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Abstract– **The arable crop sector (COP) occupies a prominent position within the European Union's agricultural sector. Within Spain, the COP sector accounts for almost a third of total Agricultural Guidance and Guarantee Fund expenses, and a half of the utilised agricultural area. The COP sector is not only relevant because of its physical and economic magnitude, but also because of the political attention it receives. The Common Agricultural Policy reforms that occurred during the 1990s paid special attention to this sector. This paper aims at determining the impacts of Agenda 2000 on a sample of Spanish COP farmers' production decisions by using an output-oriented stochastic distance function. The distance function allows assessing the reform-motivated changes on total output, input used, input composition and crop mix. It also permits to assess the impacts of the reform on farms' technical efficiency. Results show that the reform has shifted outwards the production frontier and changed output composition in favour of voluntary set aside land. With respect to input composition, Agenda 2000 has induced a decrease in land, fertilizers and other inputs in favour of labour. In addition, Agenda 2000 had a negative impact on technical efficiency.**

Keywords– **Agenda 2000, efficiency, Spanish COP sector.**

I. INTRODUCTION

The Cereal, Oilseeds and Protein crop (COP) sector occupies a prominent position within the European Union's (EU) agricultural sector. This sector represented 11% of the EU's final agricultural output and 21% of the aggregate farm income in 2003. Moreover, the total COP area amounts to 40% of the total Utilized Agricultural Area (UAA) in the EU, and 43.3% of the European Agricultural Guidance and Guarantee Fund (EAGGF) expenditures (Spanish Ministry for Agriculture, 2007a).

The EU is the third most important cereal producer in the world (behind China and the US) and accounts for 14.3% of total production, as well as 24.1% of world wheat exports and 42.9% of world barley exports (FAOSTAT, 2004). The main COP producing countries within the EU are France and Germany, followed by the United Kingdom, Spain and Italy. The rate of self-sufficiency in the EU is on the order of 118% for cereals, 80% for protein crops and 44% for oilseeds. The Spanish COP sector contributes 11% to the final agricultural output in Spain and is the third most frequent techno-economic orientation among Spanish farms, after citrus and olive. Within Spain, the COP sector accounts for 28% of total EAGGF expenses, 48% of the UAA, and 37% of total agricultural area (Spanish Ministry for Agriculture, 2007b).

Compared to other EU producers, Spanish COP yields are low with a high annual variation because of uneven rainfall (Eurostat, 2007)[1]. Further, Spanish farms are considerably smaller than other European farms with an average economic size of 21.5 European Size Units (ESU) compared to 111.4 and 68.5 ESU in the United Kingdom and France, respectively (FADN, 2006).

The COP sector is not only relevant because of its physical and economic magnitude, but also because of the political attention it receives. The Common Agricultural Policy (CAP) reforms that occurred during the 1990s paid special attention to this sector. The reform in 1992 and Agenda 2000 involved reductions in market price supports for COP crops (European Commission, 2007). The negative effects from price changes on farming incomes were compensated with area payments. In order to be eligible for these payments professional farmers were required to set aside a fixed percentage of program

[1] Over the 1995-2006 period, Spanish COP yields had an average year-to-year variation of 11% compared to less than 1% for Greece and the United Kingdom, and between 1-2% for France and Italy

crop areas and were granted a set-aside compensatory payment. A voluntary set-aside in addition to the compulsory one was also allowed and granted compensatory payments.

The area payments introduced by the CAP reforms are a partially decoupled policy measure as they are still tied to farmers' production decisions. As noted by Serra et al. (2005), although these payments do not reward an increase in yields, they do not allow full planting flexibility to farmers and thus they are expected to affect production decisions. However, because these payments are only partially decoupled, their impacts on farmers' decisions should be smaller than the impacts of price supports. Previous analyses on the effects of the CAP reforms provide empirical evidence on this hypothesis (Oude Lansink and Peerlings, 1996; Moro and Sckokai, 1999; Serra et al. 2005).

The changes involved with CAP reforms may have altered farmers' production decisions. A reduction in price supports in favor of partially decoupled payments may have motivated a more extensive use of land. This may have involved a reduction in input use, or a change in the types of inputs employed in favour of cheaper alternatives. It is also possible that farms may have altered their crop mix in response to policy reforms. In this regard, setting land aside may have become an attractive alternative to those less fertile land plots. It is also possible that changes in production decisions have altered farm technical efficiency.

