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Decomposition Analysis of Factor Cost Shares: The Case of Greek Agriculture

Giannis Karagiannis, Stelios Katranidis, and Kostas Velentzas

ABSTRACT

An alternative version of decomposition analysis, based on factor cost shares rather than input demand functions, is presented and applied to Greek agriculture. Decomposition analysis shows that most of the changes in factor cost shares during the period from 1973 to 1989 are attributed to technical change and factor substitution, while the role of the scale effect is small, except that of fertilizer. The decomposition analysis results are then used to analyze the implications of Greece's fertilizer and feed subsidy removal, which took place in 1990.

Key Words: decomposition analysis, factor cost shares, Greek agriculture.

Decomposition analysis, developed within a duality framework and based on a cost function, is used to explain changes in factor use over time (Kako 1978, 1980; Kuroda). In this framework, variation in the optimal input mix over time is explained by three effects: total factor substitution, bias in the scale (output) effect, and bias in technical change. The use of decomposition analysis has also been extended by Kuroda to include relative input use. In both cases, its empirical application can be carried out by using the estimated parameters of a flexible cost function, which does not impose any a priori restrictions on the structure of the underlying production technology. Even though the above framework has been applied only to Japanese agricultural data, it can also be inferred by using the results of other national (e.g., Ray; Baffes and Vasavada; Glass and McKillop 1990; Andrikopoulos and Brox; Karagiannis and Furtan), regional (e.g., Moschini; Glass and McKillop 1989), or sectoral studies (e.g., Ball and Chambers; McLean-Meyinsse and Okunade; Mergos and Yotopoulos).

The importance of decomposition analysis in applied economics is characterized by its ability to deal satisfactorily with simultaneous changes in many exogenous variables. In the case of cost minimization, for example, the change in the derived demand of a particular input, induced by changes in some factor prices and/or output, can be asserted within decomposition analysis. Such information cannot be obtained by using just the corresponding elasticity figures since these are only partial measures of change. Actually, elasticities can appropriately measure changes in endogenous variables only in a ceteris paribus way, that is, by holding all other exogenous variables constant except that under consideration. More-

Giannis Karagiannis is a senior researcher with the Foundation of Economic and Industrial Research; Stelios Katranidis and Kostas Velentzas are assistant professors in the Department of Economics, University of Macedonia, Thessaloniki, Greece.

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over, no information can be obtained about changes in cost structure by using the elasticity measures. In many economic problems more than one variable can change simultaneously, and response analysis could be biased and inconsistent if it is solely based on elasticity estimates. On these grounds, decomposition analysis can be helpful for analyzing policy issues in factor and product markets within a broader framework than by using a simplified ceteris paribus analysis. To some extent, decomposition analysis can be thought of as a (duality) alternative to the Floydian model extended by Gardner.

The objective of this study is twofold. The first is to propose an alternative version of decomposition analysis based on equilibrium factor cost shares rather than input demand functions. The sources of factor cost share changes are identified and attributed separately to factor substitution, scale economies, and technical change. The second objective is to apply the above framework to Greek agriculture, in which the structural characteristics are different from those of other European countries.[1] Quantitative measures of these three sources of changes in factor cost shares are expected to provide valuable information for explaining agricultural development in Greece and lead to useful policy recommendations.

The remainder of this article is organized into five sections. In the first section, the conceptual framework for decomposing equilibrium factor cost shares is developed by using a dual cost function. Next, the empirical model and the estimation procedure are described. An analysis of decomposition of factor cost share in Greek agriculture is developed in the third section, followed by a presentation of the links between decomposition analysis and policy issues in the context of Greek agriculture. In the final section, concluding remarks are provided.

Decomposition Analysis of Factor Cost Shares

In this section, we present an alternative version of decomposition analysis based on equilibrium factor cost shares, rather than input demand functions. The main advantage of the proposed modification is that it provides information on distributional issues associated with changes in exogenous (price and output) variables as well as possible alternation of cost structure. In addition, the proposed alternative seems to be more suitable for flexible functional forms resulting in factor share rather than input demand functions, such as the translog, the Minflex-Laurent translog, the CES translog, the GL translog, and the generalized Cobb-Douglas. More importantly, it can be used along with the Kako (1978, 1980) and Kuroda framework in a complementary way, as it requires exactly the same set of data and estimated elasticities. In any case, it enriches the potential analytical ability of decomposition analysis since changes in optimal input use, in cost structure, and the related distributional effects can be asserted from the econometric estimation of a dual cost function.

