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Investigation of Factors Influencing the Technical Efficiency of Agricultural Producers Participating in Farm Credit Programs: The Case of Greece

Anthony N. Rezitis, Kostas Tsiboukas, and Stauros Tsoukalas

This study investigates a number of factors influencing technical efficiency of Greek farms participating in the 1994 European Union (EU) farm credit program. Technical efficiency measures are obtained within the framework of a parametric stochastic frontier. Factors showing a positive effect on technical efficiency are value of liabilities, number of hours of mechanical operation, large land size, and rental land, whereas those showing a negative effect are value of EU product subsidies, value of off-farm family income, and hired labor. The value of investments incurred by farms because of their participation in the 1994 farm credit program does not show any significant effect on technical efficiency. The predicted levels of technical efficiency indicate that the average technical efficiency of farms 3 years after participating in the 1994 farm credit program is lower than the average technical efficiency of the same farms the year before participating in the program. Thus, the program has failed to increase the efficiency of farms.

Key Words: farm credit program, stochastic frontier, technical efficiency

JEL Classifications: Q10, Q12, Q16, Q19

The Farm Credit Program (FCP) is a policy measure implemented by the European Union (EU) since 1973 and has been available to all EU member countries since then. The program has been implemented in Greece since 1983.[1] It is financed by national (30%) and EU (70%) budgets. The aims and main guidelines of the program are set at the EU level, whereas the program is implemented at the national level. In general, farmers who want to participate in the program should submit a business development plan that provides detailed information about planned investment activities and expected total revenues. On the basis of the submitted business plans, loans at subsidized interest rates are provided primarily for investments on machinery, buildings, plantation, animals, and so on. The selection of farms is based on at least one of the following criteria: past and expected future farm income, production structure of the farm, size and planned growth of the farm, and past and expected future productivity of the farm.

Anthony N. Rezitis is assistant professor, Department of Farm Organization and Management, School of Natural Resources and Enterprise Management, University of Ioannina, Agrinio, Greece. Kostas Tsiboukas and Stauros Tsoukalas are assistant professors, Department of Agricultural Economics, Agricultural University of Athens, Athens, Greece.

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[1] Greece entered the European Union in 1981.

For the period 1983–1998, 77,510 business development plans were submitted, of which 69,937 (i.e., about 90%) were approved. The average percent subsidy provided by the FCP to the approved business plans is about 42% of the value of investments. The average value of investments of the approved business development plans is about 8 million drachmas, compared to 8.4 million drachmas of the submitted and 12.7 million drachmas of the rejected plans. This indicates that the average value of investments proposed by the rejected business development plans is greater than the average value of the submitted plans because the rejected development plans come from farms with large economic size, which however, do not fulfill all the criteria for their acceptance into the FCP.

The FCPs are intended to provide farmers with agricultural credit at subsidized rates. Such programs aim mainly to increase the productivity of farmers by improving their access to capital markets and therefore providing them with the opportunity to invest in more modern and productive technologies. There is, however, a considerable lack of consensus regarding the effectiveness of such credit programs (Adams). Specifically, the "poor but efficient" hypothesis of Shultz states that traditional farmers can be considered efficient, even though they are constrained with technological barriers that cannot be overcome by the simple provision of new capital inputs provided by credit programs alone. In addition, Steitieh, studying agriculture in southern Brazil, indicated that although credit programs give traditional farmers the opportunity to invest in more modernized capital inputs, there is no assurance that these inputs will be used in an efficient manner so as to achieve the possibility of full output gains. In particular, Steitieh (p. 96) states that "increased investment in inputs (capital formation), such as mechanized equipment and fertilizer alone is not the answer to increasing crop production. Better management, information, and utilization of resources are as important and should be equally emphasized if any benefit is to be expected from increasing expenditures on these inputs." Furthermore, Taylor, Drummond, and Gomes, examining the effectiveness of subsidized credit programs in southern Brazil, suggested that such programs had no effect on technical efficiency and a slight negative effect on allocative efficiency.

Striewe, Loy, and Koester compared the competitiveness of a group of German farms participating in a FCP with a group of nonparticipating farms, and they found that the FCP did not significantly increase the competitiveness of participating farms compared to the nonparticipating farms. Brummer and Loy analyzed technical efficiency of a group of northern Germany dairy farms that participated in the European FCP over the period 1987–1994. They observed that, on average, the program had led to a slight decrease in technical efficiency of participating farms.

The goal of this study was to evaluate the effects of factors influencing technical efficiency of Greek farms participating in the 1994 EU FCP (i.e., regulation 2328/91). A representative sample of 241 farms, randomly selected from a population of 2,600 Greek farms participating in the 1994 EU FCP is used. Two farm-level economic data sets of the 241 farms were obtained from the 1993 and 1997 annual surveys. The 1993 data set describes the economic conditions of the 241 farms the year before participation in the program, whereas the 1997 data set shows their condition 3 years after the date of participation in the program. It is assumed that all planned investments have been completed during this 3-year period (i.e., 1994–1996), as specified in the regulations of the program.