Our study assesses the impacts of Agenda 2000 on production decisions and production efficiency for a sample of Spanish COP farms. This analysis is based on an unbalanced panel of farm-level data. We utilize a frontier estimate of a distance function that accommodates multiple inputs and outputs. The distance function allows for estimation of the deviation of a farm from the distance function frontier and permits an assessment of the reform on technical efficiency. It also allows for analysis regarding the impacts of regulatory reforms on the crop mix as well as on the use of agricultural inputs. Although previous analyses focused on the effects of the CAP reforms (see Serra et al., 2005; Oude Lansink and Peerlings, 1996; Moro and Sckokai and, 2006; Anton and Cahill, 2006; Sckokai, 2005; or Coyle, 2005), no previous studies have analyzed the impacts of Agenda 2000 by separately accounting for crop production from the value of the set aside.

The next section presents an overview of the Agenda 2000 CAP policy reform and is followed by a presentation of the theoretical framework. The next sections discuss the econometric specification and empirical application. This is followed by the presentation of results and concluding comments.

II. AN OVERVIEW OF AGENDA 2000 REFORM

In 1999, the European Commission decided on new reform measures for the Common Agricultural Policy which is known as Agenda 2000. Agenda 2000 was built on the principles established by the 1992 CAP reform. Reforms occurring during the 1990s were a response to EU's CAP internal and external challenges, the first one being the increase in worldwide agricultural production, which caused falling international prices. EU prices had been traditionally maintained at high levels compared to world market prices through widespread use of price-support mechanisms. This intervention had the objective of ensuring a fair standard of living for farmers, but often led to production surpluses that were usually sold at subsidized prices in international markets.

The second challenge concerned international pressures, especially within the World Trade Organization, to reduce trade distortions caused by the CAP. The third challenge was the social dissatisfaction arising from perceived unjust redistribution efforts. The unequal distribution of agricultural support between regions and producers resulted in a decline in agriculture in some regions and overly intensive farming practices in others, which generate pollution, animal disease and food safety concerns (European Commission, 1997). Finally, the Agenda 2000 aimed at facilitating the accession to the EU of Central and Eastern European countries by reducing existing agricultural price differences.

The measures introduced by the 1990s CAP reforms reduced cereal institutional prices and abolished institutional pricing of oilseeds and protein crops. To compensate producers for their income reduction, an Arable Area Payments Scheme based on historic regional yields was introduced in 1992 and reinforced with the Agenda 2000. Eligibility to receive these payments was tied to the obligation to set aside part of the eligible land. It was established that fields set aside could not be used for any commercial purpose, with the exception of the production of non-food crops. Direct payments for set aside land were also introduced in 1992 and fixed at the same level as arable land payments. Initially, the set aside instrument was a measure to tackle excess production. In the first year after the 1992 reforms, farmers were required to set aside 15% of their arable land. The Agenda 2000 mandated 10% of the arable land be set aside and allowed for a voluntary set aside amount above 10%. The voluntary set aside program allowed producers to retire more land than under strict compulsory[2] and still receive the corresponding compensatory payments. Small scale farms were exempted from the set-aside obligation.

III. ECONOMETRIC FRAMEWORK

In the literature, most of the studies that have assumed a multiple-output technology have used a dual cost function, or have aggregated the multiple outputs into a single index. This index can be a multilateral superlative index (Tornqvist[3] or Fisher index) or simply aggregate revenue. While the first approach requires an assumption of revenue maximizing or cost- minimizing behaviour, which presupposes the availability of price information, the second can lead to aggregation problems.

Other recent studies, based on a parametric frontier approach, have attempted to model a multiple output production technology by using an input requirement function, where inputs (single or aggregate) are expressed as a function of outputs (Gathon and Perelman, 1992); or an output/input-oriented distance function (Lovell et al., 1994; and Coelli and Perelman, 1996, 2000) that uses multiple outputs and inputs. Output-oriented distance functions are used in this study.

The output distance function is an output-expanding approach to the measurement of the distance between a producer and the boundary of production possibilities. It yields the minimum amount by which an output vector can be inflated and still remain producible with a given input vector (Kumbhakar and Lovell, 2000). For multiple outputs and multiple inputs the output distance function, introduced by Shephard (1953, 1970) is defined as:

$$D_0(y,x,R) = \min_{\theta}\left\{\lambda \left| (y/\lambda) \in \mathrm{P}(x,R) \right.\right\} \qquad (1)$$

[2] Under the condition that their set-aside area does not exceed the planted COP area.

[3] Caves et al. (1982).

where y denotes a non-negative vector of outputs, $\mathrm{P}(x,R)$ describes the sets of output vectors that are feasible for each input vector x, given the external factors vector R. Parameter λ is the scalar "distance" by which the output vector can be deflated. $D_0(y,x,R)$ is homogeneous of degree one in outputs, is a convex function of y, decreases in each input, and is nondecreasing in each output. The output vector is an element of the feasible technology set such that $P(x, R)$, $D_0(y,x,R) \leq 1$. If the output vector is located on the outer boundary of the production possibility set, the distance function will take a value of unity (Lovell et al., 1994).

