Analyzing the impact of direct subsidies on the performance of the Greek Olive Farms with a non-monotonic efficiency effects model

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Abstract— **We analyse the impacts of the CAP reforms on technical efficiency of Greek olive farms. We use a production frontier function and a non-monotonic inefficiency effects model which incorporates the influences of exogenous variables on the mean and the variances of farm efficiency. We formulate policy variables (e.g. the direct subsidies) and farm characteristics as explanatory variables in the inefficiency effects model. We use the 1995-2004 FADN data to estimate the production frontier, to derive technical efficiency, and to determine the effects of the explanatory variables. The study shows that the 10-year average technical efficiency of olive farms is 69%. Direct transfers have a negative and monotonic effect on technical efficiency, while the degree of specialization has a non-monotonic effect on technical efficiency.**

Keywords— **technical efficiency, the CAP reform, non-monotonic inefficiency effects, production frontier, olive farming.**

I. INTRODUCTION

The European Union (EU) has adopted a series of reforms of its Common Agricultural Policy (CAP) since 1992: the MacSharry reform (1993-1999), the Agenda 2000 (2000-2004), and the 2003 reform (after 2005 onwards). The various CAP reforms have emerged from price support, to the production-related subsidies, and presently to decoupled payments. Olive production is a main economic activity in Greek agriculture. Since 1992, direct subsidies has been one of the major support methods to Greek olive producers in the perspective of the CAP reforms. An interesting question therefore focuses on how Greek olive farmers amend their economic performance in response to the involving EU agricultural policies.

We may expect positive or negative effects of subsidies or transfers associated with a policy change on efficiency. Subsidies increase technical efficiency if they provide farmers an incentive to innovate or switch to new technologies. However, technical efficiency might also decrease with the increase of subsidies, if farmers prefer more leisure with a higher income from subsidies (Hennessy, 1998; Findeis, 2002 and Serra et al., 2005). Thus, subsidies or transfers affect farm decisions through the income effect but how much and in what direction in the context of CAP reform is the subject of empirical study.

The objective of this paper is to analyse the impact of subsidies or direct transfers on technical efficiency of Greek olive farms. We employ a parametric stochastic frontier approach (i.e. SFA) rather than a nonparametric approach (e.g. DEA), because SFA offers a framework for linking the efficiency estimates of individual producers to a set of exogenous variables including producer characteristics (e.g. size, organizational type, and other structural factors such as level of human capital) and policy measures in an inefficiency effects model. Specifically, we use a stochastic production frontier function and an inefficiency effects model which incorporates the influences of exogenous variables on farm efficiency for the analysis. In literature, most of the technical inefficiency effects models assume that the mean of the technical inefficiency is a function of the exogenous variables, while the variance of the technical inefficiency effects is constant (e.g. Battese and Coelli, 1995). However, as discussed in the literature that variable variations in the sample, especially when there is evidence of strong firm heterogeneity and a long time span, tend to generate heteroscedasticity problem, unmodeled heteroscedasticity in the one-sided inefficiency effects model leads to biased estimates of the parameters of the frontier and the biased estimates of efficiency (Kumbhakar and Lovell, 2000; Wang, 2002; Karagiannis and Tzouvelekas, 2007). Therefore in this paper, we explicitly consider the heteroscedasticity of the inefficiency effects model as Wang (2002), in which the exogenous variables affects the mean and the variance of the technical inefficiency. By this approach, we expect to obtain an unbiased estimate of technical (in)efficiency and to show the possible non-monotonicity of the inefficiency effects. The application focuses on FADN data of Greek olive farms in the period 1995-2004. We obtain the marginal effects of the exogenous variables on the mean and the variance of the inefficiency to discuss the non-monotonicity of the inefficiency effects.

The paper is organized as follows. Section 2 presents the SFA model particularly the inefficiency effects model with non-constant variance, which is also a function of the exogenous variables. This is followed by a description of the data in section 3. Section 4 gives the estimated results. Finally in section 5 we summarize and conclude.

