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OUTPUT PRICE RISK AND PRODUCTIVITY GROWTH IN GREEK AGRICULTURE

By

*Panos Fousekis** and *Christos Pantzios***

Abstract

The objective of this paper is twofold. First, is to estimate a dual model of price risk in Greek agriculture and to assess the effects of this type of risk on farmers' production decisions. Second, is to analyze the rate of Total Factor Productivity (TFP)in the sector, during 1968-96, into components of interest. The empirical results suggest that the Greek farmers are risk averse. When the variance of output price increases by 100% the Greek farmers require an increase in the expected output price by 9.1% in order to maintain the same supply level. The technical change effects are the most important determinant of TFP growth, followed by the scale effects, the price risk effects, and the effects arising from the adjustment in the fixed factor (JEL Classification: D24, Q12).

Key Words: Price Risk, Productivity

1. Introduction

Determining the effects of risk on the behavior of the firm has been long the subject of many theoretical works in economics (e.g. Pratt, 1964; Samuelson, 1970; Sadmo 1971; Barta and Ullah, 1974; Pope, 1980; Pindyck, 1982; Chambers, 1983; Applebaum and Katz, 1986; Flacco and Larsen, 1992; Chambers and Quiggin, 1998). However, empirical applications of production models incorporating risk have been rather limited. The first empirical works in the late 1970s and early 1980s were based on ad hoc primal production models involving restrictive assumptions on technology and preferences (e.g. Just and Pope, 1979; Yassour, et. al, 1981). It was not until the early 1990s that the first dual models of price risk involving flexible functional forms

* Lecturer at the Agricultural University of Athens.
** Lecturer at the University of Patras.

and less restrictive preference structures appeared in the literature via the works of Applebaum (1991) and Coyle (1992).

However, in the light of recent international market developments, the effect that price risk may have on farm decisions in increasingly becoming a timely issue. This is mainly because while intervention policies were a prominent feature of farm sectors in the previous two decades, agriculture has been recently coming under pressure to liberalize by abolishing both domestic distortions and impediments to trade. Thus, following the reduction of protective mechanisms, price risk may well expected to elevate to an important factor in farming decisions. Nonetheless, as fas as we know the only empirical work involving duality and price risk in agriculture has been that of Coyle (1992).

In this context, the objective of the present study is twofold. First, it attempts to assess the impact of price risk on Greek farmers' decisions by estimating a dual production model. Second, based on the estimation results, it decomposes the rate of Total Factor Productivity (TFP) growth in Greek agriculture into components of interest such as scale, technological change and risk effects. It should be noted that the productivity growth in this sector has been studied in the past by a number of alternative methods including parametric, semi-parametric and non parametric (e.g. Bureau et al, 1995; Fousekis and Papakonstantinou, 1997; Mergos and Karagiannis, 1997); none of the earlier works, however, has taken price risk into consideration.

The rest of the paper is structured as follows. The next section describes the theoretical framework, while section 3 presents a decomposition of the TFP growth in the presence of output price risk and input fixity. Section 4 presents the empirical model and the estimation results while concluding remarks are summarized in the final section.

2. The Theoretical Framework

Consider a firm whose production function is given as y=f(x, k, t) where y is output, χ is a nX1 vector of perfectly variable inputs, k is the stock of a quasi-fixed input, and t is a time shift variable representing technology. The production function f is a twice continuous differentiable, non-decreasing, quasi-concave function. The firm is assumed to be competitive in both input and output price markets. It is also assumed that the prices of the perfectly variable inputs, w, are known with certainty when the production decisions are made but the output price, ρ is not known . Specifically, it is assumed here that the output price is a random variable with expected value and variance given by $E(\pi) = p$ and $Var(p) = \sigma^2_p$, respectively. As in Sadmo (1971) and Barta and Ullah (1974) the firm maximizes the expected utility of profits, $E[\upsilon(\pi)]$, where, profits are π=py-w'x and U is a Von Newman Morgenstern utility function, with a positive first derivative with respect to profit, that is, $U_\pi = U' > 0$.

