Spatial efficiency analysis of arable crops in Greece

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ABSTRACT
The article investigates technical efficiency of the sector of arable cultures in Greece, that is one of the most important sectors in Greek agriculture. However, the productive process in the arable cultures in prefectures of Greece is executed with varying efficiency affecting also seriously the economic growth of the prefectures. Aim of the article is the investigation of those factors that influence technical efficiency of arable cultures' sector in Greece regarding the prefecture as the reference level and the formulation of advisable development policy proposals. Empirical analysis is based on the simultaneous existence of spatial effects and technical inefficiencies in a special category of production functions, that is to say the quasi production function which do not have any particular specification of the labour factor due the particularities of its nature. Estimation is performed within the framework of Spatial Seemingly Unrelated Regressions (SUR) and Data Envelopment Analysis (DEA). The data which are used in the empirical analysis have been collected from the Agricultural Statistics of year 1999 of National Statistical Service.

Keywords*:* Spatial SUR, Technical Efficiency, Arable cultures, Single Area Payment Scheme,

1. Introduction

Greece is located in the southeastern part of Europe covering a total area of 132.000 km^2. Greece is divided mostly for administrative purposes into 13 regions plus one autonomous territory; Ayion Oros (Mt Athos), which is located into the Chalkidiki Peninsula and has a monastic administration, since Greek Orthodox church is responsible for its administration. The above thirteen regions are also subdivided into 51 Counties in order for them to be better administered.

One of the main economic activities of this country is based on the agricultural sector, which is dominated by small-scale farmers who almost produce the majority of agricultural products. The main products of that sector are Arable crops, Rice, Beef and veal**,** Tobacco, Olive Oil and Cotton as well as the new aids of Specific quality premium for durum wheat, Area payments for nuts, Aid for energy crops, Dairy premium. Arable cultures are one of the most important products of that sector.

However, production of arable crops is taken effect through varying technical efficient ways. The reasons for that inefficiency could be found into the traditional technology of low productivity that most of the producers use, the high cost of the productive process, the large economies of scale etc.

The estimation of technical efficiency is one of the basic notions in neoclassical microeconomic theory. This term is connected closely with the rational use of available resources, that is to say it is used to describe a productive process that uses a given set of inputs and technology in the most optimal way. A farm is regarded as technical efficient or being at the optimal point, if it can manage to produce the maximum possible output with a given set of inputs employed in its productive process. Expressing that in mathematical terms, ''an input vector $\chi \in L(y)$ is technical efficient if and only if another input vector, smaller than the previous one, does not belong to the technical efficient set ($\chi' \notin L(y)$ for $\chi' \leq \chi$, where $L(y)$ is the set of all technical efficient combinations for the production of a fixed amount of output). Thus, we specify technical efficiency in terms of farm's participation in the technical efficient subset''[1]. Thereupon, a mathematical measure of the above technical efficiency will be the function $TE(\chi) = \min[\vartheta : \vartheta \times \chi \in L(y)]$ [2]. In other words, "if no equivalent reduction in the amount of inputs can be taken place at a specific combination of inputs, then that combination is technically efficient"[3]. However, in practice, this cannot be succeeded, since the notion of technical efficiency is an ideal situation which is difficult to be achieved. Thereupon, farms have to improve their production methods in order to become technical efficient.

The interest in studying technical efficiency in agriculture emerges initially from the peculiarities that agrarian production appears to have. As time goes by, a number of studies have been focused on that concept published for several countries and employed different methodologies. Subal C. Kumbhakar (1993) estimates technical efficiency of 227 farms in India through a translog production function. Tzouvelekas, Pantzios and Fotopoulos (2001) analyze technical efficiency of organic and conventional oil-growing farms in Greece using a stochastic production frontier model based on the translog function. Xiaosong Xu and Jeffrey Scott (1997) examine technical efficiency for hydrid and conventional rice in China via a dual stochastic frontier decomposition model. Almas Heshmati and Subal C. Kumbhakar (1994) introduce farm-heterogeneity in measuring technical efficiency of Swedish dairy farms using farm- level data.

Another attempt of examining technical efficiency in agriculture has been employed by George E. Battese (1992), who investigates the estimation of technical

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[1] Kumbhakar S. - Knox Lovell C. A. (Cambridge 2000), ''Stochastic Frontier Analysis '', Cambridge University Press.
[2] Kumbhakar S. - Knox Lovell C. A. (Cambridge 2000), ''Stochastic Frontier Analysis '', Cambridge University Press.
[3] Kumbhakar S. - Knox Lovell C. A. (Cambridge 2000), ''Stochastic Frontier Analysis '', Cambridge University Press.

efficiency of individual farms. Moreover, Abdourahmane Thiam, Boris E., Bravo Ureta and Teodoro E. Rivas (2001) used a dataset of 51 observations of technical efficiency in order to provide a better comprehension of the factors influencing technical efficiency in developing country agriculture. Furthermore, E.T. Seyoum, G.E. Battese, E.M. Fleming (1998) investigated technical efficiency of two samples of maize producers in eastern Ethiopia using stochastic frontier production functions.

Objective of the article is the investigation of those factors that influence technical efficiency of arable cultures' sector in Greece regarding the prefecture as the reference level and the formulation of advisable development policy proposals. The article is divided into an introduction and 7 other sections. The second and the third give a brief overview of the Common Agricultural Policy and the contribution of arable cultures in both Greek agriculture and Greek regional development. The fourth section builds on the notion of technical efficiency, while the fifth specifies the functional form of the model. The sixth unit describes the data used to our analysis demonstrating as well their statistical nature. The seventh unit contains the results of the empirical analysis and finally the eighth section summarizes the empirical conclusion of our analysis.