Technical efficiency measures were obtained within the framework of a stochastic parametric approach. More specifically, the stochastic frontier model of Battese and Coelli (1995) was applied with a translog production function. The advantage of this approach is, first, that it allows the simultaneous estimation of the determinants of technical inefficiencies and the parameters of the production function and, second, that it permits the estimation of both time-varying inefficiencies and technical change in the production function.

This paper is organized as follows. The next two sections give the details of the empirical specification and the data used in the estimation. The fourth section presents and discusses the empirical results. Conclusions and policy implications of the study are suggested in the final section.

Model Specification

The conventional stochastic frontier approach, which was independently proposed by Aigner, Lovell, and Schmidt and Meeusen and van den Broeck, involves estimation of a function with an error term composed of two independent components. The one-sided component accounts for technical inefficiency, and the symmetric component accounts for random factors outside the farmer's control (e.g., weather, disease, floods, topography, etc.), measurement errors on the dependent variable, and other statistical noise. A comprehensive review of the literature pertaining to the econometric estimation of stochastic frontiers is provided by Bauer and Greene (1993). In this study, the Battese and Coelli (1995) model, which constitutes an extension of the conventional stochastic frontier approach, is used. The model developed by Battese and Coelli (1995) builds on Kumbhakar, Ghosh, and McGuckin and Reifschneider and Stevenson and allows for identification of factors explaining differences in efficiency levels among observed decision making units. The general stochastic frontier production function can be expressed as

$$(1)\quad Y_{it} = f(X_{it}; \beta)\exp(V_{it} - U_{it}),$$

where Y_{it} is the output of the ith farm ($i = 1, 2, \ldots, N$) at the tth time period ($t = 1, 2, \ldots, T$); X_{it} is a vector of inputs of the ith farm at the tth time period; β is a vector of parameters to be estimated; and $f(\cdot)$ denotes a functional form, such as the translog function, which is used in this study. Hence, the general stochastic frontier production function of Equation (1) is specified here as a translog function with the form

$$(2)\quad \ln Y_{it} = \beta_0 + \sum_{j=1}^{4} \beta_j \ln X_{jit} + \left(\frac{1}{2}\right) \sum_{j=1}^{4} \sum_{k=1}^{4} \beta_{jk} \ln X_{jit} \ln X_{kit} + \beta_5 t + V_{it} - U_{it},$$

where X_{jit} and X_{kit} ($j, k = 1, \ldots, 4$) denote inputs used in the production process of the ith farm at the tth time period and represent capital (X_{1it}, value in drachmas of fixed assets), labor (X_{2it}, number of hours of human labor used), land (X_{3it}, area operated in stremmas),[2] and production inputs (X_{4it}, value in drachmas); t is the linear time trend (1993 = 1 and 1997 = 2), which accounts for Hicksian neutral technological change; V_{it} is the random error that is assumed independent and identically distributed—$N(0, \sigma_V^2)$—and depends on factors outside the control of the farmer (i.e., measurements errors, weather, etc.); U_{it} is a nonnegative random variable associated with technical inefficiency of production and measures the extend to which the observed output falls below the potential output for given levels of inputs and technology. It has usually been assumed that this component has an independent and identical half-normal distribution, even though a variety of other distributional assumptions are possible (Greene 1997). However, in the Battese and Coelli (1995) model, U_{it} is specified as a function of farm-specific factors believed to influence technical inefficiency. More specifically, U_{it} is defined by the truncation (at 0) of the $N(\mu_{it}, \sigma_U^2)$ distribution, in which the general form of the farm-specific mean, μ_{it}, is specified as

$$(3)\quad \mu_{it} = \delta_0 + z_{it}\delta,$$

where z_{it} is a vector of variables explaining technical inefficiency of farms and δ is a vector of parameters to be estimated. In this study, the model of technical inefficiency effects in Equation (3) is specified as

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[2] One stremma is equal to 1,000 m^2 (about one-quarter of an acre).

$$(4)\quad \mu_{it} = \delta_0 + \delta_1 S_{it} + \delta_2 C_{it} + \delta_3 I_{it} + \delta_4 B_{it} + \delta_5 M_{it} + \delta_6 t + \delta_7 D_{1it} + \delta_8 D_{2it} + \delta_9 D_{3it} + \sum_{j=2}^{4} \delta_{1j} D_{1jit} + \sum_{k=2}^{12} \delta_{2k} D_{2kit},$$