The first order conditions for expected utility maximization may written in terms of the expected value of ρ as

$$[\bar{p}-\theta(y)]f_i=w_i, \tag{1}$$

where i=1, 2, ...n and $\theta(y)$ = -Cov[U', p)/E[U'] is the marginal risk premium which is positive, zero or negative depending on whether the firm is risk averse, risk neutral, or risk loving, respectively (Chambers, 1983). From the first order conditions it follows that $f_i/f_j=w_i/w_j$ implying that the production efficiency holds under output price uncertainly. Consequently, the firm's decision problem may be written as

$$Max_y E[U(\pi)]=max_y E[U(py-C(w,k,y,t)]=max_y U[py-C(w,k,y,t)-\Theta(y)] \tag{2}$$

The last equality in (2) is the certainty equivalent representation of the firm's decision problem, where C is the variable cost function and $\Theta(y)$ is the total risk premium (Hulten, 1986; Flacco and Larsen, 1992). The first order condition for problem (2) is

$$\bar{p}=\frac{\partial C}{\partial y}+\theta(y), \text{ where } \theta(y)=\frac{\partial \Theta}{\partial y} \tag{3}$$

Relation (3) implies that, in making the output decision, the firm takes into account the *full marginal cost* which is the sum of the marginal production cost, $\frac{\partial C}{\partial y}$, and the marginal risk premium $\theta(y)$.

The determination of the marginal risk premium requires information on the underlying utility function. As in earlier works (Applebaum 1991; Applebaum and Ullah, 1997) we employ the second order approximation.

$$E[U(\pi)] \approx U[E(\pi)- \frac{1}{2} RVar(\pi)] \tag{4}$$

where the parameter R is a measure of absolute risk aversion (Dhrymes, 1964, Chavas and Pope, 1982). R positive, zero or negative indicates risk averse, risk neutral or risk loving firm, respectively. Given the approximation (4), the total risk premium and the marginal risk premium can be written, respectively, as

$$\Theta(y)=RVar(\pi)/2=Ry^2 \sigma_p^2/2 \text{ and} \tag{5}$$

$$\theta(y)=Ry\sigma_p^2 \tag{6}$$

The preceding framework may be empirically implemented by specifying a functional form for the cost function, obtaining input demands via Shephard's Lemma and estimating the input demand system jointly with the output decision rule (3).

3. Productivity Decomposition in the Presence of Output Price Risk and Fixed Inputs

We define the rate of total factor productivity growth (RGTFP) as

$$RGTFP=\hat{Y}-\sum_{i=1}^{n} s_i \hat{x}_i \tag{7}$$

where the symbol $\wedge$ denotes change rates over time and s_i is the market share of the ith perfectly variable input. In attition, following Applebaum (1991)and Applebaum and Berechman (1991) we define the rate of growth in cost efficiency (GRCE) as the rate of growth in average costs excluding the effect of changes in variable input prices. That is,

$$RGCE = \hat{C}-\hat{y}-\sum_{i=1}^{n} s_i \hat{w}_i =(p-1)\hat{y}+s_k \hat{k}+\hat{T} \tag{8}$$

where p is the cost elasticity with respect to output, $\hat{T}$ is the rate of cost diminution (Chambres 1989) and $S_k=C_k k/C$ is the shadow share of the fixed input (Hulten, 1986; Berndt and Fuss, 1989; Morrison, 1992). The average cost, however, can be written as

$$C/Y \;=\; (\sum_{i=1}^{n} w_i x_i) / Y \tag{9}$$

Logarithmically differentiating both sides of (9) with respect to time, and substituting the result into (8) yields after some rearrangements .

$$RGTFP{=}{-}RGCE{=}{-}[(\varrho{-}1)\;\hat{y} + s_k \hat{k} + \hat{T}] \tag{10}$$

Finally, substituting (3) and (6) into (10) one obtains the decomposition of the RGTFP as

$$RGTFP= \;-\;(\frac{\bar{p}y}{C} - 1)\hat{y} - s_k \hat{k} - \hat{T} + \frac{R\sigma_\varrho^2 y^2}{C}\hat{y} \tag{11}$$

