

Economic Efficiency in Organic Farming: Evidence from Cotton Farms in Viotia, Greece

Vangelis Tzouvelekas, Christos J. Pantzios, and
Christos Fotopoulos

ABSTRACT

Using recent advances in the stochastic production frontier framework, this paper presents an empirical analysis of technical, allocative and economic efficiency of a sample of organic and conventional cotton farms located in Greece. The results suggest that both farm types in the sample examined are technically, allocatively and economically inefficient. Farmer's age and education and farm size are important factors in explaining differentials in efficiency estimates. In comparative terms, organic farms exhibit lower efficiency scores vis-à-vis their conventional counterparts in terms of technical and economic efficiency; regarding allocative efficiency both farm types are almost equally inefficient. Low efficiency scores in both types of farming may be attributed to the respective intervention policies of the last 20 years.

Key Words: *cotton, efficiency, organic farming, stochastic production frontier.*

Introduction

Cotton farming has been one of the most dynamic agricultural enterprises in Greece, characterized by high output value, high farm income and compelling export performance. However, since the mid 1990s, cotton farming in Greece has slipped into a worrying recession triggered by record-high levels in both domestic and world supply and drastic reductions in the support policy of the European Union (EU). With most of the agricultural sectors across EU facing similar recession, exclusive reliance on traditional protective policies

is no longer possible. Alternative strategies are urgently needed to ensure the survival of agricultural enterprises. Such an alternative strategy may be to introduce differentiation among varieties of agricultural products on the basis of their quality characteristics. Relatively recently, the European Commission has encouraged products of designated origin (PDO) and products of geographical indication (PGI) as ways of promoting agricultural product differentiation. Additionally, a prominent alternative of product differentiation, which received considerable attention within the EU over the last 15 years, is the use of organic farming practices in agricultural production.

Within the EU the differentiation between organically and conventionally produced commodities has already been institutionalized, as the European Commission introduced in the early 1990s a specialized framework (EU Reg-

Vangelis Tzouvelekas is in the Department of Economics, University of Crete, Greece; Christos J. Pantzios is in the Department of Economics, University of Patras, Greece; and Christos Fotopoulos is in the Department of Farm Management, University of Ioannina, Greece.

quota. The perspective of a trade liberalization in the world agricultural markets (already initiated at the latest Uruguay agreement on international trade) is expected to put additional pressure on this EU cotton policy. In this rapidly changing environment (characterized by drastic reductions in price support, increasing competition and liberalization of trade flows), the quality-based differentiation of cotton becomes an appealing alternative for dealing with plummeting prices and surplus production.

In principle, it is suggested that the differentiation of cotton via organic cultivation techniques could lead to considerable economic as well as environmental benefits. In particular: (i) organically produced cotton and its subsequent use in textile may lead to the development of niche markets and the differentiation of its price relative to the price of conventionally produced cotton, (ii) the elimination of expensive chemical inputs from cotton cultivation may lower production costs and reduce extremely high yields, and (iii) organic cultivation of cotton may result in favorable environmental effects as it is well known that conventionally cultivated cotton ranks high in the list of heavily polluting crops.

However, the application of organic techniques in cotton growing is currently facing considerable difficulties since the respective know-how (organic fertilizing, biological control techniques) is incomplete or experimental. These difficulties are reflected in the minimal percentage of organically cultivated land that is devoted to cotton growing. Specifically, the organically utilized agricultural land (OUAL) in Greece reached about 5270 ha in 1996, accounting for 0.13 percent of total agricultural land. Of the annual organic crops, cotton showed a promising start as it was grown in about 370 ha (31 percent of OUAL) in 1994. Although this acreage plummeted to only 3 percent of OUAL (i.e., 153.6 ha) in 1996, the acreage of fully organic cotton fields shows a steady growth, rising from 2.5 ha in 1994 to 7.1 ha in 1995 and 16.5 ha in 1996. These changes indicate that despite the aforementioned difficulties in organic cotton cultivation

methods a core of persistent organic cotton growers has formed in Greece.

Regarding the policy on organic cotton farming, it should be stressed that Greek organic farmers face the same regime as conventional farmers; this means that, at the minimum, they receive the price of conventional cotton (which via the EU intervention price is set higher than the world price). Any price premiums they may receive are above the price for conventional cotton. In addition, organic farmers receive financial aid in the form of acreage-based subsidies via the EU Regulation 2078/92. The basic idea behind such 'organic' subsidies is to help farmers cope with lower yields and provide them with an incentive to reduce intensive farming.³ Eligible for this 'organic' financial aid are all organic farmers irrespective of the state (in-conversion or fully organic) of their farm operations.

Methodological Framework

The current interest in efficiency measurement finds its origin in Farrell who explored the concept of the production frontier. In his influential paper, Farrell showed that productive efficiency can be broken down into two coherent components: the pure technical or physical component and the allocative or price component. The former refers to the ability of producers to avoid waste of inputs by producing as much output as the inputs at their disposal permit under the current state of technology; the latter refers to the ability of producers to contrive an optimal allocation of the inputs available in light of the prevailing output and input prices. Thus, technical inefficiency arises when actual or observed output from a given input mix is less than the maximum possible; allocative inefficiency arises when the input mix is not consistent with cost-minimization.

In recent years considerable progress has been made towards refining the production

³ In other words, the 'organic' financial aid subsidizes the acreage devoted to organic cultivation not the volume of actual production as is the case with subsidizing prices.

ulations 2092/91 and 2078/92) that allows the certification—via inspecting organizations—of commodities labeled *organic*. As a result, organic practices in the cultivation of various crops have spread across EU member-states, while organic produce is becoming appealing to consumers with food safety and environmental concerns. Although organic farming is a conceptually attractive alternative to conventional farming, in practice the actual economic performance of organic agricultural enterprises remains largely an empirical question.

