# Productivity and Subsidies in the European Union:

# An Analysis for Dairy Farms Using Input Distance Frontiers


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# Productivity and Subsidies in the European Union: An Analysis for Dairy Farms Using Input Distance Frontiers

**ABSTRACT:** This paper examines the association between agricultural subsidies and farm efficiency using data from the European Farm Accountancy Data Network (FADN) for operations specializing on dairy. The analysis covers the 18 year period going from 1990 to 2007 and includes eleven countries: Belgium, Denmark, France, Germany, Ireland, Italy, Luxemburg, the Netherlands, Portugal, Spain, and the United Kingdom. Separate translog stochastic input distance frontiers are estimated for each country. Results show high technical efficiency averages and positive average rates of technological change. In addition, higher subsidy dependence and larger size are significantly associated with lower technical efficiency across all eleven countries.

**Keywords:** Subsidies; CAP; technical efficiency; technological progress; Europe; dairy production; input distance frontiers

## 1. INTRODUCTION AND BACKGROUND

The major objective of this paper is to examine the association between agricultural subsidies and farm efficiency. We also investigate if any such association changes under different subsidy regimes, over time, and across countries. We focus on farms specializing on dairy over a period of 18 years within eleven European Union (EU) countries: Belgium, Denmark, France, Germany, Ireland, Italy, Luxemburg, the Netherlands, Portugal, Spain, and the United Kingdom (UK). Farms in the EU have been highly subsidized since the inception of the Common Agricultural Policy (CAP).

Initially the CAP relied on coupled support and this has shifted progressively toward decoupled mechanisms. Several factors have triggered this transition such as market imbalances, EU budgetary constraints, international trade agreements, uneven distribution of agricultural support, and environmental concerns (Silvis and Lapperre, 2010). Until the first CAP reform of 1992 (the MacSharry reform), farms could receive coupled support in the form of price floors for several products, enforced by purchases from public agencies. The 1992 MacSharry reform started the transition from price support to income support, by introducing direct payments, namely acreage payments for various crops and payments per head of livestock. At the same time, price floors were reduced and the direct payments were aimed at compensating for the associated income losses. During this early reform period, payments for rural development were introduced, primarily in the form of agri-environmental schemes (AES) and as compensation for farms located in less favored areas (LFA). AES are voluntary contracts aimed at promoting environmental-friendly practices and in exchange farmers receive annual payments during the duration of the contract (usually five years). AES are numerous, depending on the objective pursued. The design of AES is at the discretion of each Member State; thus, they are country specific and even region specific within a country. Typically, the AES are designed at the NUTS2 level[1]. As for LFA payments, they are intended as compensation to farmers located in disadvantaged areas in terms of agronomic, climatic and/or economic conditions. The LFA zoning is also decided by each Member State.

[1] The Nomenclature of Territorial Units for Statistics (NUTS) provides a single uniform breakdown of territorial units for the production of regional statistics for the EU.
(source: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction).

The Agenda 2000 CAP reform continued the decoupling process started in 1992 by further reducing support prices, and by introducing more compensatory direct payments. The latest modification, the Luxemburg 2003 reform, made a sharp break in the CAP's evolution by introducing full decoupling in the form of Single Farm Payments (SFP). SFP are given to producers regardless of their output level or type, even if no production comes out of the land. The only condition is to comply with management guidelines aimed at keeping land in good agricultural and environmental condition, the so-called cross-compliance requirements. SFP were introduced in the EU-15 countries in 2005 or 2006, and they could be based on a 'historic' scheme (i.e., entitlements are based on what farms received during a reference period), on a 'regionalized or flat-rate' scheme (i.e., entitlements do not vary across farms in a specific region), or on a hybrid scheme combining both historic and regional features. France, Ireland, the Netherlands and Spain have chosen the historic option, while Denmark and Germany have opted for the hybrid option. As for the UK, Scotland and Wales have implemented the historic approach, and England and Northern Ireland have applied the hybrid approach. All these policy reforms have made progress but full decoupling across the EU is not a reality yet, since during the 2003 CAP reform Member States had the option of maintaining some payments coupled to certain products, e.g. cereals and cattle.

Despite the successive reforms of the CAP, support to farmers in the EU is still relatively high. The Producer Support Estimates (PSE) percentage, defined as the percent of gross transfers from consumers and taxpayers to farmers relative to the value of gross farm receipts, hovered around 30% in the mid 1980s falling to 23.5% in 2009. By comparison, PSE for the US was 9.8% in 2009, and in Australia the PSE are now less than 5% (OECD, 2010). The high level of farm support in the EU has prompted researchers to investigate the influence of the CAP along several dimensions including a recent focus on the impact of CAP subsidies on farm efficiency and productivity, which are critical components in the competitiveness and eventual survival of different farm units and regions. These studies can provide useful information to policy makers on how agricultural policies shape the future structure of the farming sector.

The theoretical literature linking farm subsidies and efficiency or productivity is thin. Martin and Page (1983) argued that subsidies reduce managerial effort and therefore negatively impact efficiency. More recently, Serra et al. (2008) suggest that support policies affect farmers' risk-aversion and thus decisions regarding input allocation. However, their model provides ambiguous theoretical outcomes which depend on whether the changes in decisions lead to increased use of a risk increasing input. Nonetheless, the empirical literature is quite consistent in reporting that subsidies are negatively associated with farm technical efficiency (TE) (see for example a review in Latruffe, 2010). The present paper aims at contributing to the literature on this issue in two primary ways: 1) We include several diverse countries in the analysis; and 2) We include an 18 year period which is sufficiently long to capture the various CAP reforms described above. The remainder of the paper is organized as follows. Section 2 presents the methodological framework employed, followed by a description of the data and of the empirical model in Section 3. We then move to a discussion of the major results in Section 4 and the paper ends with some concluding remarks.

