Assesing the Perspectives of EU Cotton Farming: Technical and Scale Efficiencies of Greek Cotton Growers

Christos Pantzios
(*Dept of Economics, University of Patras, GREECE*)

Stelios Rozakis
(Unit of Public Economics,*INRA-INAPG,Grignon, France*)

Vangelis Tzouvelekas
(*Dept of Economics, University of Crete and National Agricultural Research Foundation, GREECE*)

Corresponding Author:
Stelios Rozakis
(and your address)

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Abstract

Utilizing the stochastic frontier approach, this paper estimates output and input-oriented technical and scale efficiency levels for a sample of cotton-growing farms in Thessaly, Greece. The empirical results suggest that Greek cotton farm operations are technically and scale inefficient. There is a considerable scope for improvement in resource use and thereby in farm income of cotton farms; Greek cotton farmers could reduce production costs by 20.4%, making more efficient utilization of the existing production technology. Factors responsible for the technical efficiency differentials observed among cotton-growers include the farmer's age and education as well as the farm's land fragmentation and output specialization.

JEL codes: *C33, D24, O13*

Key words: Technical and scale inefficiency, stochastic frontier models, cotton production, Greece.

Introduction

European Union agriculture appears to be at the crossroads. It can no longer continue to depend on the current support schemes as the financial costs of its Common Agricultural Policy – C.A.P. have boomed; the world marketplace is turning increasingly more competitive; and, potential new member-states with huge farm sectors are about to join the union. In this new environment, effective input use and rational utilization of farming techniques, that is, efficient exploitation of existing technologies is far more important than artificially high prices and farm import controls for the viability of farm operations. It follows that the measurement of existing inefficiencies in the agricultural production of the E.U. becomes of interest for at least two reasons: first, it can provide useful information on the technical efficiency of E.U. farm operations achieved in the context of current C.A.P. measures. And second, it can be used as a guideline for effective policy reforms in the direction of technical efficiency improvements in E.U. farming.

In Greek agriculture, cotton has been a crop of major importance for domestic producers and a politically sensitive issue in resent years because, as explained in the next section, within the EU cotton is primarily grown in only two member states (Greece and Spain). In the light of the considerations introduced above, assessments of the current status and especially the perspectives of Greek (and EU) cotton farming should primarily focus on the gap between the cotton farm's actual production vis-à-vis the best-practice production i.e., their technical efficiency level. In addition, CAP measures have considerably influenced the scale of production in Greek cotton farms by encouraging farmers to invest in modern equipment and expand production. Thus, possible inefficiencies stemming from the actual scale at which cotton farms operate vis-a-vis the optimal scale also merit examination. Such analyses become also interesting given the shortage of studies considering the issue of inefficiency in Greek cotton farming (an exception is Tzouvelekas *et al*, 2001).

In this context, the objective of present paper is to estimate empirically the technical efficiency levels, the determining factors and the related scale efficiency of Greek cotton farms. To that end, recent developments in the methodological framework of stochastic frontier analysis – S.F.A. which allow the measurement of technical as well as scale efficiency are utilized on a representative sample of Greek cotton farm operations.

The rest of the paper is organized as follows. A brief overview of the Greek cotton sector is provided in the next section. Methodology and the theoretical model are developed in section 3. Section 4 discusses the data and the estimation results. Policy implications derivable from this study are offered in section 5. Section 6 concludes.

2. The Greek Cotton Sector

Traditionally, cotton growing has been a prominent farming activity in Greece providing the primary input to a major domestic processing industry (cotton ginners). During the last two decades however, the sector has shown an impressively rapid expansion. The acreage cultivated with cotton almost doubled during the 1980s reaching 240 thousand ha (2.4 million stremmas[1]) in 1991, from only 120 thousand ha in 1981 and kept expanding during the 1990s reaching 430 thousand ha in 1996. The volume of cotton production swelled according to the Greek Cotton Board from only 290 thousand tons in 1981 to about 1 million tons in 1996. Within the EU, Greece has thus become the largest cotton producer, accounting for almost 70 percent of the total EU cotton production (followed by Spain); it also ranks fifth worldwide in terms of cotton yields per hectare (Avgoulas and Koutrou-Avgoula).

The sector's rapid enlargement has been mainly the result of past, high support-mechanisms of the EU cotton regime. 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 replaced since 1987 this policy regime with an intervention mechanism consisting of: (i) an target price, (ii) an aggregate production quota set at the country-level and, (iii) a levy (i.e., a reduction in the target price) when the actual cotton production of the country exceeded the predetermined aggregate production quota.