On the other hand, the importance of productive efficiency in overall farm productivity, economic performance, and competitiveness has been increasingly recognized, especially in the course of gradually liberalizing agricultural markets. Although efficiency studies have been published for several primary sectors in various countries,¹ similar research on organic farming practices is generally lacking. However, such empirical research is certainly warranted. Typically, yields are known to decrease (causing income losses) during several years after converting into organic; thus, it is suggested that organic cotton growers should receive an almost 40-percent price premium over conventional cotton prices to cover such income losses (International Cotton Advisory Committee). Therefore, if organic farming practices are socially and politically desired, then research efforts to help organic farmers improve their economic performance can have important implications for their economic survival.

More exactly, if organic farm operations exhibit considerable inefficiencies, their effort, at least in the short-run, should be to increase farm output (and thus farm income) by improving the utilization of their inputs and their allocation in the production process. On the other hand, one cannot neglect the potential improvements that could arise from narrowing the gap of the technological disadvantage between organic and conventional farming practices. Still, studying the efficiency of organic

farms today can provide policy makers with useful indications of the potential future changes in the technological conditions of such farms. This is because, irrespective of the kind of technology adopted by the farmers, it is equally important that this technology is utilized efficiently.

The Greek Cotton Sector

Cotton growing has shown an impressive expansion in Greece during the last 20 years. The sector's rapid enlargement has been mainly the result of the early high support-mechanisms of the Common Agricultural Policy (CAP) of the EU. The acreage cultivated with cotton was almost doubled during the 1980s reaching 240 thousand ha (2.4 million stremmas²) in 1991, from only 120 thousand ha in 1981 and kept expanding during the 1990s, reaching 430 thousand ha in 1996.

At the same time, the volume of production has tripled: from only 290,000 tons in 1981, it swelled to about 1 million tons in 1996 (Greek Cotton Board). Average yields have been among the highest, as Greece ranks fifth worldwide in terms of cotton yields per hectare (Avgoulas and Koutrou-Avgoula). Within the EU, Greece is the largest cotton producer, accounting for almost 70 percent of the total EU cotton production. Thus, cotton growing has become the primary farming activity (and source of income) to more than 100,000 Greek farms.

Regarding the cotton policy regime faced by Greek farmers, until 1986 the EU cotton policy was a typical deficiency payment scheme; the price received by cotton farmers was based on a target price (higher than the world price), predetermined annually by EU authorities. Faced with high financial costs, however, the EU has, since 1987, replaced this policy regime with an intervention mechanism consisting of (i) an intervention price, (ii) an aggregate production quota, and (iii) a reduction in the intervention price (i.e., a levy) when the actual aggregate production exceeded the predetermined aggregate production

¹ For a detailed review of the most important studies see the surveys of Battese (1992), Bravo-Ureta and Pinheiro and Coelli.

² One stremma equals 0.1 ha.

frontier methodology. Among the alternative frameworks proposed, an attractive methodology is that suggested by Bravo-Ureta and Rieger and Bravo-Ureta and Evenson.⁴ Based on the decomposition technique introduced by Kopp and Diewert, they presented a model which allows the measurement of both technical and allocative efficiency via the econometric estimation of a single stochastic production frontier function. Its basic idea is to use duality and, in particular, cost-minimizing input demand functions implied by Shephard's lemma to obtain estimates of allocative efficiency. However, this approach requires the use of a self-dual-functional form for the stochastic production frontier in order to have an analytically tractable solution for the dual cost function. Nevertheless, its usefulness in cross-section studies is still important, as price data necessary for the estimation of the dual frontier are usually lacking or insufficient.

A measure of input-oriented⁵ technical efficiency (*Shephard-type*) of a production unit (say, a farm) i producing output y_i via inputs x_{ij} , $j = 1, \dots, k$ can be obtained by dividing the technically efficient input vector by the actual input vector after weighing both by the input prices as (Kopp):

$$(1) \quad TE_i^I = \frac{\sum_j x_{ij}^E w_j}{\sum_j x_{ij}^A w_j}$$

where TE_i^I is the farm-specific technical efficiency, w_j are the prices of inputs $j = 1, \dots,$

k and x^T , x^A are the technically efficient and actual input vectors, respectively; x^T is defined as the optimal input vector given the farm's available technology.

Similarly, a measure of the farm's input-oriented economic (or cost) efficiency is obtained as:

$$(2) \quad EE_i^I = \frac{\sum_j x_{ij}^E w_j}{\sum_j x_{ij}^A w_j}$$

where, EE_i^I is the farm-specific input-oriented economic (or cost) efficiency, w_j are the prices of inputs $j = 1, \dots, k$ and x^E and x^A are the economically efficient and actual input vectors, respectively; x^E is defined as the optimal input vector, given input prices. Thereafter, according to Farrell's decomposition of economic efficiency, one can derive the farm's input-oriented allocative efficiency as the ratio of economic efficiency over technical efficiency.⁶ However, unlike the actual input levels x_{ij}^A which are directly observable, the technically and economically efficient input levels x_{ij}^T and x_{ij}^E need to be computed before the efficiency measures TE_i^I and EE_i^I became operational.

To that end, consider the general stochastic production frontier of the farm in question, written as:

$$(3) \quad y_i = f(x; \beta) \exp e_i$$

where, y_i is the observed output level, x is the vector of inputs used in production, β is a vector of estimable parameters, and $e_i = v_i - u_i$ is a stochastic composite error term. Its two error components, v and u , are assumed to be distributed independently from each other; v represents a symmetric and normally distributed component capturing the effects of exogenous shocks and measurement errors and u is a one-sided component representing the stochastic shortfall of output from the farm's production frontier due to output-oriented technical inefficiency (*Debreu-type*). As Kumbhakar, Ghosh and McGuckin and Battese and

⁴ The same approach has been also used by Sharma, Leung and Zaleski in analyzing productive efficiency in swine production in Hawaii.