## 2. METHODOLOGICAL FRAMEWORK

The application of frontier models in agriculture has received considerable attention by researchers around the world who have focused on a wide range of farm types using a broad array of methodologies (Battese, 1992, Bravo-Ureta and Pinheiro, 1993, Bravo-Ureta, et al., 2007, Moreira and Bravo-Ureta, 2009). More recent developments have made it possible to examine multi-input multi-output technologies using distance functions. Distance functions can be input or output oriented where the former is suitable when farms have relatively more control over inputs than outputs and the latter is more appropriate when the reverse situation prevails (Coelli, et al., 2005, Kumbhakar, et al., 2008). The distance frontiers can be deterministic, which are typically derived using data envelopment analysis (DEA), or stochastic approaches where estimation is done through econometric procedures (Färe, et al., 2008). Recent examples of studies of farm productivity in Europe using deterministic distance frontiers include the work by Balcombe et al. (2008) for Polish farms based on input oriented models while Fogarasi and Latruffe (2009) have applied output oriented specifications for French and Hungarian dairy farms. Kleinhanss et al. (2007) applied both output and input oriented models to German and Spanish livestock farms and found little difference in the results from both orientations. Work relying on stochastic input distance frontiers include Rasmussen (2010) and Sauer (2010) for Denmark, Kumbhakar et al. (2008) for Norway, and Sipiläinen (2007) for Finland. These last papers used data for farms where milk was the primary product. Examples of papers that rely on output oriented models include Zhu and Oude Lansink (2010) for crop farms from Germany, The Netherlands and Sweden, Newman and Matthews (2007) for various crop and livestock products in Ireland, Newman and Matthews (2006) for Irish dairy intensive farms, and Brümmer et al. (2002) for Germany, Poland and the Netherlands again for dairy intensive operations.

In this paper we choose a stochastic input distance frontier (IDF) and contend that farmers have relatively more control of inputs than outputs as recently articulated by Kumbhakar et al. (2008). Moreover, we choose the stochastic framework because it can readily incorporate a TE effects component and the full model can be estimated in one step. By contrast, two step models typically used along with DEA methods have received considerable criticism in the recent literature (Coelli, et al., 2005, Greene, 2008, Simar and Wilson, 2007).

Assuming that producers use a vector of $N$ inputs, $x = (x_1, \ldots, x_N) \in R_+^N$, the IDF is defined on the input set $L(y)$ as follows: $D_I(x, y) = \max\left\{\lambda : \left(\frac{x}{\delta}\right) \in L(y)\right\}$, where the input set $L(y)$ represents the set of all input vectors $x$ that are feasible for each output vector $y$, so that $L(y) = \{x \in R_+^N : x \text{ can produce } y\}$. The IDF gives the maximum amount by which an input vector can be contracted radially while still being able to produce the same output vector. The scalar input $x$ is feasible for output $y$, but $y$ can be produced with less input $\left(\frac{x}{\delta^*}\right)$, and so $D_I(x, y) = \delta^* \geq 1$ (Coelli and Perelman, 1996, Coelli, et al., 2005). From an empirical point of view, it is necessary to specify an algebraic form to estimate the IDF. Empirical research frequently relies on the relatively simple Cobb-Douglas (CD) functional form. However, given the restrictive nature of the CD, a more flexible alternative that is also commonly used in productivity studies is the translog (TL) (Bravo-Ureta, et al., 2007).

Following Coelli and Perelman (2000) and Kumbhakar et al. (2007), and assuming a TL production technology, including a smooth time trend ($t$) to account for technological progress, the IDF with $M$ outputs and $K$ inputs, can be expressed as:

$$\ln D_{it} = \alpha_0 + \sum_{m=1}^{M} \beta_m \ln y_{mit} + \frac{1}{2} \sum_{m=1}^{M} \sum_{s=1}^{M} \beta_{ms} \ln y_{mit} \ln y_{sit} + \sum_{k=1}^{K} \delta_k \ln x_{kit} + \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K} \delta_{kl} \ln x_{kit} \ln x_{lit}$$

$$+\sum_{k=1}^{K}\sum_{m=1}^{M}\rho_{km}\ln x_{kit}\ln y_{mit}t+\sum_{k=1}^{K}\phi_k \ln x_{kit}t+\sum_{m=1}^{M}\omega_m \ln y_{mit}t+\lambda_1 t+\frac{1}{2}\lambda_{11}t^2 \quad (1)$$

where $i$ = 1, 2, …, $N$; $D_{it}$ is the input distance for the $i^{th}$ firm in time period $t$; $y_{mit}$ denotes the $m^{th}$ output for the $i^{th}$ firm in time period $t$; $x_{kit}$ denotes a vector of $1*k$ inputs for the $i^{th}$ firm in time period $t$; and Greek letters are unknown parameters to be estimated.

Lovell et al. (1994) indicate that for equation (1) to qualify as a distance function it must fulfill the following regularity conditions: symmetry, monotonicity, positive linear homogeneity, non decreasing and convex in outputs ($y$), and decreasing in inputs ($x$). The convexity condition is important to ensure that the distance function displays diminishing marginal rates of technical substitution. Monotonicity requires that the first derivates of the distance function with respect to all inputs be greater than or equal to zero; in other words, an increase of any input cannot lead to lower output (Kumbhakar, et al., 2003).