As a result of the initial favorable CAP measures, cotton cultivation became gradually the primary farming activity (and source of income) for a growing number of agricultural households. Farmers diverted even marginal productivity land to cotton cultivation; invested in equipment (such as cotton harvesters, irrigation systems, and water drillings) and in general, they largely expanded their scale of operation. Naturally, negative environmental effects started to emerge as cotton ranks high in the list of heavily polluting crops; high levels of fertilizer residues have been measured in cotton fields and the excessive use of irrigation water appears to have reduced underground water supplies to alarming levels. In the wake of the latest reform in the CAP cotton regime, production expansion is not anymore associated with corresponding increases in farm revenues. However, as the production quota was imposed at the country-level, individual cotton growers routinely ignored it and kept expanding their own production. Recently, cotton growers played a leading role in loud farmer protests against the EU-imposed cotton production quota claiming that it shrinks drastically their farm income in the face of ever increasing production costs.

Methodological Framework

The current framework of efficiency measurement originates in the pioneer works of Debreu (1951), Koopmans (1951) and Shephard (1953). According to these original contributions, the technical efficiency of a production unit (e.g., a farm) can be defined in either an output-expanding or input-conserving fashion. More exactly, the technical efficiency (TE) of a farm may be defined as the ratio of the actual to the best-practice farm output, given the farm's observed input quantities, the production technology available, and its socio economic features; this is the output-oriented or *Debreu-type* measure of TE. Alternatively, the technical efficiency of a farm may be defined as the ratio of the actual to best-practice input levels, given the farm's observed output, the production technology available, and its socio economic features; this is the input-oriented or *Shephard-type* measure of TE.[2]

Both measures of technical efficiency can be obtained from the econometric estimation of a stochastic production frontier model as suggested by Battese and Coelli (1993; 1995). In particular, let us assume that the production possibility frontier of a farming technology is approximated via a translog functional specification, i.e.:

$$\ln y_i = \beta_0 + \sum_{j=1}^{J} \beta_j \ln x_{ij} + \frac{1}{2} \sum_{j=1}^{J} \sum_{k=1}^{J} \beta_{jk} \ln x_{ij} \ln x_{ik} + e_i \qquad (1)$$

where, lny_i is the logarithm of total output produced by the i^{th} farm (i=1, 2, …, n), lnx_{ij} is the j^{th} input used in the production by the i^{th} farm, β are the technology parameters to be estimated and, e_i is the composed error term consisting of two independent elements such that $e_i \equiv v_i - u_i$. The component v_i is a symmetric *i.i.d.* random term representing random variation in output due to exogenous factors, measurement errors omitted explanatory variables and statistical noise. The component u_i is a non-negative error term representing the stochastic shortfall of the ith farm's output from its production frontier due to output-oriented technical inefficiency.

Moreover, the component u_i may be viewed as a linear function of relevant explanatory variables, such as the socio economic characteristics of the farm - Battese and Coelli (1993; 1995).[3] Specifically, the one-sided error term can be expressed as:

$$u_i = g(z_{im};\delta) + \omega_i \qquad (2)$$

where, z_{im} is the m^{th} farm-specific characteristic assumed to affect technical inefficiency, δ are the parameters to be estimated and, ω_i is an *i.i.d.* error term defined by the truncation of the normal distribution such that $\omega_i \geq -[g(z_{im};\delta)]$. Given this framework, farm-specific, output-oriented technical efficiency scores are obtained using a predictor proposed by Battese and Coelli (1988; 1992).[4]

Additionally, estimation of farm-specific, input-oriented technical efficiency scores is possible within the preceding stochastic frontier specification using the approach suggested by Atkinson and Cornwell (1994). To briefly outline this approach, all inputs x in (1) may be multiplied by a scalar $\theta \in (0,1]$ so that the observed level of output is still feasible, assuming that u_i=0. In other words, the model in (1) may be re-written as:

$$\ln y_i = \beta_0 + \sum_{j=1}^{J} \beta_j \ln(\theta_i \cdot x_{ij}) + \frac{1}{2} \sum_{j=1}^{J} \sum_{k=1}^{J} \beta_{jk} \ln(\theta_i \cdot x_{ij}) \ln(\theta_i \cdot x_{ik}) + v_i \qquad (3)$$

Under weak monotonicity, output-oriented technical inefficiency should imply (and must be implied by) input-oriented technical inefficiency; therefore, we can set (3) equal to (1). Then solving for θ_i farm-specific estimates of input oriented technical inefficiency are obtained using the relevant formulas developed by Reinhard *et al*., (1999, p. 53). Input-oriented, technical inefficiency has a direct cost interpretation with one minus the degree of technical efficiency indicating the percentage reduction of production costs, if technical inefficiency is eliminated (Kopp, 1981, p. 490).[5]

In addition to technical efficiency, the scale efficiency of a farm can be readily measured within the analytical framework of the production frontier. Conceptually, scale efficiency measures how much the *ray* average productivity of an input-output combination *lying on the production frontier* differs from the maximum attainable one. Assuming a concave production function, it can be readily shown that the ray average productivity reaches a maximum when scale elasticity ε equals one. An input-output combination corresponding to scale elasticity $\varepsilon=1$ is characterized as the *technically optimal scale of production*[6]or TOSP point (Frisch, 1965). It follows that scale efficiency and scale elasticity are equal only at a TOSP point where constant returns to scale prevail; elsewhere on the production function, scale efficiency is less than 1 irrespective of whether scale elasticity is greater or less than unity. In the realistic case of an input–output combination lying *below* the production frontier, to measure scale efficiency one needs the technically efficient projection of the actual input-output combination *on* the production frontier. Since, the technically efficient projection can be measured holding constant either the inputs or the output, the resulting scale efficiency measure will be either input or output-oriented[7].