Following the seminal papers of Debreu (1951) and Farrell (1957), the efficiency of a firm can be defined and measured as the distance of its actual performance from a frontier. The distance function provides radial measures of the distance from the output bundle to the boundary of the production technology. The relationship between the distance function and radial technical efficiency is given by:

$$TE_o(x,y) = D_o(x,y,R;\beta) = e^{-u} \prec 1 \Leftrightarrow D_o(x,ye^{u},R;\beta) = 1$$

$$\text{for } u \geq 0 \qquad (2)$$

where u is a vector of independently distributed and nonnegative random disturbances that provide a measure of output-oriented technical efficiency, β is a vector of unknown parameters to be estimated, and $0 \prec TE_o(x,y) \prec 1$ is the measure of technical efficiency. If $TE_o(x,y) = (<)1$, the observation is efficient (inefficient) as it lies on (below) the frontier.

IV. ECONOMETRIC SPECIFICATION

The specification of an error component implies the model takes on a stochastic production frontier perspective as initially developed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) for production functions. Such models have two error terms. The technical inefficiency error term *(-u)* is augmented by an error component (*v*) representing other factors that might generate irrelevant noise in the data (such as measurement error and unobserved inputs). We use maximum likelihood techniques to estimate the stochastic production frontier model.

The stochastic distance function model with M outputs, K inputs and B exogenous variables can be written as

$$1 = D_o(x_{ki}, y_{mi}, r_{bi}; \beta) * \exp\{v_i - u_i\} \qquad (3)$$

where i is a subindex that denothes the ith firm in the sample, and subindices m, k and b indicate the mth output, kth input and bth exogenous factor respectively. To estimate the model in (3), we take advantage of an output distance function property which implies that $D_o(x_{ki}, \lambda y_{mi}, r_{bi}; \beta) = \lambda D_o(x_{ki}, y_{mi}, r_{bi}; \beta), \lambda \succ 0$.

After setting $\lambda = |y_i|^{-1}$, the reciprocal of the Euclidean norm of the output vector, we get $D_0(x_{ik}, \frac{y_{mi}}{|y_i|}, r_{bi}; \beta) = |y_i|^{-1} D_o(x_{ik}, y_{mi}, r_{bi}; \beta)$ which implies that $D_0(x_{ik}, y_{mi}, r_{bi}; \beta) = |y_i| . D_o(x_{ik}, \frac{y_{mi}}{|y_i|}, r_{bi}; \beta)$.

Substituting this equation into (3), we get:

$$|y_i|^{-1} = D_o(x_{ik}, \frac{y_{mi}}{|y_i|}, r_{bi}; \beta). \exp\{u_i - v_i\} \quad (4)$$

where the dependent variable is the reciprocal of the norm of the output vector chosen for normalization and the regressors are the inputs and the normalized outputs. v_{it} is a vector of random errors that are assumed to be iid $N(0, \sigma_v^2)$, and u_{it} is a vector of independently distributed and nonnegative random disturbances that are associated with output-oriented technical inefficiencies.

To empirically estimate our model, we assume that the distance function can be approximated with a translog function. This functional form has the advantages of flexibility, homogeneity and is easy to calculate when compared to other functional forms (Lovell et al. 1994, Grosskopf et al., 1997, Coelli and Perelman, 2000). Flexibility allows for substitution through the incorporation of second-order (interaction or cross-) terms across (outputs and) inputs, as well as for regulatory impacts within the function. These substitution possibilities do not require restrictive assumptions about the nature of the technological relationship.

If $D_o(x, ye^u, R; \beta)$ takes the translog form with M outputs, K inputs and B exogenous determinants, then it can be written as:

$$\begin{aligned} \ln|y| &= \beta_0 + \sum_k \beta_k \ln x_{ki} + \sum_m \beta_m \ln \frac{y_{mi}}{|y|} + \frac{1}{2} \sum_k \sum_l \beta_{kl} \ln x_{ki} \ln x_{li} + \sum_m \sum_b \gamma_{mb} \ln y_{mi} r_{bi} \\ &+ \frac{1}{2} \sum_m \sum_n \beta_{mn} \ln \frac{y_m}{|y|} \ln \frac{y_{ni}}{|y|} + \sum_k \sum_m \beta_{km} \ln x_{ki} \ln \frac{y_{mi}}{|y|} + \sum_k \sum_b \gamma_{kb} \ln x_{ki} r_b + u_i + v_i \\ & i = 1, 2, ..., N \end{aligned} \qquad (5)$$

Normalization of the translog distance function by one of the outputs allows for the imposition of homogeneity restrictions. The summation sign over m, n, (k,l), [b] implies summation over all M outputs y_m, (K inputs x_k) [B exogenous factors r_b]. The one-sided error component $u_i = \delta z_i + \eta_i$ is assumed to be an independently distributed and nonnegative truncation of the normal distribution with mean δz_i, where z_i is a ($Nx1$) vector that includes the determinants of a farm's technical inefficiency and δ is a ($Nx1$) vector of unknown parameters. $\eta_i \sim N(0, \sigma_\eta^2)$ is a random variable defined by the truncation of the normal distribution.