Consider a representative farmer whose objective is to minimize the total cost of production[2] of a single output, which is produced via

[1] Greek agriculture is characterized by small average farm size, a strong orientation toward crop production, and a high proportion of the economically active population engaged in agriculture. In contrast, in most European Union (EU) countries, the agricultural sector is characterized by an enlarged livestock sector, relatively large farm size, and only a small proportion of the active population being employed in agriculture. Despite their small size, farms in Greece are often fragmented. In the last 20 years, the output mix has remained more or less unchanged, with crop production accounting for more than 70% of total agricultural production. Among the EU countries, Greece has the highest rate of active population employed in agriculture (approximately 25%), notwithstanding its steady decline in the 1980s. On the other hand, the indices of mechanization and fertilizer use are still low compared to other EU countries despite the fast growth rates experienced during the last two decades. The above characteristics of Greek agriculture are likely to have significant effects on the cost of production, output variability, and the demand for factors of production.

[2] The use of a cost instead of a profit function is mainly due to supply and acreage controls imposed on the production of sugarcane, tobacco, cotton, processing tomatoes, and olives, which restrict their output to predetermined levels. The production of these outputs accounts for 15–20% of the total agricultural product and uses 10–15% of cultivated land.

a technical relationship, $Q = f(\mathbf{x}; t)$, where Q is output, $\mathbf{x}$ represents a vector of inputs, and t is a time trend representing technology. There exists a cost function, $c(Q, \mathbf{w}; t)$, defined as:

$$c(Q, \mathbf{w}; t) = \min_{\mathbf{x}} \{\mathbf{w}'\mathbf{x}: Q = f(\mathbf{x}; t)\},$$

where $\mathbf{w}$ is the exogenously determined input price vector. The cost function is nondecreasing, continuous, concave, and linear homogeneous in $\mathbf{w}$, and convex and nondecreasing in Q as long as $f(\mathbf{x}; t)$ is continuous, increasing, and concave in $\mathbf{x}$. Using Shephard's lemma, the equilibrium factor cost share of the ith input is obtained as:

$$S_i(Q, \mathbf{w}; t) = \partial\ln(c(Q, \mathbf{w}; t))/\partial\ln(w_i).$$

Totally differentiating $S_i(Q, \mathbf{w}; t)$ with respect to t yields equation (1):

$$\text{(1)} \quad \frac{dS_i(Q, \mathbf{w}; t)}{dt} = \left(\frac{\partial S_i}{\partial Q}\right)\left(\frac{dQ}{dt}\right) + \sum_{j=1}^{n}\left(\frac{\partial S_i}{\partial w_j}\right)\left(\frac{dw_j}{dt}\right) + \frac{\partial S_i}{\partial t}.$$

Equation (1) may be written in terms of growth ratios as:

$$\text{(2)} \quad G(S_i) = \left(\frac{1}{S_i}\right)\left(\frac{\partial S_i}{\partial\ln(Q)}\right)G(Q) + \left(\frac{1}{S_i}\right)\sum_{j=1}^{n}\left(\frac{\partial S_i}{\partial\ln(w_j)}\right)G(w_j) + \left(\frac{1}{S_i}\right)\frac{\partial S_i}{\partial t},$$

where $G(S_i) = d\ln(S_i)/dt$, $G(Q) = d\ln(Q)/dt$, and $G(w_i) = d\ln(w_i)/dt$. Using the cost share in logarithmic form, i.e., $\ln(S_i) = \ln(w_i) + \ln(x_i) - \ln(c)$, and differentiating with respect to the price of the jth input and its own price gives:

$$\text{(3a)} \quad \frac{\partial S_i}{\partial\ln(w_j)} = S_iS_j(\sigma_{ij} - 1) = S_i(n_{ij} - S_j)$$

and

$$\text{(3b)} \quad \frac{\partial S_i}{\partial\ln(w_i)} = S_i[1 + S_i(\sigma_{ii} - 1)] = S_i[1 + n_{ii} - S_i],$$