II. A PRODUCTION FRONTIER FUNCTION AND NON-MONOTONIC EFFICIENCY EFFECTS MODEL

The production frontier model with inefficiency effects model allows for a simultaneous estimation of technical efficiency and the impact of factors determining technical efficiency. A stochastic production frontier function defines the relationship between the single output (y) and a vector of inputs ($x \in R_{+}^{N}$). Each input is indexed by j or k, j or k=1, 2, …, N. The Translog specification of the frontier function for the i-th firm reads:

$$\ln y_i^t = \beta_0 + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + \sum_{k=1}^{N} \beta_k \ln x_{ki}^t + \frac{1}{2}\sum_{k=1}^{N}\sum_{j=1}^{N} \beta_{kj} \ln x_{ki}^t \ln x_{ji}^t + \sum_{k=1}^{N} \beta_{kt} \ln x_{ki}^t t + v_{it} - u_{it}, \tag{1}$$

where v_{it} is the two-sided "noise" component with $v_{it} \sim iid\, N(0, \sigma_v^2)$, and u_{it} is the nonnegative technical inefficiency component, which can be explained by a set of exogenous variables $z \in R^J$ (Battese and Coelli, 1995). Each variable from this set (z_{pit}) is indexed by p, p=1, 2, …, J, and is farm (indexed by i) and time (indexed by t) specific. The component u_{it} follows truncated normal distribution with different means and variances among farms: $u_{it} \sim N^+(\mu_{it}, \sigma_{it}^2)$. This allows for the incorporation of both determinants of inefficiency and heteroscedasticity of the inefficiency effects (Wang, 2002). Specifically, the mean μ_{it} and the variance σ_{it}^2 have the following form:

$$\mu_{it} = \delta_0 + \sum_{p=1}^{J} \delta_p z_{pit}, \tag{2}$$

$$\sigma_{it}^2 = \exp(\gamma_0 + \sum_{p=1}^{J} \gamma_p z_{pit}). \tag{3}$$

The production frontier (1) and the simultaneous non-monotonic inefficiency effects model (2 and 3) account for technical change, and time-varying and firm specific technical efficiency with heteroscedasticity. *Technical efficiency* (*TE*) is defined (Kumbhakar and Lovell, 2000) as usual:

$$TE_{it} = \exp(-u_{it}) = \exp(-\delta_0 - \sum_{p=1}^{J} \delta_p z_{pit} - w_{it}), \tag{4}$$

where w_{it} is the random component of the technical inefficiency.

By non-monotonic efficiency effect, we mean that z_{pit} (p=1,2,…J) can have, within a sample, both positive and negative effects on the production efficiency, and that the sign of the effect depends on values of z_{pit}. For instance, the z_{pit} can positively (or negatively) affect the efficiency when the values of z_{pit} are within a certain range, and the impacts can then turn negative (or positive) for values outside the range. To understand the relationships between efficiency and the exogenous factors, we need to show the marginal effect of z_{pit} on the mean and the variances of u_{it} measured by the unconditional statistics of $E(u_{it})$ and $V(u_{it})$, respectively, i.e. $\frac{\partial E(u_{it})}{\partial z_{pit}}$ and $\frac{\partial V(u_{it})}{\partial z_{pit}}$. Detailed formula can be found in Wang (2002, equations 9 and 10).

III. DATA AND ESTIMATION METHOD

Considering the production structure, we define the specialist olive farms as the farms with two-thirds of output from olive production. We have thus one output: an aggregate of olive and other products. Furthermore, we categorise one variable input and three factor inputs: capital, labour and land.

A consistent database for the estimation of the frontier models is the European Community's Farm Accounting Data Network (FADN). The FADN database (EU-FADN-DG AGRI-3 European Commission, Directorate-General Agriculture, Unit AGRI.G.3) contains information on revenues, expenses and farm's structure (e.g. farm size, land use, labour use and capital stock). We use the price indexes from EUROSTAT and calculate the Tornqvist price indexes for the aggregate output and inputs. We derive implicit quantities of inputs and output as the ratios of values to the price indexes.

Exogenous variables which may influence the mean and the variance of farm efficiency include structural variables, management variables as well as public policies (e.g. subsidies). We retrieve as much information as possible from the FADN. This includes subsidies, farm size, olive production, labour use, land use and the financial information such as long-term debts. Specifically in the inefficiency effects model, we use the share of total subsidies in the total farm revenue in percentage, the farm size in ESU unit, the degree of specialization (i.e. the share of olive output in total output) in percentage, the share of family labour in total labour use in percentage, the share of own land in the total land use in percentage, the share of long-and intermediate-term loans in the total assets in percentage. Besides, the regional differences might also play a role in farmer's decision making; therefore it is also important to give an explicit indication of the locations of the farms, which is indicated by regional dummies. Four geographical regions are distinguished. Finally, olive production efficiency also depends on the type of the location, e.g. a less-favoured area (LFA) or not, so a dummy for LFA is included. Besides, we also include the time trend in the set of exogenous variables. The whole list of the explanatory variables is shown in Table 1.

