ALTERNATIVE DYNAMICS IN AGRICULTURAL SUPPLY RESPONSE

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Abstract

Cointegration analysis and error correction modelling provide a framework of combination of the long-run, or 'equilibrium' relationships described by economic theory with the short-run dynamics found by time series analysis to explain economic data. The present paper explores the relevance of this alternative framework to agricultural supply modelling. It presents the statistical concept of cointegration, and it is shown how the use of this kind of analysis can avoid serious econometric shortcomings (spurious regressions, nonstationarity in data, inappropriate use of first differences). The theoretical basis of error correction model is also outlined. An error correction model of milk production in Greece is formed and estimated providing reasonable results for the case of cow milk.

Résumé

L'analyse de la co-intégration et la modélisation de correction de l'erreur permet de combiner les relations à long terme ou d'"équilibre" décrites par la théorie économique avec la dynamique à court terme décrite par l'analyse de séries temporelles pour expliquer les données économiques. Ce travail étudie le rapport d'un cadre alternatif de la modélisation de l'offre agricole. On présente le concept statistique de co-intégration, et on montre comment l'emploi de ce type d'analyse peut éviter des inconvénients économétriques graves (regressions factices, données non stationnaires, utilisation inadéquate des différences de premier ordre). On présente aussi la base théorique du modèle de correction des erreurs. On établit et on estime un modèle de correction des erreurs de la production de lait en Grèce en aboutissant à des résultats raisonnables dans le cas du lait de vache.

The agricultural problem, as revealed by the lagging of farmers' income of the other sectors of the economy, has been and continues to be a major concern of Greek public authorities. Rising production costs, the size of the domestic market, the inelastic nature of demand for many agricultural commodities, limited export possibilities, and perhaps, foreign competition has resulted in heavy government intervention in the form of price and income subsidies, favourable credit conditions and export-oriented incentives. Greece's full membership in the E.U. has resulted in an increase in the degree and a change in the structure of support for the agricultural sector and in particular for the dairy sector.

A thorough study of the above issues is severely constrained by the absence of supply analysis. In this paper only the effects of the Greek milk producers will be investigated.

The estimation of the Greek producers effects requires the estimation of the price elasticity of supply of milk. The factors influencing dynamic supply response have been the subject of considerable research. Supply dynamics have been associated with the dynamic nature of the production process. In the case of production from biological populations, biological time lags typically influence the nature of population dynamics, which in turn effects the dynamics of supply response (e.g. Chavas and Johnen).

The objective of this paper is to develop and estimate a dynamic milk supply response model, including all product regions and animals (cows, sheep, goats) in Greece and to investigate the factors influencing dairy animals population and milk supply response in Greece.

The econometric analysis further rejimes previous analysis of dairy supply dynamics found in the literature (i.e. La France and de Gorter etc.), using a flexible model of supply response capturing the dynamic effects (short and long-run effects) of various factors affecting supply decisions, including milk price and feed cost. The paper also explores the application of the theory of cointegration to agricultural supply analysis.

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Cointegration theory has a relatively recent history going back only eleven years (Granger, 1981). It can be regarded as the empirical manifestation of a long-run relationship between variables and provides a statistical framework which identifies and hence avoids the spurious regressions so easily specified and accepted with series which exhibit strong trend, resulting in misleading conclusions.

Error correction models are a particular form of dynamic econometric models. An error correction model can be thought of as a description of the stochastic process by which economy eliminates or corrects the equilibrium error being caused by random shocks which economic theory cannot easily specify and describe and has been used extensively in macroeconomic modelling since its appearance in the work of Davidson, Hendry, Sbra and Yeo (1978).

It has a number of advantages both in terms of its value in generating estimating equations with desirable statistical properties and in terms of the ease with which such equations may be interpreted. The most important of them are first, that the error correction model can be estimated consistently by ordinary least squares (-OLS) and second, that it provides a means of modelling long-run as well as short-run processes simultaneously.

The error correction model with the statistical concept of cointegration seems to offer a more flexible and general alternative framework to the partial adjustment model so frequently employed in agricultural supply analysis.