To obtain the frontier, $D_{it}$ is set to 1, which implies that the left hand side of equation (1) is equal to 0. A convenient way of imposing the homogeneity condition is to normalize all inputs by one of the inputs, such as the $n^{th}$ input (e.g., Coelli, et al., 2003, Coelli and Perelman, 1999). In the estimating form of the IDF, the distance term $\ln D_{it}$ is replaced by the composed error term, $v_{it}-u_{it}$; thus, equation (1) can be expressed as:

$$\ln\left(\frac{1}{x_n}\right)=\alpha_0+\sum_{m=1}^{M}\beta_m \ln y_{mit}+\frac{1}{2}\sum_{m=1}^{M}\sum_{s=1}^{M}\beta_{ms}\ln y_{mit}\ln y_{sit}+\sum_{k=1}^{K-1}\delta_k \ln x_k^*+\frac{1}{2}\sum_{k=1}^{K-1}\sum_{l=1}^{K-1}\delta_{kl}\ln x_k^*\ln x_l^*$$

$$+\sum_{k=1}^{K-1}\sum_{m=1}^{M}\rho_{km}\ln x_k^*\ln y_{mit}+\sum_{k=1}^{K-1}\phi_k \ln x_k^* t+\sum_{m=1}^{M}\omega_m \ln y_{mit}t+\lambda_1 t+\frac{1}{2}\lambda_{11}t^2+v_{it}-u_{it} \quad (2)$$

where $x_n$ is the input used to impose homogeneity and $x_k^*=\frac{x_k}{x_n}$ is the $k^{th}$ normalized input. If the composed error term, $v_{it}$ - $u_{it}$, has appropriate distributional assumptions, then the parameters of the IDF can be estimated using maximum likelihood (Coelli and Perelman, 1996). The inefficiency term, $u_{it}$, in the stochastic frontier model in equation (2) can be expressed as:

$$u_{it} = z_{it}\delta + w_{it} \quad (3)$$

where $w_{it}$ is a random variable defined by the truncation of the normal distribution with zero mean and variance $\sigma^2$, $z_{it}$ is a $(p\times 1)$ vector of variables which are hypothesized to influence firm efficiency, and $\delta$ is a $(1\times p)$ vector of parameters to be estimated (Battese and Coelli, 1995).

The input distance for the $i^{th}$ firm is given by $D_{it}=\exp(-u_i)$ (Coelli and Perelman, 1996). The term $u_i$ cannot be measured directly; hence, following Jondrow et al. (1982), it is calculated as the conditional expectation of $\exp(-u_i)$, given the composed error term. Therefore, the predictor of TE for the IDF can be estimated as $\mathrm{TE}(x,y)=E\left[\exp(-u)\middle| v-u\right]$. All calculations can be done using the STATA 10.0 software, which yields maximum-likelihood estimates for the parameters of the stochastic frontier model.

## 3. DATA AND EMPIRICAL MODEL

This paper uses farm level data for farms located in 11 European countries for the 18 year period going from 1990 to 2007. The countries included are: Belgium, Denmark, France, Germany, Ireland, Italy, Luxemburg, the Netherlands, Portugal, Spain, and the UK. This means that we focus on all old member states that were in the EU since 1990, except for Greece which has a limited number of dairy farms in the data set. The data are extracted from the European Farm Accountancy Data Network (FADN), which combines in a uniform way data from national FADNs across the EU. The FADN database consists of yearly accounting information for commercial farms over a minimum size threshold, rotating over several years, typically five; therefore, the data sets are unbalanced panels. All individual country FADN data sets contain farms classified as specialized in milk production defined as those operations where at least 66% of the farm gross margin comes from milk production. The rationale for selecting farms according to their production specialization is based on two major reasons: 1) technology differs across specializations (e.g. field crops *vs*. dairy), and thus separate efficiency frontiers might be needed; and 2) CAP modalities, in particular the types and amount of subsidies and the policy reforms overtime, are different depending on specialization.

The model incorporates two outputs and four inputs. The outputs are: $y_1$, milk produced (*Milk*), both fresh and processed, in quantity (tons); and $y_2$, the revenues from all other products (*Other*) (in Euros). The four inputs included are: $x_1$ is the number of dairy cows (*Cows*); $x_2$ is Utilized Agricultural Area (UAA) in hectares (*Land*); $x_3$ is total labor used in hours (*Labor*); and $x_4$ is all other expenses (*OExp*) (in Euros). All monetary values are deflated according to specific price indexes for agricultural inputs and outputs from EUROSTAT with 2005 as the base year. In the IDF we also include a time trend (*TT*) to capture shifts in the production frontier over time, as well as the share of land under permanent pastures (*SPasture*) in order to account for differences in land quality and dairy practices. Moreover, we include two variables linked to the CAP. As discussed above, the EU has undertaken three main reforms to the CAP, the latest one – the 2003 Luxembourg reform – introduced full decoupling in the form of the SFP. To assess the effect of decoupling on the productivity of EU dairy farms we introduce two dummies (*DecoupD*), one taking the value of 1 for the period 1990 to 2004 and the second taking the value of 1 for the years 2005 to 2007 (2005 is the year where the reform was implemented in practice). We also include a variable to capture subsidy dependence (*SubsidyD*), calculated as the ratio of total subsidies received by farms (operational + investment) over the total value of farm output.

Ten variables are included in equation (3) to explain TE: land area (*Land*) and its square value (*Land2*); the time trend (*TT*) and its square value (*TT2*); the share of rented land in UAA (*SRLand*); the share of hired labor in total labor (*SHiLab*); the percentage of milk sold relative to the total value of output, which represents de degree of specialization of the farm (*SMilk*); the debt to asset ratio (*DAsset*); the dummy for decoupling implementation (*DecoupD*); and the subsidy dependence (*SubsidyD*) (same as in the IDF).

Table 1 presents descriptive statistics for the key variables included in the models for each country. The top two rows also show the total number of farms and of observations for each country. As the table indicates, Germany and Italy have the highest number of observations and Luxemburg the lowest. Here we want to highlight the variability in average farm size in terms of land area which ranges from a high of 87.8 hectares (ha) in the UK to a low of 18.3 ha in Spain, and in labor use to produce one ton of milk, which is highest in Italy (68.71 hours/ton) and lowest in Denmark (9.96 hours/ton). Also of particular interest is the average milk yield, which is highest in the Netherlands (7.1 tons/cow) and lowest in Ireland (4.7 tons/cow).