V. ASSESSMENT OF THE IMPACTS OF THE CAP REFORM

As described above, the 1990s CAP reforms involved a reduction in price support measures in favour of area payments. While eligibility for decoupled payments was conditional on compulsory set aside, voluntary set aside was also allowed. In our analysis we distinguish between two outputs, COP production and voluntary set aside, in order to assess whether decoupling measures have reduced farmers' incentive to produce in favour of retiring land. A set of different inputs described in the empirical implementation section are also considered to determine the impacts of the reforms on agricultural input productivity and use. Finally, we are also interested in assessing the impacts of the reforms on the efficiency with farms operate. The output distance function allows analyzing these issues.

More specifically, from the output distance function we can calculate a series of first and second-order elasticities of D_0 that allow studying the impacts of regulatory measures on the aspects that we are interested in, i.e., marginal productivity of inputs, input composition, output, as well as output composition and efficiency. The overall reform impact measure on production is measured through the first-order elasticity, $\bar{\varepsilon}_{y,R}$, where

$$\bar{\varepsilon}_{y,R} = d \ln y \;_{|R=(0,1)} \quad (6)$$

where R is a dummy variable equal to 1 after the reform and equal to zero for the period before the reform. The elasticity in (6) measures the productive impact of a policy reform, i.e., whether a reform causes any shift in the production possibility frontier (PPF). A regulatory change, however, may not only involve a change in total output, but it may also impact on the crop mix, input use, and input mix. Second-order input and output elasticities allow for an evaluation of these other issues.

The output elasticity of each input, x_k, can be defined as follows:

$$\varepsilon_{y,k} = \partial \ln y / \partial \ln x_{ki} = \partial y / \partial x_{ki} (x_{ki} / y) \quad (7)$$

where $\varepsilon_{y,k}$ represents the percentage change in output y, due to a unit increase in input k. Using equation (7), we decompose $\varepsilon_{y,k}$ into its second-order components:

$$\varepsilon_{y,k} = \partial \ln y / \partial \ln x_{ki} = \beta_k + \sum_l \beta_{kl} \ln x_{li} + 2\sum_m \beta_{km} \ln \frac{y_m}{|y|} + \sum_b \gamma_{kb} r_{bi} \quad (8)$$

The four components of the $\varepsilon_{y,k}$ elasticity are: i) β_k, which measures the direct impact of input x_k on the production of y; ii) $\sum_l \beta_{kl} \ln x_{li} = \sum_l C_{kl}$, which measures the cross-effect between inputs x_k and x_l, represents the complementary ($C_{kl} > 0$) or substitution ($C_{kl} < 0$) relationship between these inputs; iii) $\sum_m \beta_{km} \ln \frac{y_m}{|y|} = \sum_m C_{km}$, which represents the impact of output y_m on x_k productivity; and, iv) $\sum_b \gamma_{kb} r_{bi} = \sum_b C_{kb}$, measures the impact of the exogenous factor (reform) on x_k productivity. As explained by Morrison, Johnston and Frengley (2000), this last measure also picks up changes in the input mix. A regulatory reform will be input saving (neutral) [increasing] if $C_{kb} < (=)[>]0$.

The tradeoff between the different outputs y and y_m is defined as the following first-order elasticity

$$\varepsilon_{y,m} = \partial \ln y / \partial \ln \frac{y_m}{|y|} \quad (9)$$

This measure reflects the shape of the PPF when the factors of production are used to their full potential. The greater the quantity of y produced, the less the production of the other output (y_m). This measure is used in the output distance function to reflect the shadow value through the y-y_m space.

Second-order elasticities of (9) can be defined as:

$$\varepsilon_{y,m} = \beta_m + \sum_n \beta_{mn} \ln y_{ni} + \sum_b \gamma_{mb} r_{bi} + 2.\sum_k \beta_{km} \ln x_{ki} \quad (10)$$

We focus on the cross term linked with the exogenous variable (reform), and its impact on the contribution of overall production: $\sum_b \gamma_{mb} r_{bi}$. More specifically, parameter γ_{mb} can be used to evaluate whether a change in reform generates a change in the slope of the PPF and thus on production composition. As detailed in Morrison, Johnston and Frengley (2000), $\gamma_{mb} < (>)0$ reflects a twist in the frontier that increases (reduces) the relative importance of y_m within the total output.