where S_{it} denotes EU subsidies (value in millions of drachmas) obtained by the ith farm at the tth time period; C_{it} denotes investment (value in millions of drachmas) incurred by the ith farm at the tth time period due to the FCP; I_{it} denotes off-farm family income of the ith farm at the tth time period (value in millions of drachmas); B_{it} denotes liabilities (value in millions of drachmas) of the ith farm at the tth time period; M_{it} denotes number of hours of mechanical operation in the ith farm at the tth time period; t denotes year (1993 = 1; 1997 = 2), which indicates that the inefficiency effects can change linearly with respect to time; D_{1it} is a dummy variable with a value of 1 (or 0) if the land size of the ith farm is greater (or less) than 100 stremmas at the tth time period; D_{2it} is a dummy variable with a value of 1 (or 0) if the ith farm rents (or does not rent) land at the tth time period; D_{3it} is a dummy variable with a value of 1 (or 0) if the ith farm hires (or does not hire) labor at the tth time period; and D_{1jit}, where $j = 1, \ldots, 4$, is a dummy variable indicating the region in which the ith farm is located. In the specification of Equation (4), three location dummies are included[3] to capture farming and environmental differences among farms located in different regions. It is assumed that farmers located in the same region apply similar farming techniques because of their proximity and are faced with a similar physical environment, soil quality, and climate; and D_{2kit}, where $k = 1, \ldots, 12$ is a dummy variable indicating the main type of agricultural output of the ith farm at the tth time period. Farms have been classified into 12 categories according to their main direction of production activity.[4] This set of dummy variables is included to capture differences in farming practices among farms producing different types of outputs.

The maximum likelihood method is used for simultaneous estimation of the parameters of the stochastic frontier translog production function in Equation (2) and the technical inefficiency effects of the model in Equation (4). Battese and Coelli (1993) present the likelihood function and its partial derivatives with respect to the parameters of the model. It is worth noting that the likelihood function is expressed in terms of the variance parameters $\sigma^2 = \sigma_V^2 + \sigma_U^2$ and $\gamma = \sigma_U^2/(\sigma_V^2 + \sigma_U^2)$ because this transformation facilitates the estimation process (Battese and Corra). The variance parameter $\gamma = \sigma_U^2/(\sigma_V^2 + \sigma_U^2)$ takes values between 0 and 1. Values of γ close to 0 indicate that the symmetric error V_{it} dominates the one-sided error U_{it}. This implies that the disparity between the observed output and the frontier output is primarily due to factors outside the control of the farmers. On the other hand, values of γ close to 1 indicate that the one-sided error U_{it} dominates the symmetric error V_{it}, and this means that the disparity between the observed output and the frontier output is mainly attributed to technical (in)efficiency. Predictions of technical efficiency of production of the ith farm at the tth time period are calculated according to Equation (5),[5]

$$(5)\quad TE_{it} = \exp(-U_{it}).$$

These predictions are obtained by using the conditional expectation of Equation (5), given the error term of the stochastic frontier (i.e., $V_{it} - U_{it}$) and evaluated with the estimated pa-

[3] The following four regions are considered: Macedonia–Thrace, Hepirus–Peloponnese–Ionian Islands, Thessaly, Sterea Hellas–Crete–Aegean Islands.

[4] Farms were classified according to their main production activity into the following 12 categories: grain, cotton, horticulture and flowers, olive crops, viticulture, sheep breeding, cattle breeding, tobacco and other tilling cultivation, other permanent cultivation, multicultivation, ruminants, and a combination of plant cultivation and animal breeding.

[5] Note that $0 \leq TE_{it} \leq 1$. Hence, a farm at time t achieves 100% technical efficiency, $TE_{it} = 1$, if the farm is able to provide the maximum output from a given level of inputs.

rameters of the stochastic frontier (Battese and Coelli 1988; Jondrow et al.).

It is possible that certain hypothesis tests can be performed in the model presented in this study (i.e., Equations [2] and [4]). First, if all the δ parameters and the variance parameter γ are 0, then the model is reduced to the traditional average production function, which assumes that all farms are fully technically efficient. A model specification such as this can be estimated by ordinary least squares (OLS) regression. Second, if the variance parameter γ is 0, then the inefficiency effects are not stochastic and the model is reduced to the traditional average production function, in which the variables explaining inefficiency (i.e., the *z*s) are included in the production function. Third, if all the δ parameters except the intercept term are 0, then the model is reduced to the panel data version model of Aigner, Lovell, and Schmidt. Finally, a number of hypothesis tests should be performed regarding restrictions on the parameters of the translog production function in order to test whether a simpler functional form, such as Cobb-Douglas, is more appropriate.[6] In this study, the generalized likelihood ratio procedure is used to test the previously mentioned hypothesis. This involves the calculation of the generalized likelihood ratio statistic,

$$(6) \qquad \lambda = -2[LLF(H_0) - LLF(H_A)],$$

where $LLF(H_0)$ and $LLF(H_A)$ are the values of the log-likelihood function under the null and alternative hypotheses, respectively. This λ statistic has asymptotic chi-square distribution or mixed chi-square distribution when the null hypothesis involves $\gamma = 0$ (Coelli 1995), with degrees of freedom equal to the number of restrictions imposed under the null hypothesis.

Data

The data set used in this paper consists of 482 observations from a complete panel of 241 farms observed during 1993 and 1997. The sample of 241 farms was randomly selected from a population of 2,600 Greek farms participating in the 1994 European FCP. The data set used in this paper was created from data obtained from two annual surveys (i.e., the 1993 and 1997 annual surveys). The 1993 annual survey provides data describing the economic conditions of farms the year before participating in the 1994 FCP, whereas the 1997 annual survey provides data showing their condition 3 years after the date of participation in the program. All planned investments were assumed to have been completed during this 3-year period (i.e., 1994–1996) because it was also expected by the program.