The empirical TL IDF model, where outputs and inputs are in natural logarithms, can be written as:

$$\ln\left(\frac{1}{x_n}\right) = \alpha_0 + \sum_{m=1}^{2}\beta_m \ln y_{mit} + \frac{1}{2}\sum_{m=1}^{2}\sum_{s=1}^{2}\beta_{ms}\ln y_{mit}\ln y_{sit} + \sum_{k=1}^{K-1=3}\delta_k \ln x_k^* + \frac{1}{2}\sum_{k=1}^{K-1=3}\sum_{l=1}^{K-1=3}\delta_{kl}\ln x_k^*\ln x_l^*$$
$$+ \sum_{k=1}^{K-1=3}\sum_{m=1}^{2}\rho_{km}\ln x_k^*\ln y_{mit} + \sum_{k=1}^{K-1=3}\phi_k \ln x_k^* t + \sum_{m=1}^{2}\omega_m \ln y_{mit} t + \sum_{c=1}^{4}\theta_c C_c + \sum_{d=1}^{4}\pi_d D_d + \lambda_1 t + \frac{1}{2}\lambda_{11}t^2 + v_{it} - u_{it} \quad (4)$$

where the subscripts $i$ and $t$ refer to the $i^{th}$ farm in the $t^{th}$ time period, respectively, $v_{it}$ and $u_{it}$ are random variables as defined in equation (2), and the Greek letters are unknown parameters to be estimated. Previous to the normalization of inputs to impose linear homogeneity discussed in equation (2), we normalize all inputs and outputs by the respective geometric mean in each country as is customarily done with the TL specification, which makes it possible to interpret the estimated first-order parameters as elasticities at the sample mean (Coelli, et al., 2003).

To compute partial production elasticities with respect to outputs from the parameters estimated for equation (4), we use the following expression:

$$e_{mit} = \frac{\partial \ln D_{it}}{\partial \ln y_{mit}} = \beta_m + \sum_{s=1}^{2}\beta_{ms}\ln y_{sit} + \sum_{k=1}^{4}\rho_{km}x_{kit} + \omega_m t\,. \quad (5)$$

The inverse of the sum of the output elasticities gives a measure of ray scale economies at the sample mean (Coelli and Fleming, 2004) and is referred to as the elasticity of scale (EOS) by Rasmussen (2010). In our case, a mathematical expression for the EOS is as follows:

$$EOS = -\left[\sum_{m=1}^{2}\frac{\partial \ln D_{it}}{\partial \ln y_{mit}}\right]^{-1}. \quad (6)$$

Another important attribute of the technology that deserves attention when using panel data concerns Technological Change (TC). For the TL IDF used here, TC is calculated as the partial derivative of $\ln D_{it}$ with respect to time at each data point, which for the $i^{th}$ farm in time period $t$ is equal to (Coelli, et al., 2003):

$$\frac{\partial \ln D_{it}}{\partial t} = \lambda_1 + \lambda_{11}t + \sum_{k=1}^{4}\phi_k x_{kit} + \sum_{m=1}^{2}\omega_m y_{mit}\,. \quad (7)$$

## 4. RESULTS

The results of the estimation of the IDF models are exhibited in Table 2 for each country separately. It is encouraging to see that all first order parameters for both inputs and outputs have the correct sign, positive and negative respectively, and all are significant at the 1% level. These signs indicate that the distance frontiers are well behaved at the geometric mean of the data. Overall, the models for the 11 countries exhibit a large number of significant parameters. The variables concerning the CAP have mixed effects on the frontier. Subsidy dependence has a significant negative shift on the frontier in four out of the 11 countries, while the shift is positive in Denmark and the Netherlands, and non-significant in the remaining four countries. Decoupling has a non-significant shift on the frontier for two countries, while the shift is significantly positive in Belgium and negative in the remaining eight countries.

The bottom part of Table 2 presents the coefficients estimated for the variables included in the efficiency effects and the results show that for all countries most of these coefficients are significant. Specifically, we observe that in all 11 countries, land area and its square value have a significant coefficient with the same sign across all countries: positive for land area and negative for its square value. This indicates that in the EU farm size is negatively associated with TE but that this relationship diminishes as size increases. The evidence presented in other studies of European farms concerning efficiency and farm size is mixed, depending on the country, the type of farming, and the size indicator (see for example a review in Latruffe, 2010). Conflicting results are found in the literature regarding the role of rented land and of hired labor on TE. Here, the share of rented land has a positive association with technical inefficiency in five countries, suggesting that tenancy status acts as a barrier to investments that would enhance productivity. The association is not significant for four countries and negative for two. The latter result suggests that the pressure of paying the rental fees leads to improved efficiency.

The results exhibit a positive association between inefficiency and reliance on hired labor except for Belgium, Ireland and Luxemburg. This is consistent with the notion that family labor requires less supervision and is more productive as it is the final claimant of residual profit (Allen and Lueck, 1998, Schmitt, 1991). A non significant association between TE and degree of specialization is ascertained for three countries: Ireland, Luxemburg and UK, while a positive and significant association is found in the remaining seven countries except Denmark. This positive association indicates that by concentrating their attention on fewer outputs farmers can be more productive.

The literature on the relationship between indebtedness and TE has yielded ambiguous results as documented by Davidova and Latruffe (2007). Here the debt to asset ratio has no significant impact on TE in four countries, and a negative significant impact in six countries. This latter finding is in agreement with Jensen and Meckling's (1976) agency cost idea in which borrowing cost are transferred to borrowers. By contrast, a positive association between TE and the debt to asset ratio, as is the case here for the Netherlands, suggests that Jensen's (1986) free cash flow concept may hold which means that farmers strive for a higher TE in order to be able to repay their loans.

These results regarding subsidy dependency suggest that farms that are relatively more dependent on subsidies exhibit lower levels of TE and this is the case uniformly for all 11 countries. These findings are consistent with those of Giannakas et al. (2001) for Canada; Bojnec and Latruffe (2009) for Slovenia; Latruffe et al. (2009) for France; Bakucs et al. (2010) for Hungary; and Zhu and Oude Lansink (2010) for Germany, the Netherlands and Sweden. In addition, Lachaal (1994) found that for the US dairy sector over the period 1972-92 TE was lowest for the years when government expenditures on dairy support were highest. As explained previously, such negative effects may be due to reduced effort or risk attitudes while Zhu and Oude Lansink (2010) argue that such finding is consistent with income an insurance effects. The findings regarding decoupling reveal a significant effect on TE in six countries, positive in five and negative in Denmark.