⁵ Within the stochastic production frontier, *model technical efficiency* can be defined in either an output-expanding or input-conserving fashion (Kumbhakar and Lovell, p. 6-7 and 46-48). The first one is the output-oriented *Debreu-type* measure, which is given by the ratio of the observed to maximum feasible output, conditional on production technology and observed input use. The second one is the input-oriented *Shephard-type* measure, which is given by the ratio of minimum feasible to observed input use, conditional on production technology and the level of output. The use of input-oriented technical efficiency is necessary for integrating properly Kopp and Diewert decomposition technique with Battese and Coelli (1995) model formulation.

⁶ The same, however, is not true if output-oriented technical efficiency is used (Kumbhakar and Lovell, p. 54).

Coelli suggest, u_i may be replaced by a linear function of explanatory variables, reflecting farm-specific characteristics. In that way, every farm in the sample faces its own frontier (given the current state of technology as well as its physical endowments), not a sample norm (Hallam and Machado). Specifically, in that formulation u_i are non-negative random variables, assumed to be independently distributed as truncations at zero of the normal distribution (with mean μ_i and variance σ_μ^2), defined by (Battese and Coelli):

$$(4) \quad \mu_i = \delta_i z_i + w_i$$

where, z_i are the explanatory variables associated with technical inefficiencies of production and δ_i are the associated parameters to be estimated. These assumptions are consistent with u_i being a non-negative truncation of the $N(z_i, \delta, \sigma^2)$ distribution.⁷ Further, the explanatory variables may also include some input variables given that the inefficiency effects are stochastic.⁸

Methodologically, the above model formulation has two distinct advantages: *first*, it gives the possibility to identify some of the reasons (such as managerial experience, ownership characteristics, etc) to explain differences in the predicted levels of inefficiencies among farms in a single stage; *second*, the decomposition of the composite error term does not require Jondrow's *et al.* predictor which does not converge to the true estimates (Greene, p. 81).

Choosing a functional form for the production frontier in (3) and estimating it econometrically via ML techniques allows the computation as well as the decomposition of the composite error term e_i using the predictor proposed by Battese and Coelli (1988). Fur-

thermore, the model formulation above allows the investigation of potential sources of inefficiency differentials between the surveyed farms in a single stage.⁹ Thereafter, the farm's output adjusted for exogenous shocks (captured by v) can be computed as ($y_i^* = y_i - v_i$).¹⁰ The technically efficient input vector is obtained by solving simultaneously equation (3) and the observed input ratios $x_{1i}/x_{ji} = k_j$, $i = 1, \dots, N$; $j = 2, \dots, K$ at output level y_i^* . For the estimation of the economically efficient input vector, the dual-cost function corresponding to (3) should be derived first. If the functional form chosen for the stochastic production frontier is self-dual, the corresponding cost frontier can be derived analytically¹¹ and then, by using Shephard's lemma, the input demand functions can be derived. Evaluating these input demand functions for y_i^* yields the economically efficient input levels, x_{ij}^E .

Data and Empirical Model

The data used in this study are part of a survey undertaken by the Institute of Agricultural Economics and Rural Sociology of the National Agricultural Foundation of Greece (N.AG.RE.F) on the cost of organic farm operations *vis-a-vis* neighboring conventional

⁹ A number of empirical studies have estimated stochastic frontier models and then in a second stage attempted to identify some of the reasons to explain differences in the predicted levels of inefficiencies among farms. This has been a useful exercise, suffering nonetheless by a considerable limitation: the two-stage estimation procedure is inconsistent in regarding its assumptions on the independence of the inefficiency effects in the two estimation stages. Thus, the two-stage estimation procedure is unlikely to provide estimates which are as efficient as those that could be obtained using a single-stage estimation procedure (Kumbhakar, Ghosh and McGuckin; Reifschneider and Stevenson).

¹⁰ Estimates on v_i are obtained after the econometric estimation of the model using the predictor suggested by Battese and Coelli (1988) for the decomposition of the composed error term. Bravo-Ureta and Evenson, Bravo-Ureta and Rieger and Sharma, Leung and Zaleski used the same approach. However, all three papers used the predictor suggested by Jondrow *et al.*, and not that of Battese and Coelli (1988).

¹¹ For the analytic derivation of the cost function in self-dual functional forms see Varian and Shepard.

⁷ The distribution of the truncation of a general normal distribution with unknown mean (μ) to be estimated permits different inefficiency distributions than the half normal to be accounted for. Distributions with large negative and positive values of μ are quite different (Battese, 1998).

⁸ This actually relates to Huang and Liu's non-neutral specification of the stochastic production frontier model.