In words, the first term on the RHS of (11) is the scale effect on the RGTFP, the second term is the effect of adjustment in the fixed input, the third term is the effect of disembodied technical change while the last term is the risk effect on the GRTFP. Apparently, for $R=0$ (risk neutrality) or for $\sigma_\varrho^2 = 0$ (absence of output price risk) the last effect vanishes. The coefficient of the scale effect, $-(\frac{\bar{p}y}{C} - 1)$, is negative when the expected revenue is greater than the variable cost (or equivalently, when expected profit is positive). The coefficient associated with the asjustment in the fixed input, $-s_k$, is positive since the shadow value of k is a negative number reflecting the variable cost savings resulting from higher stocks of this input (Hulten 1986; Berndt and Fuss 1989; Morrison 1992). The rate of cost diminution is negative when the disembodied technical change is progressive (Chambers 1989). Finally, the risk effect has a positive coefficient, $(R\sigma_\varrho^2 y^2)/C$, for the risk averse firm (that is, for a firm with $R>0$). To explain the positive coefficient of the last effect recall that, for a risk averse firm, the existence of price risk works towards lower output levels for any given expected output price. This happens because, in making the supply decision, the firm takes into account the *full marginal cost* which, under risk aversion, is higher than the marginal production cost (see relation (3)). Lower supply levels, however, result in variable cost saving which are reflected in higher (in absolute value terms) RGCE or equivalently, in higher RGTFP.

4. An Empirical Application to the Agricultural Sector in Greece (1968-1996)

For the empirical application, the cost function is specified as a Normalized Quadratic (Vasavada and Chambers, 1986) with three variable inputs, namely, Labor (X1), Land (X2), and Materials/Intermediate Inputs (X3), and one fixed input which is the Private Capital (K) in the sector[3]. Information on Labour has been obtained from the National Statistical Service of Greece (NSSG) and the Eurostat publication "Economic Accounts for Agriculture and Forestry". This input includes both family and hired labor. The input Materials includes seed, feed, fertilizers, chemicals, energy, and other miscellaneous inputs and it is available from the National Accounts of Greece (NAG). Data on both irrigated and non-irrigated land are also available from the NSSG. In the present study the acreage of irrigated and non irrigated land along with information on respective rental prices have been used to construct a "quality adjusted" Land variable as in Mergos and Karagiannis (1997) and Papanagiotou (1998). The stock of Private Capital has been calculated using the perpetual investment model (Jorgenson and Yun 1991) and investment series available from the NAG. Finally, the output variable (Y) represents both crop and livestock production and it is also available from the NAG.

The price indexes (1970=1) for Materials and Output have been obtained from the NAG. The price index for Labor has been obtained from the NSSG. The price index of land is available by the NSSG since 1975. Earlier observations have been obtained for the study of Chetui (1996). All data used for empirical application are available from the authors upon request.

The price of Materials has been used for the normalization of the cost function. In what follows, w_1 and w_2 represent the normalized prices of Labor and Land, respectively. Given, our notation, the Normalized Quadratic cost function with three variable inputs and one fixed input can be written as

$$C = a_0 + \sum_{i=1}^{2} a_i(w_i) + \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2} a_{ij}(w_i)(w_j) + a_y(Y) + a_k(K) + \sum_{i=1}^{2} a_{iy}(w_i)(Y) + \sum_{i=1}^{2} a_{ik}(w_i)(K) + \frac{1}{2}a_{yy}Y^2$$

$$+ a_{yk}(Y)(K) + \frac{1}{2}a_{kk}K^2 + \sum_{i=1}^{2} a_{it}(w_i)(t) + a_{yt}(Y)(t) + a_{kt}(K)(t) \tag{12}$$

The demand equations for the inputs (X1) and (X2) are obtained from (12) using Shephard's Lemma.

The demand equation for the input (X3), the price of which has been used for normalization, is obtained from the accounting identity, C = w1X1 + W2X2+X3 => X3 = C-w1X1-w2X2. In particular, the system of variable input demand equations is

$$X1=\alpha_1+\alpha_{11}(w_1)+a_{12}(w_2)+a_{1y}(Y)+a_{1k}(K)+a_{1t}(t) \tag{13}$$

$$X2=\alpha_2+\alpha_{12}(w_1)+\alpha_{22}(w_2)+a_{2y}(Y)+a_{2k}(K)+a_{2t}(t) \tag{14}$$

$$\begin{aligned} X3= & \ a_0-\frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2}a_{ij}(w_i)(w_j)a_y(Y)+a_k(K)+\frac{1}{2}a_{yy}Y^2+ \\ & a_{ky}(K)(Y)+\frac{1}{2}a_{kk}K^2+a_{yt}(Y)(t)+a_{kt}(K)(t) \end{aligned} \tag{15}$$

Given (12), the marginal production cost is

$$\frac{\partial C}{\partial Y}=a_y+\sum_{i=1}^{2} a_{iy}(w_i)+a_{yy}(y)+\alpha_{yk}(k)+\alpha_{yt}(t) \tag{16}$$

Given (6), equation (3) becomes

$$\bar{p}=\frac{\partial C}{\partial y}+\theta(y)=\frac{\partial C}{\partial y}+Ry\sigma_{\varrho}^{2} \tag{17}$$

Substituting the expression for the marginal production cost from (16) into (17) yields the output decision equation (output decision rule) which will be estimated simultaneously with the three input demand equations.