A key aspect of productivity that is important in this analysis is the average TE exhibited across countries and under different CAP policy regimes. Table 3 shows that high levels of average TE are observed for all countries ranging from 84.5% in Italy to 95.9% in Ireland. These averages are quite high relative to those reported in many other studies published around the world (Bravo-Ureta, et al., 2007, Moreira and Bravo-Ureta, 2009). Nevertheless, other authors using stochastic distance frontiers have also reported high TE levels for European farms. For example, Brümmer et al. (2002) found average TEs of 95.5%, 89.6% and 75.7% for dairy farms in Germany, the Netherlands and Poland, respectively, over the period 1991 and 1994. Abdulai and Tietje (2007), based on data for dairy farms in northern Germany for the period 1997-2005, found TE averages ranging from 68.0% to 94.5% depending on the econometric method used for estimation with an overall simple average equal to 85.9% across all seven methodologies compared. By contrast, Zhu and Oude Lansink (2010) in their study of crop farms in Germany, the Netherlands and Sweden report, respectively, average TE scores equal to 64.4%, 75.9% and 71.4% over the period 1995-2004. Figure 1 shows the pattern of TE averages by country during 1990-2007. In general, all countries exhibit a decreasing trend in TE averages over the period. In Spain and Italy, there is a drop in TE observed before the implementation of decoupling.

The elasticity of the distance frontier with respect to both outputs (equation 5), i.e., milk and other outputs was calculated. As shown in equation (6), the negative of the inverse of the sum of the output elasticities provides a measure of the elasticity of scale (EOS). If the EOS is equal to 1, less than 1 or greater than 1 then the technology exhibits constant, decreasing or increasing returns to scale (Coelli and Fleming, 2004). The results shown in Table 3 reveal that the EOS is higher than one for all 11 countries thus signaling increasing returns to scale for the average farm. Increasing returns to scale (at the mean) ranges from 1.25 in the UK (with the highest number of cows) and the Netherlands, to a high of 1.75 in Portugal (with the lowest number of cows).

The final component of productivity that we will address here concerns average rates of TC. Looking at the positive mean TC figures in Table 3, it seems clear that all EU countries considered experienced technological progress during the 18 year period analyzed. The highest average rate is found for Italy (1.9%) and the lowest is for Luxemburg (0.4%), Belgium and France (0.5%), and Denmark and Portugal (0.6%).

## 5. CONCLUDING REMARKS

The key research issue addressed is this paper concerns the association between agricultural subsidies and farm productivity in operations specializing on dairy. The data used are unbalanced panels from FADN for farms located in 11 European countries for the 18 year period going from 1990 to 2007. The countries included are: Belgium, Denmark, France, Germany, Ireland, Italy, Luxemburg, the Netherlands, Portugal, Spain, and the UK. The model is specified as a translog stochastic input distance frontier.

The results from the distance frontier models for each of the 11 countries exhibit high levels of statistical significance and indicate that regularity conditions are satisfied in all cases at the geometric mean of the data. Most of the coefficients of the inefficiency effects part of the models are also highly significant suggesting that the variables included do contribute to explaining the variation in TE. The findings reveal that a higher reliance on subsidies and a larger farm size are associated with lower levels of TE and this is the case uniformly for all 11 countries under analysis. The results indicate that the association between TE and reliance on rented land and higher labor, the degree of specialization on milk production and decoupling are mixed.

The analysis also shows increasing returns to scale, on average, in all cases. A key aspect of productivity that is important in this analysis is the average TE exhibited across countries and under different CAP policy regimes. The evidence presented indicates that in all countries the average TE over the period was relatively high (above 80% for all 11 countries and above 90% for nine countries) and that it has declined during 1990-2007, with a drop in Italy and Spain before the introduction of decoupling. Finally, the findings indicate that all countries have experienced positive average rates of technological progress.

A general conclusion, consistent with the literature, is that CAP public support to farms reduces their TE, a result that was found to be uniform for the 11 European countries under consideration. This effect is shown over a period of 18 years during which policy regimes shifted to more and more decoupled support. One issue that could be further developed is whether increased decoupling modifies the influence of subsidies on TE.
It is important to note that the different indicators of productivity reported in this paper were calculated individually for each country and their respective distance frontiers. Therefore, the results cannot be used to rank countries according to their level of productivity. In order to undertake such rankings it is necessary to formally analyze whether the samples have access to the same level of technology. This idea is the basis of the meta-frontier production function, an approach developed by Battese *et al.* (2004) and refined recently by O'Donnell *et al.* (2008).

Finally, a last remark is in order. This paper has only been concerned with the relationship between subsidies and productivity, and while the link seems to be negative, it does not imply that public support is globally detrimental to the agricultural sector. This is particularly important in the context of the future CAP reform, where the role of the CAP on other aspects of agriculture, such as the vitality and environmental health of rural areas, is emphasized (European Commission, 2010).