We consider one output (total output) and four inputs (one variable input, three factor inputs including capital, labour and land) for the olive specialist farms. Values for these inputs and output are obtained from FADN and their prices from EUROSTAT[1]. Descriptive statistics for the model variables are shown in Table 2. Besides, subsidies are the main concern of this paper, we therefore include them in Table 1A of the *Appendix*.

Table 1 Variables in the inefficiency effect model and definitions

Variables (vector z)	Definition
z1	Share of subsidies in the total farm revenue (%)
z2	Farm size in terms of European size units (ESU)
z3	Share of olive production in total production (%)
z4	Share of family labour in total labour use (%)
z5	Share of own land in total utilised land (%)
z6	Share of long- and intermediate-run loans in total assets (%)
t	Time trend
Dum1	1 for Makedonia-Thraki, otherwise 0
Dum2	1 for Ipiros-Peloponissos-Nissi Ioniou, otherwise 0
Dum3	1 for Thessalia, otherwise 0
Dum4	1 for Sterea Ellas-Nissi Egaeou-Kriti, otherwise 0
DumLFA	1 if the farm is located in the less favoured area, otherwise 0

Since the Translog production function can be considered as a second-order Taylor series expansion around the point of approximation, our estimation for (1) is based on the normalized variables. That is, all variables in (1) are converted into indices by normalization by the representative farm in the sample, which defines the point of approximation. The representative farm is the one whose output is closet to the mean output of the sample[2]. The estimation method used for this non-monotonic model is the maximum likelihood (ML) method. Specifically, we use the computer code written by Wang (2005) using Stata software for the estimation of the production frontier and its non-monotonic inefficiency effects of the Greek olive farms.

[1] We calculate the Tornqvist price indexes for the aggregate goods such as the total output and the variable input using the individual prices of agricultural goods from EUROSTAT.

[2] The mean output quantity of the sample is 163.67 and the output quantity of the representative farm is 163.57.

Table 2 Summary statistics of the variables (output, inputs and exogenous variables)

year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Average period values			
											mean	sd	min	max
Output (€)	16105	18597	15262	14656	13606	14436	13954	17449	14663	15505	15375	14569	291	150144
Variable Input (€)	2801	3356	3216	2913	3035	3013	2969	2987	2726	3442	3042	2764	198	27754
Capital (€)	50991	57438	59289	51462	54822	49367	52296	52197	47571	54251	52940	51178	1271	347475
Labour (hrs)	3282	3463	3225	3351	3222	3234	3031	3216	2952	2965	3198	1579	600	11646
Land (ha)	8.3	8.1	8.1	7.7	7.4	7.5	7	6.9	6.8	6.7	7.4	5.3	1.1	50.5
Subsidy share (%)	23.3	24.1	25.1	25.1	25.9	28.7	28.1	28.7	27.5	28.0	26.5	10.7	00.4	79.4
Farm size (ESU)	9.81	11.57	11.14	11.68	13.87	14.19	13.09	9.45	9.09	9.30	11.4	10.1	2	103.4
Specialization degree (%)	91.9	90.7	90.6	90.2	90.5	90.4	91.3	90.5	89.3	91.3	90.6	10.4	66.7	100
Family labour (%)	87.4	86.4	86.2	85.7	84.8	85	86.8	83.7	85.9	86	85.7	15.9	27	100
Own land (%)	92.8	93.8	92.7	93.2	92.5	92.6	92.1	92.3	91.4	90.8	92.4	19.1	0	100
Loan (%)	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.0	0	19.4
Dum1 (% of farms in MakedoniaThraki)											5.4			
Dum2 (% of farms in Ipiros-Peloponissos-Nissi Ioniou)											41.2			
Dum3 (% of farms in Thessalia)											5.7			
Dum4 (% of farms in Sterea Ellas-Nissi Egaeou-Kriti)											47.8			
DumLFA (% of farms in LFA)											34.2			

Based on 490 farms and 2492 observations.

IV. ESTIMATION RESULTS

A. Technical efficiency and determinants of technical inefficiency

Using the software developed by Wang (2005), we estimate the frontier production function and the inefficiency effects model (see Appendix for the estimated parameters) and obtain the estimates of technical efficiency (TE). We further calculate the technical efficiency change (TEC) as the percentage change of TE from one year to another.