The 241 farms are multiproduct enterprises, and they are classified into 12 categories according to their main production activity: grain, cotton, horticulture and flowers, olive crops, viticulture, sheep breeding, cattle breeding, tobacco and other tilling cultivation, other permanent cultivation, multicultivation, ruminants, and a combination of plant cultivation and animal breeding. It would be ideal to estimate separate production frontiers for each of the 12 main production activities because these 12 production activities might not be accurately represented by a single production frontier. However, this was not possible because even though detailed output data were collected for every farm, the corresponding input data for each product of each farm were not recorded separately. In other words, separate records of labor, capital, and production inputs used in each of the above 12 production activities were not recorded. Thus, the variables used in the estimation of the model are necessarily highly aggregated, and most of them are presented in value terms. Note, how-

[6] In most empirical studies examining inefficiency in the agricultural sector, simple forms of the production function, such as Cobb-Douglas, have been used. The translog production function represents a more general representation of production structure and permits the estimation of more general substitution and scale possibilities than simpler functional forms, such as Cobb-Douglas. However, this is achieved at the expense of estimating more parameters. The estimation of a translog production structure will result in inefficient estimates if the production technology is better presented by a simpler functional form. Thus, a number of hypothesis tests regarding restrictions on the coefficients of the translog functional form should be performed to test whether a simpler form, such as Cobb-Douglas, should be used.

ever, that variables in value terms are expressed in 1993 constant prices.

Table 1 presents the variables used in the estimation of the stochastic frontier production function in Equation (2) and the inefficient model of Equation (4). In the frontier production function in Equation (2), the dependent variable Y is the value in drachmas of gross farm output and includes the gross value of all final farm products and the "value added" to livestock over the year. Four inputs are considered in the estimation of the production function in Equation (2). The first input considered is the value in drachmas of capital, X_1, which includes the value of agricultural machinery and equipment, agricultural buildings, permanent cultivation, and livestock. The second input considered is labor, X_2, which is measured as the number of hours of human labor used on individual farms during the year, including operator, family, and hired labor. The third input is land area operated, X_3, measured in stremmas. The final input is the value in drachmas of production inputs, X_4, which includes expenses for fertilizer, lime, other chemicals, feeds, fodder, hay, veterinary care, and other miscellaneous livestock expenses per farm. Finally, a linear time trend, t (1993 = 1; 1997 = 2), accounts for Hicksian neutral technological change.

In the inefficiency model of Equation (4), various variables are included to explain technical inefficiency of the farms participating in the 1994 FCP.

- The value of EU subsidies for products, S, obtained by farms participating in the program.
- The value of investments, C, performed by farms participating in the program. The average value in the 1994 FCP is about 8.7 million drachmas. Farms participating in the program show particular interest toward specific investment categories. In particular, more than two-thirds of the total value of investments supported by the 1994 FCP is directed toward the following five investment categories: tractors and mechanical accessories (35.8%), drilling and related equipment (11%), greenhouses (8.4%), various mechanical equipment (7.3%), and agribusiness (6.6%). It should be stated that the purchase of additional tillable land was not financed by the program.
- The value of off-farm family income, I, of farms participating in the program.
- The value of liabilities, B, of farms participating in the program.
- The number of hours of mechanical operation, M, of farms participating in the program.
- Time, t, which indicates that the inefficiency effects can change with respect to time.
- A dummy variable, D_1, having value 1 (or 0) if the land size of the farm is greater (or less) than 100 stremmas.
- A dummy variable, D_2, having value 1 (or 0) if the farm rents (or does not rent) land.
- A dummy variable, D_3, having value 1 (or 0) if the farm hires (or does not hire) labor.
- Four dummy variables, D_{1j} ($j = 1, \ldots, 4$), indicating the region in which the farm is located. It is worth noting that farms located in Macedonia and Crete have invested in half of the total investments anticipated by the 1994 FCP.
- Twelve dummy variables, D_{2k} ($k = 1, \ldots, 12$), indicating the main type of agricultural output of farms participating in the program. The highest number of approved business development plans for the 1994 FCP comes from farms with *other permanent cultivation* (28%) as their main production activity, followed by farms with *a combination of plant cultivation and animal breeding* (14%), *horticulture and flowers* (12%), and *sheep breeding* (12%). Through the 1994 FCP, the highest investments were by farms with *grains* as their main production activity, followed by farms with *cattle breeding, a combination of plant cultivation and animal breeding, horticulture and flowers,* and *other permanent cultivation* as their main production activities. The lowest investments were performed by farms with *tobacco* as their main production activity, followed by farms with *olive crops, ruminants,* and *cotton* as their main production activities.