VI. EMPIRICAL IMPLEMENTATION

The output distance function is estimated using a sample of 2,476 COP farms over the nine-year period from 1995 to 2003, which makes for an unbalanced panel of 9,874 observations. These data are obtained from the Farm Accountancy Data Network (FADN) database using the farm type 13- specialist cereal, oilseed and protein farms. Price indices are taken from Eurostat (2006).

Although our analysis is based on farm-level data, aggregate measures are used to define some variables that are unavailable from the FADN dataset. Input and output price indices necessary to deflate all monetary variables were derived from Eurostat. The base year for the deflation of all monetary variables in 1995. The Department of Agriculture of the Catalan Government and the Spanish Ministry of Agriculture (2007) provided unpublished data on yield, percentage and payment of voluntary and compulsory set aside by year and region (Autonomous communities). These data were used to estimate farm-level voluntary set aside payments as detailed below.

We estimate a translog distance function with two outputs and five inputs, augmented by a reform variable to account for the policy impact. The two outputs, that we define represent the revenue from COP crop production, y, and the revenue generated from voluntary set aside, y_m, respectively. As noted, the distinctions between these two outputs allow us to assess whether decoupling measures have reduced farmers' incentive to produce in favour of retiring land.

FADN does not register the voluntary set aside payment; only a single variable including total (voluntary and compulsory) set-aside is available. We estimate this magnitude at the farm level by concentrating on professional producers which is defined by farms that have a COP area greater than or equal to 20 ha. Professional producers cannot receive area payments unless they comply with the compulsory set aside rules.

We estimate the obligatory set aside area by applying the percentage of compulsory set aside to COP area. Using the total set aside area provided by FADN data set and the estimated compulsory set aside area, we can approximate the voluntary set aside area. We then adjust our voluntary set aside estimation by calculating the maximum voluntary set aside. This is done by applying the maximum voluntary set-aside percentage to COP area. If the estimated value exceeds the maximum value, we replace our estimate with the maximum value. Finally, we estimate the voluntary set aside payment by applying the following formula:

$$y_m = S_a \times Y \times P \qquad (11)$$

where y_m is the estimated voluntary set aside payment (expressed in €), S_a is the estimated voluntary set aside area (ha), Y is the regional yield (tonnes/ha) applied to determine the set aside payment, and P is the voluntary set aside payment (€/tonnes).

Input variables are labour (x_L), defined as total hours spent on farm work, expenditure on fertilizers (x_F), pesticides (x_P), and other inputs such as seed costs and farming overhead (x_I). The total area allocated to COP production and set aside defines the land variable x_{LND}. To incorporate the regulatory reform variable into the translog function specification by using a dummy variable that is equal to zero before 1999 and equal to 1 otherwise (*R*). An additional dummy variable is included to reflect a less favoured area (LFA) dummy which is equal to 1 if farm is located in a LFA and 0 otherwise Vector z_i, in the technical inefficiency effects function, is a (1x5) vector that contains four determinants of technical inefficiency and a constant (z_1). The first determinant is a time trend. Since farm managers may learn from their errors, the passage of time may improve efficiency levels. The dummy variable for the regulatory reform defined as R, is also included. The reduction of price support measures in favour of decoupled payments may have altered the efficiency with which farms operate. A fourth component of vector z_i is the birth year of the holding's primary decision maker. Older farmers are expected to be less efficient in comparison to younger ones. The final covariate measures the workforce composition which is measured by the ratio of family labour hours to total labour hours. As shown by previous literature (Lambarraa et al., 2007; Serra et al., 2005) , direct costs of land rentals may create stronger incentives to work the land in a more efficient manner, relative to the opportunity costs borne by owned land.

Summary statistics for the variables of interest are presented in Table 1. The value of COP production decreased over the whole period of analysis, while voluntary set aside increased substantially (from 346 € to 673.4 €, a 94.5% growth). This resulted in a change in the output structure in favour of voluntary set aside, a result that is expected and suggests that decoupling measures reduce incentives to productively work the land. This incentive is later confirmed in the formal analysis. Input use increased throughout the period studied; pesticides, other costs and fertilizers increased from the pre-to-post reform period by 20%, 13.4% and 7.2%, respectively. Total area, however, decreased by 1.50% in the post reform period. This decrease is the result of a 0.45% decrease in COP area coupled with a over a 70% increase in the voluntary set aside area. Table 1 also shows that 60% of the farms in our sample are located in less favoured areas and the average age of farm operators is 49 years old, while family labour represents 89% of total labour used in production.

