Total Factor Productivity Adjusted for a Detrimental Input

Katerina Melfou and Evaggelos Papanagiotou[*]

Abstract

The measurement of total factor productivity in agriculture has been recently extended in order to include some 'bad' outputs that are jointly produced along with agricultural goods. In this paper, total factor productivity is decomposed into its determining factors and nitrate pollution is treated as an environmentally detrimental input. A restricted variable cost function is specified for Greek agriculture for the period 1969-1996. A constraint is assumed on nitrate pollution and the TFP estimates, which are obtained, are then decomposed into the rate of technical change effect, the scale effect and the market disequilibrium effect.

Key Words: *TFP, TRP, nitrate pollution, restricted cost function, Greek agriculture, environmental externalities*

Introduction

The development of methods associated with duality along with the extension of applications that rely on flexible functional forms led to the identification of other factors affecting total factor productivity, beyond technological progress. One set of factors that have been established, such as the realized economies of scale or the short run fixity of certain inputs is endogenous to the methodological framework of analysis used to measure productivity. Other factors affecting total factor productivity growth are not under the direct control of economic agents and are modeled as exogenous influences (Berndt and Fuss, 1986; Morrison, 1992; Fousekis, 1997).

A number of parametric and non- parametric methods have been applied in Greek agriculture, in order to decompose total factor productivity growth into its determining factors. The TFP growth rate given in Mergos (1993) is 2,36% p.a. for the period 1961-1993, calculated with the Tornqvist-Theil index and Mergos and Karagiannis (1997) estimate TFP growth rate parametrically with a translog cost function to be 2,61% p.a. on average. Velentzas (1998), employing a translog production function, indicates 0, 75% annual TFP growth rate.

The conventional measures of TFP growth correspond to a shift in the production possibility frontier. In the absence of any market failures this shift coincides with im-

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[*] Katerina Melfou,
Technological Educational Institute of Western Macedonia, School of Agriculture,
Terma Kontopoulou Street, 53100 Florina, Tel. 2385023302, e-mail: kmelfou@teikoz.gr

Evaggelos Papanagiotou
Aristotle University of Thessaloniki, School of Agriculture,
Department of Agricultural Economics - 54124, Thessaloniki, Greece, e-mail: papanag@agro.auth.gr

provements in society's welfare, (Perrin and Fulginiti 1996). Pollution being an externality to most economic activities constitutes a market failure that prevents us from identifying conventional net output growth as an ex ante welfare improvement. The assessment of economic performance warrants a wider more inclusive approach that can reflect not just the use of factors of production but resource use or 'misuse'.

Total Resource Productivity (TRP) and 'Social' Total Factor Productivity (social-TFP) are two terms coined in this context with the intention to point to non-marketable inputs and outputs and externalities (Gollop and Swinand, 1998; Barnes, 2002). There is an on-going discussion regarding the need to adjust TFP measurement in order to account for such sub-equilibrium state of affairs.

The objective of this paper is to measure TFP growth in Greek agriculture taking into account nitrate pollution, which is a negative externality, caused by the intensive methods of production employed in this industry. The paper is structured in the following way: In the next part some of the arguments relating to TRP are reviewed. The third part includes the theoretical framework in use for decomposing trends in TFP growth in Greek agriculture in the presence of a detrimental input, namely nitrate pollution. The econometric approach that is based on a restricted translog cost function is given in the fourth part, followed by the empirical results and some concluding comments in the final two parts of the paper.

Towards Total Resource Productivity

The ever increasing demands intensive agriculture makes to the resource base both in quantitative and qualitative terms have led to the generation of numerous externalities. Along with agricultural output we witness for example rising incidences of polluted aquifers due to agrochemicals, or reduced biodivercity in ecosystems adjacent to intensively cultivated land. All agricultural goods and 'bads' grouped together can be thought of as the 'multifunctional output of agriculture', (Randall 2002). It is a broad term embracing all desirable and undesirable outputs and intends to underline the importance of examining agriculture in its whole array of activities and repercussions. This should apply for agricultural productivity measurement as well.

