is very high, i.e. 90%, 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 Greece 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. PBF_{t-26} and $VMED_{t-26}$, is used because the biological cycle of Greek beef is about 26 months (Kitsopanidis 2005). 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.

Finally, three variables are used to capture the effect of the CAP on the beef market. Firstly, a twelve lag period of the annual premium paid to beef 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_t) 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_t is used to evaluate whether the knowledge of this oncoming change by cattle breeders affects beef supply or not. Thirdly, the interaction variable $PR_{t-12} \times SD_t$ is constructed by multiplying the premium rate (PR_{t-12}) with the dummy variable (SD_t) 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.

Due to of production lags, agricultural producers make input decisions without knowing the price they will receive for their products (Antonovitz and Green 1990). 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 $i = 1,2,...,1$ and PPB_{t-26} is the real producer price of beef in time $t-26$. Equation (11) is estimated for all different GARCH models. 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

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

IV. EMPIRICAL RESULTS

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 GJR-GARCH 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) statistics 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. 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[2] (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 Greek beef production.

Analyzing the parameters of NAGARCH model, presented in table 2, it can be noticed that the magnitude of b_1 is 0.204 and that of b_2 is 0.639. 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 can not 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 Greek beef industry, which is characterized by a large number of small size beef producers with a weak influence in the market.

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. 0.144, indicating that an expected beef price increase induces Greek 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 inelastic, i.e. 0.935. This result differ than the one obtained by Lianos and Katranidis (1992) 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. $a_{15} = -0.145$, indicates that volatility is an important risk factor for the beef industry. The magnitude of feed cost coefficient, i.e. $a_{16} = -0.456$, indicates that feed cost is a significant cost factor in beef production, while the veterinarian medicine

[2] 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.

cost estimated coefficient, i.e. $a_{17} = -0.059$, is smaller. This is consistent with the production process of the Greek 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. $a_{18} = -0.004$, indicating that a high milk price causes a decrease in beef supply quantity.

Parameters used to capture CAP effects, reflect the impact of policy during the examining period and provide useful information to policymakers. Firstly, the positive coefficient of the premium parameter, i.e. $a_{21} = 0.077$, confirms that the annual premium rate paid to producers has a positive effect to beef production. Since agricultural income can be very unstable, it seems that this income stabilization provided by the premium is beneficial for the producers. Secondly, the dummy variable for the period from 1/2003 to 12/2005 is negative, i.e. $a_{22} = -0.142$, 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 beef production. It turns out that even though the new CAP was decided to take place from the year 2006, the beef production was affected since the decision was made, i.e. the year 2003. This empirical result reveals a rational behavior from Greek beef producers. The knowledge of the oncoming in 2006 decouple between premium and production, lead cattle breeders to adjust their production to lower levels since 2003. It seems that EU decision to reduce and finally stop producers' income support in 2013 will probably direct many small Greek beef producers withdraw from production, a fact that will deteriorate the deficit balance in the Greek beef production. This result is consistent with the findings of Fabiosa *et al* (2005) who forecast that both the 2003 CAP reform and the EU enlargement will cause a decline in the EU beef production. Finally, the coefficient of the interaction variable ($PR_{t-12} \times SD$) is positive, i.e. $a_{23} = 0.025$, indicating that the change from a volatile to a flat annual premium per animal for the period 2003-2005 had a positive impact on beef production which is an expected outcome since this policy instrument reduces uncertainty. In particular, while the effect of the volatile annual premium of the period 1993-2002 is $a_{21} = 0.077$, the effect of the flat annual premium of the period 2003-2005 is higher, i.e. $a_{21} + a_{23} = 0.102$.