Supply analysis for livestock products

Accurate estimation of the price responsiveness of agricultural commodities is vitally important in supporting policy decisions. Government policy measures and trade negotiations rely on supply estimates for predicting the effects of changing government programs and for anticipating the consequent social benefits and costs of such programs (Mergos, 1991, Mergos and Stoforos, 1994).

Early research efforts devoted to agricultural supply response in various countries of the world have been reviewed by Askari and Cummings (1976 and 1977).

In order to include important innovations which are related to methodological issues, several economists extend their research efforts. Serious limitations which are related with the ability to provide accurate and useful information to policy makers in taking decisions cannot be overcome despite the fact that substantial resources were devoted to supply analysis over the last ten years. During this period extreme variability of livestock products and input prices has shown that performance in anticipating commodity supply response in this environment was inadequate. For this reason, a number of new

methodologies is introduced that maintain in a formal way the theoretical postulates of the theory of production in the analysis of supply response.
There are only a few studies of supply response concerning milk production in Greece (Pavlopoulos, 1967, Fotopoulos, 1989, Apostolopoulos and Kaldis, 1992, Andrikopoulos, Brox and Georgakopoulos, 1987) using either the well-known Nerlovian framework and a single equation estimation model or a log-linear single estimation framework.

The Error Correction model

The Error Correction form of dynamic specification is used to a considerable extent since its appearance in 1978 (Davidson, Hendry, Sbra, Yeo consumption function).
In order to proceed and specify the error correction model, we must point out that it can be estimated by the use of Ordinary Least Squares (OLS) estimator and appears to work well empirically. The importance of the error correction model is based on the fact that it is used for modelling long-run and short-run relationships between integrated series.
In its simplest form an error correction model involving two variables (X,Y) can be written:

$$\Delta Y_t = \delta \Delta X_t - \lambda(Y_{t-1} - \beta X_{t-1}) + U_t \qquad (1)$$

where : (U_t) stands for the disturbance with zero (0) mean, constant variance and zero (0) covariance (spherical disturbance). The short-run relationship between (Y) and (X) is measured by (δ) while (β) measures the long-run relationship between the variables of interest. The 'errors' from this long-run equilibrium are measured by ($Y_{t-1} - \beta X_{t-1}$) and this corresponds to the lagged residuals of the cointegrating regression ($Y_t = \beta X_t + V_t$).
The extent of correction of such errors by adjustments in (Y) is measured by (λ), the negative sign is very important because it shows that the adjustments are made towards restoring the long-run relationships. Short-run adjustments are guided by and are consistent with the long-run equilibrium relationship.
As it has been noted above, the particular importance of the error correction model is that it is used to model integrated series.
Where the original time series are integrated of order one I(1), consistency in the error correction model requires of its terms to be integrated of order zero I(0). Of course one can understand that this will only be the case if the series are cointegrated.
The 'Granger representation theorem' points out that where variables are cointegrated there exists a valid error correction model describing their relationship.
In order to proceed we must say that cointegration is the empirical counterpart of the theoretical notion of a long-run or equilibrium relationship. To establish that two variables (X,Y) are cointegrated, we must follow a two-stage procedure (it can also be applied in case of more than two variables). First we have to establish that the series of interest have the same basic statistical properties i.e. they are both integrated of order one I(1). The second step is to determine a linear combination of those variables (cointegrating regression) which is stationary I(0) even though the individual series are not.
The estimation of an error correction model is a two stage procedure (Hallam, 1991). It begins with the estimation of a static cointegrated regression and tests for cointegration are run. If the null hypothesis of no cointegration is rejected the second step uses the lagged residuals of the static cointegrating regression equation as the error correction mechanism, thus imposing the long-run equilibrium relationship as a restriction.
The Ordinary Least Squares (OLS) can be used during the whole procedure and it yields consistent estimates for all the parameters (Engle, Granger). The problem is that it has small sample bias in the estimation for the cointegrated regression and these may lead to bias estimates of the error correction term. A high R^2 at the stage of the estimation of the cointegrating regression may be necessary in order to get acceptable results from the two-stage procedure.