Table 1 Description of sample data

Variable	Unit of measure	Mean			Standard Error 1995-2003
		1995-1998	1999-2003	1995-2003	
Voluntary set aside	€	346	673	531.21	(1452.67)
COP outputs	€	29393.7	27379.9	31825.51	(37760.34)
Pesticides	€	1269.2	1524.1	1431.00	(2466.94)
fertiliser	€	5606.9	6014.7	5917.52	(8410.68)
Other costs	€	110.5	125.4	119.99	(143.88)
Labour	hours	2516.7	2593.5	2569.92	(2275.67)
Land	ha	115.4	113.7	115.31	(151.29)
Volunatry set aside area	ha	2.77	4.76	3.83	(0.1017)
COP area	ha	88.5	88.1	88.98	(121.07)
Less favoured area	dummy			0.60	(0.48)
Work force	ratio			0.89	(0.24)
Age*	years			49.4	(12.50)

*FADN dataset provides the manager's birth year. However, we have converted this variable to the manager's age only for the purpose of presenting more useful data in this table.
Source : EU-FADN-DG Agriculture and Rural Development G-3, Eurostat, the Spanish Ministry for Agriculture and Department of Agriculture of the Catalan Government.

VII. RESULTS

The results from translog distance function estimation are presented in Table 2. Most of the coefficients are found to be significant at the 1 % level. For output, the negative parameter of y_m (voluntary set aside payment) reflects the shape of the PPF. This shape shows an efficient combination between COP product and voluntary set aside, as well as illustrating the principle of increasing cost. As more COP product is produced (y), proportionally larger amounts of voluntary set aside (y_m) must be given up. The negative less favoured area coefficient indicates that holdings facing different environmental restrictions are less productive relative to other farms. The direct effect of reform suggests an upward shift in the PPF.

All the input cross-terms are significant except for the labour-pesticides interaction. The positive cross-terms between labour-land and labour-other input costs imply a technological complementary relationship between these pairs of inputs. Similarly, fertilizer is a technological complement to both pesticides and other input costs, while land is complementary to pesticides. On the other hand, there is a technological substitution relationship between labour and fertilizers, land and other input costs, land and fertilizers, and pesticides and other input costs.

To better interpret parameter estimates and determine the influence of the Agenda 2000, we calculate the elasticities detailed above. Results are represented in Tables 3 and 4. The elasticities with respect to labour, land, other input costs and fertilizers have the expected positive sign, whereas the elasticity with respect to pesticides is negative. Other input costs are the most productive input followed by labour, land and fertilizer. The negative sign of pesticide input elasticity may indicate an overuse of pesticides.[4]

[4] A decomposition of pesticides elasticity into its second-order components indicates that pesticides have indeed a direct positive effect on output. However, counteracting substitutability with labour and other inputs cost yield a final negative total effect.

Table 2 Maximum likelihood estimates of output distance function for COP farms in Spain

Variables	Parameter	Estimate	Standard Error
Frontier production function			
Voluntary set aside output	y_m	-.311960	(.076084)***
Labour	β_{LB}	-.721193	(.075119)***
Fertilizers	β_F	.203452	(.078484)***
Pesticides	β_P	.274075	(.068998)***
Land	β_L	-.558713	(.078117)***
Other Inputs cost	B_I	-.195878	(.120916)*
Fertilizers × Labour	$\beta_{F..LB}$	-.058970	(.020810)***
Pesticides × Labour	$\beta_{P.LB}$	-.015859	(.018280)
Land × Labour	$\beta_{L.LB}$	.169949	(.023857)***
Other Inputs × Labour	$B_{I.LB}$	.250356	(.028717)***
Fertilizers × Pesticides	$\beta_{F.P}$	.072112	(.011203)***
Fertilizers × Land	$\beta_{F.L}$	-.037889	(.016613)***
Land × Pesticides	$\beta_{L.P}$	.032638	(.012874)***
Fertilizers × Other Inputs	$\beta_{F.I}$	.085628	(.017347)***
Other Inputs × Pesticides	$B_{I.P}$	-.168219	(.017330)***
Other Inputs × Land	$B_{I.L}$	-.073208	(.026487)***
Other Inputs × y_m	$B_{I.Ym}$	-.060122	(.001954)***
Land × y_m	$\beta_{L.Ym}$	-.018853	(.006937)***
Pesticides × y_m	$\beta_{P.Ym}$	-.021614	(.005449)***
Fertlizers × y_m	$\beta_{F.Ym}$	.013157	(.005656)***
Labour × y_m	$\beta_{LB.Ym}$	.036902	(.009649)***
Labour × Reform	$\gamma_{LB.R}$	.043170	(.018999)***
Fertilizers × Reform	$\gamma_{F.R}$	-.016368	(.013986)*
Pesticides × Reform	$\gamma_{P.R}$	.003570	(.009953)
Land × Reform	$\gamma_{L.R}$	-.009892	(.012924)
Other Inputs × Reform	$\gamma_{I.R}$	-.105261	(.021506)***
y_m × Reform	$\gamma_{Ym.R}$	-.009559	(.010714)
Reform	γ_R	.490115	(.141817)***
Variables	**Parameter**	**Estimate**	**Standard Error**
Less Favoured Area	β_{LFA}	-.381870	(0.01658)***
Constant	β_0	8.37728	(.508727)***
Inefficiency effects model			
Constant	δ_0	382.186	(30.1567)***
Time	δ_T	-.190334	(.015110)***
Reform	δ_R	.823496	(.082078)***
Year of birth	δ_{YB}	-.002265	(.001563)
Workforce composition	δ_{WC}	.268113	(.094984)***
log likelihood function = -6486.99			
LR test of the one-sided error = 713.21			

