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

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Productivity and Subsidies in European Union Countries: An Analysis for Dairy Farms Using Input Distance Frontiers[1]

ABSTRACT: The major objective of this paper is to examine 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 the following seven countries: Denmark; France; Germany; Ireland; Spain; the Netherlands; and the United Kingdom. Separate translog stochastic input distance frontiers are estimated for each country. The key results show high average technical efficiency (TE) ranging from 91.8% to 94.9%, average rates of technological change going from -0.6% to 1.4%, and increasing returns to scale (1.24 to 1.44) across all seven countries. In addition, higher subsidy and hired labor dependence are found to be significantly associated with higher technical inefficiency across all seven countries. Moreover, the latest Common Agricultural Policy (CAP) regime introducing fully decoupled payments has reduced TE in all countries considered except Denmark.

Keywords: Subsidies; CAP; technical efficiency; technological progress; returns to scale; 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 seven European Union (EU) countries: Denmark, France, Germany, Ireland, Spain, the Netherlands, 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[2]. As for LFA payments, they are

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[2] 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).

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.

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 (Old Member States) 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 or 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 23.53% in 2009. By comparison, PSE for the US was 9.78% in 2009, and in Australia 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 with 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 (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 technical efficiency effects that 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 inputs vectors x that are feasible for each output vector y, so that $L(y) = \{x \in R_+^N : x \text{ can produce } y\}$. It 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 σ^2, z_{it} is a (p×1) vector of variables which are hypothesized to influence firm efficiency, and δ is a (1×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 technical efficiency (TE) for the IDF can be estimated as $\text{TE}(x,y)=E[\exp(-u)|\,v-u]$. 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 seven European countries for the 18 year period going from 1990 to 2007. The countries included are: Denmark; France; Germany;

Ireland; Spain; the Netherlands; and the UK. 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 professional 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. In addition to our focus on dairy farming, 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. Moreover, agro-environmental schemes or AES, one focus of our paper, are particularly frequent on milk farms. The model incorporates two outputs and four inputs. The outputs are: y_1, milk produced, both fresh and processed, in quantity (tons); and y_2, the revenues from all other products (in Euros). The four inputs included are: x_1 is the value of intermediate inputs (in Euros); x_2 is Utilized Agricultural Area (UAA) in hectares; x_3 is total labor used in hours; and x_4 is the value of fixed assets (in Euros). All monetary values are deflated according to price indexes for agricultural inputs and outputs from EUROSTAT with 2007 as the base year.

As discussed above, the EU has undertaken three main reforms to the CAP; thus, we create a set of dummies to capture these effects denoted by C in equation (4) below. These reforms have been implemented in different years across the seven countries that are of interest in this paper. Thus, we identify four periods for each country. For the UK, Denmark, Germany and Ireland Period 1 covers 1990-1992 (before the first CAP reform); Period 2 1993-1999 (the MacSharry reform); Period 3 2000-2004 (the second reform, the Agenda 2000); and Period 4 goes from 2005 to 2007 (the Luxemburg reform). For the Netherlands, France and Spain Periods 1 and 2 are the same as in the other four countries, Period 3 goes from 2000 to 2005 and Period 4 covers 2006 and 2007 as the Luxemburg reform was implemented later in these countries. In all cases, the reference (excluded) category is Period 1. In addition, we create dummy variables to account for agro-climatic and economic conditions based on an LFA classification code used by the FADN. The LFA codes, which reflect the location of the majority of the UAA of a holding, are as follows: LFA1 = normal areas; LFA2 = less-favored non mountainous areas; LFA3 = less-favored mountainous areas; and LFA4 = no significant areas in the member state. LFA4 exists because some countries decided to not categorize their area into LFA zones under the belief that the conditions were not so different across the county. This is for example the case for the Netherlands, for which no variable related to LFA was included. Thus we create the following dummy variables for all other six countries: D_1 is equal to 1 if the farm is located in an LFA1 and 0 otherwise; D_2 is equal to 1 if the farm is located in an LFA2 and 0 otherwise; D_3 is equal to 1 if the farm is located in an LFA3 and 0 otherwise; and D_4 is equal to 1 if the farm is located in an LFA4 and 0 otherwise. In all cases the reference category is LFA1.