Table 1. Gross Revenues and Production Costs of Organic and Conventional Cotton Farms in Viotia-Greece, 1995–96

	Organic Farms		Conventional Farms	
1. Yield (kg/stremma)	218		300	
2. Price (drachmas/kg)	296		289	
3. Value of Production (1 × 2)	64,528		86,700	
4. EU Reg.2078/92 (drachmas/stremma)	9,900		—	
<i>Gross Revenues</i>	74,428		86,700	
Production Expenses	Drachmas/ stremma	%	Drachmas/ stremma	%
1. Land Rent	20,333	30.2	24,409	34.6
2. Labor	19,123	28.4	14,179	20.1
a. Family	7,729		5,283	
b. Hired	5,873		1,787	
c. Hired Mechanical	5,521		7,109	
3. Fertilizers	2,870	4.3	3,899	5.5
4. Pesticides	—	—	2,959	4.2
5. Biological Control	113	0.2	—	—
6. Fuel	5,809	8.6	5,700	8.1
7. Power	2,203	3.3	1,995	2.8
8. Seeds	2,571	3.8	3,107	4.4
9. Irrigation	1,128	1.7	1,625	2.3
10. Insurance	534	0.8	381	0.5
11. Organic Certification	982	1.5	—	—
12. Interest on Variable Costs	1,969	2.9	2,091	2.9
13. Depreciation	9,660	14.4	10,273	14.5
<i>Total Cost</i>	67,295	100	70,618	100
<i>Gross Profit</i>	7,133		16,082	

The third and fifth column present the relevant percentage shares; one stremma equals 0.1 ha; average annual exchange rate in 1996: 1 US\$ = 240.7 drachmas; in the case of organic farms fertilizer is only organic, whereas in conventional farms only chemical.

farms. The sample used here consists of 29 organic cotton farms located in Viotia county (in the region of Sterea Ellada) during the 1995–96 harvesting period.¹² To be able to compare our findings with conventional cotton farming, we collected a second sample of 29 conventional cotton farms with similar characteristics (in terms of size, farm mechanization and commercialization, farmer's age and education) from the same area. The survey provided detailed information about production patterns, input use, average yields, and gross revenues

of the surveyed farms. A summary of this information is presented in Table 1.

Inspection of the table reveals that average cotton yield is, at present, considerably lower (about 27 percent lower) in organic farms. At the same time, prices for organic cotton are not *on the average* significantly different from conventional cotton prices—although they fluctuate widely across the examined farms, ranging from 240 drs/kg (1 US\$/kg) to 345 drs/kg (1.43 US\$/kg). This fluctuation in prices received for organic cotton is not surprising given that the marketing channels for organic cotton in Greece are still at an infant stage, while consumers are not yet fully aware of the benefits of using organic cotton in textiles. The combination of significantly lower yields

¹² In Viotia county organic cotton production has been systematically applied since the early 1990s, using an almost homogenous technology; all organic cotton farms included in the sample have been growing organic cotton for at least three years.

Table 2. Summary Statistics of the Variables

Variable	Organic		Conventional	
	Mean	Standard Deviation	Mean	Standard Deviation
Output (thousands Drachmas)	3,520	1,839	9,102	7,059
Area (stremmas)	53	40	98	81
Labor (hours)	775	429	521	311
Fertilizers & Pesticides (Drachmas)	8,646	3,667	6,830	4,113
Other Costs (thousands Drachmas)	461	384	1,420	1,280

and lack of considerable price premiums results in lower average revenues for organic cotton farms, despite the additional subsidy of 9900 drs/stremma (411.3 US\$/ha) to organic cotton growers, via the EU Reg. 2078/92.

Regarding production costs, land, labor and capital expenses appear to be dominant in both types of farming, though at different levels. As expected, labor expenses (family and hired) in organic farming are much higher compared to those of conventional farms, while the fertilizing expenses (organic fertilizer and biological control costs) are remarkably lower in organic farms compared to conventional cotton farms. Overall, however, the cost of producing organic cotton does not appear considerably different from the production cost of conventional cotton; for the sample examined the total cost of organic cotton is only 5 percent lower than that of conventional cotton. This underlines the need to cope with the problem of low profitability of organic cotton growers, especially at the current stage where organic cotton farming in Greece is at its infancy.

For the purposes of the present analysis, the stochastic production frontier function used to analyze the underlying technology of the Greek cotton farms is specified to be of a Cobb-Douglas form. That is:

$$(5) \quad \ln y_i = \beta_0 + \sum_{j=1}^J \beta_j \ln x_{ji} + v_i - u_i \quad \text{and}$$

$$u_i = \delta_0 + \sum_{m=1}^M \delta_m \mu_{mi} + w_i$$

where, $i = 1, 2, \dots, N$ denotes *cross-section* units (farm operations); $j = 1, 2, \dots, J$ denotes the *applied inputs*; $m = 1, 2, \dots, M$

denotes the *explanatory variables* i.e., variables explaining differences in farm efficiencies among the units examined; v_i is the classical error term capturing random noise and measurement error in the production frontier; w_i is a random variable defined by the truncation of the normal distribution with zero mean and constant variance such that the point of truncation is $w_i \geq -\delta_i z_i$.

The list of variables (a summary of their statistics is presented in Table 2) included in (4) is as follows: y_i is the annual organic (or conventional) cotton production measured in drachmas¹³; x_{Li} is the total labor, comprising hired (permanent and casual), family and contract labor, measured in working hours; x_{Fi} is the total amount of fertilizers and pesticides applied in the production measured in drachmas (in organic farms this refers to organic fertilizers and biological weed and pest control); x_{Ai} is the total area under organic or conventional cotton cultivation measured in stremmas; x_{Ci} are the other cost expenses comprising the value of seeds, fuel, electric power and interest on fixed assets measured in drachmas; μ_{AGi} is the farmer's age in years; μ_{AG2i} is the farmer's age in years squared; μ_{SZi} is the farm's size in stremmas; μ_{EDi} is the farmer's education measured in years of schooling; μ_{SCI} is the farm's stock of capital inputs (including machinery, inventories and buildings) expressed in drachmas; μ_{FOi} is the share of family labor expenses to total labor expenses.

¹³ We expressed the dependent variable in monetary units (drachmas) instead of physical units (kilograms) in an attempt to incorporate into the analysis the quality difference between organic and conventional cotton as that is reflected in their market price.