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**Table 1. Descriptive Statistics for the Main Variables by Country: Averages 1990-2007**

| | BELGIUM | DENMARK | FRANCE | GERMANY | IRELAND | ITALY | LUXEMBURG | THE NETHERLANDS | PORTUGAL | SPAIN | THE UK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| # observations | 5014 | 8004 | 21512 | 30085 | 7578 | 32118 | 3821 | 7390 | 9038 | 22642 | 13119 |
| Dairy cows | 49.8 | 81.8 | 40.9 | 52.6 | 46.6 | 37.8 | 40.5 | 65.8 | 26.8 | 31.1 | 93.5 |
| Labor (Hrs) | 4946.6 | 4308.2 | 3529.1 | 5033.2 | 3980.4 | 5375.3 | 3853.5 | 4320.5 | 4510.2 | 3576.1 | 6148.4 |
| UAA (ha) | 43.2 | 82.6 | 63.7 | 69.6 | 50.1 | 32.9 | 73.6 | 40.6 | 18.9 | 18.3 | 87.8 |
| Milk (tons) | 276.5 | 588.8 | 235.5 | 343.8 | 232.5 | 219.9 | 256.4 | 478.1 | 151.4 | 185.1 | 589.1 |
| Dairy Cows/UAA | 1.3 | 1.2 | 0.7 | 0.9 | 1.0 | 1.9 | 0.6 | 1.7 | 2.3 | 2.7 | 1.2 |
| Milk/Dairy Cow | 5.5 | 6.9 | 5.6 | 6.0 | 4.7 | 4.9 | 6.2 | 7.1 | 5.3 | 5.3 | 6.0 |
| Milk/UAA | 7.1 | 7.9 | 4.1 | 5.3 | 4.8 | 9.9 | 3.6 | 12.0 | 13.0 | 14.8 | 7.2 |
| Labor/Milk | 23.11 | 9.96 | 18.90 | 20.72 | 27.58 | 68.71 | 17.64 | 11.77 | 52.40 | 37.11 | 14.77 |

## Table 2. Maximum Likelihood Parameter Estimates for Input Stochastic Distance Frontiers (ISDF), by Country

| | BELGIUM | DENMARK | FRANCE | GERMANY | IRELAND | ITALY | LUXEMBURG | THE NETHER-LANDS | PORTUGAL | SPAIN | THE UK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cows | 0.41634 *** | 0.31679 *** | 0.43168 *** | 0.50271 *** | 0.54479 *** | 0.52178 *** | 0.36494 *** | 0.46014 *** | 0.51030 *** | 0.53826 *** | 0.53077 *** |
| Land | 0.06609 *** | 0.12786 *** | 0.12731 *** | 0.01845 *** | 0.04812 *** | 0.01484 *** | 0.26200 *** | 0.10528 *** | 0.05024 *** | 0.04909 *** | 0.03176 *** |
| Labor | 0.17945 *** | 0.24222 *** | 0.14778 *** | 0.16437 *** | 0.12322 *** | 0.21325 *** | 0.11494 *** | 0.13651 *** | 0.24654 *** | 0.20389 *** | 0.12720 *** |
| Milk | -0.51927 *** | -0.62932 *** | -0.58820 *** | -0.66833 *** | -0.64258 *** | -0.65822 *** | -0.49254 *** | -0.69979 *** | -0.61569 *** | -0.63361 *** | -0.70635 *** |
| Other | -0.17362 *** | -0.15356 *** | -0.10922 *** | -0.08043 *** | -0.11797 *** | -0.03348 *** | -0.14127 *** | -0.10293 *** | -0.02553 *** | -0.02269 *** | -0.09506 *** |
| TT | 0.00475 *** | 0.00563 *** | 0.00578 *** | 0.01442 *** | 0.01089 *** | 0.01718 *** | 0.00404 *** | 0.00836 *** | 0.00640 *** | 0.00991 *** | 0.00966 *** |
| TT2 | -0.00093 *** | -0.00011 | 0.00086 *** | -0.00101 *** | 0.00161 *** | -0.00164 *** | -0.00105 *** | -0.00076 *** | 0.00037 | 0.00090 *** | 0.00104 *** |
| Cows2 | -0.28585 *** | -0.21815 *** | -0.14459 *** | -0.24809 *** | -0.06168 | -0.10324 *** | -0.21820 *** | -0.42948 *** | 0.04006 * | 0.00345 | -0.15517 *** |
| Land2 | 0.04284 | 0.05533 *** | 0.08482 *** | 0.01174 | 0.08060 *** | -0.05408 *** | 0.10950 * | 0.00247 | 0.01642 *** | 0.04065 *** | -0.01059 |
| Labor2 | -0.13595 *** | -0.19434 *** | -0.15327 *** | -0.06194 *** | 0.04161 ** | -0.01015 | -0.16193 *** | -0.11794 *** | 0.05624 *** | -0.05686 *** | -0.03014 ** |
| Milk2 | -0.23800 *** | -0.17755 *** | -0.25745 *** | -0.23217 *** | -0.06590 *** | -0.12269 *** | -0.27235 *** | -0.27444 *** | -0.20085 *** | -0.13635 *** | -0.18169 *** |
| Other2 | -0.13395 *** | -0.10192 *** | -0.00970 *** | -0.02724 *** | -0.01820 *** | -0.00347 *** | -0.06442 *** | -0.08520 *** | -0.00183 *** | -0.00044 * | -0.04825 *** |
| CowsTT | -0.00512 *** | 0.00357 * | 0.00994 *** | 0.00034 | -0.00551 *** | -0.00493 *** | 0.00521 ** | 0.00083 | -0.00388 *** | -0.01116 *** | -0.00325 *** |
| LandTT | 0.00028 | -0.00462 *** | -0.00427 *** | -0.00448 *** | 0.00580 *** | 0.00350 *** | 0.00050 | -0.00216 ** | 0.00199 *** | 0.00417 *** | 0.00052 |
| LaborTT | 0.00218 | 0.01061 *** | -0.00543 *** | 0.00987 *** | 0.00353 *** | 0.00355 *** | -0.00259 * | 0.00185 * | 0.00907 *** | 0.00787 *** | 0.00006 |
| MilkTT | 0.00228 ** | -0.00228 * | -0.00639 *** | 0.00559 *** | 0.00807 *** | 0.00199 *** | 0.00117 | 0.00043 | 0.01049 *** | 0.00881 *** | 0.00190 *** |
| OtherTT | 0.00060 | 0.00788 *** | 0.00047 | 0.00139 *** | -0.00001 | 0.00199 *** | 0.00006 | 0.00268 *** | -0.00120 *** | 0.00149 *** | 0.00183 *** |
| CowsLand | 0.10519 *** | 0.00381 | -0.02648 ** | 0.02854 *** | -0.05407 *** | 0.05755 *** | -0.01161 | 0.07662 *** | -0.00416 | -0.06154 *** | 0.01186 |
| CowsLabor | 0.13972 *** | 0.20463 *** | 0.17212 *** | 0.20725 *** | 0.02986 | 0.12093 *** | 0.10386 *** | 0.21519 *** | -0.01316 | 0.12529 *** | 0.12861 *** |
| CowsMilk | 0.17527 *** | 0.13304 *** | 0.12539 *** | 0.17427 *** | -0.01249 | 0.17306 *** | 0.20155 *** | 0.25981 *** | 0.08015 *** | 0.13813 *** | 0.10155 *** |
| CowsOther | -0.14171 *** | -0.01719 | -0.03337 *** | -0.00846 | 0.02742 ** | -0.00678 *** | -0.06416 *** | -0.09836 *** | -0.00595 * | -0.02632 *** | 0.00239 |
| LandLabor | -0.04005 | -0.03830 * | -0.04290 *** | -0.04144 *** | -0.04337 *** | -0.03726 *** | -0.05723 * | -0.00851 | -0.01726 ** | 0.00863 ** | -0.01762 * |
| LandMilk | -0.02866 * | 0.06249 *** | -0.02347 *** | -0.02644 *** | 0.04755 *** | -0.04727 *** | -0.05489 * | -0.02840 ** | -0.00708 | 0.02044 *** | -0.03429 *** |
| LandOther | 0.09437 *** | -0.02308 *** | 0.04761 *** | 0.00086 | -0.01971 ** | -0.00860 *** | 0.04900 ** | 0.03504 *** | 0.00328 * | 0.01081 *** | 0.00539 |
| LaborMilk | -0.12548 *** | -0.21373 *** | -0.17901 *** | -0.14085 *** | -0.04281 *** | -0.08220 *** | -0.18518 *** | -0.17513 *** | -0.09681 *** | -0.11598 *** | -0.07256 *** |
| LaborOther | 0.02574 * | 0.03689 *** | 0.03354 *** | 0.04465 *** | 0.00346 | 0.01413 *** | -0.02646 * | 0.05250 *** | -0.00119 | 0.00977 *** | 0.02623 *** |