respectively, where σ_{ij} refers to the Allen-Uzawa partial elasticity of substitution and n_{ij} refers to the derived demand elasticity. Substituting (3a) and (3b) into (2) yields:

$$\text{(4a)} \quad G(S_i) = \left(\frac{\partial\ln(S_i)}{\partial\ln(Q)}\right)G(Q) + \sum_{i\neq j}^{n} S_j(\sigma_{ij} - 1)G(w_j) + [1 + S_i(\sigma_{ii} - 1)]G(w_i) + B_i(Q, \mathbf{w}; t)$$

or

$$\text{(4b)} \quad G(S_i) = \left(\frac{\partial\ln(S_i)}{\partial\ln(Q)}\right)G(Q) + \sum_{i\neq j}^{n} (n_{ij} - S_j)G(w_j) + [1 + n_{ii} - S_i]G(w_i) + B_i(Q, \mathbf{w}; t),$$

where $B_i(Q, \mathbf{w}; t)$ is the overall bias in technical change, defined as $B_i(Q, \mathbf{w}; t) = \partial\ln(S_i(Q, \mathbf{w}; t))/\partial t$ (Binswanger 1974b; Antle and Capalbo).

The left-hand side of equations (4a) and (4b), $G(S_i)$, represents the observed percentage change of the ith input's factor cost share during a particular period of time. The main task is to decompose the magnitude of this change into three separate components due to changes in prices, output, and technology, respectively. Each of these components correspond to the total factor substitution, the bias in scale (output), and the technical change effect. In order to obtain quantitative measures of these effects separately, estimates of the (Hicksian) derived demand or the Allen-Uzawa partial elasticities of substitution are required.[3] These are ob-

[3] Following Blackorby and Russell's assertion, input demand elasticities are used in the empirical implementations because they provide more concrete and accurate information about input substitutability than the Allen-Uzawa partial elasticities of substitution.

tained through an econometric estimation of a dual cost function, which should ideally be as flexible as possible in order to allow for a quite general representation of production technology.

The first term on the right-hand side of (4) is the bias in scale (output) effect, which is identified with the nonhomotheticity of the underlying production technology. This term allows the cost shares to change over time in the absence of technical change or changes in factor prices. Bias in the scale effect vanishes if the cost function is weakly separable in output[4] or, equivalently, if the production function is homothetic. Then, changes in output level or scale do not affect the factor cost shares, and thus $\partial \ln(S_i)/\partial \ln(Q) = 0$. Hence, the structure of production cannot be neglected in determining the bias in the scale effect. The second and third terms on the right-hand side of (4) measure the total substitution effect due to changes in factor prices for a given output level. The second term represents the cross-price effect, and the third term is the own-price effect. The functional form of the underlying production function plays a crucial role in measuring the total substitution effect. The last term corresponds to the technical change effect, and it is identified with the bias of technical change (in the Hicksian sense). The bias in technical change relates the impact of technical change on the average increase of a factor share relatively to the shares of the other factors of production, ceteris paribus. The technical change effect vanishes under Hicks-neutral technical change. Hicks neutrality implies that $B_i(Q, \mathbf{w}; t) = 0$; that is, the factor cost shares do not change over time. Technical change is said to be relatively ith factor-using (saving) if $B_i(Q, \mathbf{w}; t) > (<) 0$.

The above methodology can easily be extended to the decomposition of the ratio of any pair of factor cost shares. That is, the relative growth rate of any pair of factor cost shares may be analyzed rather than each individual factor cost share. The change over time in the growth rate of a ratio of factor cost shares is given by subtracting any two versions of equation (4) for $i \neq j$, i.e.:

$$\text{(5a)} \quad G(S_i) - G(S_j) = \left(\frac{\partial \ln(S_i)}{\partial \ln(Q)} - \frac{\partial \ln(S_j)}{\partial \ln(Q)}\right) G(Q) + \sum_{k=1}^{n} S_k(\sigma_{ik} - \sigma_{jk}) G(w_k) + (G(w_i) - G(w_j)) + B_{ij}(Q, \mathbf{w}; t)$$