Table 3. MLE of the Cobb-Douglas Stochastic Production Frontiers for the Organic and Conventional Cotton Farms in Viotia-Greece, 1995–96

Parameter	Organic Farms		Conventional Farms	
	Estimate	Standard Error	Estimate	Standard Error
Stochastic Frontier Model				
b_0	0.422	(0.062)*	0.129	(0.018)*
b_L	0.010	(0.006)***	0.065	(0.043)***
b_F	0.139	(0.078)**	0.096	(0.032)*
b_A	0.616	(0.351)**	0.688	(0.072)*
b_C	0.095	(0.032)*	0.159	(0.050)*
Returns to scale	0.860		1.008	
Inefficiency Effects Model				
δ_0	0.005	(0.002)*	0.141	(0.029)*
δ_{AG}	-0.010	(0.003)*	-0.001	(0.000)**
δ_{AG^2}	0.000	(0.000)***	0.000	(0.000)***
δ_{SZ}	-0.047	(0.029)***	-0.206	(0.092)*
δ_{ED}	-0.052	(0.021)*	-0.050	(0.034)***
δ_{SC}	0.050	(0.039)	-0.042	(0.038)
δ_{FO}	0.049	(0.061)	0.001	(0.009)
$\hat{\sigma} = \sqrt{\sigma_u^2 + \sigma_v^2}$	0.186	(0.084)**	0.561	(0.241)**
$\hat{\gamma} = \sigma_u^2/\sigma^2$	0.927	(0.236)*	0.911	(0.326)*
$\ln(\theta)$		-40.541		-11.332

L: labor; *F*: fertilizers and pesticides; *S*: seeds; *A*: acreage; *C*: other cost expenses; *AG*: farmer's age; *AG2*: farmer's age squared; *SZ*: farm's size in stremmas; *ED*: farmer's education; *SC*: farm's stock of capital; *FO*: share of family labor to total labor expenses.

* Significant at the 1% level; ** significant at the 5% level; *** significant at the 10% level.

Following Zellner Kmenta and Dreze, cotton farmers are assumed to be price takers maximizing expected profits and facing exogenous output and input prices. Based on these assumptions the production function specified in (5) can be consistently estimated, separately for the organic and conventional cotton sample, using the maximum likelihood technique.

Empirical Results

Production Structure

The maximum likelihood¹⁴ estimates of the Cobb-Douglas stochastic production frontiers and the inefficiency effects models for the organic and conventional cotton farms are pre-

sented in Table 3. Even though the logarithmic value of the likelihood function is small, it is rather satisfactory considering that we deal with cross-section data, normalized around the sample means prior to ML estimation. The ratio parameter¹⁵, γ , is statistically significant at the 1-percent level, implying that farm-specific efficiency is likely to be highly significant in explaining the total variability of organic and conventional cotton produced. Further, the

¹⁵ It must be pointed out that "... γ is not equal to the ratio of the variance of the technical inefficiency effects to the residual variance. This is because the variance of u_i is equal to $[(\pi - 2)/\pi]\sigma^2$ not σ^2 . The relative contribution of the inefficiency effects to the total variance term (γ^*) is equal to $\gamma^* = \gamma/[\gamma + \{(1 - \gamma)\pi/(\pi - 2)\}]$ " (Coelli, Rao and Battese, p. 188). In our case, the computed values of the variance-ratio parameter (γ^*) imply that 82.2 and 78.8 percent of the differences between the observed and the maximum frontier output for organic and conventional cotton farming, respectively, are due to the existing differences in efficiency levels among farmers.

¹⁴ The estimation of the stochastic frontier models was carried out using the FRONTIER 4.1a computer package, kindly provided by T.J. Coelli.

Table 4. Hypotheses Testing for the Inefficiency Effects Model

Null Hypothesis	Calculated Likelihood Ratio Statistic		Tabulated χ^2 ($\alpha = 0.05$)
	Conven-		
	Organic Farms	tional Farms	
$H_0: \gamma = \delta_m = 0$	28.17	35.24	$\chi^2_8 = 15.51$
$H_0: \gamma = 0$	13.58	20.82	$\chi^2_2 = 5.99$
$H_0: \delta_m = 0$	18.09	17.40	$\chi^2_7 = 14.07$

statistical significance of modeling farm effects is examined using likelihood ratio tests. The results of the statistical testing are presented in Table 4. The first null hypothesis, which specifies that the inefficiency effects are absent from the model, is strongly rejected. The second null hypothesis which specifies that the inefficiency effects are not stochastic but are directly included in the production frontier model is also rejected. Finally, the third hypothesis which assumes that the inefficiency effects are not a linear function of the variables considered herein is also rejected. This indicates that the joint effects of these explanatory variables on the inefficiencies of production is significant although the individual effects of one or more variables may not be statistically significant (i.e. δ_{SC} and δ_{FO}). Hence, the inefficiency effects are clearly stochastic and are not unrelated to the age, the level of formal education of farmers, and the farm's size.

Regarding the parameter estimates, all four are statistically significant in both models. In both types of farming, land is the foremost significant input exhibiting the highest elasticities values though at different levels (0.616 and 0.688 in organic and conventional farms, respectively). For the rest of the applied inputs, however, their significance in cotton production differs between the organic and conventional practices. The existence of potential differences between the two farming practices was also tested by estimating the production frontier function jointly including dummy variables for each method of cultivation. The val-

ue of the corresponding likelihood-ratio test was found to be 47.8, considerably higher than the corresponding tabulated value of the chi-squared distribution at the 1-percent level of significance. Returns to scale were found to be close to unity for conventional farms (1.008) and clearly diminishing for organic farms (0.860). Based on restricted maximum likelihood estimation, the hypothesis of constant returns to scale is accepted for conventional cotton farms, while for organic farms the relevant hypothesis is rejected.