Table 1. Variables Used in the Estimation

Variable	Description[a]
Stochastic Frontier Model	
Gross Farm Output (Y)	Gross value (in drachmas) of all final farm products and the 'value added' to livestock over the year.
Capital (X_1)	Value (in drachmas) of agricultural machinery, equipment and buildings, permanent cultivation, and livestock during the year.
Labor (X_2)	Number of hours of operator, family, and hired farm labor during the year.
Land (X_3)	Area operated (in stremmas) during the year.
Production Inputs (X_4)	Value (in drachmas) of expenses on fertilizer, lime, other chemicals, feed, fodder, hay, veterinary care, and other miscellaneous livestock expenses during the year.
t	Time trend (i.e., 1993 = 1; 1997 = 2).
Inefficiency Model	
S	Value of EU product subsidies obtained by the farm (in millions of drachmas).
C	Value of investments incurred by the farm from its participation in the 1994 FCP (in millions of drachmas).
I	Value of off-farm family income (in millions of drachmas).
B	Value of liabilities (in millions of drachmas).
M	Number of hours of mechanical operation during the year.
t	Time trend (i.e., 1993 = 1; 1997 = 2).
D_1	1 if the land size of the farm is greater than 100 stremmas; 0 otherwise.
D_2	1 if the farm rents land; 0 otherwise.
D_3	1 if the farm hires labor; 0 otherwise.
D_{11}	1 if the region is Macedonia–Thrace; 0 otherwise.
D_{12}	1 if the region is Hepirus–Peloponnese–Ionian Islands; 0 otherwise.
D_{13}	1 if the region is Thessaly; 0 otherwise.
D_{14}	1 if the region is Sterea Hellas–Crete–Aegean Islands; 0 otherwise.
D_{21}	1 if the main production activity is grain; 0 otherwise.
D_{22}	1 if the main production activity is cotton; 0 otherwise.
D_{23}	1 if the main production activity is horticulture and flowers; 0 otherwise.
D_{24}	1 if the main production activity is olive crops; 0 otherwise.
D_{25}	1 if the main production activity is viticulture; 0 otherwise.
D_{26}	1 if the main production activity is sheep breeding; 0 otherwise.
D_{27}	1 if the main production activity is cattle breeding; 0 otherwise.
D_{28}	1 if the main production activity is tobacco and other tilling cultivation; 0 otherwise.
D_{29}	1 if the main production activity is other permanent cultivation; 0 otherwise.
D_{210}	1 if the main production activity is multicultivation; 0 otherwise.
D_{211}	1 if the main production activity is ruminants; 0 otherwise.
D_{212}	1 if the main production activity is combination of plant cultivation and animal breeding; 0 otherwise.

[a] Variables in the value terms are expressed in 1993 constant prices.

Results

Following Battese and Coelli (1995), maximum likelihood estimation is employed to simultaneously estimate the parameters of the stochastic frontier production function in Equation (2) and the technical inefficiency effects model of Equation (4). The model parameters are estimated with the FRONTIER 4.1 program (Coelli 1996). The estimation results for the stochastic translog production function in Equation (2) and the technical inefficiency effects of the model of Equation (4) are presented in Table 2.

The *t*-statistics presented in Table 2 provide an indication of the statistical significance of the corresponding coefficients.[7] The *t*-statistics of the coefficients of the translog production frontier indicate that half of the coefficients are significantly different from zero at the 5% level. This might suggest that the model shows a fairly good fit, given the presence of multicollinearity resulting from the inclusion of squared and interaction terms in the translog specification (Dawson; Hallam and Machado).[8]

The economic interpretation of the estimated coefficients of the translog production function can be accomplished with partial production elasticities. The elasticities of output with respect to inputs at the point of approximation are given by the first-order coefficients of the translog production function. Hence, from the estimates of the first-order coefficients shown in Table 2, the elasticities of output with respect to inputs have the following values (*t*-statistics follow in parentheses): capital .022 (0.379), labor .290 (5.264), land .020 (0.529), and production inputs .564 (7.914). The estimators of the elasticity for capital and land are quite low in value and statistically insignificant at the 5% significance level. In contrast, the output elasticities for production inputs and labor are statistically significant at the 5% level of significance. The estimator of elasticity for production inputs is the highest in value followed by the estimator of elasticity of labor. Hence, the estimators of the partial production elasticity indicate that the most important production factor is production inputs followed by labor. This result is also supported by the study of Rezitis, Tsiboukas, and Tsoukalas. The coefficient of the time trend, β_5, indicates that the value of output increased by a small but statistically insignificant rate over the period. In other words, the results indicate that there has not been any technical change during the period studied.[9]

Generalized likelihood ratio tests given by Equation (6) are performed to test various null hypotheses as listed in Table 3. Test 1 tests the null hypothesis that the Cobb-Douglas specification is an appropriate representation of the frontier production function against the alternative translog function form. The null hypothesis is rejected by the likelihood ratio test at the 5% significance level and hence favors the translog specification. Test 2 tests the null hypothesis of constant returns to scale (CRS) in the translog production function. The restrictions required to impose CRS in the translog specification of Equation (2) are presented in Table 3. In this study, these restrictions are imposed through a normalization of the output and the inputs by dividing them all by land.[10] The null hypothesis of CRS is rejected by the test at the 5% significance level. It is worth noting that the sum of the production elasticities at the point of approximation is less than 1 (i.e., .895), indicating the presence of

[7] An absolute *t*-ratio value greater than 1.96 suggests that the corresponding coefficient is significantly different from 0 at the 5% level.