Before we interpret the results, we test whether there does exist the heteroscedasticity in the inefficiency effects model which explains the non-monotonicity of the inefficiency effects. We use the Likelihood Ratio (LR) statistics to do the test, comparing the log-likelihood function under the null hypothesis (H_0) and under the alternative hypothesis (H_1). That is: $LR = -2[\lambda(H_0) - \lambda(H_1)]$, where $\lambda(H_0)$ and $\lambda(H_1)$ are the log likelihood functions under null and alternative hypothesis. The null hypothesis H_0 is that there is no heteroscedasticity, i.e. $\gamma_1 = \gamma_2 = ... = \gamma_J = 0$. The alternative hypothesis H_1 is that there exists heteroscedasticity. Using the Stats code developed by Wang (2005), we obtain $\lambda(H_0) = -1528.2$, and $\lambda(H_1) = -1469.15$, therefore $LR = -2[\lambda(H_0) - \lambda(H_1)] = 118.1$. There are 11 exogenous variables (i.e. J=11), the 5% critical value is $\chi^2_{0.95}(11) = 19.68$. Since LR>19.68, we reject the null hypothesis (at the 5% level of significance) that there is no heteroscedasticity in the inefficiency effects model. Therefore, choosing a model which can accommodate the non-monotonic inefficiency effects is appropriate. We are confident in interpreting the results based on the non-monotonic inefficiency effects model.

The results for TE are shown in Table 3. It shows that the average technical efficiency of the Greek olive farms in 1995-2004 is 69%. Technical efficiency is in the range of 64% to 75% in this period, with the lowest (64%) in 2001 and the highest (75%) in 2002.

Table 3 Technical efficiency in 1995-2004

Year	Mean	St. d	Min	Max
1995	0.692	0.189	0.119	0.997
1996	0.702	0.184	0.023	0.993
1997	0.657	0.225	0.039	0.985
1998	0.702	0.164	0.216	0.983
1999	0.670	0.195	0.192	0.979
2000	0.685	0.176	0.058	0.982
2001	0.643	0.206	0.106	0.974
2002	0.749	0.152	0.162	0.986
2003	0.693	0.182	0.092	0.985
2004	0.722	0.188	0.102	0.971
Average	0.691	0.188	0.023	0.997

Table 4 gives the distribution of the farms in the different ranges of the technical efficiency score in each year. It shows that 548 farms out of 2492 farms (22%) have an efficiency score between 70-80, and 498 farms out of 2492 (20%) have an efficiency score between 80~90.

The parameter signs of the inefficiency effects model (see the part under *mu* in the table of Appendix 1) show the average impacts of the exogenous variables on the technical inefficiency. It shows that the share of total subsidies received in total revenue (z_1) has positive impacts on the technical inefficiency. This share (which reflects the share of *direct transfers* or *decoupled subsidies* in the total farm revenue) has thus negative impacts on the technical efficiency, indicating the motivation for improving technical efficiency is lower when farmers obtain direct transfers. *This implies that direct transfers or decoupled subsidies decrease the technical efficiency of the Greek Olive farms*. The second exogenous variable is farm size (z2), which has also negative impacts on technical efficiency, indicating the larger the farm, the lower the technical efficiency. Similarly, the other exogenous variables (z3 to z5) have negative impacts, though only z4 (the share of family labour in the total labour use) has significant negative impacts, indicating that the higher the share of family labour, the lower the technical efficiency. Time has, on average, negative impacts on the technical inefficiency, meaning that technical efficiency change over time is on average positive. The regional dummies (Dum2 and Dum4) have positive impacts on the technical efficiency, implying that the technical efficiency is higher in these two regions (Ipiros-Peloponissos-Nissi Ioniou and Sterea Ellas-Nissi Egaeou-Kriti) than in the reference region (Makedonia-Thraki), while Thessalia (Dum3) is technically less efficient than Makedonia-Thraki, though statistically not significant. As a whole, the mean technical efficiency for each region is 68%, 70%, 58% and 70% respectively. Besides, the sign of coefficient of DumLFA is positive in the inefficiency effects model, indicating that the less-favoured area is also less efficient, compared to the other regions.

However, it should be noted that the above discussion only holds for the average impacts of the exogenous variables on technical efficiency. With the model capacity, we may also discuss if these impacts are monotonic, i.e. if the impacts are in one direction with the increase of the exogenous variables. In the next section, we will derive the marginal effects of the exogenous variables on inefficiency and discuss the non-monotonicity of the inefficiency effects.