Practically, farm-specific, output and input-oriented scale efficiency scores can be computed from the parameter estimates of the production frontier (1) utilizing formulae developed by Ray (1998). Specifically, the output-oriented scale efficiency SE^O of the i-th farm may be computed as:

$$SE_i^O = \exp\left[\frac{(1-\varepsilon_i)^2}{2b}\right] \tag{4a}$$

and the input-oriented scale efficiency SE^I as:

$$SE_i^I = \exp\left[\frac{\left(1-\sqrt{\varepsilon_i^2 - 2bTE_i^O}\right)^2}{2b}\right] \qquad \text{(4b)}$$

where, ε_i is the scale elasticity of the i^{th} farm (equal to the sum of the output elasticities of the respective inputs), TE_i^O is the output-oriented technical inefficiency of the i^{th} farm and, $b = \sum_{j=1}^{J}\sum_{k=1}^{J}\beta_{jk}$. Since by definition $0 \leq SE \leq 1$ it is required that $b<0$. In the absence of technical inefficiency both measures of scale efficiency are equal to each other, while when $\varepsilon_i=1$ then output-oriented scale inefficiency equals also to one.

Data and Estimation

Data

The data used in this paper come from a questionnaire survey of 172 cotton farms in Thessaly (central Greece) for the cropping year 1995/1996. Thessaly is one of the major agricultural regions of the country and historically it has been a prime area for cotton farming. Summary statistics of the key-variables of the surveyed farms appear in Table 1.

The variables involved in the analysis are measured as follows. In the production frontier equation (1) the dependent variable is the total annual cotton production measured in kilograms, while the independent variables include: (*a*) total labor, that is, hired and family (paid and unpaid) labor related to cotton production measured in hours; (*b*) farm land devoted to cotton cultivation measured in stremmas; (*c*) total amount of chemical fertilizers and pesticides applied in cotton production measured in kilograms; (*d*) total amount of seeds used in cotton production measured in kilograms and; (*e*) total value of capital (machinery etc) used in cotton cultivation, measured in euros (EUR) - 1 EUR equals 0.95 USD.

In the inefficiency model (equation 2) the variables used to explain the farm's inefficiency include: (*a*) the "specialization" of the farm measured as the share of output other than cotton in the farm's total output; (*b*) the age of the farmer measured in years; (*c*) the formal education of the farmer measured in years of schooling; (*d*) the value of the farm's total assets (comprising of the value of mechanical equipment, cultivated land and infrastructure) measured in EUR and; (*e*) the land fragmentation measured as the number of plots cultivated with cotton in each farm.

Estimation results

The ML parameter[8] estimates of the translog production frontier (1) and the inefficiency model (2) are listed in Table 2. More than 2/3 of the estimated parameters in the production frontier and all the estimated parameters in the inefficiency model are found to be statistically significant at least at the 5% level. The relatively low value of the likelihood function is satisfactory for a cross-section data setting, indicating a good fit of the data. Moreover, the estimated production frontier satisfies all the regularity conditions, namely positive and diminishing marginal productivities, at the point of approximation. Specifically, monotonicity conditions are satisfied since all the marginal products are positive, while the determinants of the principal minors of the bordered Hessian matrix alternate their signs indicating diminishing marginal productivities. Restrictive forms such as the Cobb-Douglas, the homogeneous, linear homogeneous and homothetic translog were tested and rejected at the 5% level of significance.

The estimated variance of the one-sided error term is found to be $\sigma_u^2 = 0.0719$ and that of the statistical noise $\sigma_v^2 = 0.1445$. The ratio parameter, γ, is positive and statistically significant at the 1% level.[9] The corresponding variance parameter, γ^*, is estimated to be 0.7975 implying that the 79.75% of output variability is explained by the corresponding differences in output-oriented technical inefficiencies of cotton farms. The statistical significance of the variables used to explain technical inefficiency and the specification of the production frontier is further examined using conventional likelihood-ratio tests. Several hypotheses are examined and the results are presented in Table 3.