2. Aspects of Common Agricultural Policy

Common Agricultural Policy (CAP) has already fulfilled four decades of application, during which was revised many times. Its last reform started on June 2003, continued on April 2004 with the Mediterranean products and will be completed this year with the sugar, the fruits and vegetables and the wine sector. The new CAP Reform will completely change the way EU supports its farm sector. Its goal is on the one hand, to provide farmers reasonable standard of living and consumers better quality food at fair prices and on the other hand, to keep farm aids "untouched from the enemy fire" of World Trade Organization's criticism. Food safety, preservation of the rural environment and value for money are now all key concepts resulting into making CAP more demand driven. The reasons for that reform can be summarized to the following:

- The continuous enlargement of the European Union,
- The need for simplifying agricultural policy, stabilizing agricultural income and safeguarding of clear-cut perspectives of the European farmers,
- The unequal distribution of agricultural support amongst the European regions resulting into the abandonment of agriculture and by extension to the expansion of regional inequalities and the growth of regional problem,
- The negotiations with the World Trade Organization concerning agricultural products,
- The increased consumer's demand for safer nourishment and the continually increased sensitization of public opinion for protecting environment.

The legal base of that reform refers basically to the Council Regulation (EC) No 1782/2003 of 29 September 2003 "establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers and amending Regulations (EEC) No 2019/93, No 1452/2001, (EC) No 1453/2001, (EC) No 1454/2001, (EC) 1868/94, (EC) No 1251/1999, (EC) No 1254/1999, (EC) No 1673/2000, (EEC) No 2358/71 and (EC) No 2529/2001" and tops off with Council's regulations (EC) No. 1783/2003, (EC) 864/2004 and European Commission's Regulations No (EC) 795/2004, (EC) 796/2004, (EC) 1973/2004.

The new reform of Common Agricultural Policy introduces some new notions such as: “Single Area Payment”, “Cross-Compliance” model, “Degressivity-Modulation”, system of supplying agricultural advises, Regimes of Special Aid. In the context of the new reform, farmers are no longer paid just to produce food. Nowadays CAP is becoming more demand-driven. It takes consumers’ and taxpayers’ concerns fully into account, while giving EU farmers the freedom to produce what the market really wants. The past farm-supports will be united into a Single Farm Payment and be paid to farmers once per annum just by filling up a simple Aid Application, namely *Single Farm Payment Aid Application*, independently of what or how much they produce. Until nowadays, the more farmers produced, the more subsidy payments they received. Under the new system farmers will still receive an amount of subsidy that constitutes a stable agricultural income, but the link to production has been broken. More specifically, the amount of subsidy, namely *Payment Entitlement*, will be a function of two factors: the amount of subsidy granted to the farmer during the reference period 2000-2002 (or 1999-2002 for the olive oil regime) and the number of the eligible hectares cultivated into the aforementioned periods. More specifically, the amount of Payment Entitlement is extracted by dividing the three-year average of the total amounts of payments granted to a farmer during the reference period 2000-2002 (or the four-year average of total payments granted during 1999-2002 for the olive oil regime) (called Reference Amount) by the three-year or four year average number of hectares that farmer cultivated and gave right to direct farm aids during the aforementioned period (called Reference Area). However, taking the aforementioned subsidy presupposes on the one hand, the maintenance of at least the 80 % of the eligible hectares cultivated during the historical period and on the other hand, the respectfulness of communal guides regarding environmental, food safety and animal welfare standards. Farmers who fail to do this will face reductions in their direct payments (a condition known as ‘cross-compliance’). Severing the link between subsidies and production (usually termed ‘decoupling’) will make EU farmers more competitive and market-oriented. They will be free to produce according to what is most profitable for them while still enjoying a desirable stability of income.

The regimes taking part into the Single Farm Payment Scheme are the old aids of Arable crops, Rice, Beef and veal**,** Tobacco, Olive Oil and Cotton as well as the new aids of Specific quality premium for durum wheat, Area payments for nuts, Aid for energy crops, Dairy premium.

3. The importance of Arable Crops in Greek Regional Development

One of the most important regimes getting into the Single Farm Payment Scheme is Arable Crops. In this sector are included the cereals (Wheat, Rye, Barley, Oat, Maize, Sorghum in grains), Oil-seeds (Rape, sunflower, Soya), proteins (peas, sweet lupine, broad beans, lathyrus) and grass silage.

The arable cultures constitute one of the most important and productive sectors of Greek agriculture. Their long-lasting presence in Greek agriculture and the important role taking hand in the growth of countryside on account of their export orientation and the attraction of a big percentage of Community subsidies from the E.A.G.G.F.- Guarantees Section, render these in a foremost place amongst the Greek agricultural products adding to them particular interest for study. Moreover, this interest is also strengthened by the gravity European Union adds protecting them with a particular legal regime objecting to the expansion of competitiveness in the interior of member states against the imports from third countries and the respect of environment.

The importance of arable cultures is depicted from the fact that the E.A.G.G.F. - Guarantees Section gives subsidies of 17 billions of Euros roughly to this sector each year corresponding to the 40% of used agricultural area and the 21% of total agricultural income of European Union[4]. Regardless of Greece, arable cultures cover the 34% of cultivated extents while their production is calculated in 4.600.868 tons. Moreover that particular sector plays also very important role in Greek economy absorbing the 18% of Community subsidies annually and participating in a great degree into the exports of Greece. However, the mapping out of policy for the arable cultures imposes taking into consideration a line from factors[5], which are the following:

- The objectives of national economic policy, which seem to promote the concept of efficiency even sometimes against equality.
- The basic aims of national regional policy that many times tend they encourage the configuration of model of local growth.
- The geographical shaping of Greece, the size of country and the climatic conditions.
- The geographical distribution of urban centres and the demographical density of big urban centres and regions
- The continuously increasing regional inequalities and the complexion of regional problem.
- The economic framework that would promote Greece's regional development.
- The economic articulation of Greek regions, as well as other factors, such as their system of urban centres and their geographical location, are playing a very important role in the formulation of the right developmental strategy affecting most the sections concern the priorities in the backward territories, integrated development programs and the diffusion centres of development.