or

$$\text{(5b)} \quad G(S_i) - G(S_j) = \left(\frac{\partial \ln(S_i)}{\partial \ln(Q)} - \frac{\partial \ln(S_j)}{\partial \ln(Q)}\right) G(Q) + \sum_{k=1}^{n} (n_{ik} - n_{jk}) G(w_k) + (G(w_i) - G(w_j)) + B_{ij}(Q, \mathbf{w}; t),$$

where $B_{ij}(Q, \mathbf{w}; t)$ is the pairwise bias in technical change, defined by Antle and Capalbo (pp. 36–40) as $B_{ij}(Q, \mathbf{w}; t) = \partial \ln(S_i(Q, \mathbf{w}; t))/\partial t - \partial \ln(S_j(Q, \mathbf{w}; t))/\partial t$. Technical change with respect to a pair of inputs is defined to be Hicks-neutral if and only if $B_{ij}(Q, \mathbf{w}; t) = 0$. On the other hand, technical change is biased toward the ith factor—and therefore against the jth factor—if $B_{ij}(Q, \mathbf{w}; t) > 0$, and vice versa.

The relative contribution of each of the above mentioned effects depends on both the stability of the exogenous variables and the magnitude of the corresponding elasticities. A relatively large effect could be associated with a corresponding large elasticity and significant changes in the related exogenous variables. If, for example, input prices have been stable over time, then the relative contribution of the

[4] The cost function is weakly separable if $c(Q, \mathbf{w}; t) = h(Q; t) \cdot g(\mathbf{w}; t)$, where $g(\mathbf{w}; t)$ is the unit cost function with the same properties as $c(Q, \mathbf{w}; t)$, and $h(Q; t)$ is continuous and differentiable in Q and t and decreasing in Q. In logarithmic form, $\ln(c(Q, \mathbf{w}; t)) = \ln(h(Q; t)) + \ln(g(\mathbf{w}; t))$. Then, $\partial \ln(c)/\partial \ln(w_i) = \partial \ln(g(\mathbf{w}; t))/\partial w_i = S_i$, and $\partial \ln(S_i)/\partial \ln(Q) = 0$. The cost function is weakly separable in a given input partition if the production function is weakly separable in the same partition and weakly homothetically separable. The latter is a necessary but not a sufficient condition for the former (see also Chambers, p. 74).

total substitution effect would be near zero regardless of the magnitude of the relevant elasticities. On the other hand, inelastic demand responses depress the magnitude of the total substitution effect to small values regardless of input price changes over time. Similarly, the magnitude of the scale effect depends on both output variability and the value of $\partial \ln(S_i)/\partial \ln(Q)$. Finally, the magnitude of the effect of technical change depends on the relative strength of the bias in technical change.

Empirical Model and Estimation Procedure

In the empirical modeling, the translog cost function (developed by Christensen, Jorgenson, and Lau 1971, 1973) is used. Even though the translog has been widely used in applied production economics, some limitations are still associated with it. First, the translog form cannot satisfy curvature conditions (concavity) globally, but only locally (Diewert and Wales 1987).[5] That is, the concavity of the translog cost function with respect to input prices should either be checked at each data point or be imposed.[6] Usually, though, this property is checked just at the point of approximation. Definitely, whenever curvature conditions are not satisfied globally, the discussion of the empirical results should be limited to these data points where this property holds. This necessarily narrows the applicability of the empirical findings.

Second, the translog functional form has an appealing Taylor series interpretation, and therefore elasticity estimates are unbiased only when all data lie in the region of convergence, i.e., at the positive orthant (Driscoll). Whenever explanatory variables have a distribution that is skewed to the right (e.g., prices and output in cost functions), a quadratic form such as the translog may be inappropriate. Nevertheless, functional forms that employ logged arguments have larger regions of convergence than those of quadratic and Leontief specifications. On the other hand, the economic performance of various flexible functional forms, based on empirical studies of comparison, has yielded mixed results (see, for example, Appelbaum; Berndt and Khaled; Guilkey, Lovell, and Sickels; Chalfant; Despotakis; Diewert and Wales 1987; Baffes and Vasavada; Shumway and Lim). Moreover, given that economic theory provides no adequate information about the appropriate functional form for each study case, the choice made is somehow arbitrary based solely on the advantages and limitations of alternative functional forms.