In particular, the null hypothesis that the traditional average response function adequately represents the structure of the cotton farms examined is rejected. This is true regardless of whether farm inefficiency effects are present (*i.e.*, $\gamma = \delta_0 = 0$) or absent (*i.e.*, $\gamma = \delta_0 = \delta_m = 0$) from the production frontier model. The null hypothesis that farm-specific output-oriented technical inefficiency is not a linear function of the considered variables (*i.e.*, $\delta_0 = \delta_m = 0$) is also rejected at the 5% level of significance.[10] Finally, the estimated model cannot be reduced to Stevenson's (1980) truncated half-normal model as the null hypothesis that $\delta_m = 0$ is rejected.

Given the production parameter estimates, basic features of the production structure, namely output elasticities and returns to scale are computed and shown in Table 4. Inspection of the table reveals that the output elasticity with respect to land is the largest among the inputs considered followed by the output elasticities with respect to capital and seeds.

Fertilizer and labor on the other hand exhibit the lowest output elasticities. It is worth noting that these low output elasticities are consistent with the real situation in hand. The low output elasticity with respect to fertilizer may well reflect the diminishing returns on soil fertility the excessive use of chemical fertilizers in cotton farming started to have in the plain of Thessaly (indeed, excessively high concentrations of fertilizer residues have been repeatedly measured in Thessaly's soil). In addition, the low output elasticity with respect to labor may be related with the highly mechanized techniques utilized by the Greek cotton farmers. Returns to scale (computed as the sum of the estimated output elasticities with respect to inputs) are found to be increasing with an average value of 1.365. Moreover, the hypothesis of constant returns to scale is rejected at the 5% level of significance. Thus an equiproportional increase of all inputs by 1% is expected to yield an average increase of 1.37% in cotton output.

These findings seem to suggest that Greek cotton farmers have achieved economies of scale and adopted technological innovations. The important question however is whether and cotton producers have been using such farming technologies efficiently i.e., exploiting their full potential and whether they have fully exploited the advantage of scale economies. These issues are examined in the following section.

Technical and Scale Efficiency Scores

Columns 2 and 3 in Table 5 list the output and input-oriented technical efficiency (denoted as TE^O and TE^I, respectively) of the farms examined in the form of a frequency distribution within a decile range; the remaining columns do the same for the output and input-oriented scale efficiency (SE^O and SE^I, respectively). The table reveals that the cotton farms examined have been considerably inefficient both technically and scale-wise. This implies that, Greek cotton growers have not been successful neither in achieving the maximum producible output from the existing technology nor in exploiting fully their scale economies.

More exactly, output-oriented technical efficiency has an average value of 62.2% implying that the farms examined could have produced on the average, 37.8% more cotton with the same input quantities and the current state of technology. Moreover, TE^O scores vary considerably across farms ranging from a minimum of 33.1% to a maximum of 97.1%. Only a small portion of the cotton farms (11.6%) achieved output-oriented technical efficiency above 80%. This means that the majority of the sample participants faces severe technical inefficiency problems (about 58% of the surveyed farms achieved technical efficiency below 60%). Medium-sized (50-100 stremmas) farms have an average TE^O of 63.9%, whereas small-sized farms (<50 stremmas) have the lowest TE^O score (59.5%).

Similarly, input-oriented technical efficiency has an average value of 79.6% implying that the farms examined could have produced the observed cotton quantity using on the average, 20.4% less input quantities within the current state of technology. It should be noted that TE^O scores are greater than the corresponding TE^I scores due to the existence of increasing returns to scale; this holds for all cotton farms in the sample.[11] The variation of individual TE^I scores is also considerable ranging from 21.4% to 97.0%. Medium and small sized cotton farms appear to have similar average TE^I scores (78.4% and 78.8%, respectively), while small-sized farms a somewhat higher one (81.9%).

As noted in the previous section, the average TE^I score of 79.6% also implies that (on the average) the observed cotton output levels could have been produced with 20.4% less production costs without altering production technology. In Table 6 the potential cost reductions from eliminating input-oriented technical inefficiency are shown for the three classes of cotton farms considered.[12] Our calculations indicate that large-sized cotton farms would be able to reduce their actual costs by 21.1%; medium-sized farms by 21.6%; and small farms by 18.1% had they operated at full technical efficient levels. In absolute terms, these potential cost savings would be on the average, EUR 16.3/stremma; for each of the three classes of farm size considered (i.e., small, medium and, large farms) these potential cost savings would be EUR 6.1/stremma, EUR 14.8/stremma, and EUR 27.9/stremma, respectively. Potential cost savings are higher for large farms due to substantially higher cost of production. Reducing therefore technical inefficiency could substantially improve the economic viability of cotton farms.

Regarding scale efficiency, the average output-oriented scale efficiency SE^O is found to be 81.0%, whereas the average input-oriented scale efficiency SE^I is 85.6%. The former measure implies that cotton producers could produce 19.0% more output by operating at optimal scale wherein their ray average productivities are maximal. Similarly, the latter implies that cotton producers could produce the same level of output with 14.4% less cost by operating at optimal scale. Moreover, the benefit of operating at optimal scale would be larger for small cotton farms: the average SE^O and SE^I scores are found to be 78.6% and 85.6% for small-sized farms respectively, whereas the corresponding scores are 82.1% and 86.89% for large-sized farms.