Specification and data requirements

The specification of the model provides a stylized description of the salient features of the process by which the data on the variables of interest are believed to be genetated. The description takes the form of a statistical model make up of a systematic and a stochastic component (Hallam, D. 1990).
The idea of regressing herd rather than output on price is not very difficult to understand. Herd is really a proxy variable since planned output (the variable to be explained) cannot be directly observed. It is, however, possible to use realised output as a proxy for planned output. But realised output could differ significantly from planned output due to the impact of random factors (e.g. diseases) on dairy animals output.
However, herd is generally under the direct control of the farmer and hence it is usually accepted as the proxy variable for output. So the number of dairy animals (-cows, sheep, and goats) is considered as the dependent variable in consructing the supply model of milk production in Greece. The fact that the explanatory variables that were used for the analysis of supply response (price of milk, price of feed) were administrative set, the dependent variable actually used was herd (former empirical evidence suggest the same).
Economic theory postulates that one of the main determinants of supply is the price of the product. According to economic theory, also, there is a positive relationship between the price and the quantity supplied, and that farmers respond equally to rises as well as to falls in the price of the product. The existence of a positive relationship between price and quantity supplied is based on the assumption of profit maximisation.
After the incorporation of the price of milk as an important variable for the estimation of supply response in Greek dairy industry, the model takes the following form:

$$H = f\ (PM) \qquad (2)$$

where,
H : Herd
PM : Price of milk

It is of significant importance to point out here that the production process, as it has already been explained, is mainly influenced by the existing market conditions in the previous periods.
Thus, the price of milk, lagged by one or two periods depending upon the biological and technical characteristics of each animal population has been introduced as an explanatory variable in all equations. So we can extend the above model (2) by the incorporation of the dynamics of the relationship:

$$H = f\ (PM_{t-n}) \qquad (3)$$

where n = 0,1,2,3,4.....,n

Another economic factor influencing supply is the relevant input prices. The most important inputs for the Greek milk sector have been: a) labour, b) feedstuff and c) capital.

a) Labour
Under the Greek production patterns most of the labour required is provided by the family. A major exception is the cow's milk sector where due to the intensification of the production process, extra labour units are required.
The high cost of annual labour during the last decade has created a pressure for it to be replaced by some form of capital (mainly in the calf rearing sector).
Another important point concerning the use of labour as a main input in supply analysis is the lack of data. Thus, the price of labour have not been included as an explanatory variable for the estimation of supply response.

b) Feedstuff
Feedstuff is considered as the most important input in the analysis of supply response for any livestock product. In the

case of sheep and goat milk production and due to their biological and technical characteristics, the price of feedstuff mixtures were used to explain changes in the dependent variable (herd). In the case of cows milk production, considering as before the biological and technical features of the production process, a significant feedstuff price that was used, was the price of barley.

c) Capital
Due partly, to lack of data and partly to the fact that all milk producing sectors (except cow's milk production) in Greece do not use capital as a main input, the price of capital has not been included as an explanatory variable. In particular, in the case of sheep and goat milk production, capital has not been included in the supply models as an explanatory variable because these sectors are not yet developed enough and so the use of capital is of limited significance. In the case of cows' milk production, as we have already mentioned, capital is used (in a small extend) but the data available have not permitted the use of this variable into the supply model.
We can extend now the supply model above (3) by taking into consideration the available information about the relevant inputs:

$$H = f\,(PM_{t-n},\ PF_{t-n}) \tag{4}$$

where,
PF_{t-n}: Price of feedstuff n = 0,1,2,3,4......,n

Another important factor which influences the quantity of a product coming into the market and producers decisions, is the existence of competitive products. Economic theory prescribes competitive products, among other things, as products competing for common factors of production. In the case of Greek milk production the competing products are mainly cows, sheep and goat milk products. Some problems however, are encountered in this case:
i) Sheep and goats milk are mainly used for the production of several byproducts (i.e. cheese, butter) on the other hand cows milk is mainly pasteurised and than consumed. In this sense these products can not be considered as substitutes.
ii) These products cannot be considered also as substitutes in production because they are produced by different production systems. Another problem is encountered here due to lack of data. The available data for the prices of sheep and goat milk cover a period from 1964 to 1984, whereas the available data for the price of cows cover a period from 1971 to 1990. Thus, if we use the prices of sheep and goat milk as explanatory variables for determining the supply response of cow milk production we loose a significant number of degrees of freedom. The resulting loss of degrees of freedom can lead to less reliable parameter estimates, and in the limit can make estimation impossible.
All price variables used in the formulation of the milk supply model are considered in real terms. The consumer price index has been used as a deflator in this study (C.P.I.).[1]

Another economic factor that have a significant influence upon producers decisions regarding the dependent variable (-herd) is the number of dairy animals of the previous period. This is based on the fact that producers make their economic decisions by taking into consideration the number of dairy animals that they already have. We can expand again our supply model by considering all the available information that we already have:

$$H = f\,(PM_{t-n},\ PF_{t-n},\ H_{t-1}) \tag{5}$$

where,
H_{t-1} : The number of dairy animals in the previous period.
It is pointed out by D. Hallam (1990) "Arriving at the final specification for the equations of a model is frequently an iterative process with trial specifications revised in the light of their correspondence with economic and other a priori criteria, and their performance against various statistical criteria".
As it is known by econometric theory, the process of econometric modelling can be seen as a sequence of stages: specification, estimation, validation and finally application. Estimation of the model requires that the variables of interest are defined in terms of observable and of course available data. The appropriateness of data have a crusial effect upon the estimation of the model and its applicability. The data used for modelling Greek dairy industry were provided by the Ministry of Agriculture and by N.S.S. (National Statistical Service of Greece). The data set created a number of problems which are mainly related a) to their non experimental origin (-they were generated by a dynamic, interdependent economic system and they were subject to influences of policy), b) to the separation of the user from data collection and c) to its deficiencies i.e. missing observations, innacuracy.
In the particular case of modelling cow, sheep and goats milk supply response, the available data sets (there were no alternative data sets) caused various problems. The most significant of them were:
1) The length of the data set was small i.e. for the number of dairy goats we had only 19 available observations and for the number of dairy cows we had only 18 with the immediate consequence that we didn't have the opportunity to use long lags in order to express the dynamics (if this was needed) and also, the tests for cointegration (Johansen approach) were proved to have less reliability.
2) The data set for the number of dairy sheep proved to be innacurate and with great inconsistencies. The immediate result was that estimation had caused several difficulties and also that the estimated elasticities were biased (Morgenstern, 1963). The plot of the cumulative sum of the squares (CUSUMSQ) of the recursive residuals was the indication of structural break (we had significant divergences from zero for the recursive residuals).

Estimation and evaluation of the model

With the theoretical foundations of the model developed and specified in the previous sections, unbiased estimations of the parameters of the model will be sought through econometric methods. As it has been pointed out, the estimation of an error correction model is a two-stage procedure. It begins with the estimation of a static cointegrating regression and then tests for cointegration. In the second step, it uses the lagged residuals of the cointegrating regression as the error correction mechanism (Hallam, 1991).
As it has been previously pointed out, cointegration between variables involved in a model is a prerequisite for the error correction model. To ensure that the variables of interest are cointegrated we must first establish that they have the same basic statistical properties. In particular, they must be integrated of the same order. To test the order of integration, we have used the Dickey-Fuller test and the Augmented Dickey-Fuller test (Darnell and Evans, 1990).
The Dickey-Fuller test tests the hypothesis that p is equal to unity against the alternative that p is less than unity in

$$X_t = p'\,X_{t-1} + W_t \tag{6}$$

Where w is a random variable with zero mean and constant variance. The above equation is reformulated, by substracting X_{t-1} from each side, as

$$\Delta X_t = p'\,X_{t-1} + W_t \tag{7}$$

where p′ is equal to (p − 1). p′ will be equal to zero if (X) has a unit root, and will be negative and significantly different from zero if (X) is stationary (i.e. constant mean and a finite constant variance).
The results of the D.F. and A.D.F. tests for the case of cow milk production are presented in **table 1**. It is important to point out here that the dependent variable is the number of dairy cows and the explanatory variables that were used are the price of milk and the price of feed.
The above tests clearly show that the se-