The regional developmental policy should aim at the complete exploitation of every particular characteristic each prefecture does have and the protection of regional internal economies of regions from the diffusive forces by the poles. The determination of the regional and intersectoral priorities that require need for intervention and constitutes one of the basic presuppositions for the application of a successful developmental policy, is a basic acceptable undoubtedly condition by both the model of polar growth and the model of integrated development. In this effort the more technically efficient prefectures in the production of arable cultures are used as the main axes through which growth is diffused into the other underdeveloped prefectures sweeping along in a completed program of balanced growth raising regional inequalities at the same time[6]. Moreover, it is investigated which arable cultures are technically more effective within the context of prefecture so as to turn the prefecture over these cultures increasing its total technical effectiveness. Finally, the promotional industries that use arable cultures as raw material in the production

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[4] European Committee, General management of Agriculture, "Reform of CAP: Arable cultures ".

[5] Papadaskalopoulos Athanassios. (Athens 1995), "Templates and policies of Regional development", Papazisi's Publications.

[6] ''In this point we stress the point that an opening of collaboration with the remainder countries of Balkan Peninsula would constitute an additional motive of improving technical efficiency of arable cultures' production providing also an additional motive of regional economic growth''-Konsolas, Papadaskalopoulos, Ranos, Sidiropoulos (Athens 1993), " Regional Prospects in Greece – A Gremi-E.E.C. Research Project national Report '', Regional Development Institute of Greece.

are strengthened contributing, in parallel, into the competitiveness of both local enterprises and regional economies since they constitute the main levers of growth diffusion.

4. Technical Efficiency of Greek agricultural farming

The agricultural farm is the basic economic unit of production, which does have almost exclusively familial character in Greece. Consequently, agricultural micro-economics considers agrarian farming to undertake production. The agricultural products in each administrative region of the country are produced by the mass of economic units (producers) in competitive market for inputs and outputs. Each producer owns certain agricultural farming[7] using the same technology of production with the aggregate prefectural economy. So, the mass of agricultural farmings is aggregated into groups (called sectors of production) depending on the species of the cultivated product. The agricultural farms are characterized by the fact that they are set out into perfectly competitive markets and their operation is influenced by random factors such as meteorological factors affecting heavily the productive result. Moreover, the familial character of farms in the Greek agriculture has as a main characteristic the seasonal work of the members of household resulting into the weak econometric specification of the factor of work. This means that the effect of this factor is added in the residuals.

The aggregation of agricultural farms in a sector has as a consequence the embodied technology of production to produce only one product. According to Kumbahkar - Lovell, the production technology of a sector is defined as the convex hull $GR = \{(y,x): x \text{ can produce } y\}$, where GR portrays the set of all feasible productive possibilities of a sector, y is the non-negative vector of produced output of agricultural product in each prefecture, and x is the vector of inputs, used in the production within the same prefecture. The available productive factors, potentially employed in the prefecture are described by the set $L(y) = \{x : (y,x) \in GR\}$, where $L(y)$ is the set of all vectors of inputs which can produce some quantity of agricultural product $y, \forall y \in R^{+}$. Finally the potentially produced quantities of a sector within the prefecture are portrayed by the set $P(x) = \{y : (y,x) \in GR\}$, where $P(x)$ is the mass of quantities of agricultural products, produced by the vectors of inputs $x \in R_{+}^{N}$.

The vectors of potentially produced output and all the available inputs determine the production function. More specifically, $f(x) = \max\{y : y \in P(x)\}$ implies $f(x) = \max\{y : x \in L(y)\}$, where $f(x)$ is the production function. The production function or production frontier is the geometrical locus of extreme points of the set of all feasible possibilities.

The formation of productive process using vectors does not distinguish the prefectures characterized by technically effective productive process. From the utilization of inputs point of view, a production procedure is technically effective, if no smaller quantity of input from the one used does not ensure the given level of production. From the set of all available productive factors, the set of effective vectors of inputs $Eff\ L(y)$ is the one that $Eff\ L(y) = \{x : x \in L(y), x' \leq x \text{ implies } x' \notin L(y)\}$

[7] Kitsopanidis G. I. - Kamenidis H.C. (Thessalonica 2003), *"Agricultural Economics'"*, G Publication, Publications Zi'ti.

while the production isoquant arises from the set of all available inputs and is defined as $Isoq\, L(y) = \{x : x \in L(y), \lambda x \notin L(y), \lambda < 1\}$. From the viewpoint of potentially produced output, a productive process is characterized as technically effective if $Eff\ P(x) = \{y : y \in P(x), y' \geq y \text{ implies } y' \notin P(x)\}$, which means that a given quantity of input cannot produce bigger quantity of product from the one already produced. Respectively, the arisen output isoquants $Isoq\, P(x) = \{y : y \in P(x), \lambda y \notin P(x), \lambda > 1\}$ depict the sets of all output vectors that can be produced with each input vector $\{\chi\}$. The production isoquants are the more flexible definitions of technical efficiency (Kumbhakar, p. 45, 2000), and the Cobb-Douglas production function implies that $\mathrm{Eff\ L\ (y) = Isoq\ L\ (y)}$ and $\mathrm{Eff\ P\ (x) = Isoq\ P\ (x)}$, so it is adopted for the analysis of technical efficiency of arable cultures

Moreover, according to Yotopoulos (1971), the Cobb-Douglas production function is the most advisable production model into the study of agricultural sector. Moreover the measurement of technical efficiency is achieved by the utilisation of production function, since the agrarian farming and the productive sector accordingly; produce only one product [Kumbhakar (2000)].

The production frontier represents the index mark in estimating technical efficiency, since it depicts the maximum attainable output set. Each point onto the production frontier is technically effective, while any other away from it is either not effective or unfeasible. Consequently, a technically efficient farm is the one operates onto the production frontier. As a matter of fact, however, due to the particularities and the imperfections of the sector of arable cultures in Greece, which have as direct consequence the non-exploitation of all prospects of agricultural farming, it is usually extremely difficult or impossible for a Greek farm to produce onto the production frontier[8]. For that reason, it is empirical better if we estimate the distance between the actual points of production of agricultural farmings resulted through empirical observations and the theoretically ideal points of production that each economic unit wishes to produce and are located onto the production frontier. By this way, it is possible to estimate how near or far is located a farming from the optimal production point. These functions constitute the substance and the most basic component of the theory of technical efficiency. The estimation of this distance can be faced substantially from two different optical views, since it can be estimated in practice as Input Distance Function or $D_I(y,x)$ but also as Output Distance Function $D_0(y,x)$. These terms of distance functions can be expressed in mathematic determinations as following [9]:

- $D_I(y,x) = \max\{\lambda : x/\lambda \in L(y)\}$. That attributes the maximum attainable outputs that a producer's given vector of inputs and technology can be radially contracted and remains still feasible for the output vectors that it produces.