Sources of Efficiency Differentials

The sources of (output-oriented) technical inefficiency in the farms examined may be detected by studying the parameter estimates of the inefficiency model in the lower part of Table 1. It is worth noting that all these parameter estimates are statistically significant indicating that each of the six explanatory variables employed in the analysis affects considerably the inefficiency of the farms examined. Bearing in mind that the explanatory variables in the inefficiency model are regressed against the technical *in*efficiency level of each farm, the following may be noted.

A positive relationship is found between the farmer's education and the TE^O score of his farm. This lends support to Welch's (1970) hypothesis about the "worker effect", that is, the notion that education is a strong complement with most of the inputs utilized in the production process; moreover, schooling may enhance the information acquisition process and the efficiency in the use of the acquired information. A positive relationship is also found between TE^O and the farmer's age (and therefore experience). This is in accordance with the notion that – besides education - hands-on experience obtained through years and learning-by-doing are critical factors in determining individual performance particularly in crop production[13]. However, the impact of age on the degree of technical efficiency need not be monotonically increasing: that is, young cotton producers may well be expected to become more efficient over time up to a point where the relationship between age and efficiency is levelled off; but as they approach the retirement age efficiency declines. This notion of decreasing returns to human capital is captured by the negative relationship found between TE^O and the variable $(Age)^2$.

On the other hand, a negative relationship is found between TE^O scores and the degree of land fragmentation in the cotton farms examined. This is consistent with the notion that farms consisting of several (often widely spread) parcels of land may be less efficient since they face increased difficulties in allocating inputs and coordinating production efforts. It also lends support to the view that farm-land fragmentation (stemming from hereditary rules and legislation that practically inhibits farmland concentration) is a major structural problem in Greek agriculture. Farm size (measured as the value of farm's total assets) appears to be positively related to TE^O suggesting that large (in terms of market value) cotton farms are more technically efficient. Similar findings regarding the relationship between farm size and efficiency levels are reported by other authors (Seale; Hallam and Machado;) although there are studies reporting contradictory results (Taylor, Drummond and Gomes; Bravo-Ureta and Evenson; Kalaitzandonakes).

Lastly, TE^O is found to be negatively related to farm specialization (i.e., the share of crops other than cotton in farm's total output). That is, farms specializing in cotton production appear to be more technically efficient than cotton farms involved additionally in production of other crops. This is also a reasonable finding reflecting factors such as higher skills or better-coordinated production efforts of farmers relying almost exclusively on cotton production. More importantly, this finding reflects the massive entrance of farmers into cotton cultivation in recent years to take advantage of high support prices: producers lacking experience and skills in cotton farming and employing marginal productivity land have simply added cotton growing to their activities. It is clear that such marginal cotton growers cannot be as technically efficient as farmers highly specialized in cotton production.

Policy implications

Given that Greece has been the major EU cotton-producing country, the empirical results of the present study yield interesting insights about the impact of C.A.P. measures on EU cotton production, and more importantly on the prospects of EU cotton farming. In particular, our analysis indicates that the benefits CAP offered to cotton producers have come at a rather heavy opportunity-cost, namely, at the expense of considerable technical and scale inefficiency. To be more explicit, the satisfactory farm income that CAP regime has secured to cotton growers (via administrative prices, set well above world levels) allowed them to disregard efficiency considerations in the ways they apply their production technology.

The resulting efficiency distortion however is becoming a factor of critical importance for Greek (and EU) cotton growers for at least two reasons. First, EU itself has taken a course of gradual reduction of its expensive farm programs; cotton is among the primary candidates for support reduction given that it is a crop interesting only two member-states (Greece, and Spain). Second, any liberalization of the world agricultural markets will only intensify competition, thus making technical efficiency a major determinant for the survival of cotton producing countries. It is then clear that future reforms of the CAP cotton regime should explicitly address efficiency considerations in preparing Greek and other EU cotton growers to cope with price support reductions and face an increasingly competitive international marketplace.

The considerable technical and scale inefficiency in Greek cotton farming becomes also important in the light of the attitude Greek cotton farmers have been taking against the CAP cotton regime: as already mentioned, they have repeatedly protested claiming that their revenues are severely reduced by the current EU regime (outlined in section 2). This study indicates however that instead of blindly demanding higher prices to secure their income, cotton farmers could achieve the same result via cost savings stemming from the reduction of their technical and scale inefficiency.[14]

Thus, the primary policy suggestion derivable from our study is that in future CAP reforms, measures explicitly addressing the efficient use of existing technology are urgently needed for Greek (and EU) cotton farming to survive. Such measures become of even greater importance as EU policies of high administrative prices can no longer continue. Specific guidelines for reducing technical inefficiency in cotton farming may include: (i) measures to improve the ability of cotton farmers to apply efficiently the existing technology e.g., measures designed to improve education, information acquisition, and learning-by-doing processes, (ii) measures to reduce land fragmentation by adjusting the existing legislation framework and providing appropriate incentives, and (iii) measures to favor reasonable specialization of cotton farming by discouraging occasional or marginal cotton growers.