The need to extend TFP to TRP is pointed out by Gollop and Swinand (1998) and two estimates are compared for the US agricultural sector during the period 1972-1993. The first one is of TFP growth and the other of TRP growth that accounts for the environmental regulations for pesticides that were imposed on the farm sector. The TRP estimates derive from a welfare maximization model and shadow prices are used for the effect of pesticides on ground water.[1] According to their findings TRP growth rates are lower to TFP growth rates during the period of increased groundwater pollution from pesticides. The opposite was found during periods of pollution reduction whereby TRP growth rates exceed conventional TFP estimates. Consequently, in this case TFP growth rates overestimate productivity growth when pollution is rising and underestimate it when pollution is reduced.

A similar conclusion is reached in the case of the Canadian pulp and paper industry (Hailu and Veeman, 2001) where conventional productivity measures based on a variety of methods, consistently underestimate productivity growth when compared to environmentally adjusted measures because they do not take into account the reduction in pollution achieved by this industry through investment in pollution abatement capital.[2]

In U.K. agriculture the construction of a 'social' TFP Tornqvist index that includes two externalities, pesticide and nitrogen pollution, produces diverging results when compared to the regular TFP growth index (Barnes, 2002). In the '70s the environmentally adjusted measure reduces TFP growth while from the 80's onwards there is a growth in social-TFP as pesticide and nitrogen use is falling.

Smith (1998) questioned on several grounds whether pollution reductions should be perceived as productivity improvements with reference specifically to U.S. agriculture. Firstly, the agents responsible for pollution creation are not the same as the ones having to accept the external costs hence it is not appropriate to use such shadow prices, a point made by Weaver (1998) as well. Secondly, the polluting emissions index should not appear in both the aggregate output index and the individual's preference function as if polluting emissions on the one hand and environmental quality experienced by people on the other are identical notions, a criticism also extended to Fare and Grosskopf (1998)[3]. The third point deals with the issue of the marginal unit of pollution, stressing that emissions may come from other sources as well, not nessacarily concentrated geographically and might be influenced by the averting actions of other agents.

Another criticism regarding the handling of externalities in productivity analysis is the need to incorporate into it all types of environmentally interactive technologies, (Weaver, 1998). Apart from the classic externalities the issue of quasi-public goods is addressed for which consumption is not exclusive and are therefore expected to influence the productivity of more than one good. The third type of environmentally interactive technologies concerns damage control inputs such as pesticides for example, that have an indirect impact on productivity by maintaining output levels leading thus to what is termed as conditional productivity.

The conceptual problems relating to environmentally adjusted productivity measurement extend to the issue of sustainability as well. Another approach to assess the sustainability of agricultural systems, should we consider the long-term trend in environmentally adjusted productivity as insufficient, is to define separate indicators of agro-ecosystems health and consequently relate them to TFP trends (Byerlee and Murgai, 2001).

Theoretical Framework

Agricultural technology is approximated with a restricted variable cost function (Berndt & Fuss 1986; Kulatilaka 1987; Mergos and Karagiannis, 1997):

$$(P, Q, Z, t) = G\,(P, Q, Z, t) + \sum_{k=1}^{m} r_k Z_k \qquad (1)$$

where C denotes the total cost of production, G the variable cost of production, P is the vector of prices for the variable inputs, Q the vector of outputs, Z is the vector of those inputs that are fixed or subject to some availability constraint, r_k is the vector of shadow prices for these fixed inputs and t is the time trend. Producers are assumed to minimize the variable production cost and choose some stock level of the quasi- fixed inputs.

The following properties hold for the restricted variable cost function (Chambers 1988): it is continuous in factor prices (P) and output (Q), monotonic, non- decreasing in P and Q and linearly homogeneous and concave in P. Differentiation with respect to factor prices, gives a set of cost- minimizing factor demands (Shephard's lemma):

$$X^* = h\,(P, Q, Z, t) \tag{2}$$

The restricted variable cost function satisfies another property, that is short-run variable costs are non-increasing in constrained inputs: $-\frac{\partial G}{\partial Z_k} = r_k$ where, r_k denotes the shadow price of the quasi-fixed input k. This means that a unit increase in the stock of input k brings about a reduction in variable costs by r_k. Differentiation with respect to fixed inputs produces partial cost elasticities that reveal the flexibility of optimal variable costs to changes in the levels of fixed inputs. In the present case the shadow cost elasticity (e_k) for the detrimental input was estimated in the following manner (Morrison, 1988):