Four variables are included in equation (3) to explain TE: 1) z_1 is the economic size of the holding expressed in European size units (ESU, calculated as total standard gross margin in Euros divided by 1,200); 2) z_2 is the percentage of milk sold relative to the total value of output, which represents de degree of specialization of the farm; 3) z_3 is the subsidy share calculated as total subsidies received by the farm (operational + investment) over the total value of output and thus represents the level of dependency on subsidies; and 4) z_4 is the share of hired labor in total labor.

Table 1 presents descriptive statistics for all variables included in the models and 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 has the highest number of farms and the Netherlands the lowest. Here we want to highlight the variability in average farm size which ranges from a high of 87.8 hectares (ha) in the UK to a low of 17.9 ha in Spain. Also of particular interest is the relatively heavy reliance on hired labor in Denmark and the UK while the opposite is the case in Spain and France. In addition, the highest level of average subsidies relative to the value of output is for France (12.8%), Germany (12.7%) and Ireland (12.6%) while the lowest is for the Netherlands (3.5%) followed by Spain (4.5%).

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

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

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:

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

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:

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

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):

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

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 seven countries exhibit a large number of significant parameters. The bottom part of Table 2 shows the coefficients estimated for the variables (*z*) included in the efficiency effects and the results show that for all countries all these coefficients are significant except for two. Specifically, we observe that in all seven countries, subsidy share and hired labor share have a positive and significant coefficient. These results suggest that farms that are relatively more dependent on subsidies exhibit lower levels of TE and this is the case uniformly for all seven countries. This 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 technical efficiency 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.

Conflicting results are found in the literature regarding the role of hired labor on farms' TE. Here, the effect is uniform across the seven countries. The finding concerning the positive association between inefficiency and a higher reliance on hired labor 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). Another *z* variable included in the efficiency effects is farm size (in ESU) and the results show a negative and significant association with TE in four of the seven countries, France, Ireland, The Netherlands and Spain. The opposite is found for Germany and the UK, while no significant effect is found for Denmark. The evidence presented in other studies of European farms concerning efficiency and farm size is also mixed, depending on the country, the type of farming, and the size indicator (see for example a review in Latruffe, 2010). The last variable included in the inefficiency effects is the degree of specialization on milk production and these results are again mixed. A negative and significant association between TE and degree of specialization is ascertained for Denmark, France, Germany and the UK, suggesting a complementary relationship between risk reduction and efficiency, while the opposite is the case for Ireland, the Netherlands and Spain, where farm specialization and TE move in the same direction indicating that by concentrating their attention on fewer outputs farmers can be more productive.

Table 3 presents the elasticity of the distance frontier with respect to both outputs (equation 5), i.e., milk and other outputs, and summarizes the number of violations detected after calculating these elasticities at each data point for each country. Theory indicates that these elasticities should be negative (Coelli and Fleming, 2004) and the numbers in Table 3 show that all seven models are very well behaved on this regard, particularly for milk. 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 in Table 3 reveal that the EOS is higher than one for all seven countries thus signaling increasing returns to scale for the average farm. The average EOS figures go from a low of 1.235 for Denmark to a high of 1.443 for Spain. The Table also shows that the violations from the expected positive sign for the EOS are zero in all countries except for France where only seven violations are computed. Moreover, if we look at average farm size in hectares, shown in Table 1, and the EOS measures we can detect a generally inverse relationship. That is, higher measures of EOS correlate with lower average size in hectares. This issue clearly deserves further analysis.