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[8] "The main reasons that contribute to be a producer or an agricultural farming unable to produce onto the production frontier, are the high rates of illiteracy, the mistrust into the introduction of new production technologies in the productive process, the lack of capital and basic infrastructure etc", Tewodros Aragie kebede (June 2001), *" Farm Household Technical Efficiency: A Stochastic Frontier analysis - a Study of rice producers in Mardi Watershed in the Western Development Region of nepal "*, Department of Economics and Social Sciences, Agricultural University of Norway.

[9] Kumbhakar S. - Knox Lovell C. A. (2000), *Stochastic Frontier Analysis*, Cambridge University Press, Cambridge

- $D_0(y,x) = \min\{\mu : y/\mu \in P(x)\}$. That attributes the minimal sum from which an output vector should be underestimated and still remains feasible in the production from a given set of inputs.

5. Specification of the model

A production frontier or technology production constitutes the base for the estimation and measurement of technical efficiency. A productive system or a productive unit is regarded as technical efficient if it is able to produce the maximum possible output from any given bundle of inputs (or alternatively a given level of product with the minimal quantity of inputs). More specifically, a farm is technically effective, when it produces onto the production frontier.

Empirical analysis of the model extends the method of corrected least squares that was proposed initially by Winsten. That extension consists in the control and the correction of the estimators of production function. Thus, the emerged result is consistent and unbiased estimators for the input parameters and consistent but biased estimator for the constant. After that, the biased constant term (α) of the model is corrected by shifting up the regression curve so as the new production boundary to close in all the observations from above converting the residuals into negative apart one which is null. That means that a farm is unable to produce outside from the production frontier of the sector. This correction took effect in the residuals of the previous stage of analysis subtracting from each the value of the highest. At the end, technical efficiency of each prefecture was estimated by the function $TE_i = \exp\{-\hat{u}_i^*\}$ using the new residuals set.

The Cobb–Douglas production function is of the form $\ln Y_i = a + \beta_1 \ln X_{1i} + \beta_{2i} \ln X_{2i} + \varepsilon_i$, where Y is the vector of the produced quantity of arable crops, X_{1i} X_{2i} are the vectors of the independent variables of the model, that is to say a variable for the machinery used and the surface of the cultivated areas in acres respectively. Actually, Cobb–Douglas production function is quasi production function, i.e. does not have any particular specification of the labour factor due the particularities of its nature. Finally β_1, β_2 are the coefficients of technological parameters of the model. In this specification regression residuals incorporate both the efficiency and spatial effects, because regardless of the efficiency of the prefecture economy, all sorts of corps are produced simultaneously and under the same regime, as far as the physical, administrative and economic conditions are concerned. In other words spatial effects capture all the other factors. These effects are assumed that are described by a properly constructed contiguity matrix. Consequently the model for each sort of cultivation is now of the form (values in logarithms):

$$y = X\beta + \rho W\varepsilon + u,$$

where y is a $\mathrm{N}\times 1$ vector of observations of the dependent variable, N=1,2,…,50 the number of prefectures, W is the $\mathrm{N}\times\mathrm{N}$ spatial contiguity matrix that depicts the structure of space, ρ is spatial autocorrelation parameter, X is the $\mathrm{N}\times 3$ matrix of observations of independent variables, including constant term, β is a 3×1 vector of regression coefficients and $\rho W\varepsilon + u$ is the vector of errors, that is to say the logarithm of technical efficiency of the prefecture (u) and the spatial spillover effects of the other prefectures ($\rho W\varepsilon$). The single equation specification does not take under consideration the fact that there may be dependence among the errors in different equations. For example, local administration, or economic conditions affect all sorts of production. So, in order to incorporate cross equation relationships among residuals we adopt a spatial SUR specification. Thus our model in matrix form is

$$\begin{bmatrix} y_{wheat} \\ y_{maize} \\ y_{barley} \\ y_{beans} \end{bmatrix} = \begin{bmatrix} X_{wheat} & 0 & 0 & 0 \\ 0 & X_{maize} & 0 & 0 \\ 0 & 0 & X_{barley} & 0 \\ 0 & 0 & 0 & X_{beans} \end{bmatrix} \begin{bmatrix} \beta_{wheat} \\ \beta_{maize} \\ \beta_{barley} \\ \beta_{beans} \end{bmatrix}$$

$$+ \begin{bmatrix} \rho_{wheat} & \rho_{maize} & \rho_{barley} & \rho_{beans} \end{bmatrix} \begin{bmatrix} W & 0 & 0 & 0 \\ 0 & W & 0 & 0 \\ 0 & 0 & W & 0 \\ 0 & 0 & 0 & W \end{bmatrix} \begin{bmatrix} \varepsilon_{wheat} \\ \varepsilon_{maize} \\ \varepsilon_{barley} \\ \varepsilon_{beans} \end{bmatrix} + \begin{bmatrix} u_{wheat} \\ u_{maize} \\ u_{barley} \\ u_{beans} \end{bmatrix}$$

and in stacked form is $\mathbf{Y}=\mathbf{X}\boldsymbol{\beta}+\boldsymbol{\rho}\mathbf{W}\boldsymbol{\varepsilon}+\mathbf{u}$, where $\mathbf{Y}$, $\boldsymbol{\varepsilon}$ and $\mathbf{u}$ are 200×1 column vectors, $\mathbf{X}$ is a 200×12 matrix, $\boldsymbol{\beta}$ is a 12×1 column vector, $\boldsymbol{\rho}$ is 4×1 row vector and $\mathbf{W}$ is 200×200 matrix. The more suitable method of estimation is the method of Maximum Likelihood [Anselin, (1988)].