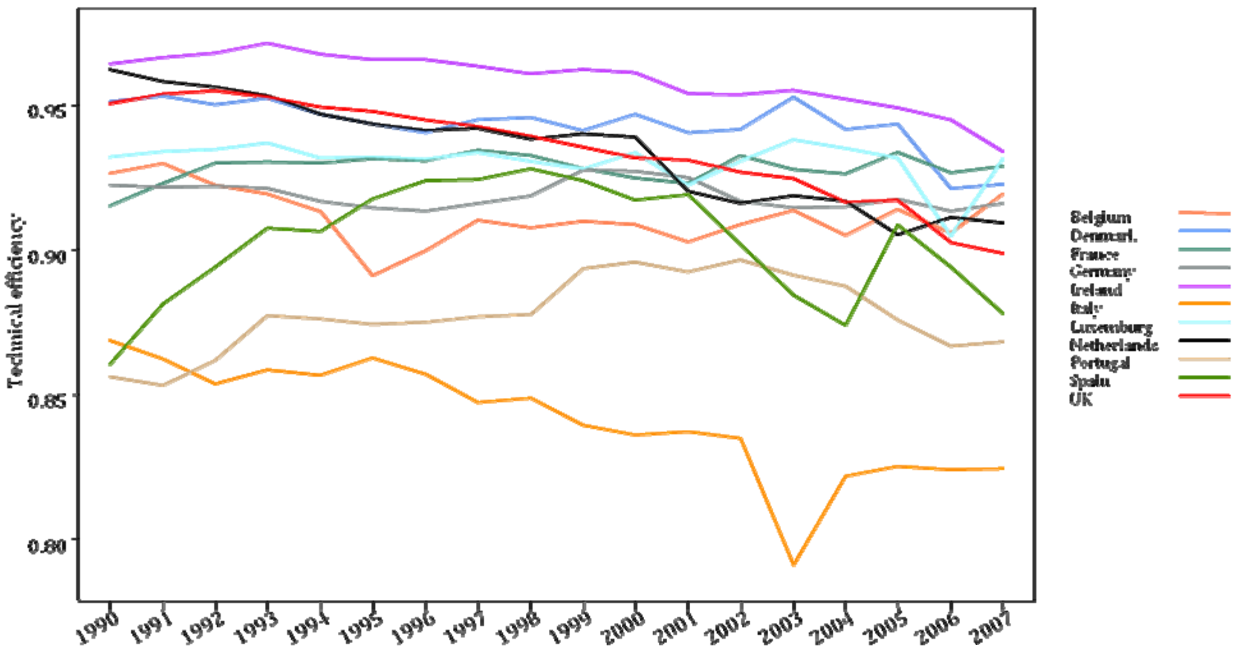
| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MilkOther | 0.16768 *** | 0.06854 *** | 0.03687 *** | 0.06015 *** | 0.01324 ** | 0.00304 ** | 0.01801 | 0.10233 *** | 0.00654 *** | -0.00971 *** | 0.06213 *** |
| SPasture | 0.01617 * | -0.02055 * | -0.09990 *** | 0.06357 *** | -0.00523 | -0.03808 *** | -0.00127 | -0.01510 ** | 0.16390 *** | 0.06297 *** | 0.00029 |
| DecoupD | 0.02768 ** | -0.02642 *** | -0.00320 *** | -0.00450 *** | -0.00256 *** | -0.00500 *** | -0.00196 ** | -0.00157 *** | -0.00106 | 0.00061 | -0.00526 *** |
| SubsidyD | -0.00184 ** | 0.04684 *** | 0.00155 | -0.01137 ** | -0.03460 *** | 0.00371 | 0.00062 | 0.03116 *** | 0.09251 *** | -0.03821 *** | -0.00477 |
| _cons | 0.13067 *** | 0.02377 ** | 0.12439 *** | 0.07925 *** | 0.03201 *** | 0.25045 *** | 0.11393 *** | 0.13290 *** | 0.06641 *** | 0.07252 *** | 0.07575 *** |
| OExp | 0.33812 | 0.31313 | 0.29323 | 0.31447 | 0.28387 | 0.25013 | 0.25811 | 0.29807 | 0.19293 | 0.20877 | 0.31026 |
| OExpTT | 0.00266 | -0.00956 | -0.00025 | -0.00572 | -0.00381 | -0.00212 | -0.00312 | -0.00053 | -0.00719 | -0.00089 | 0.00267 |
| CowsOExp | 0.04094 | 0.00971 | -0.00105 | 0.01230 | 0.08590 | -0.07524 | 0.12595 | 0.13767 | -0.02274 | -0.06720 | 0.01471 |
| LandOExp | -0.10798 | -0.02084 | -0.01543 | 0.00116 | 0.01684 | 0.03379 | -0.04066 | -0.07058 | 0.00500 | 0.01226 | 0.01636 |
| LaborOExp | 0.03628 | 0.02801 | 0.02405 | -0.10387 | -0.02810 | -0.07352 | 0.11530 | -0.08874 | -0.02582 | -0.07706 | -0.08085 |
| MilkOExp | -0.02113 | 0.01819 | 0.07709 | -0.00698 | 0.00774 | -0.04359 | 0.03853 | -0.05629 | 0.02374 | -0.04259 | 0.00530 |
| OtherOExp | 0.02160 | 0.00337 | -0.04778 | -0.03705 | -0.01117 | 0.00124 | 0.04161 | 0.01081 | 0.00387 | 0.00573 | -0.03401 |
| OExpOExp | 0.03076 | -0.01688 | -0.00757 | 0.09041 | -0.07464 | 0.11497 | -0.20060 | 0.02165 | 0.04356 | 0.13199 | 0.04978 |
| **Inefficiency effects** | | | | | | | | | | | |
| Land | 0.13837 *** | 0.01731 *** | 0.06783 *** | 0.01393 *** | 0.09698 *** | 0.01438 *** | 0.12708 *** | 0.07429 *** | 0.03475 *** | 0.05796 *** | 0.01249 *** |
| Land2 | -0.00060 *** | -0.00002 *** | -0.00018 *** | -0.00001 *** | -0.00029 *** | -0.00002 *** | -0.00038 *** | -0.00029 *** | -0.00004 *** | -0.00020 *** | -0.00001 *** |