A key aspect of productivity that is important in this analysis is the average TE exhibited across countries and under different CAP policy regimes. As was discussed earlier, alternative policy regimes were introduced in the model through a set of dummies for four periods where Period 1 denotes the pre-reform phase and is the reference (excluded dummy) category. The remaining three dummies relate to distinct policy reforms which came into effect in somewhat different years as already explained. The results in Table 4 show that in five countries average TE was highest in Period 1, i.e., prior to the reforms while in five cases the lowest is observed in Period 4. However, overall, average TE is very high for all countries, exhibits no clear pattern and experiences little variation within a country across policy regimes. The biggest spread is for Germany where average TE goes for a high of 95.8% in period 1 to a low of 88.9% in period 4. However, upon a closer look three groups of countries emerge. France, Germany, the Netherlands and the UK are in one group, for which the average period efficiencies decrease consistently across the four periods. Denmark is alone in a group, with the same decrease as the previous group observed over the three first periods, but a recovery in the last period. Finally, Ireland and Spain comprise the third group, where average efficiency increases over the first three periods and then decreases in the fourth period. One interesting finding is that the last period, namely the period following the introduction of the decoupled SFP (2005/2006-2007) is beneficial only to Denmark. Table 4 also shows average TE across LFAs and not much difference is observed. Regarding AES subsidies, in most of the countries (except Spain where the opposite is seen) farms with AES subsidies present a lower average TE, confirming the negative link between efficiency and subsidies.

The last row in Table 4 presents the overall average TE for all farms for each country and these scores range from a low of 91.8% for Germany to a high of 94.9% for Denmark. 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 an average TE 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.

The final component of productivity that we will address here concerns average rates of TC by period for all farms, and then separated by with/without AES and by LFA. Looking at the figures in Table 5, it seems clear that the rates of TC that we have measured are fairly variable and without any clear patterns across countries but quite low and in several instances we observe negative numbers. It suffices to focus on the overall averages which range from a low of -0.6% for the Netherlands to a high of 1.4% for Spain. Negative rates of technological progress, i.e., technological digress, although contrary to what is usually expected a priori, have also been reported for dairy farms in Europe. For example, Kumbhakar and Heshmati (1995) found an average rate of technological progress equal to -0.82 for a sample of Swedish dairy farms over the period 1976-1988.

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. We also examined if any such association changes under different subsidy regimes, over time, and across countries. The data used are unbalanced panels from FADN for farms located in seven European countries for the 18 year period going from 1990 to 2007. The countries included are: Denmark; France; Germany; Ireland; Spain; the Netherlands; and the United Kingdom (UK). In addition, dummy variables account for agro-climatic conditions and four variables are included in the technical inefficiency effects: 1) farm size; 2) degree of specialization; 3) subsidy dependence; and 4) hired labor dependence. The model is specified as a translog stochastic input distance frontier.

The results of the estimation of the distance frontier models for each of the seven countries exhibit high levels of statistical significance and indicate that regularity conditions are satisfied in all cases at the geometric mean of the data. The coefficients of the inefficiency effects part of the models are also highly significant suggesting that the z variables included are significant contributors to explaining the variation in TE. The results reveal that farms that are relatively more dependent on subsidies and on hired labor exhibit lower levels of TE and this is the case uniformly for all seven countries under analysis. The findings also reveal that farm size has a negative and significant association with TE in four of the seven countries while the opposite is found in two of them. The results concerning degree of specialization on milk production and TE are also mixed where four countries display a negative and significant association while the opposite is the case for the other three.

The analysis also shows increasing returns to scale, on average, in all cases and an overall inverse relationship between such returns and average farm size. 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 results indicate that in five countries the average TE was highest in the period prior to the reforms while the lowest level of TE is observed in the most recent years in five countries. The successive policy regimes have consistently decreased farm average TE for France, Germany, the Netherlands and the UK. And, except for Denmark, the other six countries have seen a decrease in their TE after the implementation of the decoupled SFP. The overall average TE ranges from a low of 91.8% for Germany to a high of 94.9% for Denmark. Finally, the estimated average rates of technological change do not exhibit any clear patterns within countries but are fairly low with some instances of technological digress.