$$ek = -\frac{\partial \ln G}{\partial \ln Zk}$$

A dual measure for the rate of TFP growth in a temporary equilibrium can be obtained in the following way (Berndt and Fuss, 1986). The total derivative of the shadow variable cost function with respect to time gives:

$$\frac{dC}{dt} = \sum_{i=1}^{n} \frac{\partial C}{\partial P_i}\frac{dP_i}{dt} + \sum_{j=1}^{J} \frac{\partial C}{\partial Q_j}\frac{dQ_j}{dt} + \sum_{k=1}^{m} \frac{\partial C}{\partial Z_k}\frac{dZ_k}{dt} + \frac{\partial C}{\partial t} + \sum_{k=1}^{m}\left[r_k\frac{dZ_k}{dt} + Z_k\frac{dr_k}{dt}\right] \tag{3}$$

Taking into account that:

$S_i = \frac{\partial \ln C}{\partial \ln P_i}$ is the cost share of variable input i, $e_{ct} = \frac{\partial \ln C}{\partial t}$ is the rate of technical change, $e_j^{cq} = \frac{\partial \ln C}{\partial \ln Q_j}$ is the cost elasticity with respect to output j, $e_k^{cz} = \frac{\partial \ln C}{\partial \ln Z_k} = -\frac{r_k Z_k}{C}$ is the shadow elasticity of the quasi-fixed inputs and $\dot{P}_i$, $\dot{Q}_j$ are the growth rates of factor prices P and output Q equation (3) becomes:

$$\frac{d\ln C}{dt} = \sum_{i=1}^{n} S_i \dot{P}_i + \sum e_j^{cq}\dot{Q}_j + e_{ct} + \sum_{k=1}^{m}\left(\frac{Z_k r_k}{C}\,\frac{d\ln r_k}{dt}\right) \tag{4}$$

Turning to the equation of total cost,

$$C = \sum_{i=1}^{n} P_i\, X_i + \sum_{k=1}^{m} r_k Z_k \tag{5}$$

and taking the total derivative with respect to time t and dividing by C produces:

$$\frac{d\ln C}{dt} = \sum_{i=1}^{n} S_i \dot{P}_i + \sum_{i=1}^{n} S_i \dot{X}_i + \sum_{k=1}^{m} \frac{r_k Z_k}{C} \dot{r}_k + \sum_{k=1}^{m} \frac{r_k Z_k}{C} \dot{Z}_k \tag{6}$$

Equating (4) and (6) gives:

$$\sum_{i=1}^{n} S_i \dot{X}_i = e_{ct} + \sum_{j=1}^{j} e_j^{cq} \dot{Q}_j + \sum_{k=1}^{m} e_k^{cz} \dot{Z}_k \tag{7}$$

Equation (8) can be obtained by subtracting the Divisia index for output from equation (7):

$$\dot{TFP} = -e_{ct} + \left(1 - \sum e_j^{cq} \right) \dot{Q}_j - \sum e_k^{cz} \dot{Z}_k \tag{8}$$

Equation (8) shows that the rate of change in total factor productivity $(\dot{TFP})$ is determined by a number of factors. The first one is the rate of change of technological progress, the second factor gives the influence of scale economies and the third reveals the effect of the lack of adjustment of the quasi -fixed inputs to their long-term equilibrium levels.[4]

Empirical Approach

A translog cost function is used for Greek agriculture with aggregate data for the period 1969-1996. The sector is assumed to be in equilibrium with respect to a subset of variable inputs given the observed levels of the quasi-fixed inputs. Hence, there is no possibility of substitution between the quasi-fixed inputs and the variable inputs (Capalbo, 1988). The functional form that is adopted is the following (Capalbo 1988; Mergos and Karagiannis, 1997):

$$\begin{aligned} \ln G = {} & \alpha_o + \alpha_q \ln Q + \sum_{i=1}^{n} \alpha_i \ln P_i + \sum_{i=1}^{n} \beta_i \ln Z_i + \frac{1}{2} \gamma_{qq} (\ln Q)^2 + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln P_i \ln P_j + \\ & + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \delta_{ij} \ln Z_i \ln Z_j + \sum_{i=1}^{n} \rho_{iq} \ln Q \ln P_i + \sum_{i=1}^{n} \sum_{j=1}^{n} \rho_{ij} \ln P_i \ln Z_j + \sum_{i=1}^{n} \pi_i \ln Q \ln Z_i + \\ & + \varphi_t T_t + \frac{1}{2} \varphi_{tt} T^2 + \varphi_{tq} \ln Q \cdot T + \sum_{i=1}^{n} \varphi_{it} \ln P_i \cdot T + \sum_{i=1}^{n} \varphi_{zit} \ln Z_i \cdot T \end{aligned} \tag{9}$$