At this point it must be stressed that the empirical model, contains two variables, namely, the expected value and the variance of the output price $\bar{p}$ and σ_{ϱ}^{2}, respectively, which are not directly observable; therefore they must be approximated by the available data. In the literature several approaches to accomplish this task have been proposed. Chavas and Holt (1990) and Coyle (1992) approximate the current expected output price and its variance as the weighted average of past prices and variances. Applebaum

(1991) uses a model of rational expectations. The most recent approach, (Applebaum and Ullah, 1997) involves the estimation of a VAR(1), ARCH(1) model; this approach is employed in the present paper as well. Details about the estimation of the AR(1), ARCH(1) model are offered in the Technical Appendix.

The system of equations has been estimated by the SURE method (Judge et. al 1988) in the TSP program. To avoid simultaneous equations bias which may arise due the appearance of the output variable (Y) on this RHS, the fitted (expected) values of a regression of Y on prices, the stock of the fixed input, and a time trend have been employed as an instrumental variable in the place of the observed output series .

TABLE 1

Coefficient Estimates and t — Statistics

PARAMETER	ESTIMATE	t-Satistic
a_1	695415	5.1*
a_{11}	-394.1	-2.63*
a_{12}	33.81	0.44
a_{1y}	0.15	4.57*
a_{1k}	0.023	0.38
a_{1t}	-350.5	-5.07*
a_2	-109383	-2.97*
a_{22}	-81.14	-0.49
a_{2y}	0.004	0.21
a_{2k}	-0.007	-0.41
a_{2t}	58.45	3.08*
a_0	-40638	-4.35*
a_{yk}	-0.00002	-4.07*
a_{kk}	0.000004	3.49*
a_{yy}	0.000034	0.82
a_{yt}	-0.0065	-2.01*
a_{kt}	0.0031	0.46
a_k	14.13	2.17*
a_y	-6.69	-0.51
R	0.00001	2.38*

*, Statistically significant coefficients at 5% level or less.

	Coefficient of Determination	DW - Statistic	JB-Statistic+
Labor Demand	0.99	1.75	0.53
Land Demand	0.985	1.72	0.77
Materials Demand	0.98	1.94	1.02
Output Decision Rule	0.7	1.72	1.72

+ The tabulated value of the Chi-squared with 2 degrees of freedom is 5.99.

Table I presents the estimated coefficients along with the corresponding t — statistics. The Labor demand equation and the Land demand equation have been corrected for first order serial correlation. The system appears to fit the data reasonably well. The coefficients of determination range from 0.7 for the Output decision equation to 0.99 for the Labor demand equation. The calculated DW-statistics range from 1.71 for the Land demand equation to 1.94 for the Materials demand equation. The Jarque-Bera statistic range from 0.53 for the Labor demand equation to 1.56 for the Output decision equation suggesting that the residuals, in all cases, follow the normal distribution. The estimated cost function is increasing in the input prices and the output level and decreasing in the stock of the quasi-fixed input. The own-price effects are all negative. Also the cost function is convex in output and the stock of the fixed input.

The coefficient R, which measures the absolute risk aversion is positive and statistically significant at 5% level or less implying that Greek farmers are risk averse. To evaluate the practical consequences of the risk aversion behavior we have calculated the elasticity of the expected output price with respect to the output price variance. The average magnitude of this elasticity is 0.091 implying that if the price variance were to increase by 100% the Greek farmers would require a 9.1% increase in the expected price in order to maintain the same supply level .