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 seven 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. Our paper has shed light on this question by separating the 18-year period into the various policy reforms, and results seem to differ across countries. Further research is needed to understand whether the differences across periods are only due to the policy regime change. Finally, a last remark is in order. This paper has only been concerned with the relationship between support and TE, 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).

Table 1. Descriptive Statistics for the Main Variables by Country

Country / data	Denmark	France	Germany	Ireland	Netherlands	Spain	UK
Total # of farms	2,377	4,711	5,936	2,245	1,444	5,298	3,996
Total # of observations	8,019	21,512	30,095	7,581	7,368	23,107	13,109
Total milk (ton L)	590.1 *480.2*	235.5 *145.9*	343.9 *660.3*	232.3 *181.3*	477.8 *311.6*	190.9 *220.4*	589.4 *485.5*
Other outputs (€)	77,375.4 *87,287.3*	41,322.2 *34,315.9*	62,151.5 *179,066.1*	35,076.6 *31,228.9*	71,148.8 *62,371.6*	18,627.6 *19,593.4*	67,920.5 *65,927.7*
UAA (ha)	82.5 *59.4*	63.7 *36.5*	69.6 *145.1*	50.1 *30.4*	40.6 *24.4*	17.9 *23.3*	87.8 *67.6*
Labor (hours)	4,312.3 *1,821.6*	3,529.7 *1,532.7*	5,036.8 *11,003.0*	3,980.0 *1,808.6*	4,323.5 *1,668.5*	3,582.3 *1,680.7*	6,149.6 *3,044.0*
Fixed assets (€)	929,401.7 *831,331.2*	272,367.0 *173,791.2*	373,370.6 *675,286.5*	240,113.4 *191,682.7*	491,132.1 *322,124.9*	197,751.1 *179,838.6*	340,554.8 *269,004.9*
Intermediate inputs (€)	180,485.9 *143,591.8*	74,100.3 *48,138.4*	114,339.7 *255,391.4*	63,363.4 *49,323.4*	128,926.1 *76,905.0*	48,439.6 *56,587.4*	158,566.5 *127,221.5*
AES (% farms with AES payments)	19.9	23.7	39.5	12.2	20.6	1.0	12.8
LFA (codes)	1,2,3	1,2,3	1,2,3	1,2	4	1,2,3	1,2
ESU	133.2 *96.7*	50.6 *31.2*	76.0 *145.2*	49.9 *33.3*	117.8 *69.7*	25.8 *26.6*	106.3 *77.5*
Milk over output (%)	75.5 *11.2*	70.7 *13.3*	68.6 *17.1*	70.0 *14.8*	77.5 *13.5*	73.7 *26.8*	76.0 *13.6*
Subsidies over output (%)	9.1 *5.4*	12.8 *19.8*	12.7 *11.2*	12.6 *16.6*	3.5 *5.6*	4.5 *24.7*	7.7 *8.5*
Hired labor over total (%)	25.1 *22.4*	3.2 *9.9*	10.5 *19.1*	10.0 *18.4*	5.0 *11.0*	2.5 *10.2*	24.8 *25.6*