The output variable (Q) includes all agricultural produce, crop and livestock and the three variable inputs (P) used are labor, intermediate inputs and land.[5] The two quasi-fixed inputs (Z) are capital and nitrate pollution, which is modeled as a detrimental input, a “counter-productive” input.[6]

The growth rate of nitrogenous fertilizers applied is taken as a proxy to the growth rate in nitrate pollution. This assumption is made based on data from the regular sampling and testing of waters in all the main rivers of Greece which suggests that nitrate levels are rising ("Environmental Statistics" NSSG). Yearly averages of nitrates detected in this type of surface waters were calculated and then regressed against the quantity of nitrogenous fertilizers (one-year lag) and time. The quantity of nitrates depends, as expected, on the quantity of nitrogenous fertilizers used in the previous period. The growth rate of the forecasted variable denoting nitrate levels was found to exceed the growth rate of nitrogenous fertilizer quantities applied in agriculture. Hence, using the growth rate of nitrogenous fertilizers as a proxy to the growth rate of nitrate pollution, if anything, it might underestimate the true growth rate given the cumulative nature of this type of pollutant[7].

By applying Shephard's lemma to (9) in its logarithmic form we obtain:

$$S_i = \frac{\partial \ln G}{\partial \ln P_i} = \alpha_i + \sum_{i=1}^{n} \rho_{iq} \ln Q + \sum_{j=1}^{n} \gamma_{ij} \ln P_j + \sum_{j=1}^{n} \rho_{ij} \ln Z_j + \varphi_{it} T \qquad (10)$$

S_i is the cost share of variable input i, that is: $S_i = \frac{P_i X_i}{\sum_i P_i X_i}$ where p_i, is the price of input i and X_i is the quantity of that input. The revenue share is given by:

$$R = \frac{\partial \ln G}{\partial \ln Q} = \alpha_q + \gamma_{qq} \ln Q + \sum_{i=1}^{n} \rho_{iq} \ln P_i + \sum_{i=1}^{n} \pi_i \ln Z_i + \varphi_{tq} \cdot T \qquad (11)$$

In (11), R indicates the revenue share to variable costs hence $R = \frac{P^* Q}{G}$, where P^* and Q correspond to the price and quantity of agricultural output respectively.

The variable cost elasticity with respect to output is given by:

$$\varepsilon^{cq} = \frac{\partial \ln G}{\partial \ln Q} = a_q + \gamma_{qq} \ln Q + \sum_{i=1}^{n} \rho_{iq} \ln P_i + \sum_{i=1}^{n} \pi_i \ln Z_i + \varphi_{tq} \cdot T \qquad (12)$$

Partial cost elasticities with respect to the quantities of the quasi –fixed inputs are calculated in the following manner (Morrison, 1988):

$$\varepsilon_{\kappa}^{GZ} = -\frac{\partial \ln G}{\partial \ln Z_k} = -\left(\beta_i + \sum_{i=1}^{n} \delta_{ij} \ln Z_k + \sum_{i=1}^{n} \rho_{ij} \ln P_i + \sum_{i=1}^{n} \pi_i \ln Q + \sum \varphi_{zit} \cdot T \right) \qquad (13)$$

The rate of change of technological progress is a function of the level of output, of variable input prices and of the quantities of fixed inputs and is given by:

$$e_{ct} = \varphi_t + \varphi_{tt} \cdot T + \varphi_{tq} \ln Q + \sum_{i=1}^{n} \varphi_{it} \ln P_i + \sum_{i=1}^{n} \varphi_{zit} \ln Z_i \qquad (14)$$

Statistical tests can be carried out in order to determine whether the growth rate of technological progress is equal to zero, in which case the growth rate in total factor productivity can be attributed to scale economies and to the non-adjustment of quasi-fixed inputs to their long term equilibrium levels. In order for $e_{ct} = 0$ a number of parameters should be zero:

$$\varphi_t = \varphi_{tt} = \varphi_{tq} = 0 \quad \text{and} \quad \sum_{i=1}^{n} \varphi_{it} = \sum_{i=1}^{n} \varphi_{zit} = 0$$