Conclusions

Recent international economic developments and the reform of the EU cotton regime clearly signal that the continuation of the highly protective policy schemes enjoyed by the Greek cotton-growers during the last two decades does not seem possible any longer. New policy measures aiming to make the use of inputs and the existing farming technologies more effective are far more important in an increasingly competitive and rapidly changing, global economic environment. In the present paper we attempted to assess the performance of Greek cotton farms in this respect, by analysing the technical and scale efficiency levels of a representative sample of cotton growers in Thessaly, Greece.

Our empirical findings suggest that, in general, the cotton farms examined are technically and scale inefficient. The 1980s high support policies of the EU appear to have considerably contributed to the inefficiencies observed. Our analysis indicates that significant cost reductions can be achieved by optimising input use; in addition, significant gains can be obtained for individual farms by exploiting fully their scale economies. Factors responsible for the technical efficiency differentials observed among cotton growers appear to be the farmer's age, the farmer's education level, the farm's land fragmentation and the farm's output specialization. Policy recommendations derivable from our study suggest that future reforms of the CAP cotton policy should explicitly address this inefficiency problem if EU cotton farming is to survive. Such policies could include measures to improve farmer's education, information acquisition and learning-by-doing processes; reduce land fragmentation; and, discourage occasional or marginal cotton growers.

References

Aigner, D.J., Lovell, C.A.K., Schmidt, P., 1977. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics* 6, 21-37.

Atkinson, S.E., Cornwell, C., 1994. Estimation of output and input technical efficiency using a flexible functional form and panel data. *International Economic Review* 35, 245-255.

Avgoulas C. and A. Koutrou-Avgoula. “Cotton” In *Developments and Respectives in the Agricultural Sector* eds G. Mergos and K. Papageorgiou, pp. 85-109 Stamoulis publishers, Athens, 1997 (in Greek).

Banker, R.D., 1984. Estimating the most productive scale size using DEA. *European Journal of Operational Research* 17, 35-44.

Battese, G.E., Coelli, T.J., 1988. Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data. *Journal of Econometrics* 38, 387-399.

Battese, G.E., Coelli, T.J., 1992. Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. *Journal of Productivity Analysis* 3, 153-169.

Battese, G.E., Coelli, T.J., 1993. A stochastic frontier production function incorporating a model for technical inefficiency effects. Working Paper 93/05, Department of Econometrics, University of New England, Armidale, Australia.

Battese, G.E., Coelli, T.J., 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics* 20, 325-332.

Bravo-Ureta, B.E. and R.E. Evenson “Efficiency in Agricultural Production: The Case of Peasant Farmers in Eastern Paraguay”, *Agricultural Economics* 1994 (10): 27-37.

Coelli, T.J., 1992. Computer program for frontier production function estimation: Frontier version 2.0. *Economics Letters* 39, 29-32.

Debreu, G., 1951. The coefficient of resource utilization. *Econometrica* 19, 273-292.

Färe, R., Lovell, C.A.K., 1978. Measuring the technical efficiency of production. *Journal of Economic Theory* 19, 150-162.

Frisch, R. 1965. *Theory of production*, Dordrecht: D. Reidel.

Greene, W.H. Frontier production functions in *Handbook of applied econometrics, Volume II: Microeconomics*, M.H. Pesaran and P. Schmidt (eds), Oxford: Blackwell Publishers, 1999.

Hallam, D. and F. Machado “Efficiency Analysis with Panel Data: A Study of Portuguese Dairy Farms”, *Euopean Review of Agricultural Economics* 1996 (23): 79-93.

Kalaitzandonakes, N.G., 1993. Price protection and productivity growth. *American Journal of Agricultural Economics* 76, 722-732.

Kodde, D.A., Palm, F.C., 1986. Wald criteria for jointly testing equality and inequality restrictions. *Econometrica* 54, 1243-48.

Koopmans, T.C., 1951. An analysis of production as an efficient combination of activities. In Koppmans, T.C. (ed.), Activity analysis of production and allocation. Cowles Commission for Research in Economics, Monograph No 13. Wiley, New York.

Kopp, R.J., 1981. The measurement of productive efficiency: A reconsideration. *Quarterly Journal of Economics* 96, 477-503.

Kumbhakar, S.C., Ghosh, S., McGuckin, J.T., 1991. A generalized production frontier approach for estimating determinants of inefficiency in US dairy farms. *Journal of Business and Economic Statistics* 9, 279-286.

Meeusen, W., Van der Broeck, J., 1977. Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review* 18, 435-44.