Averages. Standard deviation in italics

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

Variable	Denmark	France	Germany	Ireland	Netherlands	Spain	UK
Interm. Inputs, II	0.633	0.660	0.642	0.670	0.602	0.696	0.703
UAA	0.088 ***	0.122 ***	0.097 ***	0.102 ***	0.216 ***	0.047 ***	0.072 ***
Labor, LB	0.279 ***	0.218 ***	0.261 ***	0.227 ***	0.182 ***	0.258 ***	0.225 ***
Assets, AS	0.129 ***	0.141 ***	0.160 ***	0.196 ***	0.173 ***	0.271 ***	0.193 ***
Other output, OO	-0.333 ***	-0.394 ***	-0.303 ***	-0.201 ***	-0.204 ***	-0.075 ***	-0.348 ***
Milk, MK	-0.480 ***	-0.399 ***	-0.451 ***	-0.563 ***	-0.552 ***	-0.622 ***	-0.463 ***
T	-0.002	0.006 ***	0.010 ***	0.007 ***	-0.004 ***	0.013 ***	0.001
$t^2/2$	0.001 ***	0.002 ***	-0.003 ***	0.001 ***	0.003 ***	-0.003 ***	-0.002 ***
II*t	-0.0002	0.0004	-0.004	-0.006	0.001	-0.005	0.006
UAA*t	-0.0003	0.003 ***	-0.007 ***	0.008 ***	0.003 ***	0.001 ***	-0.001 **
LB*t	0.011 ***	0.001	0.012 ***	-0.001	0.003 **	0.009 ***	-0.001
AS*t	-0.011 ***	-0.004 ***	-0.001 ***	-0.001	-0.007 ***	-0.006 ***	-0.003 ***
OO*t	0.001 *	-0.003 ***	0.001 **	0.001 ***	0.011 ***	0.0002 **	-0.0003
MK*t	0.007 ***	0.004 ***	0.005 ***	0.006 ***	-0.006 ***	0.011 ***	0.005 ***
UAA*II	-0.022	-0.031	-0.012	-0.025	-0.116	0.008	0.041
UAA*UAA/2	0.012 ***	0.011 ***	0.011 ***	0.019	-0.003	0.007 ***	-0.103 ***
UAA*LB	0.012	0.006	0.015 **	-0.033 **	0.102 ***	-0.006 ***	0.014
UAA*AS	-0.003	0.014 *	-0.014 *	0.038 **	0.016	-0.009 ***	0.048 ***

UAA*OO	0.002	-0.010 **	-0.008 ***	0.005 *	0.036 ***	0.0004 ***	-0.057 ***
UAA*MK	0.023 ***	0.009	-0.0004	0.0001	0.035 ***	-0.008 ***	0.022 ***
LB*II	-0.014	-0.001	-0.076	-0.056	-0.053	-0.132	-0.121
LB*LB/2	0.014	0.054 ***	0.003	0.117 ***	-0.058 **	0.084 ***	0.106 ***
LB*AS	-0.011	-0.058 ***	0.058 ***	-0.028	0.009	0.053 ***	0.001
LB*OO	0.031 **	0.019 ***	0.006 **	0.0002	0.032 ***	-0.0005	0.022 ***
LB*MK	-0.102 ***	-0.069 ***	-0.081 ***	-0.015	-0.118 ***	-0.007	-0.014
AS*II	-0.052	-0.061	-0.016	-0.014	0.029	-0.135	-0.020
AS*AS/2	0.067 ***	0.106 ***	-0.028 ***	0.003	-0.054 ***	0.090 ***	-0.029 **
AS*OO	-0.003	0.002	0.007 ***	0.007 **	0.002	0.002 ***	0.019 ***
AS*MK	0.012	-0.019 **	0.023 ***	0.009	0.047 ***	0.093 ***	0.020 ***
OO*II	-0.030	-0.011	-0.005	-0.012	-0.070	-0.002	0.016
OO*OO/2	-0.029 ***	-0.030 ***	-0.026 ***	-0.018 ***	-0.009 ***	-0.007 ***	-0.028 ***
OO*MK	0.022 ***	0.006	0.013 ***	0.007 ***	0.042 ***	0.003 ***	0.013 ***
MK*II	0.068	0.079	0.058	0.006	0.035	-0.078	-0.029
MK*MK/2	-0.127 ***	-0.176 ***	-0.156 ***	-0.074 ***	-0.150 ***	-0.100 ***	-0.101 ***
II*II/2	0.088	0.094	0.105	0.094	0.140	0.258	0.100
LFA2	0.017	-0.068 ***	-0.034 ***	-0.031 ***		0.004	-0.020 ***
LFA3	-0.039 ***	-0.119 ***	-0.042 ***			0.001	
Period 2	0.055 ***	0.107 ***	-0.032 ***	0.014	0.023 ***	0.026 ***	0.019 ***
Period 3	0.048 ***	0.121 ***	0.007	0.075 ***	0.049 ***	0.026 **	0.068 ***
Period 4	0.145 ***	0.068 ***	0.069 ***	0.051 ***	0.048 ***	0.026 *	0.087 ***
Constant	0.023 ***	0.024 ***	0.196 ***	0.062 ***	0.048 ***	0.123 ***	0.138 ***
Inefficiency Effects							
Size in ESU	0.001	0.012 ***	-0.001 ***	0.014 ***	0.007 ***	0.016 ***	-0.0002
Milk share	0.182 ***	0.141 ***	0.070 ***	-0.080 ***	-0.038 ***	-0.078 ***	0.164 ***
Subsidy share	0.135 ***	0.044 ***	0.090 ***	0.046 ***	0.105 ***	0.038 ***	0.089 ***
Labor share	0.021 ***	0.013 ***	0.025 ***	0.016 ***	0.013 ***	0.017 ***	0.017 ***
Constant	-22.138 ***	-16.673 ***	-11.055 ***	-0.905 ***	-3.137 ***	0.045	-19.466 ***