Another hypothesis that can be tested is that of constant returns to scale and if the hypothesis is not rejected by the data then economies of scale do not affect the growth rate of TFP. This hypothesis is equivalent to the following restrictions on the parameters of equation (9):

$$\alpha_q + \sum \beta_i = 1 \quad \text{and} \quad \gamma_{qq} + \sum \rho_{ij} = \sum \rho_{ji} + \gamma_{qq} = \sum \rho_{iq} + \sum \pi_i = \sum \rho_{ij} + \sum \delta_{ij} = \varphi_{tq} + \sum \varphi_{zit}$$

The estimated model consists of the cost function, three factor share equations and a revenue share equation. Seemingly Unrelated Regressions was the method used for estimation because there are across equation restrictions (Zellner, 1962).[8] The method is considered to be the most appropriate because it gives estimators with all the desirable properties (Oberhofer and Kmenta, 1974). Due to the adding-up property of the variable inputs cost shares it is possible to remove any equation during estimation. However, SUR is sensitive to which equation is excluded and for this reason the method Iterative SUR is used instead, in order to avoid singularity of the estimated variance-covariance matrix across equations.

Symmetry was imposed on the parameters and the variable cost function was assumed to be linearly homogeneous in input prices. This implies the following parameter restrictions:

$$\gamma_{ij} = \gamma_{ji}, \; \delta_{ij} = \delta_{ji} \text{ and } \Sigma\alpha_i = 1, \qquad \Sigma\gamma_{ji} = \Sigma\rho_{iq} = \Sigma\rho_{ij} = \Sigma\varphi_{it} = 0$$

Empirical Results

The values of the estimated coefficients are reported in Table 1. The requirement for theoretical consistency at the point of approximation is to assess the monotonicity and curvature conditions (Antle and Capalbo, 1988). The model satisfies the necessary and sufficient conditions for monotonicity in prices since the estimated cost shares of the variable factors are greater than zero. At the point of approximation, the estimated variable cost function is non-decreasing in variable input prices and output quantity and non-increasing in quasi-fixed input levels.[9] Regarding the curvature conditions, the variable cost function is concave in terms of input prices since the principal minors of the Hessian matrix are H_{11}= -0,134, H_{22}= -0,21 and H_{33}= -0,41. The coefficient of the time trend has a negative value φ_t= -0,013 and is statistically significant indicating technological progress.

Table 1. Estimated Coefficients of the Translog Variable Cost Function, 1969-1996.

Parameter	*Value*	*t - statistic*
α_o	0.049	1.13
α_q	1.558	15.18
α_1	0.571	37.45
α_2	0.215	31.00
α_3	0.214	
β_1	–0.216	–1.35
β_2	–0.474	–0.95
γ_{qq}	–0.667	–1.61
γ_{11}	0.120	4.60
γ_{12}	–0.045	–2.17
γ_{13}	–0.075	
γ_{22}	0.107	5.91
γ_{23}	–0.062	
γ_{33}	0.009	0.13
δ_{11}	–0.801	–1.22
δ_{12}	0.746	0.56
δ_{22}	–2.583	–1.06
ρ_{1q}	0.486	10.23
ρ_{2q}	–0.187	–5.88
ρ_{3q}	–0.299	
ρ_{11}	0.003	0.10
ρ_{12}	–0.096	–1.30
ρ_{21}	–0.007	–0.51
ρ_{22}	–0.003	–0.08
ρ_{31}	0.004	
ρ_{32}	0.098	
π_1	0.073	0.35
π_2	0.400	0.81
φ_{1t}	–0.012	–6.65
φ_{2t}	0.010	11.27
φ_{3t}	0.002	
φ_{z1}	0.003	0.17
φ_{z2}	0.053	1.21
φ_{tq}	0.000	0.01
φ_t	–0.013	–1.63
φ_{tt}	0.001	1.00

The values of the parameters where no t-statistic is given have been determined by the imposed restrictions

The hypothesis of constant returns to scale is tested using the Wald test. The computed value of the test statistic is W=12,96 and is larger than the critical value 11,07 at the 5% level of significance with 5 degrees of freedom. The hypothesis of constant returns to scale is rejected at the 5% level of significance but is not rejected at the 1% level of significance. The hypothesis of zero growth rate of technological progress is also tested using the Wald test. The test statistic is W=13,49 and again the hypothesis is rejected at the 5% level of significance but is not rejected at the 1% level of significance with 5 degrees of freedom.