Note: ***, ** and * indicate that the parameter is significant at the 1% and 5% and 10% respectively.

Table 3 Inputs elasticities decomposition $\varepsilon_{y,k}$

Input elasticities	Value	Standard Error
$\varepsilon_{y,LB}$	0.96169	(0.00186)***
β_{LB}	-0.72119	(.075119)***
$C_{F.LB}$	-0.21280	(0.00056)***
$C_{P.LB}$	-0.03071	(0.00018)***
$C_{L.LB}$	0.75422	(0.00123)***
$C_{I.LB}$	1.12315	(0.00185)***
$C_{Ym.LB}$	0.02494	(0.00036)***
$C_{R.LB}$	0.02374	(0.01044)***
$\varepsilon_{y,P}$	-0.20659	(0.00095)***
β_P	0.27407	(.068998)***
$C_{LB.P}$	-0.12165	(0.00009)***
$C_{P.F}$	0.26023	(0.00069)***
$C_{L.P}$	0.14484	(0.00023)***
$C_{I.P}$	-0.75467	(0.00124)***
$C_{Ym.P}$	-0.01141	(0.00016)***
$C_{R.P}$	0.00196	(0.005474)
$\varepsilon_{y,L}$	0.32468	(0.00094)***
β_L	-0.55871	(0.07511)***
$C_{LB.L}$	1.30361	(0.00100)***
$C_{F.L}$	-0.13673	(0.00036)***
$C_{P.L}$	0.06321	(0.00038)***
$C_{I.L}$	-0.32843	(0.00054)***
$C_{Ym.L}$	-0.01274	(0.00018)***
$C_{R.L}$	-0.00544	(0.00710)***
$\varepsilon_{y,I}$	1.283442	(0.00228)***
β_I	-0.19587	(0.12091)**
$C_{LB.I}$	1.92037	(0.00147)***
$C_{F.I}$	0.30901	(0.00082)***
$C_{P.I}$	-0.32579	(0.00200)***
$C_{L.I}$	-0.32489	(0.00053)***
$C_{Ym.I}$	-0.04063	(0.00059)***
$C_{R.I}$	-0.05789	(0.01182)***
$\varepsilon_{y,F}$	0.10653	(0.00115)***
β_F	0.20345	(0.07848)***
$C_{LB.F}$	-0.45233	(0.00034)***
$C_{P.F}$	0.13966	(0.00085)***
$C_{L.F}$	-0.16814	(0.00027)***
$C_{I.F}$	0.38415	(0.00063)***
$C_{Ym.F}$	0.00889	(0.00013)***
$C_{R.F}$	-0.00900	(0.00769)***

$\varepsilon_{y,LB}$ $\varepsilon_{y,P}$ $\varepsilon_{y,L}$ $\varepsilon_{y,I}$ and $\varepsilon_{y,F}$ are the elasticities of labour, pesticides, land and fertilizers respectively

Note: ***, ** and * indicate that the parameter is significant at the 1% and 5% and 10% respectively.