Karagiannis G., and C. J. Pantzios (2002). To Comply or not to Comply with Policy Regulations – the case of Greek Cotton Growers: A Note. *Journal of Agricultural Economics, 53(2)* (forthcoming).

Ray, S.C. 1998. Measuring scale efficiency from a translog production function. *Journal of Productivity Analysis* 11, 183-194.

Reifschneider, D., Stevenson R., 1991. Systematic departures from the frontier: A framework for the analysis of firm inefficiency. *International Economic Review* 32, 715-723.

Reinhard, S., Lovell, C.A.K., Thijssen, G.J., 1999. Econometric estimation of technical and environmental efficiency: An application to Dutch dairy farms. *American Journal of Agricultural Economics* 81, 44-60.

Shephard, R.W. (Ed.), 1953. *Cost and production functions*. Princeton UP, Princeton.

Stevenson, R.E., 1980. Likelihood functions for generalized stochastic frontier estimation. *Journal of Econometrics* 13, 58-66.

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", *American Journal of Agicultural Economics* 1986(68): 110-119.

Tzouvelekas, V., Pantzios, C. J., Fotopoulos, C., 2001. Economic efficiency in organic farming: Evidence from cotton farms in Viotia, Greece. *Journal of Agricultural and Applied Economics* 33, 35-48.

Weersink, A., Turvey, C.G. and Godah, A., 1990. Decomposition measures of technical efficiency for Ontario dairy farms. *Canadian Journal of Agricultural Economics* 38, 439-56.

Welch, F., 1970. Education in production. *Journal of Political Economy* 8, 35-59.

Table 1

Summary Statistics of the Variables by Size Class

Variable	Small (<50 str)		Medium (50-100 str)		Large (>100 str)	
	Mean	Stdev	Mean	Stdev	Mean	Stdev
Output (kgs)	10,646	4,101	20,030	7,442	38,914	12,754
Labour (hours)	804	459	1,574	1,242	2,890	2,030
Capital (EUR)	1,014	86	2,781	145	7,157	1,063
Fertilizers (kgs)	2,944	219	6,564	243	14,542	1,598
Seeds (kgs)	157	17	408	30	1,082	103
Land (stremmas)	38	9	76	13	138	38
Specialization (%)	87	19	93	12	91	11
Age (years)	54	7.0	53	6.8	52	6.6
Education (years)	2.0	0.3	2.1	0.4	2.1	0.5
Total Assets (EUR)	10,076	1,601	15,563	2,466	18,440	3,449
Fragmentation (# of plots)	2.7	1.6	4.7	3.2	7.9	4.9

Table 2

Parameter Estimates of the Translog Stochastic Production Frontier and Inefficiency Effects Model for Greek Cotton Farms

Parameter	Estimate	Std Error	Parameter	Estimate	Std Error
Stochastic Production Frontier					
β_0	0.1350	(0.0319)*			
β_L	0.0962	(0.0398)**	β_{CF}	-0.1502	(0.1935)
β_C	0.2749	(0.0697)*	β_{CS}	-0.3112	(0.1556)**
β_F	0.1078	(0.0470)**	β_{CA}	0.0553	(0.1444)
β_S	0.3458	(0.0674)*	β_{CC}	0.2537	(0.0930)*
β_A	0.5472	(0.0633)*	β_{FS}	0.0085	(0.2692)
β_{LC}	0.0153	(0.0975)	β_{FA}	0.1419	(0.0684)**
β_{LF}	-0.0821	(0.1312)	β_{FF}	-0.2832	(0.1274)**
β_{LS}	0.2707	(0.0949)*	β_{SA}	0.0975	(0.0421)**
β_{LA}	-0.1521	(0.0722)**	β_{SS}	0.0100	(0.1206)
β_{LL}	0.0337	(0.0124)*	β_{AA}	-0.1380	(0.0673)**
Inefficiency Model					
δ_0	-1.0766	(0.1480)*			
δ_{Spec}	0.3789	(0.1473)**	δ_{Edu}	-0.1985	(0.0816)**
δ_{Age}	-0.7147	(0.3560)**	δ_{Ass}	-0.0030	(0.0011)*
δ_{Age2}	0.0073	(0.0036)**	δ_{Frg}	0.0978	(0.0307)*
σ^2	0.2164	(0.0643)*	γ	0.9156	(0.0359)*
$Ln(\theta)$	-14.398				

L denotes labor, *C* capital, *F* fertilizers, *S* seeds, *A* area, *Spec* farm's specialization, *Age* farmer's age, *Edu*r farmer's education, *Ass* assets and *Frg* farm's fragmentation.

*(**) indicate significance at the 1 (5)% level.