The cost-output elasticity is reported in table 2 and has been calculated on the basis of equation (12). It expresses the percentage change in total production costs when output increases by 1%, while the prices of variable inputs and the stock levels of quasi-fixed inputs remain constant. In the short run increases in total output by 1% bring about greater percentage changes (1,5%) in total costs. During the period 1969-1996 a slight rise in this elasticity has been observed.

Short run returns to scale can be obtained as the inverse of cost output elasticities and in this case decreasing returns to scale have been found for Greek agriculture, 0,67 on average for the whole period. Returns to scale have been decreasing slightly from 0,64 in the 70's and 80's to 0,63 in the 90's (table 2) indicating that a rise of similar proportions in all variable inputs leads to somewhat bigger increases in variable costs.

Table 2. Variable Cost Elasticities, 1969-1996

Period	*Cost-Output Elasticity*	*Returns to Scale*	*Cost Elasticity w.r.t. Detrimental Input*	*Cost Elasticity w.r.t. Capital*
	(1)	*(2)*	*(3)*	*(4)*
1969-1979	1,30	0.63	–0.07	–0.54
1980-1989	1,54	0.65	–0.15	–0.51
1990-1996	1,59	0.63	–0.09	–0.38
1969-1982	1,35	0.64	–0.08	–0.55
1983-1996	1,57	0.64	–0.13	–0.42
1969-1987	1,40	0.64	–0.11	–0.54
1988-1996	1,58	0.63	–0.10	–0.39
1969-1996	1,50	0.67	–0.11	–0.46

The cost elasticity with respect to capital is negative during the whole period, which means that capital's shadow price has been higher than its market price. It appears that producers perceived its marginal contribution to production to be above its market price. The shadow cost elasticity of the detrimental input reveals that the existence of nitrate pollution doesn't seem to be beneficial to producers in terms of much lower production costs. More specifically, a 1% rise in the stock of the externality brings about a slight reduction (0,1 %) in total costs. Conversely, a 1% reduction in the externality level is expected to increase costs by 0,1% (table 3).

The average growth rate in TFP-adjusted for the externality was estimated 2,47% p.a. on average during 1969-1996 (table 4) and has been falling over the entire period.

This estimate is based on the assumption that the stock of the externality has increased over the period under examination and that is expected, ceteris paribus, to make a positive contribution to productivity growth. Average yearly increases in TFP growth rate were 4,9% p.a. in the 70's while in the following two decades fell to 2,2% and 1,9% p.a. respectively.

The growth rate in productivity is attributed to the following factors: the rate of change of technical progress, economies of scale and the effect of the lack of adjustment of quasi-fixed inputs to their long-run equilibrium levels. The growth rate of technical progress reveals the rate with which variable costs are reduced due to technical change affecting the sector when output, variable input prices and the stock levels of quasi-fixed inputs are held constant.

Technical progress has had an overwhelming positive influence in the TFP growth rate, certainly over the 70's and the 80's where the relative share of technical progress in the productivity growth rate was 73% and 69% respectively (table 4). This result may have some implications regarding policies that could be implemented in order to encourage technical change in the direction of sustainability of farming systems. The type of technical change that will be favored through investment in research and technology is expected to have an important contribution in the sector's productivity growth.

Another determining factor for TFP growth rate is the type of scale economies that prevail during the period under examination. When the sector is experiencing decreasing economies of scale the second term in equation (8) is negative and when it benefits from increasing economies of scale the term is positive. In this case it appears that scale economies is an important factor affecting TFP growth rate, exerting a negative influence in the first two sub periods and a positive influence in the latter sub period (table 3).

Table 3. Total Factor Productivity 1969-1996.