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

Periods and Countries: UK, Denmark, Germany and Ireland: Period 1 (reference): 1990-1992, Period 2: 1993-1999, Period 3: 2000-2004, Period 4: 2005-2007; the Netherlands, France and Spain: Period 1 (reference): 1990-1992, Period2: 1993-1999, Period 3: 2000-2005, and Period 4: 2006-2007.
LFA codes indicate the location of the majority of the UAA of the holding: LFA1 (reference) = not in less-favored areas (i.e. in “normal” areas); LFA2 = in less-favored not mountain areas; LFA3 = in less-favored mountain areas; and LFA4 = no significant areas in the member state or region (i.e. no LFA in the country).

Table 3. Average Production Elasticities, Number of Violations and Economies of Scale (EOS)

Country/ Category	Denmark	France	Germany	Ireland	Netherlands	Spain	UK
Other outputs	0.334	0.392	0.303	0.201	0.213	0.075	0.348
# violations	11	52	105	32	34	625	75
% violations	0.137	0.242	0.349	0.422	0.461	2.705	0.572
Milk output	0.483	0.401	0.450	0.564	0.547	0.625	0.466
# violations	0	16	6	0	0	1	0
% violations	0.000	0.074	0.020	0.000	0.000	0.004	0.000
EOS							
Average	**1.235**	**1.299**	**1.365**	**1.315**	**1.321**	**1.443**	**1.239**
Std. deviation	0.126	0.791	0.239	0.109	0.083	0.175	0.126
Minimum	0.727	-64.452	0.596	0.991	0.658	1.121	0.979
Maximum	2.526	34.497	5.775	2.875	1.964	13.897	3.186
# violations	0	7	0	0	0	0	0
% violations	0.00	0.03	0.00	0.00	0.00	0.00	0.00

Table 4. Technical Efficiency Estimates by Country and Subgroups

Country/ Category	Denmark	France	Germany	Ireland	Netherlands	Spain	UK
Period							
Period 1	0.980	0.958	0.967	0.927	0.939	0.909	0.955
Period 2	0.956	0.944	0.924	0.926	0.932	0.932	0.944
Period 3	0.915	0.915	0.900	0.930	0.918	0.939	0.927
Period 4	0.948	0.901	0.889	0.917	0.890	0.928	0.900
Agri-Environmental Scheme (AES) payments							
No	0.955	0.941	0.932	0.927	0.929	0.930	0.940
Yes	0.922	0.908	0.897	0.920	0.909	0.943	0.909
Less Favored Area (LFA)							
LFA1	0.929	0.942	0.925	0.926		0.921	0.933
LFA2	0.930	0.936	0.913	0.926		0.925	0.941
LFA3	0.968	0.911	0.931			0.938	
LFA4					0.9252		
OVERALL	**0.949**	**0.933**	**0.918**	**0.926**	**0.925**	**0.930**	**0.936**

Periods and Countries: UK, Denmark, Germany and Ireland: Period 1: 1990-1992, Period 2: 1993-1999, Period 3: 2000-2004, Period 4: 2005-2007; the Netherlands, France and Spain: Period 1: 1990-1992, Period 2: 1993-1999, Period 3: 2000-2005, and Period 4: 2006-2007.