Table 3

Model Specification Test

Hypothesis	LR-statistic	Critical Value (α=0.05)
$\gamma = \delta_0 = 0$	14.71	$\chi^2_{(2)} = 5.14$
$\gamma = \delta_0 = \delta_m = 0 \ \ \forall m$	38.27	$\chi^2_{(8)} = 14.85$
$\delta_0 = \delta_m = 0 \ \ \forall m$	30.25	$\chi^2_{(7)} = 14.07$
$\delta_m = 0 \ \ \forall m$	26.57	$\chi^2_{(6)} = 12.59$

Note: When the null hypothesis involves the restriction of γ=0 then the test statistic follows a mixed chi-squared distribution the critical values of which are obtained from Kodde and Palm (1986, table 1).

Table 4

Production Elasticities and Returns to Scale of Greek Cotton Farms by Size Class

	Small (<50 str)	Medium (50-100 str)	Large (>100 str)	All Farms
Labor	0.0893	0.0645	0.0957	0.0832
Capital	0.2691	0.2880	0.2621	0.2731
Fertilizers	0.1818	0.1596	0.0946	0.1453
Seeds	0.1483	0.2336	0.4068	0.2629
Area	0.7034	0.6079	0.4905	0.6006
RTS	1.3919	1.3536	1.3497	1.3651

Table 5

Frequency Distribution of Technical and Scale Efficiency

Efficiency (%)	TE_i^O	TE_i^I	SE_i^O	SE_i^I
<20	0	0	0	0
20-30	0	1	0	0
30-40	2	1	1	0
40-50	7	9	1	1
50-60	91	7	7	2
60-70	33	16	13	13
70-80	19	36	45	25
80-90	15	59	68	64
>90	5	43	37	67
N	172	172	172	172
Mean	62.20	79.56	81.02	85.67
Minimum	33.11	21.45	34.45	40.79
Maximum	97.12	97.02	100.00	100.00
Small (<50 str)	59.54	81.94	78.67	82.75
Medium (50-100 str)	63.91	78.42	81.83	86.80
Large (>100 str)	62.28	78.89	82.16	86.90

Table 6

Potential Cost Savings for Cotton Farms by Size Class

	Actual Cost per Stremma[1]	Potential Cost Reduction[1]
Small (<50 str)	33.9	6.1 (18.1)
Medium (50-100 str)	68.1	14.8 (21.6)
Large (>100 str)	132.6	27.9 (21.1)
All Farms	78.2	16.3 (20.4)

[1] In EUR. One stremma equals 0.1 ha. Numbers in parentheses are the corresponding percentage values.

Endnotes

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[1] One stremma equals 0.1 ha.

[2] The two measures of technical efficiency differ by the degree of returns to scale; thus they coincide under constant returns to scale (Färe and Lovell, 1978).

[3] The main advantage of Battese and Coelli (1993; 1995) formulation is that it allows the measurement of output-oriented technical inefficiency and the examination of its differentials among farmers in a single-stage. The two-stage approach, frequently used in the relevant literature, has been recognized as one that is inconsistent with the assumption of identically distributed inefficiency effects in the stochastic frontier, which is necessary for the ML estimation of the model (Reifschneider and Stevenson, 1991; Kumbhakar *et al.*, 1991).

[4] The predictor is based on the conditional expectation of u_i (or the function of u_i, depending on whether the dependent variable is in levels or in logs) upon the observed value of e_i Battese and Coelli (1993) provide the formula of the respective likelihood function along with its first-order partial derivatives.

[5] This duality property between physical inputs and total cost is not palatable for output-oriented technical inefficiency, expect in the special case of constant returns to scale.

[6] In the context of data envelopment analysis (DEA) it is called *most productive scale size*-MPSS (Banker, 1984).

[7] A geometric exposition of this point is presented in Ray (1998).

[8] The estimation of the stochastic frontier model was carried out using the FRONTIER computer program (Coelli, 1992).

[9] It should be noted here 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 is equal to $[(\pi - 2)/\pi]\sigma_u^2$ not σ_u^2. The relative contribution of the inefficiency effects to the total variance term is equal to $\gamma^* = \gamma/\{\gamma + [\{(1-\gamma)\pi\}/(\pi - 2)]\}$ (Greene, 1999, p. 101).

[10] Another way of viewing this hypothesis is that the stochastic frontier model reduces to the original half-normal frontier model suggested independently by Aigner *et al.*, (1977) and Meeusen and Van der Broeck (1977).

[11] Although individual technical efficiency scores are not reported herein are available from the authors upon request.

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[12] These estimates are obtained by multiplying total average cost by $\left(1 - TE_i^I\right)$.

[13] However, Weersink *et al*., (1990) argued that inexperienced farmers tend to acquire more easily knowledge about recent technological advances than their older counterparts.

[14] In a different analytical framework Karagiannis and Pantzios (2002) show that full compliance with (rather than consistent violation of) the country-level production quota imposed by the current EU cotton regime would make Greek cotton farmers better-off. The empirical results of the present study come as an additional building block to the view that Greek cotton farmers can maintain their farm income by fully abiding to production controls and reducing production costs via efficiency improvements rather than persistently demanding ever higher, administrative prices.