The aggregate spatial interaction for all the prefectures, that is to say the spatial variance-covariance matrix, is estimated in the same way as the time series adopting a particular functional formation of spatial relations. This formation requires that the form of the contiguity structure for each prefecture (topology or spatial arrangement of data, that is to say the finding of neighbouring prefectures) is predefined. This means that the spatial contiguity matrix W is predetermined. In our case, the spatial contiguity matrix W is a square $\mathrm{N} \times \mathrm{N}$ matrix, where N is the number of prefectures of the sample data that arable cultures flourish. Moreover, the non-null elements of that matrix indicate the presence of a neighbouring relation. The relation of contiguity is of the form of a binary variable ($w_{ij} = 1$, that is to say that geographic units I and J are neighbouring, while the diagonal elements of the spatial contiguity matrix W are equal to zero [Cliff and Ord (1981), Anselin (1988)]. By this way, that is to say the null value of the diagonal elements in association with the normalization of the lines of the matrix so as the sum of elements for each line to be equal with the unit, the product Wy expresses the contribution of the geographic system to the determination of the value of the variable in each prefecture [LeSage, (2002)]. In more formal terms, when the lines of a spatial contiguity matrix W are normalized (in other words $\sum_j w_{ij} = 1$ for each line i), the spatial lag for the value of variable y in a geographic unit i, y_i will be equal to $\sum_j w_{ij} y_j$ and the spatial contiguity matrix has been converted to a spatial weights matrix. The structure of spatial weights matrix ensures that besides the explanatory variables, the only fact taken into consideration into the determination of the value of y_i, is the value of the variable y that correspond to the neighbouring geographic units i, j, since $w_{ij} = 0$ for all the non-neighbouring geographical units y_i.

In order to estimate the efficiency of arable crops production we specify a proper DEA model by exploiting the spatial SUR results. DEA specification is output oriented in order to meet the requirements of regional policy for not keeping unused inputs. That is the estimation of $D_0(y,x)$. The main feature of DEA is the comparison of the numerator to the denominator of a ratio [Seiford, Thrall (1990)]. In our case this ratio is the observed aggregate prefecture production to what should have been produced, i.e. the average best practice in production, by all producers in the prefecture. As average best practice is defined the expected value of dependent variable corrected by adding the value of the largest positive residual, according to the COLS procedure [Greene (1999)]. In other words as average practice is defined the fitted value of the estimated regression and as average best practice is defined the correction of this value by shifting upwards the fitted values by the amount of the largest positive residual. So, the efficiency problem is the estimation of the output distance $D_0(y_j, \hat{y}_j)$. A prefecture is characterized as efficient if no other prefecture may produce the standardized output with less inputs, i.e. the actual production not to correspond to the average best practice and consequently the distance between them to be equal to zero. Thus, for each prefecture the objective is to minimize the ratio $\frac{y_j}{\hat{y}_j}$ with the usual constraint $\mu\hat{y}_j = 1$, where $\hat{y}_j$ is the corrected fitted value or average best practice and y_j is the actual level of production which was observed. The computational problem is to maximize the actual aggregate output succeeded of prefecture j, subject to the constraint that this level of output is no less than the best practice observed, which is the expected value of output for the current level of inputs, which were used for the production. According to DEA literature [Charnes et al. (1994)], it is much easier to estimate the dual linear programming problem or the envelopment form. In our case the envelopment form has the following specification.

$$\max_{\phi,\lambda_1,\dots,\lambda_N} \quad 1\phi + 0\lambda_1 + 0\lambda_2 + \cdots + 0\lambda_N$$

subject to:

$$\begin{array}{ccccccccccccc} 0\phi & + & y_1\lambda_1 & + & y_1\lambda_1 & + & \cdots & + & y_1\lambda_1 & \leq & y_j \\ \hat{y}_j\phi & - & \hat{y}_1\lambda_1 & - & \hat{y}_2\lambda_2 & - & \cdots & - & \hat{y}_N\lambda_N & \leq & 0 \\ 0\phi & + & \lambda_1 & + & \lambda_2 & + & \cdots & + & \lambda_N & = & 1 \end{array}$$

$$\lambda_j, \phi \geq 0,\ \lambda_j, \phi \in \Re$$

6. Data

The data set used in the present survey has been collected by the National Statistical Service of Greece in the context of Agricultural Statistics of Greece conducted in the year 1999. More specifically, the survey uses detailed cross sectional aggregated data that correspond to the observations of different units on the production, area and machinery for the most important arable cultures (Wheat, Maize, Barley, and Beans), cultivated into the prefectures of Greek State. Furthermore, we suppose that the prefectures cultivate all four products simultaneously. That is the reason why we excluded the prefecture of Chios from our analysis, since the production of maize is null. A summary of descriptive statistics for the variables used in the analysis is shown in the Table 1a and 1b below:

Table 1a
Arable Cultures in Greece

	Production in tons			
	Wheat	Maize	Barley	Beans
Sum	1976554	2003846	287286	23571
Mean	38756	39291	5633	462
Median	14006	19107	3005	221
Std. Deviation	59457	52845	7764	825
Coefficient of variation	153%	134%	138%	178%
Skewness	2.29	1.64	2.97	3.28
Kurtosis	5.84	2.22	11.81	10.31
	Arable areas in .000m^2			
	Wheat	Maize	Barley	Beans
Sum	8266533	2106469	1266372	116305
Mean	162089	41303	24831	2280
Median	64138	19224	14115	1297
Std. Deviation	233302	54261	31055	3167
Coefficient of variation	144%	131%	125%	139%
Skewness	1.84	1.72	1.82	2.90
Kurtosis	2.60	2.75	2.82	9.00

Source: Data Analysis, National Statistical Service of Greece, *Agricultural Statistics of Greece, 1999*

It must be noted that the agricultural machinery can be used for all kinds of cultures. Specialized equipment is used only for the wheat production.