Table 1. Residuals tests for supply response equation and price equation									
supply response equation									
	GARCH (1,1)	**NGARCH (1,1)**	**GARCH-M (1,1)**	**TS-GARCH (1,1)**	**EGARCH (1,1)**	**NAGARCH (1,1)**	**QGARCH (1,1)**	**AGARCH (1,1)**	**VGARCH (1,1)**
$Q(6)$	2.953 (0.815)	3.705 (0.716)	2.822 (0.831)	13.986 (0.029)	14.652 (0.023)	3.411 (0.756)	25.649 (0.000)	4.672 (0.587)	2.460 (0.872)
$Q(12)$	10.855 (0.541)	8.993 (0.703)	10.341 (0.586)	19.919 (0.055)	19.589 (0.075)	9.117 (0.693)	31.597 (0.001)	9.978 (0.618)	8.835 (0.716)
$Q(18)$	20.249 (0.319)	24.508 (0.139)	17.685 (0.476)	27.700 (0.667)	31.283 (0.027)	23.612 (0.168)	42.371 (0.001)	27.490 (0.070)	19.624 (0.354)
$Q^2(6)$	0.417 (0.998)	1.857 (0.932)	0.408 (0.998)	2.951 (0.815)	4.194 (0.650)	1.467 (0.962)	4.532 (0.605)	1.910 (0.928)	0.761 (0.993)
$Q^2(12)$	0.967 (0.999)	2.445 (0.998)	0.798 (0.999)	4.462 (0.973)	6.260 (0.902)	1.965 (0.999)	5.784 (0.926)	2.539 (0.998)	1.122 (0.999)
$Q^2(18)$	1.537 (0.999)	3.136 (0.999)	1.229 (0.999)	5.489 (0.998)	7.398 (0.986)	2.265 (0.999)	7.263 (0.987)	3.265 (0.999)	1.663 (0.999)
price equation									
$Q(6)$	4.581 (0.598)	1.405 (0.965)	3.170 (0.787)	6.163 (0.405)	4.650 (0.589)	2.126 (0.907)	1.837 (0.934)	2.983 (0.810)	1.696 (0.945)
$Q(12)$	12.103 (0.437)	9.033 (0.700)	13.947 (0.304)	17.496 (0.132)	16.161 (0.184)	10.829 (0.543)	17.235 (0.141)	14.147 (0.291)	9.331 (0.674)
$Q(18)$	19.203 (0.340)	19.407 (0.367)	19.484 (0.362)	22.630 (0.205)	22.777 (0.199)	19.342 (0.371)	25.887 (0.102)	24.907 (0.127)	19.408 (0.367)
$Q^2(6)$	2.047 (0.915)	0.842 (0.991)	1.788 (0.938)	2.101 (0.910)	2.559 (0.862)	1.183 (0.977)	0.849 (0.990)	2.520 (0.866)	1.077 (0.982)
$Q^2(12)$	2.747 (0.997)	1.314 (0.999)	3.406 (0.991)	3.463 (0.983)	3.683 (0.988)	1.930 (0.998)	2.794 (0.997)	3.752 (0.987)	1.574 (0.999)
$Q^2(18)$	5.502 (0.998)	5.423 (0.998)	5.018 (0.998)	14.553 (0.991)	5.007 (0.988)	5.394 (0.998)	10.666 (0.907)	12.189 (0.837)	4.445 (0.999)
$Q(6)$	4.581 (0.598)	1.405 (0.965)	3.170 (0.787)	6.163 (0.405)	4.650 (0.589)	2.126 (0.907)	1.837 (0.934)	2.983 (0.810)	1.696 (0.945)
$Q(12)$	12.103 (0.437)	9.033 (0.700)	13.947 (0.304)	17.496 (0.132)	16.161 (0.184)	10.829 (0.543)	17.235 (0.141)	14.147 (0.291)	9.331 (0.674)
SIC	1415.16	1415.87	1418.41	1417.29	1411.74	1419.98	937.97	1416.25	1394.32
Figures in brackets are p-values									

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}
1.972 (0.000)	2.060 (0.000)	1.988 (0.000)	2.104 (0.000	2.175 (0.000)	2.125 (0.000)	2.162 (0.000	2.114 (0.000)	2.022 (0.000)	2.005 (0.000	2.018 (0.000)	2.124 (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 (0.012)	0.144 (0.000)	-0.145 (0.000)	-0.456 (0.000)	-0.059 (0.000)	-0.004 (0.000)	0.712 (0.000)	0.134 (0.000)	0.076 (0.000)	-0.142 (0.000)	0.025 (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}
0.966 (0.000)	0.862 (0.000)	-0.124 (0.005)	0.081 (0.000)	-0.142 (0.000)	0.124 (0.000)	0.192 (0.000)	-0.226 (0.000)	-0.118 (0.000)	0.149 (0.000)	-0.067 (0.000)	0.150 (0.000)
							GARCH factors				
c_{12}	c_{13}						b_0	b_1	b_2	b_3	
-0.095 (0.000)	-0.000 (0.000)						0.001 (0.000)	0.204 (0.000)	0.639 (0.000)	-0.030 (0.000)	
Figures in brackets are p-values											

V. CONCLUTIONS

This paper examined the beef supply response in Greece. 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 elasticities are positive and 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 Greek 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. Finally, the premium paid to beef producers appear to have a significant positive role in the beef supply level, and the decoupling between premium and production, introduced by the last CAP reform, has already a negative impact on the Greek beef production.

The results of the present study should be taken into consideration by the Greek 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 Greek beef producers to participate in specialized investment programs, financed jointly by the Greek government and the EU, in order to modernize production, improve their performance in the level of providing standardized packing products and be more competitive.

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