The translog cost function is given as:

$$\text{(6a)} \quad \ln(c) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln(w_i) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{m} \alpha_{ij}\ln(w_i)\ln(w_j) + \beta_1 \ln(Q) + \frac{1}{2}\beta_2(\ln(Q))^2 + \sum_{i=1}^{n} \delta_i \ln(Q)\ln(w_i) + \sum_{i=1}^{n} \mu_i t \ln(w_i) + \gamma_1 t \ln(Q) + \vartheta_1 t + \frac{1}{2}\vartheta_2 t^2,$$

where w_i $(i = 1, \ldots, 7)$ are the price indices of land rent, agricultural wages, user cost of capital, feed, energy, fertilizer, and all other intermediate inputs. Using Shephard's lemma, the factor cost share equations are:

$$\text{(6b)} \quad S_i = \alpha_i + \sum_{j=1}^{m} \alpha_{ij}\ln(w_j) + \delta_i \ln(Q) + \mu_i t.$$

Symmetry and linear homogeneity imply the following set of restrictions, respectively, in the estimated parameters:

[5] A functional form is locally curvature correct if it satisfies the appropriate curvature properties at a single point (the point of approximation for the translog), and is globally curvature correct if it satisfies the correct curvature condition at all data points (Diewert and Wales 1995). Functional forms being globally curvative correct are preferred to locally curvative correct ones.

[6] There are, however, globally curvature correct functional forms such as the symmetric generalized McFadden (see, for example, Diewert and Wales 1987, 1995; Rask).

Table 1. Derived Factor Demand Price Elasticities for Greek Agriculture, 1973–89

	Price of:						
	Land	Labor	Capital	Feed	Energy	Fertilizer	Other Intermed. Inputs
Land	−1.11	0.19	0.53	0.33	−0.26	0.05	0.29
Labor	0.07	−0.47	0.43	−0.06	0.08	0.09	−0.13
Capital	0.31	0.71	−1.63	−0.13	0.38	−0.01	0.40
Feed	0.82	−0.40	−0.55	−0.70	−0.14	0.36	0.73
Energy	−0.72	0.64	1.81	−0.16	−1.32	−0.29	0.18
Fertilizer	0.29	1.36	−0.13	0.76	−0.54	−1.79	0.02
Other Intermed. Inputs	0.39	−0.68	1.30	0.55	0.08	0.01	−1.53

Note: Elasticity calculations are based on relationships developed by Binswanger (1974a).

$$\alpha_{ij} = \alpha_{ji} \qquad \forall\ i, j$$

and

$$\sum \alpha_i = 1, \qquad \sum \alpha_{ij} = 0,$$

$$\sum \mu_i = 0, \quad \text{and} \quad \sum \delta_i = 0.$$

The system of equations (6b) is estimated with an iterative seemingly unrelated regression (ITSUR) method, which adjusts for cross-equation contemporaneous correlation. This procedure ensures that estimates are invariant to the excluded equation and that they also converge asymptotically to maximum likelihood estimates.[7] In the presence of first-order autocorrelation and given that (6b) depicts a singular equation system, a procedure (introduced by Berndt and Savin) is used for ITSUR estimation.[8] This procedure relies on the assumption that there is only one autocorrelation coefficient for the whole system. The data set used to estimate (6b) is discussed in the appendix.

Decomposition of Factor Cost Shares in Greek Agriculture

The empirical results of the decomposition analysis of factor cost shares in Greek agriculture are presented in table 2. The scale (output) and the total substitution effects are calculated using the estimated elasticities (see table 1) and equation (4). The relative contribution of the scale and the total substitution effect depends on the magnitude of the relevant elasticities and the magnitude of changes in exogenous variables, i.e., input prices and output. The technical change effect is measured by subtracting the output effect and the total substitution effect from the observed changes in the predicted factor cost share. During the period from 1973 to 1989, a significant change in the factor cost shares of land, labor, and capital occurred, while the corresponding change for the other inputs was relatively smaller. Technical change and factor substitution contributed most to changes in

[7] The estimated parameters are not reported here, but are available from the authors upon request. At the point of approximation (1980), the predicted cost shares are all positive, implying that (6a) was found to be monotonic and nondecreasing in input prices. Concavity of (6a) is satisfied as the principal minors of the Hessian matrix alternate in sign. The system of equations (6b) has been estimated with symmetry and homogeneity as maintained properties. The other two properties (i.e., Hicksian neutrality and weak separability) are tested since they should not hold a priori. Their existence is significant, however, for the decomposition analysis results. In particular, if Hicks-neutral technical change prevails, the last term of (4) vanishes. On the other hand, homotheticity implies that the first term of (4) vanishes.