Table 4 Farm numbers under different ranges of technical efficiency in each year

	Range of technical efficiency (%)								
Year	<30	30~40	40~50	50~60	60~70	70~80	80~90	>90	Total
1995	10	8	14	24	34	57	36	25	208
1996	10	14	13	19	44	64	62	25	251
1997	26	13	16	21	36	54	45	27	238
1998	7	7	13	34	62	61	53	29	266
1999	9	28	28	38	39	56	55	34	287
2000	9	10	18	31	56	72	50	27	273
2001	10	24	41	30	36	37	41	34	253
2002	4	2	15	17	36	77	66	39	256
2003	6	8	18	36	58	44	38	40	248
2004	5	6	13	42	21	26	52	47	212
Total	96	120	189	292	422	548	498	327	2492

B. Marginal effects on inefficiency

The marginal effects of z_{pit}, namely the share of total subsidies in the total farm revenue, farm size, the degree of specialization, the share of family labour, the share of own land and the share of long- and intermediate-term loans in the total assets, on technical inefficiency, are discussed in terms of the two statistics, $E(u_{it})$ and $V(u_{it})$. As pointed out in Bera and Sharma (1999), the variance of inefficiency $V(u_{it})$ also measures the 'production uncertainty'. The marginal effects $\frac{\partial E(u_{it})}{\partial z_{pit}}$ and $\frac{\partial V(u_{it})}{\partial z_{pit}}$ are calculated after the model's parameters are estimated. Furthermore, we also calculate the marginal effect of an amount of 1000 € subsidies on technical inefficiency.[3]

Table 5 reports the sample means of the marginal effects and the average marginal effects of the first and the last quarter of the sample (ordered by the values of the variables but ordered by the

[3] Marginal effect of subsidies can be obtained from the marginal effect of z1 (the share of total subsidies in the total farm revenue). Since the total farm revenue is the sum of total output (*TO*) plus the total subsidies (*S*), or $z_1 = S/(TO+S)$, the marginal effect can therefore be calculated by: $\frac{\partial E(u)}{\partial S} = \frac{\partial E(u)}{\partial z_1}\frac{\partial z_1}{\partial S} = \frac{\partial E(u)}{\partial z_1}\frac{TO}{(TO+S)^2}$, assuming that *S* is not related to *TO* under decoupling so that $\frac{\partial z_1}{\partial S} = \frac{TO}{(TO+S)^2}$.

value of effects for time). It shows the marginal effects of each exogenous variable on $E(u_{it})$ and $V(u_{it})$, measuring how an increase in the value of the variable changes the expected inefficiency and the distribution of inefficiency, i.e. production uncertainty (Bera and Sharma, 1999).

Table 5 Marginal effects of exogenous variables on inefficiency

	Sample average	1st quarter average	4th quarter average
Marginal effects on $E(u_{it})$			
Share of subsidies in revenue (%)	0.0227	0.008	0.0412
Total subsidies (1000 €)	*0.0017*	*0.0035*	*0.0007*
Farm size (ESU)	0.0044	0.0043	0.0047
Specialization degree (%)	0.0007	***-0.0006***	***0.0011***
Share of family labour in labour use (%)	0.0099	0.0061	0.0123
Share of own land in land use (%)	0.0012	0.001	0.0012
Share of loans in assets (%)	-0.0128	-0.0132	-0.0124
Time	-0.0174	-0.031	-0.0055
Marginal effects on $V(u_{it})$			
Share of subsidies in revenue (%)	0.0037	0.0003	0.0068
Total subsidies (1000 €)	0.0003	0	0.0006
Farm size (ESU)	0.0008	0.0001	0.0015
Specialization degree (%)	-0.0006	-0.0015	-0.0001
Share of family labour in labour use (%)	0.0045	0.0009	0.0089
Share of own land in land use (%)	0.0005	0.0001	0.0011
Share of loan in assets (%)	-0.0068	-0.0136	-0.0013
Time	-0.0042	-0.0078	-0.0008

Firstly, we discuss how *each exogenous variable* influences the expected technical inefficiency (see the upper part of Table 5). For the *subsidy share*, it has positive effect on technical inefficiency. The impact of this share is monotonic on the technical inefficiency, as the higher the share, the higher its marginal effect. The mean marginal effects of 1000€ subsidies on technical inefficiency is 0.0017, implying that the average farm will have an increase of 0.17% in technical inefficiency, or a decrease of 0.12% in technical efficiency[4]. In the 10 year period, the mean total subsidies received by the Greek olive farms are 4878 € (Appendix 1). This implies there is an increase of 0.83% in technical inefficiency, or a decrease of 0.57% in technical efficiency due to this amount of subsidies.