Table 1b
Total number of agricultural machines of all kinds used

	for wheat	for all other
Sum	465325	401277
Mean	9124	7868
Median	7578	6096
Std. Deviation	7082	6166
Coefficient of variation	78%	78%
Skewness	1.21	1.66
Kurtosis	1.48	4.22

Source: Data Analysis, National Statistical Service of Greece, *Agricultural Statistics of Greece year 1999*

Production of arable cultures, regardless of the species, is the quantity that an agricultural farming produces, that forgathering with all other farming of the prefecture gives the aggregate production. Farming area is the surface of ground that a farm has at its disposal for the agricultural production of a product that pro rata with the production, gives the cultivated area of the prefecture at the aggregated level. As far as the machinery is concerned, this corresponds to the quantity of different machinery used in the farming production. Since machinery for producing maize, Barley and Beans are almost the same, they are considered to be one variable, while the machinery used for wheat is distinguished as separate variable. Moreover, as far as the coefficient of variation is concerned, we observe that the higher value in production appears to be for the beans, while the cultivated areas for wheat appear to have the highest coefficient of variation moving from the one prefecture to the other.

7. Empirical results

The technical efficiency for arable cultures has been estimated with the method of Spatial Seemingly Unrelated Equations. In this method, each equation corresponds to a different arable cultivation. All separate equations are estimated jointly so as to obtain more efficient estimators.

Table 2 depicts the results of maximum likelihood estimations for the production function of each arable cultivation. Estimations were carried out with the use of CML module (constrained maximum likelihood) of GAUSS 5.0.

Table 2
Estimation results of production of arable crops in Greece

Parameters	Estimates	Std. err.	t-stat	Parameters	Estimates	Std. err.	t-stat
Wheat-C	-3.2717	0.3866	8.46	s_{11}	0.0865	0.0192	4.51
Wheat-A	0.9284	0.0223	41.63	s_{12}	0.0826	0.0270	3.06
Wheat-M	0.2730	0.0566	4.82	s_{13}	0.0493	0.0140	3.52
Maize-C	-1.7855	0.5940	3.01	s_{14}	0.0388	0.0182	2.13
Maize-A	1.0587	0.0329	32.18	s_{21}	0.0826	0.0270	3.06
Maize-M	0.0816	0.0694	1.18	s_{22}	0.2163	0.0501	4.32
Barley-C	-2.6728	0.3408	7.84	s_{23}	0.0445	0.0208	2.14
Barley-A	0.9516	0.0251	37.91	s_{24}	0.0949	0.0306	3.10
Barley-M	0.1790	0.0468	3.82	s_{31}	0.0493	0.0140	3.52
Beans-C	-2.4621	0.5785	4.26	s_{32}	0.0445	0.0208	2.14
Beans-A	0.9782	0.0460	21.27	s_{33}	0.0725	0.0149	4.87
Beans-M	0.0994	0.0592	1.68	s_{34}	0.0274	0.0158	1.73
rho_1	-0.2912	0.1551	1.88	s_{41}	0.0388	0.0182	2.13
rho_2	-0.5732	0.1119	5.12	s_{42}	0.0949	0.0306	3.10
rho_3	-0.4335	0.1624	2.67	s_{43}	0.0274	0.0158	1.73
rho_4	0.1492	0.2439	0.61	s_{44}	0.1617	0.0326	4.96

Source: Data Analysis Results

From the inspection, it is obvious that all the coefficients and the constants have the right sign. Almost all of them are statistically significant either at 5% or 1%. Exceptions are the spatial autocorrelation coefficient of beans production and some of the corresponding cross equation standard deviations of the variance-covariance matrix. s_{34}, is statistically significant at 5%, as well as s_{43}. The same is true for the coefficient of machinery for beans production. Finally, it must be noted that the statistical significance of spatial autocorrelation coefficients ascertains the spatial formulation of the equations, while the significance of the cross equation standard deviations verifies the SUR specification [Goldberger, p.326 (1991)].

After the estimation of the system of the equations, we perform a Data Envelopment Analysis using the average best practice (as it has emerged from the Spatial SUR model) and the observed practice (as it has emerged from the sample) in order to extract the technical efficiency of each Greek prefecture for each arable cultivation. DEA estimation has been performed with the EMS software version 1.3.0.

Table 3 displays the estimated technical efficiency of each prefecture in producing Arable crops. Bold figures indicate efficiency.

Table 3
Technical Efficiency of Arable Culture per Greek prefecture

Prefecture	Wheat	Maize	Barley	Beans
01-AETO	107.3%	101.7%	106.4%	110.2%
02-ARGO	106.8%	122.0%	107.9%	125.7%
03-ARKA	102.0%	105.7%	109.2%	114.7%
04-ARTA	105.2%	106.0%	110.4%	109.7%
05-ATTI	106.3%	170.0%	100.8%	**100.0%**
06-ACHA	106.4%	101.8%	105.3%	102.5%
07-BOIO	100.2%	109.1%	112.1%	118.5%
08-GREV	108.7%	108.2%	102.6%	115.7%
09-DRAM	102.9%	103.3%	107.7%	105.8%
10-DODE	110.1%	122.3%	102.7%	**100.0%**
11-EBRO	104.2%	**100.0%**	108.7%	116.3%
12-EYBO	104.6%	104.4%	104.8%	106.9%
13-EYRY	104.9%	112.7%	111.6%	109.5%
14-ZAKY	112.9%	111.1%	121.9%	112.2%
15-ILIA	103.3%	101.1%	106.5%	100.8%
16-IMAT	105.0%	105.8%	108.2%	151.5%
17-IRAK	116.2%	**100.0%**	**100.0%**	104.0%
18-THES	**100.0%**	110.1%	116.8%	114.0%
19-SALO	102.5%	104.0%	105.6%	116.0%
20-IOAN	**100.0%**	105.8%	113.6%	112.8%
21-KABA	102.8%	101.9%	110.4%	100.9%
22-KARD	100.9%	104.3%	109.3%	111.5%
23-KAST	**100.0%**	112.8%	113.2%	108.0%
24-KERK	**100.0%**	**100.0%**	**100.0%**	**100.0%**
25-KEFA	110.1%	121.8%	115.1%	102.7%
26-KILK	102.7%	107.9%	109.0%	118.0%
27-KOZA	102.1%	105.7%	103.5%	119.1%
28-KORI	105.2%	111.8%	106.8%	112.1%
29-KYKL	119.6%	105.2%	**100.0%**	104.2%
30-LAKO	103.7%	114.6%	107.3%	134.4%
31-LARI	**100.0%**	103.8%	**100.0%**	113.4%
32-LASI	110.0%	100.6%	101.5%	117.0%
33-LESB	107.6%	106.8%	102.2%	106.6%
34-LEYK	120.0%	124.0%	100.1%	**100.0%**
35-MAGN	104.7%	115.9%	105.9%	121.7%
36-MESS	107.9%	106.2%	104.6%	112.4%
37-KSAN	100.4%	102.5%	111.3%	104.5%
38-PELL	105.1%	101.9%	106.3%	107.7%
39-PIER	102.0%	105.7%	109.0%	114.9%
40-PREB	103.6%	106.3%	112.6%	114.2%
41-RETH	113.2%	132.0%	106.3%	120.6%
42-RODO	102.8%	108.5%	108.6%	111.6%
43-SAMO	119.2%	**100.0%**	115.2%	**100.0%**
44-SERR	104.0%	101.8%	106.9%	115.4%
45-TRIK	102.4%	103.8%	108.1%	106.6%
46-FTHI	102.1%	105.9%	106.5%	107.9%
47-FLOR	104.8%	103.5%	101.4%	**100.0%**
48-FOKI	107.7%	115.5%	112.5%	112.7%
49-CHAL	101.8%	117.8%	109.7%	111.6%
50-CHAN	124.0%	109.7%	105.0%	123.8%