[8] More recently, Moschini and Moro proposed an alternative procedure which allows autocorrelation coefficients to vary across factor share equations.

Table 2. Decomposition Analysis of Equilibrium Factor Cost Shares for Greek Agriculture, 1973–89

	Growth Rate of Cost Share	Scale (Output) Effect	Own-Price Effect	Cross-Price Effect	Total Substitution Effect	Technical Change Effect
Land	−0.033	0.001	−0.044	0.038	−0.006	−0.028
Labor	−0.035	−0.001	−0.020	−0.010	−0.030	−0.004
Capital	0.072	0.001	−0.165	0.147	−0.018	0.089
Feed	0.016	0.000	−0.042	0.075	0.033	−0.017
Energy	0.019	−0.001	−0.069	0.080	0.011	0.009
Fertilizer	−0.002	0.003	−0.130	0.113	−0.017	0.012
Other Intermed. Inputs	0.025	0.001	−0.083	0.105	0.022	0.002

factor cost shares.[9] The role of the output (scale) effect was small except for fertilizer.[10] Finally, the own-price effect was negative as expected for all factor cost shares.

Results of our study show that the factor cost share of land decreased by an annual average rate of 3.3%, mainly due to a land-saving technical change and total factor substitution. The cross-price effect moved in the opposite direction relative to the own-price effect, which was negative, and thus it favored the increase of land share in the total cost of production. The own-price effect, however, was strong enough to offset the cross-price effect and eventually to cause a decrease in the land cost share. In addition, the output effect was also negative and resulted in a decrease of the land cost share, ceteris paribus, though its contribution was relatively small (i.e., around 3%).

The share of labor in the total cost of production declined at an annual average rate of 3.5%. This change is largely explained by the total substitution effect and by the technical change effect. Moreover, both the own- and the cross-price effects resulted in a labor share decrease. According to the sign of the total substitution effect, a reduction in the labor share occurred, as its factor price became relatively more expensive than that of the other inputs. The scale effect also contributed to a labor share decrease, but at a lower rate.

In contrast, our findings show that the cost share of capital grew by an annual average rate of 7.2%. The expanding use of capital inputs has been associated with the rapid modernization of agriculture during the period from 1973 to 1989. The main source of the growth of the capital cost share has been technical change. Even though the total substitution effect moved in the opposite direction, it was not enough to offset the positive contribution of technical change. It should be noted that the cross-price effect was in favor of a capital share increase, and this fact indicates that relative prices favored the more intensive use of capital. Finally, the contribution of the scale effect was low.

The cost share of feed showed an average annual increase of 1.6%. The total substitution effect was positive and resulted in an increase of the share of feed, whereas the technical change effect was in the saving direction. In this case, the direction of the total factor substitution effect was determined by the cross-price effect, implying that relative prices have

[9] The hypothesis of Hicks-neutral technical change is rejected at the 5% level of significance. Based on the likelihood ratio test, the calculated value is found to be 115, whereas the tabulated value of χ^2 with six degrees of freedom is just 12.6. Consequently, the effect of technical change is statistically different than zero and is presented in the reported results of decomposition analysis.

[10] The hypothesis that factor cost shares are invariant to changes in output level is also rejected at the 5% level of significance. The calculated value of the likelihood ratio test is found to be 20.4, while the corresponding value of χ^2 distribution with six degrees of freedom is 12.6. This hypothesis testing ensures the existence of the scale effect which is identified with nonhomotheticity of (6a).

favored the use of feed. This is an evolution which can be attributed to the existence of a feed subsidy paid by the Greek government throughout the sample period. Moreover, there was no scale effect in this case.