There are similar effects on the technical inefficiency for *farm size*, *share of family labour*, *share of own land*. For the *share of long-term loan in the total assets*, the marginal effect is negative, implying a positive effect on the efficiency. Moreover, its impact is larger if the share of loan is higher. Interestingly for the *degree of specialization*, the average marginal effect of the sample is positive (0.0671), while in the first-quartiles it is negative (-0.0647) and in the fourth-quartile it is positive (0.1155). The opposite marginal effects in these two quartiles indicate that the degree of specialization affects efficiency non-monotonically in the sample. When the specialization degree is low, an increase in specialization reduces the production inefficiency, while too much specialization increases the production inefficiency, probably due to the loss of flexibility of allocation of the different types of resources. Therefore it is worthwhile to keep a certain level of the specialization of production, but not be completely specialized in one product.

[4] Marginal effect on technical efficiency can be approximately calculated as: $\frac{\partial TE_{it}}{\partial z_{pit}} = -TE_{it} \times \frac{\partial E(u_{it})}{\partial z_{pit}}$, because $TE_{it} = \exp\{-u_{it}\}$.

Secondly, in order to facilitate the interpretation of the impacts of direct subsidies on the technical inefficiency in different circumstances we report the marginal effects of subsidies on technical inefficiency by year, by specialization degree, by farm size classes, by geographical regions, and by the type of location (Table 6). It shows that the marginal effects of subsidy ratio changes over time, following the same trend of the change of the subsidy ratio over time (see Table 2). It indicates that a higher subsidy ratio in the total farm revenue leads to a higher effect on the technical inefficiency, implying that direct transfers have negative impacts on technical efficiency. Table 6 also shows that the higher the farm size, the higher the marginal effects of subsidies on the technical inefficiency, which means that the larger farms are more sensitive to the subsidies and tend to have a lower technical efficiency when receiving subsidies. As for the specialization degree, the more specialization, the more positive effect on the technical inefficiency. This probably can be explained that if a farm is specialized in olive, it is easier to reduce technical efficiency due to the lack of possibilities to switch, upon receiving subsidies. The four geographical regions have different production conditions and thus have different reactions to the subsidies. For example, the effect of subsidy on technical inefficiency in Thessalia is the highest, which corresponds to the lowest technical efficiency among four regions. Finally, if the farm is located in the less favoured area, the marginal effect of subsidy on technical inefficiency is higher and the technical efficiency is lower. The mean technical efficiency is 64% in the less favoured area, while 72% in other area.

Thirdly, the marginal effects also differ with respect to the distribution of inefficiency or the production uncertainty measured by $V(u_{it})$ (see the lower part of Table 5). For subsidy share, a higher subsidy share tends to increase the production uncertainty probably because the farmers becomes less interested in production due to the higher extra income. For bigger farm size, the production uncertainty is higher. Similarly for the share of family labour and share of own land, the higher uncertainty related to the higher shares is probably due to the low valuation of the family labour and own land compared to hired labour and land. For the specialization degree, it has negative effect on the production uncertainty, showing that the degree of specialization probably contributes to a better production technology; while in the first-quartile the effect is higher than in the fourth-quartile, implying that a too high specialization degree has less effect on reducing the production uncertainty. For the share of loans, it reduces (has negative effect) on the production uncertainty, and in the first-quartile the effect is higher than in the fourth-quartile, implying the uncertainty is lower in the first-quartile than in the fourth-quartile. It can be seen that within the sample the uncertainty is generally consistent with the inefficiency, meaning that if a firm reaches its most efficient level it also has the least production uncertainty.

Finally, we can also translate the marginal effects of subsidy share or subsidies on the technical inefficiency into the change on the output, because $\partial E(\ln y)/\partial z_1 = -\partial E(u)/\partial z_1$ or $\partial E(\ln y)/\partial S = -\partial E(u)/\partial S$. The mean marginal effect of subsidy share on technical inefficiency is 0.0227, which corresponds to a decrease of output by 2.2%. This means the output level will be 2.2% lower if the share of total subsidies in the total revenue increases by 1%. The mean marginal effect of 1000 € is 0.0017, implying a decrease of output level by 0.17% by receiving 1000 € subsidies. On the average, the Greek Olive farm receives 4878€ (Table 1A), which causes 0.83% loss of output.