[1] Of course an alternative solution was to use as deflator the index of prices received by farmers. The problem associated with the second deflator was the fact that there were no data available and due to the fact that both consumer price index and the index of prices received by the farmers go hand in hand, the formerused as a deflator.

ries of interest are having the same basic statistical properties [they all are integrated of order two I(2)].
The second condition for cointegration is that there should exist some linear combination of the data series. This linear combination is the residual from a static ordinary least squares regression.

In order to test for cointegration we used Johansen's approach (available in Microfit). The results of this test are presented in **table 2**.
To estimate the error correction model we used the lagged residuals from the cointegrating regression of Hc on PM and Pf, estimated using ordinary least squares. The results are as follows:

$$DDHc = \underset{(1.08)}{8358.2} + \underset{(4.00)}{24123.9DDPM_t} + \underset{(3.01)}{14761.3DDPM_{t-2}} - \underset{(-2.59)}{17742.3DDPF_t} + \underset{(-3.88)}{0.2RES_{t-1}} + \underset{(1.56)}{0.28Hc_{t-1}} \quad (8)$$

R^2 = 0.56
R^2 = 0.43
D.W.-stat. = 1.97
Dh-stat. = 1.85
F-stat. = 4.28

Figures in the parentheses are t-statistics. Goodness of fit is acceptable with an R^2 of 0.56. The Durbin-Watson statistic indicates no serial correlation problems in the residuals although it is biased due to the fact that a lagged dependent variable exists between the explanatory ones. The Dh-statistic is appropriate in cases where the number of observations is greater than 30 (in this case, we have only 19). The value of F-statistic shows that the regression is significant.
Considering the price of milk and the price of feed as explanatory variables in this error correction model, the following comments can be made:
– The coefficients of all price variables have the correct sign and have been found to be significantly different from zero.
– The short-run elasticities are:

$$Epm = 0.50 \quad (9)$$
$$Epf = 0.55 \quad (10)$$

The coefficients of the remaining variables of the model: the lagged dependent variable and the lagged residuals (RES) of the cointegrating regression have the right signs (in particular the sign of the lagged residuals must be negative in order to show that adjustments are made towards restoring the long-run equilibrium). The lagged residuals are proved to be significantly from zero. On the other hand, the lagged dependent variable was not significantly different from zero but it has been used because of the positive effect that it had in solving the problem of autocorrelation in the disturbance term.
The coefficient of the lagged residuals (-0.24) measures the extent of correction of divergences from the long-run equilibrium. It indicates a rather low value with a corresponding slow adjustment.
In order to estimate the long-run equilibrium relationship between the variables of interest we use the unrestricted form of the error correction model. Then, the long-run coefficient is calculated to give the following results:

$$Epm = 1.75 \quad (11)$$
$$Epf = 2.10 \quad (12)$$

According to what has already been mentioned in the previous paragraphs concerning cointegration and its relation to error correction models, the tests that have been run on the time series concerning sheep and goat milk production (DF, ADF) proved that they were integrated of order one I(1). The results of the tests are presented in **tables 3** and **4** respectively. In the case of sheep milk production the variables used were: the number of dairy sheep (Hs), the price of sheep milk (Psm) and the price of feed (Pf) (**table 3**). In the case of goat milk production the variables used were: the number of dairy goat (Hg), the price of goat milk (Hgm) and the price of feed (Pfd) (**table 4**).
The next step is to determine that a linear combination of the data series exists which is stationary I(0). This has been accomplished by the use of Johansen approach (the results are in **tables 5**, **5.1**, **6**, **6.1** respectively). As it can be seen from the results, the series for both sheep and goat are cointegrated, so, there must exist a valid error correction model. The problem that arises here is that despite the numerous attempts we did not succeed in getting a valid E.C.M.. In particular, the sign of the coefficient that measures the extent of correction of the divergence from the long-run equilibrium, was in every case positive.
In order to found what leads to such unexpected results, various tests have been run. First of all, we used the plot of autocorrelation function to establish the stationarity of the series. In addition, CUSUMQ (Cummulative sum of square residuals) has been used to test for structural shifts.
These tests have led us to the following conclusions:

Table 1 ***D.F and A.D.F tests for the variables: number of dairy cows (Hc), price of milk (PM) and price of feed (PF).***

Variables	Statistic	Sample	Observations	Without Trend	With trend
DDHc	D.F.	1972-1990	19	−2.80(−3.02)	−2.79(−3.67)
	A.D.F.	1973-1990	18	−2.20(−3.04)	−2.15(−3.69)
DDPM	D.F	1972-1990	19	−4.39(−3.02)	−3.87(−3.67)
	A.D.F	1973-1990	18	−3.84(−3.04)	−4.59(−3.69)
DDPF	D.F	1972-1990	19	−5.00(−3.04)	−4.86(−3.69)
	A.D.F	1973-1990	18	−5.37(−3.05)	−5.42(−3.71)

(Source: Computed)

Table 2 ***Johansen maximum likelihood procedure. Cointegration LR test based on trace of the stochastic matrix.***

List of eigenvalues in descending order:
0.85368 0.26015 0.6014E-3

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r = 0	r >= 1	44.4778	31.5250	28.7090
r <= 1	r >= 2	6.0382	17.9530	15.6630
r <= 2	r = 3	0.012031	8.1760	6.5030

– The analysis of goat milk supply response by the use of an error correction model is quite problematic due to the fact that the available data set was small and so the results that we got from Johansen method may be misleading. Since we cannot get a valid error correction model from our data set, we have to assume (following Granger's representation theorem) that the variables available are not cointegrated. Consequently, there can be no long-run relationship between the variables and regressions linking them will be spurious.

– The estimation of supply response for sheep milk production by the use of E.C.M. presents serious difficulties which are primarily related to the problematic data set for the number of dairy sheep. The CUSUMQ test showed that this data set had structural breaks. As a result, any attempt to model this data set will not produce well-established empirical estimates.

Summary and conclusions

The principal objective of this paper was to analyse some aspects of the milk economy in Greece, in order to reveal the special characteristics of the sector and its importance for the country as a whole. To meet this objective, the estimation of the supply function of milk production in Greece was imperative.
In order to get estimates for the supply of

Table 3 ***Unit root tests for the variables: Hs, Psm, Pf.***

Variables	Statistic	Sample	Observations	Without Trend	With trend
DHs	D.F	1965-1986	22	–3.02(–2.60)	–3.55(–3.46)
	A.D.F.	1966-1986	21	–3.04(–2.33)	–4.48(–3.69)
DPsm	D.F	1965-1986	22	–4.39(–3.02)	–4.86(–3.69)
	A.D.F	1966-1986	21	–3.84(–3.04)	–5.42(–3.71)
DPf	D.F	1965-1986	22	–5.00(–3.04)	–8.14(–3.63)
	A.D.F	1966-1986	21	–5.37(–3.05)	–4.26(–3.64)

(Source: Computed)

Table 4 ***Unit root tests for the variables: Hg, Pgm, Pfd.***

Variables	Statistic	Sample	Observations	Without Trend	With trend
DHg	D.F	1965-1984	20	–3.49(–3.01)	–3.40(–3.35)
	A.D.F.	1966-1984	19	–3.75(–3.02)	–3.68(–3.66)
DPgm	D.F	1965-1986	22	–7.62(–3.00)	–7.91(–3.63)
	A.D.F	1966-1986	21	–3.89(–3.01)	–4.00(–3.64)
DPfd	D.F	1965-1986	22	–5.04(–3.03)	–6.14(–3.43)
	A.D.F	1966-1986	21	–5.35(–3.15)	–4.22(–3.54)

(Source: Computed)