In the case of the energy cost share, however, both the total substitution and the technical change effects moved in the same direction, while the scale effect did not favor the use of energy. The total substitution and the technical change effects equally shared the increase in energy factor cost share during the period under consideration. Moreover, relative prices favored energy use even though its price has significantly risen.

In the case of fertilizer, the situation is exactly the opposite. Its factor cost share remained unchanged from 1973 to 1989 (a slight decrease of 0.2% annually can be considered negligible). A strong scale effect, along with a fertilizer-using technical change, was not enough to offset the negative substitution effect. Also, the increase in the price of fertilizer offsets the positive contribution of the cross-price effect. This was mainly due to fertilizer price subsidization which artificially reduced its price.

Decomposition Analysis and Policy Issues

In addition to the valuable information that can be obtained through decomposition analysis for agricultural development in Greece, the above results may also be used for analyzing the impact of agricultural policies on factor use and cost structure. In particular, the implications of removal of fertilizer and feed subsidies in 1990 are considered. This example is used to illustrate the fitness of decomposition analysis in cases where more than one exogenous variable changes simultaneously. This is a case that cannot satisfactorily be treated by elasticity measures. Using the above framework, changes in cost structure as well as in factor demands can be evaluated. For these purposes, equation (4) is used under various scenarios of changes in exogenous variables.[11] The obtained results depend on the magnitude of estimated elasticities and on the hypothesized changes in factor prices and output.

Until 1990, the Greek government had set a maximum price for fertilizer and feeds, both of which were lower than their equilibrium prices. Since the mechanism of floor price was used, the level of per unit subsidy was not known. Consequently, the increase of their prices during the 1990–91 crop year may not be fully attributable to subsidy removal, but may also be influenced by market forces. To analyze changes in the cost structure and their corresponding distributional effects, an increase of 10% is assumed for both feed and fertilizer price; the prices of other inputs are presumed to be constant. Two scenarios are developed with respect to output changes.

Initially, the case of no output changes is considered; that is, the impact of subsidy removal is analyzed under the scenario of a zero output increase during the 1990–91 crop year. It is also assumed that technical change is unaffected by this policy change, which appears to be a reasonable assumption, at least in the short run. Under these circumstances, it is predicted that the factor cost share of land will decrease by 0.7%, the share of labor by 4%, and the share of energy by 3.8%. On the other hand, the factor cost shares of capital, feed, fertilizer, and other intermediate inputs will increase by 5.3%, 5.1%, 7.5%, and 5.6%, respectively. The decreases of the factor cost share of land and labor are due to technical change, while that of energy is due to its complementary relationship with both feed and fertilizer. The increase of feed share is attributed to price increases and its complementary relationship with fertilizer. For fertilizer, the increase is due to price changes, its complementary relationship with feed, and technical change. Finally, for capital, technical change is an important factor since its share is expected to decrease, at least partially, due to the complementary relationship with both feed

[11] Obviously, many other scenarios can also be analyzed with different rules of change among factor prices, output decreases, or even changes in the biases of technical change. Such cases could be extremely valuable in evaluating potential impacts of policy changes or in forecasting changes in cost structure and input use.

and fertilizer. The resulting distributional effects follow immediately.

In the case where a subsidies removal is accompanied by a 1% increase in agricultural output, the corresponding figures are −1.3%, −3.4%, 4.8%, 5.2%, −3.3%, 8%, and 5% for land, labor, capital, feed, energy, fertilizer, and other intermediate inputs, respectively. The insignificant differences between the results obtained under the two scenarios are expected since, as noted earlier, the contribution of the output effect was found to be relatively small. It is easy to show that for the set of estimated elasticities presented in table 1, there are percentage changes for the prices of fertilizer and feed which may result in no changes in the factor cost shares for some of the inputs considered. Also, a different set of percentage price changes may have opposite impacts on some factor cost shares. A simulation technique can be used to find these critical values of price changes and elasticities.

Summary and Conclusions

A modified version of decomposition analysis, based on factor cost shares instead of input demand functions, was applied to Greek agriculture. The decomposition analysis of the seven aggregate factors (land, labor, capital, feed, energy, fertilizer, and the other intermediate inputs) produced three major findings: (*a*) technical change and factor substitution mainly contributed to the change in factor cost shares; (*b*) the role of the output (scale) effect was small, except for fertilizer; and (*c*) the own-price effect, as expected, was negative for all factor cost shares.