Greek prefectures do not have great differences in technical efficiency as is shown in Table 4.

Table 4
Summary statistics

statistic	Wheat	Maize	Barley	Beans
$\bar{y}$	106.0%	109.3%	107.4%	111.6%
σ	5.7%	11.3%	4.8%	9.5%
$\sigma/\bar{y}$	5.4%	10.3%	4.5%	8.5%

Barley is produced with the smallest differences in technical efficiency among prefectures as having the lowest coefficient of variation (4.5% differences on the average), although demonstrates the bigger average inefficiency. On the contrary maize production shows the greatest disparities in efficiency. Wheat production demonstrates the smallest average inefficiencies. On the other hand beans production shows the highest average inefficiency.

Efficiency is positively correlated with the size of the cultivation at prefecture level as is depicted in Diagram 1. The size of the cultivation is measured in production volume. It must be noted also, that the efficiency level shows much greater variability in the prefectures with small volumes of production in all sorts of cultivations.

Diagram 1
Relationship between technical efficiency and size of cultivation area

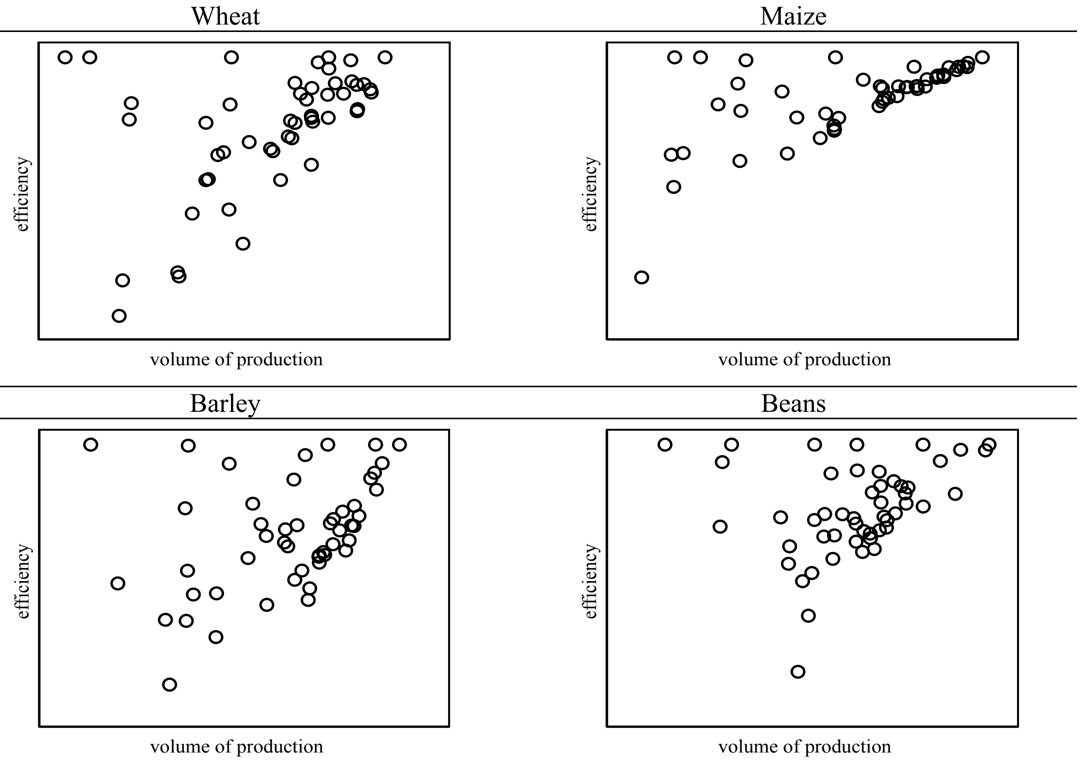

Table 5 proves statistically the fact that efficiency is positively correlated with the size of production. All results are statistically significant at 1% level of significance.

Table 5
Spearman correlation coefficient between actual production and efficiency

statistic	Wheat	Maize	Barley	Beans
Spearman-rho	.539(**)	.594(**)	.452(**)	.375(**)

Finally, Table 6 depicts a classification of prefectures according to their efficiency level, i.e. technically efficient, above and below the average efficiency level.