Table 5 ***Johansen maximum likelihood procedure. Cointegration LR test based on trace of the stochastic matrix.***

List of eigenvalues in descending order:
0.83525 0.50735 0.087811 –0.0000

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r = 0	r >= 1	54.6674	34.9100	32.0030
r <= 1	r >= 2	16.7972	19.9640	17.8520
r <= 2	r = 3	1.9301	9.2430	7.5250

Table 5.1 ***Johansen maximum likelihood procedure. Cointegration LR test based on maximal eigenvalue of the stochastic matrix.***

List of eigenvalues in descending order:
0.83525 0.50735 0.087811 –0.0000

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r = 0	r >= 1	37.8702	22.0020	19.7660
r <= 1	r >= 2	14.8671	15.6720	13.7520
r <= 2	r = 3	1.9301	9.2430	7.5250

Table 6 ***Johansen maximum likelihood procedure. Cointegration LR test based on trace of the stochastic matrix.***

List of eigenvalues in descending order:
0.75286 0.43546 0.21917 –0.0000

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r = 0	r >= 1	46.5557	34.9100	32.0030
r <= 1	r >= 2	17.2019	19.9640	17.8520
r <= 2	r = 3	5.1952	9.2430	7.5250

Table 6.1 ***Johansen maximum likelihood procedure. Cointegration LR test based on maximal eigenvalue of the stochastic matrix.***

List of eigenvalues in descending order:
0.75286 0.43546 0.21917 –0.0000

Null	Alternative	Statistic	95% Critical Value	90% Critical Value
r = 0	r >= 1	29.3539	22.0020	19.7660
r <= 1	r >= 2	12.0066	15.6720	13.7520
r <= 2	r = 3	5.1952	9.2430	7.5250

milk in Greece, the error correction model was used. A major problem arise in the supply analysis, because of the lack of data, a number of explanatory variables that would have been used and would have been considered useful, have been left out. Some of these variables are: the price of competitive products, the price of some inputs (machinery, labour). These variables were of particular importance in the present paper but the available data covered a very short period (5-10 years). The error correction model, as it was mentioned in the previous paragraphs, due to deficiencies of the data set (length, mistakes in measurement) gave an outcome which was problematic.

In the case of sheep and goat milk supply, due to the fact that we did not find a valid E.C.M. and following Granger's representation theorem, the data series are assumed not to be cointegrated. The importance of the fact is that a long-run equilibrium relationship could not exist between the variables of interest.

In the case of cow milk supply, the model gave some good results. The price variables had the correct signs and proved to be significant. The lagged dependent variable was not significant but it was included in the model due to its positive effect for the autocorrelation (Judge et al. 1988).

As far as the price elasticitiy (output, input) of supply is concerned the following can be said:

a) The estimates of the short-run elasticity can be considered as quite reasonable. The producers were found to respond in an expected level to milk price as well as to feed price.

b) The lon-run elasticity estimates were as expected (due to prior knowledge) for the case of cow milk production.

The analysis presented in this paper suggests that modelling dairy population dynamics (if the data set permits) provides considerable insights in the economic adjustments taking place on dairy farms (Gardner, 1987). The results show that farmers respond moderately (particularly in the long-run) to changing relative prices in the management decisions concerning the size and the productive use of the dairy herd. They also indicate the importance of a constant monitoring of the dairy support price in the design of dairy policy. Indeed, given a rather small short-run supply elasticity, setting the support price higher than the market equilibrium price may not create noticeable excess supply of dairy products in the short-run (Maddala, 1977). However, the long-run effects of such a policy may be very costly since, once herd size has been expanded, the elimination of excess supply can become a rather difficult task. Regional supply response may be interesting given the diverse nature of production in different parts of the country. The dynamics of dairy production along with the ability to move production units and output across regions should be important in determining the distribution of production. Additional research topics include the effects of irreversibility and uncertainty on decision making. For example, how such factors influence the timing of decisions and indirectly, the dynamics of supply response. Also, our analysis is limited to a partial equilibrium approach. Additional research is needed to expand the analysis at the sector level (Data-Based Dynamics).

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