From the parameter estimates of the Cobb-Douglas production frontier reported in Table 3, the parameters of the corresponding dual-cost functions (for both methods of cultivation) can be recovered. Specifically, the dual-cost frontiers for organic and conventional cotton production are:

$$\begin{aligned} \ln C_{OR} = & 4.705 + 1.032 \ln Y_{OR}^* \\ & + 0.001 \ln w_L + 0.143 \ln w_F \\ & + 0.636 \ln w_A + 0.122 \ln w_C \\ & \text{organic farms} \end{aligned}$$

$$\begin{aligned} \ln C_{CV} = & 11.164 + 0.942 \ln Y_{CV}^* \\ & + 0.061 \ln w_L + 0.090 \ln w_F \\ & + 0.648 \ln w_A + 0.150 \ln w_C \\ & \text{conventional farms} \end{aligned}$$

where, w_i indicates the price per unit of input utilized in the production of organic and conventional cotton ($i = L, F, A, E$ where L : labor; F : fertilizers and pesticides; A : area; C : other cost expenses) and Y_i^* is the organic (or conventional) cotton production level, adjusted for the statistical and measurement errors captured by v_i .

Economic Efficiency

The estimated farm—specific, technical, allocative, and economic efficiency—measures for both methods of cultivation are presented in Table 5, in the form of frequency distribution within a decile range. Regarding technical efficiency, the table reveals that, on the average, conventional cotton farms are 80.4 percent ef-

Table 5. Frequency Distribution of Technical, Allocative and Economic Efficiency Ratings of the Organic and Conventional Cotton Farms in Viotia-Greece, 1995–96

Range %	Technical Efficiency		Allocative Efficiency		Economic Efficiency	
	Organic	Conv.	Organic	Conv.	Organic	Conv.
<20	0	0	0	0	0	0
20–30	1	0	0	0	1	0
30–40	2	0	0	0	2	2
40–50	2	2	0	0	4	4
50–60	3	3	3	1	13	5
60–70	4	3	5	6	6	10
70–80	4	4	7	7	3	7
80–90	6	6	8	9	0	1
90–100	7	11	6	6	0	0
Mean	71.63	80.40	80.25	82.04	57.48	65.96
Min	26.83	43.24	55.91	58.48	21.46	33.26
Max	98.39	99.98	99.15	99.01	72.70	82.57
t-statistic	6.568		0.214		5.268	

efficient in utilizing their technology; on the other hand, organic cotton farms are on the average 71.63 percent efficient in utilizing their own (organic farming) technology. In addition, a t-test on the statistical difference between the average technical efficiency scores in the two samples showed that there is indeed a statistically significant difference in the average technical efficiency between organic and conventional cotton farms.¹⁶ Furthermore, the variation of efficiency ratings is much lower in conventional farms; almost 72 percent of them exhibit an efficiency score between 70 and 100 percent, whereas in organic farms the corresponding figure is only 58 percent. It must be pointed out, however, that the lower technical efficiency estimates of organic farms should not be interpreted as an advantage of conventional farming practices over organic ones. Since both samples have similar characteristics (size, location, mechanization, farmer's age and education), these differences may simply mean that organic farmers are fac-

ing more difficulties than their conventional counterparts in exploiting fully the potential of the existing state of technology. Indeed the lower technical efficiency matches with the fact that organic farming practices have been only recently introduced in Greece, the respective know-how is currently incomplete or experimental, and extension services are largely absent.

Regarding allocative efficiency, organic farms appear to be on the average 81.25 percent efficient, whereas conventional farms are 82.04 percent. However, a t-test on the significance of the observed difference between the average allocative efficiency scores showed that this difference is statistically insignificant; in other words, both organic and conventional cotton farms seem to achieve, on the average, similar allocative efficiency levels in using their respective inputs. It may be noted that for organic farms the estimated average allocative efficiency is well above the average technical efficiency, implying that organic cotton growers have achieved a better allocation of their inputs given output and input prices. Nevertheless, it is still feasible to reduce cost by a further input re-allocation. Similarly, conventional farms exhibit an average allocative efficiency higher than their average technical efficiency by almost 2 percent. The higher av-

¹⁶ The null hypothesis that there is no difference between the computed efficiency estimates for each method of cultivation was tested using the t-test $t = (\bar{x}_{OR} - \bar{x}_{CV}) / \sqrt{(S_{OR}^2/n_{OR}) + (S_{CV}^2/n_{CV})}$, where \bar{x}_i , S_i^2 and n_i are the mean, standard deviation and sample size of the efficiency estimates for organic and conventional farming (Maddala, 1992).

erage allocative estimates in both types of cotton farming are rather logical considering that it is easier for farmers to make adjustments and operate closer to cost-minimization conditions rather than fully use the existing state of (conventional or organic farming) technology. In total, economic efficiency was also found to vary significantly between the two methods of cotton cultivation; average economic efficiency was 54.21 and 61.97 percent for organic and conventional cotton farms, respectively. The significantly lower average economic efficiency for organic cotton farms is mainly due to their lower degree of technical efficiency. This implies that relatively more cost savings may be achieved by improving technical rather than allocative efficiency, although considerable savings could be realized by improving both. This is a rather important finding as currently the fiscal cost for supporting cotton farming is quite high within the EU.