TABLE 2

Cost Elasticity, Shadow Share of Private Capital and Marginal Risk Premium in Greek Agriculture (1968-96)

Year	Cost Elasticity	Shadow Share of K	Marginal Risk Premium
1968	2.01	-0.43	0.28
1969	1.91	-0.39	0.27
1970	1.72	-0.34	0.29
1971	1.65	-0.31	0.31
1972	1.52	-0.27	0.31
1973	1.46	-0.23	0.31
1974	1.44	-0.22	0.27
1975	1.44	-0.19	0.32
1976	1.39	-0.18	0.34
1977	1.37	-0.15	0.30
1978	1.32	-0.15	0.33
1979	1.31	-0.14	0.34
1980	1.30	-0.17	0.32
1981	1.35	-0.19	0.33
1982	1.36	-0.22	0.38
1983	1.40	-0.23	0.42
1984	1.41	-0.21	0.38
1985	1.41	-0.24	0.47
1986	1.44	-0.26	0.46
1987	1.46	-0.28	0.34
1988	1.50	-0.29	0.38
1989	1.52	-0.31	0.42
1990	1.58	-0.34	0.45
1991	1.68	-0.35	2.11
1992	1.74	-0.39	1.87
1993	1.75	-0.39	0.86
1994	1.76	-0.41	0.39
1995	1.80	-0.41	0.74
1996	1.84	-0.42	0.46

Table 2 presents the cost elasticity, the shadow share of the fixed input (which is also the elasticity of variable cost with respect to the stock of this input) and the marginal risk premium over the period 1968-96. The cost elasticity ranges from 1.31 in to 1980 to 2.01 in 1968 with an average value 1.54. Our empirical results therefore suggest that the sector exhibits decreasing returns to scale, throughout the examined period. The elasticity of variable cost with respect to capital ranges from - 0.14 in 1980 to -0.43 in 1968 with an average value of -0.27 indicating that an increase in the level of K by 100% would, ceteris paribus, result to a variable cost reduction of 17%, on average. The marginal risk premium ranges from 0.276 in 1969 to 2.11 in 1991 with an average value of 0.51.

TABLE 3

Decomposition of TFP Growth in Greek Agriculture (1968-96)

	(1)+	(2)	(3)	(4)	(5)
YEAR	**RGTFP (%)**	**Scale Effects(%)**	**Fixed Input Effects (%)**	**Rate of Technical Change(%)**	**Risk Effects (%)**
1968	2.19	-6.16	4.73	1.38	2.23
1969	1.31	-5.27	3.24	1.44	1.89
1970	0.19	-4.63	1.57	1.48	1.77
1971	0.74	-4.21	1.69	1.51	1.73
1972	0.74	-3.86	1.49	1.56	1.54
1973	2.21	-2.12	1.61	1.66	0.74
1974	0.48	-2.54	0.62	1.66	0.74
1975	0.79	-2.55	0.82	1.71	0.80
1976	1.30	-1.72	0.61	1.74	0.66
1977	1.31	-1.58	0.80	1.64	0.46
1978	1.24	-1.14	0.31	1.75	0.32
1979	1.21	-1.26	0.42	1.68	0.37
1980	1.65	-0.03	0.016	1.87	0.08
1981	1.27	-0.59	-0.12	1.84	0.15
1982	1.11	-0.59	-0.31	1.89	0.12
1983	1.22	-0.36	-0.31	1.82	0.08

(cont'd)

1984	1.55	-0.78	0.42	1.81	0.10
1985	2.13	-0.14	0.38	1.89	0.019
1986	1.03	-0.03	-0.81	1.88	0.0035
1987	0.87	0.06	-1.11	1.92	-0.0047
1988	0.88	-0.35	-0.79	2.05	0.025
1989	1.45	0.07	-0.65	2.03	-0.0046
1990	1.63	-0.12	-0.25	1.99	0.01
1991	1.78	0.46	-0.78	2.19	-0.10
1992	2.35	0.68	-0.50	2.27	-0.09
1993	-0.38	-1.46	-1.17	2.14	0.11
1994	0.017	-0.82	-1.34	2.16	0.02
1995	2.48	1.18	-0.08	2.23	-0.04
1996	1.68	0.55	-1.07	2.22	-0.01

+, (l) = (2) + (3) + (4) + (5)

Average Values

1968-81	1.19	-2.71	1.27	1.64	0.99
1982-96	1.32	-0.11	-0.61	2.03	0.014
1968-96	1.26	-1.14	0.29	1.84	0.48

Table 3 presents the rate of TFP growth in Greek Agriculture over 1968-96 and its decomposition into scale effects, effects arising from adjustments in the fixed input, technical change effects, and risk effects. The average RGTFP over the period 1968-96 is 1.26 percent per annum. This number is close to 1.41 percent which has been reported by Fousekis and Papakonstantinou (1997). It is smaller, however, than the value of 2.36 reported by Mergos and Karagiannis (1997) and larger than the value of 0.52 reported by Bureau et. al (1995) . The technical change effect (rate of disembodied technological change) has an average of 1.84 percent per annum. The scale effect has an average of 1.36 percent per annum. The effect of the adjustment in the fixed input has an average of 0.29 percent per annum while the risk effect an average of 0.48 percent per annum. It appears, therefore, that the most important determinant of the behavior of TFP growth over the examined period is the technical change, followed by the scale effects, the risk effects and the adjustments of the fixed input.