V. CONCLUSION

We apply the stochastic frontier framework and FADN data of the Greek olive farms to estimate the production frontier function and the non-monotonic inefficiency effects model for the period 1995-2004, when different CAP reforms take place. Particularly we use an inefficiency effects model with the unique property of accommodating non-monotonic efficiency effects, allowing the exogenous variables to affect the mean and the variance of the inefficiency term (i.e. heteroscedasticity). This type of model is capable of analysing non-monotonic effects of exogenous variables on inefficiency.

Using this model, we calculate the time-varying and firm-specific technical efficiency and the yearly technical efficiency change. Our hypothesis test for the existence of the heteroscedasticity also supports that we should choose a model which can consider the non-monotonicity of the efficiency effects. We find that the average technical efficiency is 69%. By checking the signs of the parameters of each exogenous variable in the inefficiency effects model, we may find the impacts of each exogenous variable on the technical inefficiency. The share of total subsidies in the total farm revenue has negative impacts on the technical efficiency, indicating the motivation of improving technical efficiency is lower when farmers obtain specific extra income. The study suggests that the 2003 CAP reforms (changes in the transfers related to production) have profound impacts on the technical efficiency and technical efficiency change. *It suggests that direct transfers or decoupled subsidies decrease the technical efficiency of the Greek Olive farms*.

It is also interesting to check the marginal effects of each exogenous variable on the mean and the variance of inefficiency, which might give an indication of the non-monotonicity of the inefficiency effects of the exogenous variables and the production uncertainty. For the share of total subsidies (*direct transfers* or *decoupled subsidies*) in the total farm revenue, it has positive effect on technical inefficiency and its impact is monotonic: the higher the share, the higher the marginal effect, probably due to the low motivation of improving efficiency related to the income effect. A higher share of *direct transfers* or *decoupled subsidies* in the total farm revenue tends to increase the production uncertainty probably due to the laziness arising from the extra income. It is interesting to note the different signs of the coefficient for the *degree of specialization* in the inefficiency effects model for the first-quartile and the fourth-quartile of the sample, showing a non-monotonic effect of this variable. When the specialization degree is low, an increase in specialization reduces the production inefficiency, while too much specialization increases the production inefficiency, probably due to the loss of flexibility of allocation of the different types of resources.

We find that the marginal effects of subsidies on the technical efficiency differ in different circumstances, e.g. by specialization degree, by farm size classes, by geographical regions, and by the type of location. The larger farms are more sensitive to the subsidies and tend to have a lower technical efficiency when receiving subsidies. If a farm is specialized in olive, it easily reduces the technical efficiency upon receiving subsidies due to the lack of possibilities to switch. The different geographical regions have different production conditions and thus have different reactions to the subsidies. Finally, if the farm is located in the less favoured area, the marginal effect of subsidy on technical inefficiency is higher than in other area. As a whole, the marginal effects of share of subsidies on technical inefficiency is positive, or on technical efficiency is negative. A 1000€ subsidy will cause a 0.17% increase of the technical inefficiency, or a 0.12% of the decrease of the technical efficiency, corresponding a 0.17% of the decrease of the output level. In 1995-2004, the total subsidies received by the average Greek olive farms caused a decrease of the output by 0.83%.

We may draw some policy implication of the CAP reform (e.g. the direct transfers) based on this empirical study. The direct transfers or decoupled subsidies might have negative impacts on the technical efficiency in the case of Greek olive farms. Increase of the direct transfers also increases the production uncertainty. Specialization of production can have positive or negative impacts on the technical efficiency, thus stimulating a proper degree of specialization is needed in order to achieve the highest technical efficiency. Besides, subsidies in different circumstances may have different levels of impacts on the technical efficiency. Thus we may require different policies, for e.g. different regions or different types of location, to reduce the negative impacts of direct subsidies or to achieve the spatial convergence.

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Appendix Subsidies and estimation results

Table 1A Total subsidies of Greek olive specialist farms

1995	1996	1996	1997	1998	1999	2000	2001	2002	2003	2004	average
4158	5430	5430	4227	4760	4061	5591	4310	6102	4651	5469	4878

Source: FADN.