Period	*TFP Growth Rate*	*Scale Effect*	*Disequilibrium Effect*	*Technical Change Growth Rate*
	(1)	*(2)*	*(3)*	*(4)*
1969-1979	4,9	–0,65	0,10	3,60
1980-1989	2,2	–0,66	0,61	1,52
1990-1996	1,9	0,39	1,10	0,41
1969-1982	4,6	–0,91	0,17	3,29
1983-1996	1,88	0,16	0,89	0,83
1969-1987	3,8	–0,72	0,30	2,78
1988-1996	1,91	0,35	1,02	0,54
1969-1996	2,47	–0,37	0,56	2,28

Finally, the third term in equation (8) reflects the effect of the lack of adjustment of quasi-fixed factors to their long run equilibrium levels, hence, it includes the influence pollution has on TFP growth. The sign of e_k that is the cost elasticity with respect to the detrimental input, expresses either uderutilization or overutilization of the detrimental input and depending on the growth rate of the input Z_k, the third term in equation (8) might exert an either positive or negative influence on TFP growth. In this case, the negative sign of this shadow elasticity indicates overutilization of the detrimental input and given the positive growth rate of Z_k, the third term has a positive influence on TFP growth. The disequilibrium effect is found positive and increasing over the whole period (table 3).

Conclusions

Evidence produced in other countries show that TFP growth rates overestimate productivity growth when pollution is rising and underestimate it when pollution is reduced by environmental regulations and investment in pollution abatement capital. There are certain indications that groundwater nitrate levels are rising in Greece and taking into account the absence of regulatory intervention, TFP growth rates may overestimate productivity growth in the agricultural sector.

The approach taken in this paper was to measure the TFP growth rate for Greek agriculture and to decompose it into its determining factors, introducing nitrate pollution as a detrimental input. Productivity growth was found to rise at an annual rate of 2,46 % on average, for the period 1969-1996 but decreasing during the examined period. The factors affecting productivity were technical progress having a major impact on TFP growth rate, returns to scale and the market disequilibrium effects of quasi-factors of production. The joint effect of the market disequilibrium factors on TFP growth with nitrate pollution being treated as one of the two quasi-fixed inputs was positive.

The moderate rise in the cost output elasticity during the examined period may be associated with the rise in nitrate pollution that is now integrated as an input leading to further increases in production costs. The small value of the shadow cost elasticity that has been found for the detrimental input indicates that a potential reduction in the externality level is expected to only marginally increase costs.

Notes

1. The rate of reduction of pollution in their productivity equation is weighted by shadow prices, calculated as the difference between the marginal social value of a unit of clean water and the marginal abatement cost of improved groundwater quality.
2. The various productivity growth estimates are based on methods that range from the Tornqvist index, simple and adjusted for output scale effects, to Malmquist indexes based on input distance and output distance functions and nonparametric analysis (DEA).
3. Fare and Grosskopf (1998), employ an output distance function in order to calculate shadow prices for firms outputs and then add into the model consumer preferences for good and bad outputs. Shephard's dual lemma is used to compute consumer shadow prices that are in turn compared to producer shadow prices, both of which are expected to be equal in equilibrium.
4. This last term means that the market prices of quasi – fixed inputs don't reflect their marginal contribution to production and the value of their marginal product is not

equal to their market price. This fact indicates a shift away from the steady – state equilibrium hence it is better to use their shadow prices in order to assess their marginal contribution to production (Mergos and Karagiannis, 1997).

5. Expenditure on labour includes family and hired labour, intermediate inputs are fertilizers, pesticides, energy, lubricants, seeds, feedingstuff and other. Data were obtained from the Ministry of Agriculture, The National Statistical Service of Greece-National Accounts and Eurostat- Economic Accounts for Agriculture and Forestry.
6. Pittman (1981, 1983) was the first to bring in pollution not only as an undesirable output but as an input as well, an approach followed by Reinhard et al. (1999) where the nitrogen surplus is regarded as an environmentally detrimental input in Dutch dairy farming.
7. Estimates may differ should actual long-term pollution data become available and calculations are extended to include pesticide pollution of groundwater and surface waters as well.
8. In effect equations are correlated through their error terms. This correlation can be explained by the fact that the relative share equations are formed as the solution to the problem of minimization of variable cost of production. Hence, producers' optimal choice for the quantity of an input has a direct influence on the quantities of all the other inputs as well as on the variable production costs (Capalbo, 1988).
9. The values of the relevant coefficients are α_1=0,571 α_2=0,215 α_3=0,214 α_q=1,558 β_1= -0,216 and β_l= -0,474.

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