Focusing at the sub-periods 1968-81 and 1982-96 it may be observed that the average rate of TFP growth in the second sub-period is (slightly) higher than that in the first sub-period. The scale effect in the second sub-period is substantially smaller than that in the first one. This may be largely attributed to the supply control measures introduced in the context of the Common Agricultural Policy of the E.U. in the late 1980s. The rate of technical change in the second sub-period, however, is higher than that in the first sub-period suggesting that the sector has enjoyed recently greater benefits from technological innovations. The effect of the adjustment in the fixed input has been positive in the first sub-period but negative in the second sub-period. This is the direct result of the disinvestment of private capital in Greek agriculture during the most recent years. Finally, the risk effect is smaller in the second sub-period. To explain this, one may recall that the coefficient of the risk effect is positive for risk averse firms implying that the contribution of price risk in productivity growth rises, ceteris paribus, with the rate of growth in output. In the second sub-period, due to the supply control measures, the rate of growth in output is much lower than in the first sub-period (4.3% vs 0.45%). This has as a consequence a smaller risk effect in the second sub-period.

It would be desirable to compare the results of this paper to those of earlier works on duality and price risk. As mentioned in the Introduction, however, the number of empirical applications in this area is quite limited. At the same time, risk attitudes may well vary with the sector and the country under consideration. The most relevant works are those of Coyle (1992) on the Canadian Agriculture, and Appelbaum (1991) on US Textile industry. As is the case here, those studies find that producers are risk averse and that price risk does affect output supply and input demand decisions. The empirical , evidence, therefore, suggests that neglecting the effects of risk is likely to result into mis-specified structural production models. Appelbaum (1991) considers, in addition, the influence risk on TFP growth. He finds that price risk works towards higher productivity levels since it forces producers to make decisions according to the full marginal cost which includes the risk premium. He concludes, however, that the effect of price risk on TFP growth is small relative to the effects of scale and technical change. These findings are largely consistent with the empirical results obtained here.

5. Conclusions

The present study has two objectives: first, to estimate a dual model of price risk in Greek agriculture and to assess the effects of this type of risk on the farmer's production decisions and, second, to refine the rate of TFP growth in Greek agriculture in light of price risk and to analyze TFP growth into components of interest.

The empirical findings suggest that the Greek farmers are risk averse. Indeed, the elasticity of the expected output price with respect to the output price variance is estimated to be 0.091 implying that if the price variance were to increase by 100%, the Greek farmers would require a 9.1% increase in the expected price in order to maintain the same supply level. The average annual rate of TFP growth over the period 1968-96 is found to be about 1.26%. Regarding the sources of this TFP growth the technical change effects appear to be its most important determinant, followed by the scale effects, the risk effects, and the effects arising from the adjustment in the quasi-fixed input.

These findings provide an interesting insight about the recent developments in the agricultural policies of the EU and the rest of the world. Following a long period of guaranteed agricultural prices and other types of financial support to its farm sector, in recent years the E.U. seems to be adding new considerations to its Common Agricultural Policy (CAP); these among others include: a)the alignment of surplus agricultural production to consumer demand, b)the gradual dismantling of domestic support policies and agricultural trade impediments, and above all c) drastic reductions of the EU budget deficit much of which is the result of high financial support to agriculture in earlier years. In particular, the EU has already taken twice (via the 1992 McSharry Reform and the Agenda 2000 reform package) steps in that direction.

These reforms involve substantial reductions in the subsidies of major EU produced commodities such as meats, dairy, and cereals and a partial dismantling of trade barriers which used to isolate the EU agriculture from the rest of the World. Consequently, these may weel be expected to result in lower aggregate supply levels. At the same time, as shown earlier the Greek agricultural sector experiences, at the aggregate level, decreasing returns to scale (cost elasticity higher than unity). Therefore, lower supply levels due to these new EU agricultural policies may work, ceteris paribus, towards higher rates of TFP growth in Greek agriculture.