| TT | 0.02862 | -0.29310 *** | -0.28672 *** | -0.06968 *** | -0.03909 | 0.00252 | -0.11223 | 0.13951 ** | -0.04755 | -0.40602 *** | 0.00847 |
| TT2 | -0.00691 ** | -0.00113 | 0.00739 *** | -0.00017 | 0.00214 | 0.00199 | -0.00525 | -0.00557 | 0.00089 | 0.02407 *** | 0.00322 |
| SRLand | 0.35352 * | 0.78283 *** | 0.00773 | 0.39525 *** | -0.38040 | 0.51597 *** | 0.27615 | 0.21618 * | -0.01898 | -0.26961 *** | -0.44334 *** |
| SHiLab | 0.04314 | 2.21541 *** | 1.62104 *** | 0.56977 *** | -0.47621 | 1.45157 *** | 0.31580 | 0.54560 ** | 1.28838 *** | 0.33794 * | 1.07746 *** |
| SMilk | -2.39812 *** | 11.92923 *** | -2.51608 *** | -2.90132 *** | 2.69411 | -3.63498 *** | 0.85482 | -2.36796 *** | -3.66052 *** | -3.90917 *** | -0.34565 |
| DAsset | -0.16569 | 0.69143 *** | -0.10513 | 0.75700 *** | -1.41752 | 0.51013 *** | 1.03492 *** | -0.56545 *** | -0.01931 | 1.31788 *** | 2.23190 *** |
| DecoupD | -0.29926 | 0.76269 *** | -0.48262 *** | -0.30580 *** | -0.19247 | -0.33776 *** | 0.54915 | -0.10474 | 0.23232 | -1.44244 *** | -0.49973 ** |
| SubsidyD | 7.30354 *** | 12.55426 *** | 4.08350 *** | 5.72812 *** | 2.63471 *** | 0.49211 *** | 2.80659 *** | 7.28276 *** | 0.89506 *** | 1.34217 *** | 5.39059 *** |
| _cons | -8.04792 *** | -15.86399 *** | -5.44488 *** | -3.57319 *** | -12.22104 *** | -1.28252 *** | -12.17661 *** | -6.64872 *** | -1.33541 *** | -0.75985 *** | -7.04296 *** |
| # obervations | 5014 | 8004 | 21514 | 30085 | 7578 | 32120 | 3821 | 7390 | 9040 | 22642 | 13119 |
| Log likelihood | 3352.8 | 6151.4 | 13503.1 | 20789.2 | 5437.4 | 2715.3 | 3080.7 | 6543.0 | 3664.4 | 8763.1 | 9431.7 |

Level of significance: ***1%; ** 5%; *10%**
Underlined parameters are recovered from the homogeneity condition.

**Table 3. Productivity Results: Averages 1990-2007**

| | Belgium | Denmark | France | Germany | Ireland | Italy | Luxemburg | The Netherlands | Portugal | Spain | The UK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TE | 0.911 | 0.944 | 0.928 | 0.919 | 0.959 | 0.845 | 0.931 | 0.937 | 0.879 | 0.903 | 0.937 |
| EOS | 1.450 | 1.283 | 1.480 | 1.350 | 1.319 | 1.460 | 1.660 | 1.249 | 1.748 | 1.542 | 1.250 |
| TC | 0.005 | 0.006 | 0.005 | 0.014 | 0.011 | 0.019 | 0.004 | 0.009 | 0.006 | 0.010 | 0.009 |

**Figure 1. Average Technical Efficiency by Country during 1990-2007**



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