Table 4 Second-order $\varepsilon_{y,m}$ and $\bar{\varepsilon}_{y,R}$ components

Input elasticities	Value	Standard Error
Voluntary set aside (Y_m) elasticity $\varepsilon_{y,m}$		
$\varepsilon_{y,m}$	-0.38200	(0.00049)***
β_m	-0.31196	(0.07608)***
$C_{Ym.I}$	-0.26972	(0.00044)***
$C_{Ym.L}$	-0.08367	(0.00013)***
$C_{Ym.P}$	-0.04186	(0.00025)***
$C_{Ym.F}$	0.04748	(0.00012)***
$C_{Ym.LB}$	0.28306	(0.00021)***
$C_{Ym.R}$	-0.00525	(0.00589)
Reform elasticity $\bar{\varepsilon}_{y,R}$		
$\varepsilon_{y,R}$	0.24650	(0.00075)***
$C_{R.LB}$	0.33113	(0.00025)***
$C_{R.F}$	-0.05907	(0.00015)***
$C_{R.P}$	0.00691	(0.00691)
$C_{R.L}$	-0.04390	(0.00007)***
$C_{R.I}$	-0.47222	(0.00077)***
$C_{R.Ym}$	-0.00646	(0.00009)***
$C_{R.R}$	0.49011	(0.14181)***

Note: ***, ** and * indicate that the parameter is significant at the 1% and 5% and 10% respectively.

The reform-related component of the labour input elasticity suggests that Agenda 2000 had a positive impact on labour productivity (table 3). Conversely, and consistent with parameter estimates, the marginal productivity of fertilizers, other inputs, and land decreased as a response to regulatory changes. CAP reforms do not seem to have had a significant impact on pesticide productivity. Changes in input productivity are associated with changes in input composition involving an increase in the labour share to the detriment of land, fertilizer and other inputs costs' shares.

It is important to recognize that our sample farms mainly use family labour which is generally unpaid and thus involves an opportunity cost, not a direct cost. Hence, farms are changing input composition in favour of an increase in opportunity costs to reduce direct costs in other inputs. This result is compatible with sample farms expecting to receive lower income per unit produced after the policy reform.

For output, the first order elasticity, $\varepsilon_{y,m}$, reflects the shape of the production possibility frontier. In Table 4, we can see that the trade off between COP production and voluntary set aside is about -0.38 through the period studied, implying that an additional percentage of COP produced leads to a 0.38 percent decline in set aside. Compatible with parameter estimates presented in table 2, the regulatory component of this elasticity shows an increased share of voluntary set aside on total production as a response to Agenda 2000.

The impact of reform on overall production or productivity is measured by $\bar{\varepsilon}_{y,R}$ and is presented in the second section in Table 4. The global regulatory impact of the reform is positive, which suggests that the PPF shifts outwards after reform (γ_R) with the output composition, as already noted, changing in favour of land set aside ($\gamma_{Ym.R}$), the components of the $\bar{\varepsilon}_{y,R}$ indicates that the impact of reform is large and positive for the productivity of labour and largely negative for other input costs, fertilizers and land, which confirms the input composition change described above.

The estimated δ coefficient vector addresses the determinants of farms' technical inefficiency, and the impact of Agenda 2000 on technical efficiency. All parameters are statistically significant except the birth year of the primary decision maker that is close to significant. The negative coefficient for the time variable suggests that, contrary to our expectations, technical inefficiency of COP farms has been decreasing over time. The coefficient representing farmer's birth year suggests that younger farmers are more efficient than older ones. This result may be explained by the fact that younger farmers may be more likely to introduce efficiency-improving changes in their holdings relative to older ones. The family labour coefficient is positive, indicating that farms with a higher proportion of unpaid labour are less efficient relative to the farms with a higher proportion of remunerated work. These results are compatible with results from Lambarraa et al. (2007) and Latruffe et al. (2004).

Finally, the reform coefficient indicates a significant impact on the technical efficiency of Spanish COP farms. Specifically, Agenda 2000 seems to have had a relevant effect on the technical efficiency level of Spanish COP farms. This result is compatible with reduced motivation to produce efficiently as a response to the lower rents associated from production.

VIII. CONCLUDING REMARKS

This paper focuses on the impacts of Agenda 2000 on a sample of Spanish COP farmers' production decisions by using an output-oriented stochastic distance function. Given the partitioning of output into COP and the value of the set aside, the distance function permits the assessment of the reform-motivated changes on multiple outputs), inputs used, input composition and crop mix. It also permits to assess the impacts of the reform on farms' technical efficiency. The results show that the reform has shifted the PPF outwards and changed output composition in favour of voluntary set aside land. Reduced COP prices as a result of policy changes are likely to have encouraged farmers to participate in the voluntary set aside program. With respect to input composition, Agenda 2000 has induced a decrease in land, fertilizers and other inputs in favour of labour. Since farms in our sample mainly use unpaid family labour, results suggest that input composition is changing to reduce total direct costs in favour of opportunity costs. The reduction in fertilizer use as a result of Agenda 2000 clearly contributes positively toward the environmental goal of the reform. In addition, Agenda 2000 had a negative impact on technical efficiency; which is compatible with reduced motivation to produce efficiently as a response to the lower rents derived from producing.

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