[8] Dawson and Hallam and Machado note that the estimates of the production frontier parameters are not of primary interest when the goal is to measure efficiency; in this case, the overall power of the estimated function is of greater importance.

[9] The time trend, *t*, was included in the production function in Equation (2) to account for Hicksian neutral technical change. The production function in Equation (2) was also extended to capture nonneutral technical change by incorporating terms such as the interactions between the logs of inputs and the time trend. The null hypothesis that the coefficients of the interactions between the logs of the inputs and the time trend were equal to 0 could not be rejected at the 5% significance level.

[10] Results will be invariant to the choice of input used for normalizing the other input and output variables.

Table 2. Maximum Likelihood Estimates for Parameters of the Stochastic Frontier with Inefficiency Effects Model Involving Farm-Specific Variables

Parameter	Variables	Estimate	Standard Error	*t*-Statistic
Stochastic Frontier				
β_0		0.8296	0.0908	9.1378**
β_1	$\ln X_1$	0.0221	0.0584	0.3786
β_2	$\ln X_2$	0.2899	0.0551	5.2635**
β_3	$\ln X_3$	0.0195	0.0369	0.5294
β_4	$\ln X_4$	0.5637	0.0712	7.9139**
β_5	t	0.0027	0.0487	0.0551
β_{11}	$(\ln X_1)^2$	0.0380	0.0191	1.9895*
β_{22}	$(\ln X_2)^2$	0.0706	0.0122	5.7899**
β_{33}	$(\ln X_3)^2$	−0.0055	0.0134	−0.4096
β_{44}	$(\ln X_4)^2$	0.0465	0.0230	2.0217*
β_{12}	$\ln X_1 \times \ln X_2$	0.1018	0.0476	2.1395*
β_{13}	$\ln X_1 \times \ln X_3$	−0.0199	0.0322	−0.6209
β_{14}	$\ln X_1 \times \ln X_4$	0.0038	0.0477	0.0792
β_{23}	$\ln X_2 \times \ln X_3$	−0.0043	0.0229	−0.1865
β_{24}	$\ln X_2 \times \ln X_4$	−0.1499	0.0345	−4.3467**
β_{34}	$\ln X_3 \times \ln X_4$	0.0165	0.0363	0.4554
Inefficiency Model				
δ_0		−11.4238	2.5035	−4.5632**
δ_1	S	0.3093	0.0513	6.0263**
δ_2	C	−0.0190	0.0143	−1.3304
δ_3	I	0.5534	0.0596	9.2891**
δ_4	B	−0.0411	0.0204	−2.0214*
δ_5	M	−1.4525	0.1320	−11.0032**
δ_6	t	2.8098	0.3691	7.6131**
δ_7	D_1	−2.7442	0.4748	−5.7797**
δ_8	D_2	−1.2379	0.2993	−4.1369**
δ_9	D_3	1.1981	0.3998	2.9965**
δ_{12}	D_{12}	−3.2567	0.6684	−4.8720**
δ_{13}	D_{13}	−2.1280	0.6546	−3.2508**
δ_{14}	D_{14}	0.1124	0.6519	0.1724
δ_{22}	D_{22}	5.5352	1.9255	2.8747**
δ_{23}	D_{23}	−2.1543	1.0678	−2.0175*
δ_{24}	D_{24}	1.8179	0.9119	1.9935*
δ_{25}	D_{25}	3.5643	1.7377	2.0512*
δ_{26}	D_{26}	1.4118	0.7093	1.9904*
δ_{27}	D_{27}	1.1436	1.5201	0.7523
δ_{28}	D_{28}	1.8443	0.9253	1.9931*
δ_{29}	D_{29}	5.9922	1.8059	3.3179**
δ_{210}	D_{210}	1.3435	1.6138	0.8325
δ_{211}	D_{211}	0.6489	1.8509	0.3506
δ_{212}	D_{212}	3.6076	1.5848	2.2763*
Variance Parameters				
σ^2		3.2659	0.4287	7.7598**
γ		0.9749	0.0043	226.6608**
Log-likelihood Function		−293.5515		

Notes: Significant at the ** 1% or * 5% level.