Table 6
Efficiency groups of Greek prefectures

WHEAT	MAIZE	BARLEY	BEANS
18-THE	24-KER	24-KER	24-KER
20-IOA	11-EBR	17-IRA	34-LEY
23-KAS	17-IRA	31-LAR	05-ATT
24-KER	43-SAM	29-KYK	47-FLO
31-LAR	32-LAS	34-LEY	10-DOD
07-BOI	15-ILIA	05-ATT	43-SAM
37-KSA	01-AET	47-FLO	15-ILIA
22-KAR	44-SER	32-LAS	21-KAB
49-CHA	06-ACH	33-LES	06-ACH
03-ARK	21-KAB	08-GRE	25-KEF
39-PIE	38-PEL	10-DOD	17-IRA
27-KOZ	37-KSA	27-KOZ	29-KYK
46-FTH	09-DRA	36-MES	37-KSA
45-TRI	47-FLO	12-EYB	09-DRA
19-SAL	31-LAR	50-CHA	33-LES
26-KIL	45-TRI	06-ACH	45-TRI
21-KAB	19-SAL	19-SAL	12-EYB
42-ROD	22-KAR	35-MAG	38-PEL
09-DRA	12-EYB	38-PEL	46-FTH
15-ILIA	29-KYK	41-RET	23-KAS
40-PRE	27-KOZ	01-AET	13-EYR
30-LAK	03-ARK	15-ILIA	04-ART
44-SER	39-PIE	46-FTH	01-AET
11-EBR	20-IOA	28-KOR	22-KAR
12-EYB	16-IMA	44-SER	49-CHA
35-MAG	46-FTH	30-LAK	42-ROD
47-FLO	04-ART	09-DRA	28-KOR
13-EYR	36-MES	02-ARG	14-ZAK
16-IMA	40-PRE	45-TRI	36-MES
38-PEL	33-LES	16-IMA	48-FOK
04-ART	26-KIL	42-ROD	20-IOA
28-KOR	08-GRE	11-EBR	31-LAR
05-ATT	42-ROD	26-KIL	18-THE
06-ACH	07-BOI	39-PIE	40-PRE
02-ARG	50-CHA	03-ARK	03-ARK
01-AET	18-THE	22-KAR	39-PIE
33-LES	14-ZAK	49-CHA	44-SER
48-FOK	28-KOR	21-KAB	08-GRE
36-MES	13-EYR	04-ART	19-SAL
08-GRE	23-KAS	37-KSA	11-EBR
32-LAS	30-LAK	13-EYR	32-LAS
10-DOD	48-FOK	07-BOI	26-KIL
25-KEF	35-MAG	48-FOK	07-BOI
14-ZAK	49-CHA	40-PRE	27-KOZ
41-RET	25-KEF	23-KAS	41-RET
17-IRA	02-ARG	20-IOA	35-MAG
43-SAM	10-DOD	25-KEF	50-CHA
29-KYK	34-LEY	43-SAM	02-ARG
34-LEY	41-RET	18-THE	30-LAK
50-CHA	05-ATT	14-ZAK	16-IMA

More specifically in wheat cultivation, the technically efficient prefectures are Thesprotia, Ioannina, Kastoria, Kerkyra, Boiotia, Ksanthi and Larissa, while the second group of 25 prefectures is more efficient than the average efficiency level (average efficiency of the group 1.03) and the third group of 18 prefectures is less efficient than the average (average efficiency of the group 1.12). As far as the technical efficiency in producing maize, we observe that it has greater differences in technical inefficiency. Excluding Evros, Irakleion, Kerkyra and Samos whose production is technically efficient, the other prefectures are divided into the 30 more efficient prefectures than the average (average efficiency of the group 1.04) and the 16 less efficient prefectures (average efficiency of the group 1.20). Barley production appear to be technically efficient in Iraklion, Kerkyra, Kyklades, Larissa and Leukada whereas the next 21 prefectues are more efficient than the average (average efficiency of the group 1.04) and the last 24 lie below average (average efficiency of the group 1.11). Finally, the efficient prefectures that produce beans are Attica, Dodekanisa, Kerkyra, Leukada, Samos, Florina. Above average are the next 19 prefectures (average efficiency of the group 1.05) and below average the last 25 (average efficiency of the group 1.18).

8. Conclusions

In this paper a methodology for evaluating the technical efficiency of arable corps in Greek prefectures is proposed. The model is build up by estimating a spatial SUR model and then applying a DEA model on the estimated values of the spatial SUR model. The model has been applied to data collected from the Greek National Statistical Service, in order to suggest policy measures. The model has successfully described the efficiency pattern of the cultivations. In view of the results, arable cultures cultivation in Greek prefectures is not quite different as far as the technical efficient is concerned. Each arable culture has a different pattern of technical efficiency, while there are great disparities in the production amongst the prefectures of the country.

Being some prefectures more technical efficient than others may not be a result of a better productive process, but because of the distinguishable character of Greek farming. Greek farming is dominated by small-scale farmers who need to improve total factor productivity. Moreover, the multi-partition character of Greek agricultural area results into the diminution of the magnitude of Land Reclamation works, the diminution of the industrialization of farming exploitations and of the specialization of productive process. Furthermore, the level of the average return per stremmas is affected negatively by the small-scale agrarian farms and the cost of production is raised continuously. Moreover, taking into account the fact that subsidy will take the form of a stable agricultural income for the forthcoming years regardless of the size of the production; farmers will need to produce with the least attainable cost.

Thereupon, we realize the need for applying a regional policy objecting, on the one hand, to the repeal of regional disparities in production and the resolution of regional problem, and, on the other hand, the improvement of technical efficiency of arable cultures sector. The main points of such a regional developmental strategy should be the following:

- The formulation of a proper development model taking under consideration size and volume effects.
- The determination of the regional and intersectoral priorities for intervention in the area of farm size.

- Regional Administration and Programming.

However, the crucial question that arises now is how the multi- partitioned Greek farms will manage to improve their technical efficiency under the new status quo of Common Agricultural Policy. The answer to that question may demands to provide a deeper analysis of technical efficiency in that sector focusing more on the particularities and characteristics of each agricultural farm. The level of prefecture is too wide in extensive terms in order to suppose that all the agrarian farmings do have single characteristics and consequently single confrontation.

In a future extension of the model, more factors affecting the technical efficiency of the arable cultivations will be included and their effect on the results will be studied. Further the effect of differently defined spatial weight matrices W will be tested on the perspective of incorporating the spatial effects more accurately for each type of cultivation. Finally this method will be applied to analyze the efficiency patatterns incorporating time effects in DEA framework by using window analysis.

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