From a policy point of view, policies dealing with technical change and factor prices are expected to have a great impact on input use. In particular, policies affecting adoption and diffusion rates of new technologies and R&D expenses seem to be more efficient for land, labor, capital, and other intermediate inputs use, while factor price policies (e.g., subsidies/taxes for a more intensive/extensive use of a factor) seem to be more efficient for fertilizer use in Greek agriculture. This has actually been accomplished by an input subsidy program employed throughout the 1973–89 period under consideration. The program was supported by the Greek government and changed the movement of relative prices. However, it was not strong enough to induce a bias toward fertilizer-using technical change. The program's termination in 1990 had (as was shown) significant impacts on the annual use of fertilizer, given that fertilizer's derived demand is price elastic. On the other hand, policies associated with the scale effect (e.g., farm size, infrastructure, and irrigation) may have significant impact on fertilizer use only.

This study has shown that decomposition analysis is more accurate than elasticity analysis in considering policy issues, as it can take into account more information regarding output changes and biases in technical change, as well as simultaneous changes in all or some exogenous variables. Unfortunately, this potential use of decomposition analysis was not mentioned by either Kako (1978, 1980) or Kuroda as an alternative for dealing with policy issues. Future research may focus on multiproduct technologies and situations of temporary equilibrium.

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Appendix

A Laspeyres index is used to measure output quantity. This index is approximated by the value of total agricultural (crop and livestock) production at constant (1980) prices. Thus, it is assumed either that there is no substitution between outputs or that output prices vary proportionally (Diewert). This is a reasonable assumption, since output mix has remained unchanged during the period from 1973 to 1989. The relevant data are taken from the National Statistical Service of Greece (NSSG) publication, *Agricultural Statistics.*

Land rent expenditures are measured by the product of per unit land rent and the hectares of cultivated land, excluding fallow land. Data on the price index of land are taken from the NSSG publication, *Agricultural Price Indices,* and are reprinted by Eurostat. It should be mentioned that the index for land rent refers only to rented agricultural land. Nevertheless, in this study, it is used as a proxy for land rent of all cultivated land excluding fallow land. This is our best option, since there are no available data for owner-cultivated land. Consequently, it is implicitly assumed that the user cost of land is the same for farmers who own their land and for farmers who are non-owners. Then, a money measure of the per unit land rent is obtained by transforming the land rent index to a value measure via 1977 average land rent as reported in *Structural Research on Crop and Livestock Production* (NSSG 1980). Land area (cultivated and fallow) data are provided in the NSSG publication, *Agricultural Statistics.*

Labor expenditures include expenses on both family and off-family workers. The off-family labor expenses are given by Eurostat. Wages for off-family agricultural labor can be calculated by using the off-family labor expenditures and the units of off-family labor provided by the Agricultural Bank of Greece (ABG, p. 678). Then, by maintaining the assumption that family and off-family labor are paid at the same rate, and by multiplying this wage by the sum of family and off-family labor units (as given by ABG), expenditures for labor can be obtained. Thus, labor is considered to be a homogeneous input, since there are no expenses for nonpaid family labor (hired and nonpaid family workers). Data on the agricultural wage rate of hired labor are provided in NSSG's *Agricultural Statistics.*

Capital includes buildings, structures, land improvement, machinery, and transportation equipment. The user cost of capital is constructed as the sum of economic depreciation of capital assets plus a real interest rate on the wealth stock. Data on the depreciation of capital assets and the value of net fixed capital stock are taken from the Ministry of National Economy's publication, *Net Fixed Capital Stock and Depreciation of Fixed Capital Stock* (1983 and 1989). A nominal long-run annual interest rate for agricultural loans deflated by the capital price index is used for the real interest rate. The data for the nominal long-run interest rate are provided by ABG, and the data for capital price index are taken from the NSSG publication, *Agricultural Price Indices.*

Data on the expenditures for feed, energy, fertilizer, and the other intermediate inputs are taken from Eurostat, and their corresponding price indices from NSSG's *Agricultural Price Indices.* The category of other intermediate inputs includes seeds, pesticides, chemicals, and pharmaceutical products and materials.