LFA codes indicate the location of the majority of the UAA of the holding: LFA1 = not in less-favored areas (i.e. in "normal" areas); LFA2 = in less-favored not mountain areas; LFA3 = in less-favored mountain areas; and LFA4 = no significant areas in the member state or region (i.e. no LFA in the country).

Table 5. Technological Change by Country and Subgroups

Country/Category	Denmark	France	Germany	Ireland	Netherlands	Spain	UK
Period							
Period 1	-0.010	-0.013	0.029	-0.005	-0.020	0.032	0.018
Period 2	-0.005	-0.001	0.016	0.003	-0.009	0.021	0.006
Period 3	0.002	0.015	0.0002	0.014	0.002	0.005	-0.007
Period 4	0.008	0.025	-0.010	0.020	0.008	-0.009	-0.017
OVERALL	**-0.002**	**0.005**	**0.009**	**0.007**	**-0.006**	**0.014**	**0.002**
Agri-Environmental Scheme (AES) payments							
No - All periods	**-0.004**	**0.002**	**0.013**	**0.007**	**-0.007**	**0.014**	**0.004**
No - Period 1	-0.010	-0.013	0.029	-0.005	-0.020	0.032	0.018
No - Period 2	-0.005	-0.001	0.017	0.002	-0.009	0.021	0.007
No - Period 3	0.001	0.014	0.001	0.015	0.002	0.005	-0.007
No - Period 4	0.008	0.025	-0.010	0.021	0.009	-0.009	-0.016
Yes - All periods	**0.002**	**0.014**	**0.003**	**0.013**	**-0.001**	**0.003**	**-0.010**
Yes - Period 1							
Yes - Period 2	-0.003	0.003	0.015	0.004	-0.008		0.003
Yes - Period 3	0.002	0.015	-0.0005	0.011	0.002	0.004	-0.008
Yes - Period 4	0.007	0.025	-0.010	0.018	0.008	-0.001	-0.018
Less Favored Area (LFA)							
LFA1 - All periods	**0.003**	**0.003**	**0.011**	**0.009**		**0.014**	**0.003**
LFA1 - Period 1		-0.013	0.030	-0.002		0.032	0.018
LFA1 - Period 2	-0.002	-0.001	0.016	0.006		0.020	0.007
LFA1 - Period 3	0.002	0.014	0.001	0.015		0.004	-0.007
LFA1 - Period 4	0.008	0.025	-0.009	0.021		-0.008	-0.017
LFA2 - All periods	**0.004**	**0.006**	**0.008**	**0.006**		**0.014**	**0.001**
LFA2 - Period 1		-0.012	0.029	-0.007		0.031	0.018
LFA2 - Period 2	0.001	-0.0001	0.016	0.00004		0.021	0.006
LFA2 - Period 3	0.001	0.015	-0.0004	0.013		0.004	-0.008
LFA2 - Period 4	0.008	0.025	-0.011	0.020		-0.011	-0.017
LFA3 - All periods	**-0.007**	**0.007**	**0.017**			**0.015**	
LFA3 - Period 1	-0.010	-0.012	0.031			0.033	
LFA3 - Period 2	-0.006	0.0003	0.022			0.022	
LFA3 - Period 3		0.015				0.006	
LFA3 - Period 4		0.025	-0.014			-0.007	
LFA4 - All periods					**-0.006**		
LFA4 - Period 1					-0.020		
LFA4 - Period 2					-0.009		
LFA4 - Period 3					0.002		
LFA4 - Period 4					0.008		

Periods and Countries: UK, Denmark, Germany and Ireland: Period 1: 1990-1992, Period 2: 1993-1999, Period 3: 2000-2004, Period 4: 2005-2007; the Netherlands, France and Spain: Period 1: 1990-1992, Period2: 1993-1999, Period 3: 2000-2005, and Period 4: 2006-2007.

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