Concerning the sources of these efficiency differentials among sample participants, the estimates of the inefficiency effects model presented in Table 3 imply the following: the age of the farmer as a proxy of entrepreneurial skill level is an important factor in explaining technical efficiency variation in both methods of cultivation; the negative value of the squared term underlines the notion of decreasing returns to human capital. Farm size is positively related to efficiency levels and it is more evident in conventional farms. Similar findings concerning the possible relationship between farm size and efficiency levels are reported by other authors (Seale; Hallam and Machado) although some studies report contradictory results (Taylor, Drummond and Gomes; Bravo-Ureta and Evenson). Recently, Kalaitzadonakes, examining New Zealand's beef and sheep sector, argued that protectionism can have a positive effect on efficiency and thus on productivity growth only in small farms with small capital stock that face low prices; for large farms protectionism tends to generate technical inefficiencies and thus productivity losses. Although this finding is based on neo-classical theoretical rigidities it may be assumed that the relationship between farm

size and economic efficiency is subject to the peculiarities of the sector and of course on particular policy support measures. Education also has a positive significant part to play in determining efficiency differentials among organic and conventional cotton farmers, indicating that Welch's hypothesis about the "worker effect" is supported by the current data set. Given that education is a strong complement to most of the inputs utilized in the production process—such as chemical or organic fertilizers and pesticides, irrigation, mechanical equipment and high-yielding varieties—its importance is indispensable. Finally, a farm's stock of capital and the share of family to total labor expenses does not seem to have any conjunction with the existing level of efficiency.

For the low efficiency scores in both organic and conventional cotton farms one should seek an explanation in the relevant policy scheme governing the sector the last 20 years. The EU intervention policy applied to the Greek cotton sector since the country's accession into the EU in 1981 induced cotton farmers to increase production but prevented them from operating under *laissez-faire* conditions. This lack of competition and entrepreneurial motives apparently has made Greek cotton farmers less responsive to market signals. Moreover, although EU-subsidizing schemes in the form of unit subsidy did not eliminate variability in cotton prices and, therefore, risk, they did increase the farmers' expected returns. This in turn enhanced the willingness of both *risk-averse* and *risk-neutral* producers to produce more. In a vertical market system framework, this is translated into increased demand for inputs and probably to inefficiency related to input allocation in the production process. In other words, although protectionism may stimulate investment and new technology adoption, efficiency may decrease particularly when subsidized farm prices are high (Mundlak; Tzouvelekas et al.).

Regarding the adoption of new technologies, farmers facing poor extension services, inadequate know-how, and in some cases farmers with low literacy rates have great difficulty understanding technological innova-

tions and of course exploiting their full potential (Feder, Just and Zilberman). In our study, this is well manifested by the low technical efficiency scores of both conventional and organic farms which still have significant room for improvement. Indeed, on the average, the organic and conventional farmers examined can improve their performance (in terms of raising their technical efficiency) by almost 30 and 20 percent, respectively.

Concluding Remarks

Recent developments in world agricultural markets and the reforms in the Common Agricultural Policy of the EU clearly signal that continuation of the highly protective policy schemes enjoyed by the Greek cotton farmers during the last two decades is no longer possible. Hence alternative strategies to sustain the economic viability of the sector are urgently required. Lately the concept of organic cultivation has been suggested as a promising alternative to cotton farmers. In this paper we attempt to draw some conclusions about the current technical, allocative and economic efficiency of a sample of Greek organic and conventional cotton farms using the stochastic decomposition methodology.

Our empirical findings suggest that, in general, organic and conventional cotton farms in the sample examined are technically, allocatively, and economically inefficient. High support policies applied to cotton production after Greece's accession into the EU might be responsible for the current level of inefficiency (price subsidies still constitute a significant part of farm gross revenues in both the organic and conventional farms). Costless output (and thus income) increases may, however, be obtained by optimizing input use; larger gains may be achieved by improving technical efficiency. In comparative terms, conventional cotton farms seem to exhibit higher efficiency scores *vis-a-vis* their organic counterparts particularly in technical efficiency. The underlying reason seems to be the difficulties faced by organic farmers in exploiting fully the potential of the existing organic farming tech-

nologies given the recent introduction of organic farming practices in Greece.

In addition to the productive inefficiencies exhibited by Greek organic cotton farms it is also worth noting that currently there are no established price premiums for the organic cotton produce; in the sample examined, price premiums received by organic cotton growers ranged anywhere from zero up to the rather high level of 50 drachmas per kg above the conventional cotton price. This is because established channels for the explicit marketing of organically grown cotton as an organic commodity do not yet exist in Greece. Certainly, this is another direction wherein there is scope for further improvements. It is evident therefore that the national and EU institutions should primarily begin to set up conditions for the improvement of the farming technologies for organically produced cotton, coupled with efforts to develop specialized organic marketing channels. Measures aiming at the improvement of organic farm efficiency (i.e. extension services to improve farmers' know-how, provision of the necessary infrastructure) should be chosen over the existing subsidization schemes in designing policies for the enhancement of the organic farming sector. This will prove beneficial in maximizing the anticipated benefits of any future change in the technological conditions of organic farming practices.

References

- Avgoulas C. and A. Koutrou-Avgoula. "Cotton." In *Developments and Perspectives in the Agricultural Sector* eds G. Mergos and K. Papa-georgiou, pp. 85-109 Stamoulis publishers, Athens, 1997 (in Greek).
- Battese, G.E. "Frontier Production Functions and Technical Efficiency: A Survey of Empirical Applications in Agricultural Economics." *Agr. Econ.* 7(1992): 185-208.
- Battese, G.E. "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data." *Empir. Econ.* 1995(20): 325-332.
- Battese, G.E. "Comment on 'Efficiency Analysis with Panel Data: A Study of Portuguese Dairy