Table 2A Estimated frontier function and non-monotonic inefficiency effects model

	Coef.	Std.	z	P>|z|	[95% conf. Interval]	
Ln (*output*)						
Ln (*variable input*)	0.4941	0.0457	10.81	0.000	0.4045	0.5836
Ln (*capital*)	0.0330	0.0354	0.93	0.352	-0.0365	0.1024
Ln (*labour*)	0.1225	0.0675	1.81	0.070	-0.0099	0.2549
Ln (*land*)	0.3497	0.0655	5.34	0.000	0.2214	0.4781
time	0.0107	0.0154	0.69	0.487	-0.0195	0.0409
Ln (*variable inputs*)**2	-0.0046	0.0273	-0.17	0.865	-0.0581	0.0488
Ln (*variable inputs*)*Ln (*capital*)	-0.0451	0.0307	-1.47	0.142	-0.1054	0.0151
Ln (*variable inputs*)*Ln (*labour*)	-0.2216	0.0502	-4.41	0.000	-0.3200	-0.1232
Ln (*variable inputs*)* Ln (*land*)	0.0578	0.0449	1.29	0.198	-0.0301	0.1458
Ln (*capital*)**2	0.0137	0.0135	1.01	0.311	-0.0128	0.0402
Ln (*capital*)* Ln (*labour*)	0.0662	0.0468	1.42	0.157	-0.0255	0.1578
Ln (*capital*)* Ln (*land*)	-0.0502	0.0349	-1.44	0.151	-0.1186	0.0183
Ln (*labour*)**2	-0.1844	0.0523	-3.52	0.000	-0.2870	-0.0818
Ln (*labour*)* Ln (*land*)	0.2869	0.0693	4.14	0.000	0.1511	0.4228
Ln (*land*)**2	0.0167	0.0414	0.40	0.686	-0.0644	0.0978
Time* Ln (variable inputs)	-0.0209	0.0065	-3.24	0.001	-0.0336	-0.0083
Time* Ln (*capital*)	0.0045	0.0051	0.90	0.371	-0.0054	0.0144
Time* Ln (*labour*)	0.0486	0.0101	4.81	0.000	0.0288	0.0684
Time*Ln (*land*)	-0.0037	0.0086	-0.44	0.661	-0.0205	0.0130
Time_square tsquare	0.0001	0.0013	0.07	0.942	-0.0025	0.0027
Constant	0.3284	0.0546	6.01	0.000	0.2213	0.4355
μ						
Subsidy share	0.0589	0.0040	14.80	0.000	0.0511	0.0667
Farm size	0.0109	0.0028	3.86	0.000	0.0053	0.0164
Specialization degree	0.0064	0.0047	1.35	0.178	-0.0029	0.0156
Share of family labour	0.0075	0.0017	4.49	0.000	0.0042	0.0108
Share of own land	0.0008	0.0011	0.72	0.473	-0.0014	0.0029
Share of loans	-0.0036	0.0142	-0.25	0.801	-0.0315	0.0243
Time	-0.0362	0.0130	-2.78	0.005	-0.0618	-0.0107
Ipiros-Peloponissos-Nissi Ioniou	-0.8070	0.1154	-6.99	0.000	-1.0332	-0.5807
Thessalia	0.1695	0.1600	1.06	0.289	-0.1441	0.4831
Sterea Ellas-Nissi Egaeou-Kriti	-1.0621	0.1502	-7.07	0.000	-1.3565	-0.7677
Less Favoured Area	0.3377	0.1069	3.16	0.002	0.1282	0.5472
Constant	-2.1519	0.5345	-4.03	0.000	-3.1995	-1.1042

σ_{it}^2						
Subsidy share	-0.0133	0.0063	-2.10	0.036	-0.0258	-0.0009
Farm size	-0.0008	0.0093	-0.08	0.934	-0.0190	0.0175
Specialization degree	-0.0133	0.0079	-1.67	0.095	-0.0288	0.0023
Share of family labour	0.0446	0.0070	6.36	0.000	0.0309	0.0584
Share of own land	0.0055	0.0043	1.29	0.195	-0.0028	0.0139
Share of loans	-0.0746	0.0930	-0.80	0.422	-0.2570	0.1077
Time	-0.0145	0.0256	-0.57	0.570	-0.0646	0.0356
Ipiros-Peloponissos-Nissi Ioniou	1.5993	0.5166	3.10	0.002	0.5868	2.6117
Thessalia	1.3541	0.6573	2.06	0.039	0.0658	2.6423
Sterea Ellas-Nissi Egaeou-Kriti	1.2453	0.5295	2.35	0.019	0.2076	2.2831
Less Favoured Area	-0.5236	0.2053	-2.55	0.011	-0.9260	-0.1212
Constant	-5.5516	1.2013	-4.62	0.000	-7.9061	-3.1970
σ_{v}^2						
Constant	-2.1437	0.0600	-35.75	0.000	-2.2612	-2.0262