Table 3. Generalized Likelihood Ratio Tests of Hypotheses for Parameters of the Stochastic Frontier Production Function and Inefficiency Effects Model[a]

Test		Null hypothesis	λ	Critical Value	Decision
1	H_0:	$\beta_{11} = \beta_{22} = \beta_{33} = \beta_{44} = \beta_{12} = \beta_{13} = \beta_{14} = \beta_{23} = \beta_{24} = \beta_{34} = 0$	34.700	18.307	Reject H_0
2	H_0:	$\beta_1 + \beta_2 + \beta_3 + \beta_4 = 1$ $\beta_{11} + \beta_{12} + \beta_{13} + \beta_{14} = 0$ $\beta_{12} + \beta_{22} + \beta_{23} + \beta_{34} = 0$ $\beta_{13} + \beta_{23} + \beta_{33} + \beta_{34} = 0$ $\beta_{14} + \beta_{24} + \beta_{34} + \beta_{44} = 0$	12.418	11.071	Reject H_0
3	H_0:	$\gamma = \delta_0 = \delta_1 = \cdots = \delta_{211} = \delta_{212} = 0$	222.201	35.827	Reject H_0
4	H_0:	$\gamma = 0$	190.731	2.706	Reject H_0
5	H_0:	$\delta_1 = \delta_2 = \cdots = \delta_{211} = \delta_{212} = 0$	206.048	35.173	Reject H_0

Note: λ is the generalized likelihood ratio statistic given by Equation (6) in this paper.
[a] All tests performed at the 5% significance level.

decreasing returns to scale in the production technology. This result is also supported by the study of Rezitis, Tsiboukas, and Tsoukalas. The null hypothesis explored in test 3 assumes that all farms are fully technically efficient. The restrictions required for testing this hypothesis are that all δ parameters and the variance parameter, γ are 0. The null hypothesis is rejected in favor of the alternative hypothesis, which supports that at least one of the farms is not fully technically efficient.[11] Test 4 tests the null hypothesis that the variance parameter γ is 0. If the null hypothesis is correct, then the model is reduced to a traditional mean response function, in which the variables explaining inefficiency are included in the production function. In this case, the parameters δ_0 and δ_6 are not identified. Thus, the critical value for the test statistic for this hypothesis is obtained from a mixed chi-square distribution with three degrees of freedom.[11] The null hypothesis is rejected in favor of the alternative hypothesis, which supports $\gamma \neq 0$. The final test examines the null hypothesis of whether the variables included in the inefficiency effects model have no effect on the level of technical inefficiency (i.e., all the δ parameters except the intercept term are 0). Again, the null hypothesis is rejected, indicating that the joint effect of the variables included in the inefficiency effect model is statistically significant.

The parameter estimates for the inefficiency model (i.e., the δs) presented in Table 2 suggest a number of factors that could explain technical inefficiency. Nineteen of 24 parameters are statistically significant at the 5% level, which suggests a fairly good fit of the inefficiency model. The positive and statistically significant sign of the coefficient of EU product subsidies (S) indicates that an increase in the value of EU product subsidies obtained by the farm will result in an increase in the value of the technical inefficiency effect and, hence, a decrease in technical efficiency. This conforms to the expectation that EU product subsidies induce farmers to increase production in order to receive the subsidies but, however, decrease farmers' incentives to achieve higher productivity and profitability and, in turn, reduce their motivation for improving efficiency in the production process. The statistically insignificant coefficient of investments C incurred by the farm by its participation in the 1994 FCP shows that investments from program participation do not have any significant effect on technical efficiency. This finding is in agreement with other studies (i.e., Brummer and Loy; Shultz; Steitieh; Striewe, Loy, and Koester; Taylor, Drummond, and Gomes), which argue that although credit programs do

[11] Note that for this hypothesis test, the λ statistic has a mixed chi-square distribution because the null hypothesis involves $\gamma = 0$ (Coelli 1995). Following Coelli and Battese, the critical value for this test is taken from Kodde and Palm (table 1, p. 1246).

give farmers the opportunity to invest in more modernized capital inputs, they do not provide assurance that these inputs will be used in an efficient manner that allows farmers to realize the full extent of possible output gains.

The positive and statistically significant sign of the coefficient of off-farm family income (I) indicates that an increase in the value of off-farm income will cause an increase in the value of technical inefficiency effect and, hence, a decrease in technical efficiency. This is expected because the allocation of more time to off-farm work has a negative effect on farm activities and, as a result, reduces efficiency, even though it generates extra cash for the family. The negative and statistically significant sign of the coefficient of liabilities (B) indicates that an increase in the value of liabilities will cause a decrease in technical inefficiency and, hence, an increase in technical efficiency. This result is expected because as liabilities rise, farmers seek to improve efficiency in production to increase profits and offset the higher level of liabilities. Furthermore, this finding is supported by the increase of the debt-to-assets ratio for the farms participating in the program (i.e., from 3% in 1993 to 3.5% in 1997, on average).