In addition, lowering the EU trade barriers will expose the European farmers to international price variability, thus increasing, output price risk. Given that (according to our empirical results) Greek farmers are risk averse, they will "internalize" this type of risk by equating expected prices to the full marginal production cost. With a positive risk premium and a higher price variability the rate of TFP growth (or equivalently the cost efficiency) will tend to rise in accordance with equation (11) in Part 3 of the paper. Overall, the empirical results of this paper suggest that the technological characteristics of the production (decreasing returns to scale) in conjunction with the attitudes of farmers (risk aversion) are likely to render the latest reforms of the EU agricultural policies beneficial for the sector, at least as far as its efficiency growth is concerned.

In the near future, the output price risk is expected to acquire even greater importance in production decisions if the drive for the liberalization of agricultural markets worldwide continues. For empirical researchers interested in this issue, the economic theory of duality provides a useful tool for modeling and evaluating the impact of this type of risk. An additional major source of risk in agriculture is the variability in yields. To the best of these authors' knowledge, no visible progress has been made so far in incorporating yield variability in dual models. The work of Coyle (1992) suggests that the concept of the indirect utility function may be useful in this direction. The non-linearities involved in the implementation of this concept (even for simple models such as the Linear Mean Variance one), however, constitute a serious obstacle to the empirical analysis.

Technical Appendix: Estimating the AR(1), ARCH(l) Model for the Output Price

Following Enders (1995) we estimate first the AR(1) model for the output price, (A.1) $p=b0+b1*p(-1)$

where u is the error term. For the period 1966-96 the estimated value of b0 is 0.377 with t — statistic 1.79, the estimated value of b1 is 1.08 with t — statistic 81.98, and the coefficient of determination is 0.995. The fitted values of from model (A.1) are used as a proxy for the expected values of ρ in the estimation of the simultaneous equations system in section 4.

We calculate the squared residuals from (A.1) and we regress them on their lagged values,

$$\text{(A.2)}\quad (\hat{u})^2 = c0 + c1*(\hat{u}(-1))^2 \ (-1)]^2 + e$$

where e is the error term. For the period 1967-96 the estimated value of c0 is 0.36 with t — statistic 1.62, the estimated value of c1 is 0.52 with t — statistic 2.05, and the coefficient at determination, is 0.131. With a sample on η observations, under the null hypothesis of no ARCH errors, the test statistic T*R (where R is the coefficient of determination) follows the Chi-squared distribution with one degree of freedom. Here, the empirical value of the test statistic is 3.93 which is greater than the tabulated critical value (2.84) at 5% level. The nul hypothesis of no ARCH errors (that is, of constant residual variance in every observation) is rejected. Therefore, the fitted values of the model (A.2) can be used as a proxy to the unknown variance of the output price in the estimation of the simultaneous equations system in section 4.

Notes

1. Applebaum and Ullah (1997) show that it is possible to incorporate input price risk in the analysis. This, however, can be implemented through a primal not a dual model. In addition, if the inputs are bought in the beginning of production period, as it is often the case with agriculture, the input price risk is likely to be small.

2. For details on the derivation of relation (10) see Appleabum (1991) who obtains a similar decomposition of the RGTFP (and the RGCE) in a model without fixed inputs.

3. Admittedly the distinction of inputs into perfectly variable and fixed is to some degree arbitrary. In past empirical studies (e.g Weaver, 1983; Vasavada and Chambers, 1986; Coyle, 1992) Labour, Capital, and Land have been used individuality or in combinations as fixed inputs. In other empirical studies (e.g Veletzas et al 1992; Glass and McGillop, 1990) all inputs have been treated as variable. Fousekis and Papakonstantinou (1997) employing statistical tests found evidence of capital fixity in Greek agriculture. Based on this result, we decided to treat capital as a fixed input in the present study.

4. The use of expected (ex ante) levels of output in the estimation of agricultural cost functions instead of the actual (ex post) levels has been also suggested by Pope and Just (1998).

5. This elasticity is derived for relation (17) as $\frac{\partial \bar{p}}{\partial \sigma_{\varphi}^2}\frac{\sigma_{\varphi}^2}{\bar{p}} = (Ry\sigma_p^2)/\bar{p}$.

6. The differences must be attributed to the different methodologies and assumptions employed in each study.

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