- Farms'." *Eur. Rev. Agr. Econ.* 1998 (25): 259–262.
- Battese, G.E. and T.J. Coelli. "Prediction of Firm-Level Technical Efficiencies with a Generalized Frontier Production Function and Panel Data." *J. of Econ.* (1988)38: 387–399.
- Bravo-Ureta, B.E. and A.E. Pinheiro. "Efficiency Analysis of Developing Country Agriculture: A Review of the Frontier Function Literature." *Agr. Res. Econ. Rev.* 1993(22): 88–101.
- Bravo-Ureta, B.E. and L. Rieger. "Dairy Farm Efficiency Measurement Using Stochastic Frontiers and Neo-classical Duality." *Amer. J. Agr. Econ.* 1991(73): 421–428.
- Bravo-Ureta, B.E. and R.E. Evenson. "Efficiency in Agricultural Production: The Case of Peasant Farmers in Eastern Paraguay." *Agr. Econ.* 1994 (10): 27–37.
- Coelli, T.J. "Recent Developments in Frontier Modeling and Efficiency Measurement." *Australian J. Agr. Econ.* 1995 (39): 219–245.
- Coelli T.J., R. Rao and G.E. Battese. "An Introduction to Efficiency and Productivity Analysis." Boston: Kluwer Academic Publishers, 1998.
- EU Regulation 2092/91, *Gazette of the European Communities*, Vol. L198/14, 22.7.91
- EU Regulation 2078/92, *Gazette of the European Communities*, Vol. L215/90, 30.7.92
- Farrell, M.J. "The Measurement of Productive Efficiency." *J. Royal Statis. Soc. Series A*, 1957 (120): 253–281.
- Feder, R., R.E. Just and, D. Zilberman. "Adoption of Agricultural Innovation in Developing Countries: A Survey." *Econ. Develop. and Cultural Change* 1985(33): 255–298.
- Greek Cotton Board. *Report on Cotton Cultivation in 1996*. Greek Cotton Board-Athens 1996 (in Greek).
- Greene, W.H. "The Econometric Approach to Efficiency Analysis." In *The Measurement of Productive Efficiency: Techniques and Applications*, eds. H.O. Fried, C.A.K. Lovell and P. Schmidt, 68–119. New York: Oxford University Press, 1993.
- Hallam, D. and F. Machado. "Efficiency Analysis with Panel Data: A Study of Portuguese Dairy Farms." *Eur. Rev. Agr. Econ.* 1996 (23): 79–93.
- International Cotton Advisory Committee. "Growing Organic Cotton." Washington: ICAC, 1996.
- Jondrow, J., C.A.K. Lovell, I.S. Materov, and P. Schmidt. "On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model." *J. Econometrics* 1982(23): 269–274.
- Kalaitzandonakes, N.G. "Price Protection and Productivity Growth." *Amer. J. Agr. Econ.* 1994(76): 722–32.
- Kopp, R.J. "The Measurement of Productive Efficiency: A Reconsideration." *Quar. J. of Econ.* 1981 (96): 477–503.
- Kopp, R.J. and W.E. Diewert. "The Decomposition of Frontier Cost Function Deviations into Measures of Technical and Allocative Efficiency." *J. Econometrics* 1982(19): 319–331.
- Kumbhakar, S.C., B. Biswas, and D.V. Bailey. "A Study of Economic Efficiency of Utah Dairy Farmers: A Dual System Approach." *Rev. Econ. and Statis.* 1989(71): 595–604.
- Kumbhakar, S.C., S. Ghosh, and J.T. McGuckin. "A Generalised Production Frontier Approach for Estimating Determinants of Inefficiency in US Dairy Farms." *J. Bus. and Econ. Statis.* 1991(9): 279–286.
- Kumbhakar, S.C. and C.A.K. Lovell. *Stochastic Frontier Analysis*. Cambridge University Press: Cambridge, 2000.
- Maddala, G.S. *Introduction to Econometrics* New York: MacMillan, 1992.
- Mundlak, Y. "Endogenous Technical Change and the Measurement of Productivity." In *Agricultural Productivity Measurement and Explanation*, eds S.M. Capalbo and J.M. Antle. Washington DC: Resources for the Future, 1988.
- Reifschneider, D. and R. Stevenson. "Systematic Departures from the Frontier: A Framework for the Analysis of Firm Inefficiency." *Inter. Econ. Rev.* 1991(32): 715–723.
- Seale, J.L. Jr. "Estimating Stochastic Frontier Systems with Unbalanced Panel Data: The Case of Floor Tile Manufactories in Egypt." *J. Appl. Econometrics*, 1990(5): 59–74.
- Sharma, K.R., P.S. Leung, and H.M. Zaleski. "Technical, Allocative and Economic Efficiencies in Swine Production in Hawaii: A Comparison of Parametric and Nonparametric Approaches." *Agricultural Economics* 1999(20): 23–35.
- Shepard, R.W. *Theory of Cost and Production Functions*. Princeton, New Jersey: Princeton University Press, 1970.
- Taylor, T.G., H.E. Drummond, and A.T. Gomes. "Agricultural Credit Programmes and Production Efficiency: An Analysis of Traditional Farming in Southeastern Minas Gerais, Brasil." *Amer. J. Agr. Econ.* 1986(68): 110–119.
- Tzouvelekas, V. D. Giannakas, P. Midmore, and K. Mattas. "Decomposition of Olive-Oil Produc-

- tion Growth into Productivity and Size Effects." Annual Meetings of the American Agricultural Economics Association, Toronto 27–30 July, 1997.
- Varian, H.R. *Microeconomic Analysis*. New York: W.W. Norton and Co, 1992.
- Welch, F. "Education in Production." *Journal of Political Economy* (1970)8: 35–59.
- Zellner, A., J. Kmenta, and J. Dreze. "Specification and Estimation of Cobb-Douglas Production Function Models." *Econometrica* 1966(34): 784–795.