The negative and statistically significant sign of the coefficient of the number of hours of mechanical operation (M) shows that an increase in the hours of mechanical operation will cause an increase in technical efficiency. The positive and statistically significant sign of the coefficient of time (t) indicates that the rate of technical inefficiency increases with time. In other words, the rate of technical inefficiency in the sample of 241 farms is greater in 1997 than the rate of technical inefficiency in 1993. The negative and statistically significant sign of the coefficient of the dummy variable of land size (D_1) shows that farms with large land size are more efficient than farms with small land size. The negative and statistically significant sign of the coefficient of the dummy variable that indicates whether the farm rents land (D_2), shows that farms that rent land are more efficient than farms that do not rent any land. The positive and statistically significant coefficient of the dummy variable that indicates whether the farm hires labor (D_3) shows that farms that hire labor are less efficient than farms that do not hire labor. This conforms to the expectation that family labor is more concerned about production processes on the farm than hired labor is. The coefficients of the regional dummies (D_{12}–D_{14}), as well as the coefficients of the main production activity dummies (D_{22}–D_{212}) show a significant variation of technical efficiency across regions and among production activities. It is worth noting that 2 (8) of 3 (11) coefficients corresponding to regional (main production activity) dummy variables are statistically significant.

The γ parameter associated with the variance of the technical inefficiency effects in the stochastic frontier is estimated to be close to unity (i.e., $\gamma = 0.9749$). This result indicates that technical inefficiency effects are a significant component of the total variability of output for the sample of 241 farms during 1993 and 1997.

The predicted levels of technical efficiency of each farm for the years 1993 and 1997 are aggregated into frequency distributions with class interval 0.1 and presented in Table 4. The results show a wide range in the level of technical efficiencies across farms in the 2 years. The ranges of farm-level technical efficiencies for 1993 and 1997 are 9.95–92.2% and 1.4–93.3%, respectively. None of the farms in the 2 years is fully technically efficient. Therefore, given the existing level of inputs, there is a possibility to increase farm output between 7.8 and 90.051% for 1993 and 6.7 and 98.60% for 1997. The sample means (SD) of technical efficiency for 1993 and 1997 are 74.0% (15.3%) and 69.5% (18.8%), respectively. These results indicate deterioration in technical efficiency from 1993 to 1997 because the mean value of technical efficiency decreases and the standard deviation increases. Moreover, the number of farms in the sample with an efficiency higher than 70% falls from 162 in 1993 to 147 in 1997. The sample means of efficiency measures indicate that, on average, output falls short of the maximum possible level by 26% in 1993 and 30.5% in 1997. Thus, given the existing inputs, there is a po-

Table 4. Frequency Distribution of Farm-Level Technical Efficiency

Technical Efficiency	1993 Frequency (Percentage)	1997 Frequency (Percentage)
$0.0 \le TE < 0.1$	1 (0.4%)	3 (1.2%)
$0.1 \le TE < 0.2$	0 (0.0%)	3 (1.2%)
$0.2 \le TE < 0.3$	4 (1.7%)	4 (1.7%)
$0.3 \le TE < 0.4$	6 (2.5%)	13 (5.4%)
$0.4 \le TE < 0.5$	8 (3.3%)	11 (4.6%)
$0.5 \le TE < 0.6$	22 (9.1%)	25 (10.4%)
$0.6 \le TE < 0.7$	38 (15.8%)	35 (14.5%)
$0.7 \le TE < 0.8$	51 (21.2%)	56 (23.2%)
$0.8 \le TE < 0.9$	96 (39.8%)	80 (33.2%)
$0.9 \le TE \le 1.0$	15 (6.6%)	11 (4.6%)
Descriptive Statistics of *TE*		
Sample Mean	0.740	0.695
Sample SD	0.153	0.188
Minimum	0.0995	0.014
Maximum	0.922	0.933

Note: TE is technical efficiency.

tential to increase the average farm output by 26 and 30.5% for the respective years.

The predicted levels of technical efficiency presented in Table 4 indicate that average technical efficiency of the farms 3 years after participating in the 1994 FCP (i.e., in 1997) is lower than the average technical efficiency of the same farms observed the year before participating in the 1994 FCP (i.e., in 1993). Thus, the program has failed to increase the efficiency of farms.

Conclusions and Policy Implications

This study investigated a number of factors that influenced the technical efficiency of Greek farms participating in the 1994 European FCP. Technical efficiency measures are obtained within the framework of the stochastic frontier approach of Battese and Coelli (1995). Among the factors showing a positive effect on the technical efficiency of farms participating in the program are value of liabilities, number of hours of mechanical operation, land size greater than 100 stremmas, and rental land. Factors showing a negative effect on technical efficiency are value of EU product subsides, value of off-farm family income, and hired labor. The results also show significant variation of technical efficiency across the regions in which the farms are located, as well as among the various production activities of the farms.

Finally, the value of investments incurred by the farms as a result of their participation in the 1994 FCP does not show any significant effect on technical efficiency. In addition, the predicted levels indicate that the average technical efficiency of farms 3 years after participating in the 1994 FCP is lower than the average of the same farms the year before participating in the program. Thus, the farm program has failed to increase the efficiency of farms. This finding supports the general idea that although investments from farm credit programs give farmers the opportunity to use more modern capital inputs, additional inputs, such as better management, information, and better utilization of resources, are needed to improve efficiency in the production process and thus to achieve the maximum output gains possible.[12]

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[12] It should be stated that these inputs (i.e., management, education, experience, information, degree of utilization of resources, etc.) are not available in the data set used in this study. Otherwise, these inputs would have been included in the technical inefficiency model.

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