Competitiveness of dairy farms in three countries: the role of CAP subsidies

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Abstract—**This paper investigates the impact of CAP subsidies on the competitiveness of dairy farms in Germany, the Netherlands, and Sweden. Technical efficiency results show that coupled subsidies have negative impacts in Germany and the Netherlands, but no significant impacts in Sweden. Decoupled subsidies negatively affect technical efficiency in each country and to a larger extent than coupled subsidies. Relative productivity results indicate that Dutch technology leads to the highest output, followed by technologies in Germany and Sweden. Dutch farms can improve their competitiveness by exploring their current production potential. Besides improving efficiency, German and Swedish farms may have options to improve their production technology.**

Keywords— **technical efficiency, output distance function, dairy farm, subsidy, relative productivity.**

I. INTRODUCTION

Dairy policy within the EU Common Agricultural Policy (CAP) is complex and involves many policy instruments such as price support programs and various subsidies. Since 1992, the CAP has gone through three major reforms, which have changed the subsidy policy of dairy production remarkably. In 1992, the MacSharry reform introduced a movement from price support to direct farm payments based on the area farmed and livestock kept. The reform reduced the intervention prices for butter and dairy products by 9% and 7.5%, respectively [1, 2]. The second reform, Agenda 2000, expanded the shifts towards direct payments. Intervention prices for butter and milk powder were reduced by 15%, starting in 2005. The cuts were compensated by the introduction of yearly direct payments in the form of a dairy premium and additional payments such as "top-up" premium and area payment [3]. In 2003, the Fischler reform further weakened the link between subsidies and production. Relative to Agenda 2000, the intervention price cuts were brought forward one year, and the intervention price for butter was further reduced by 10%. In exchange, the compensation payments were increased. In short, the various CAP reforms have undergone a long process from price support, to the production-related subsidies, and eventually to the decoupled payments [4].

Various agricultural support policies influence optimal decisions through different mechanisms [5]. The impact of subsidies on the farms' economic performance is an interesting question for policy makers who want to evaluate the effects of their decisions [6]. Since the economic performance can be measured by efficiency and productivity measures [7], one way to investigate the effects of EU's support policies on the farms economic performance is to study the impact of CAP subsidies on the farms' technical efficiency (TE). One may expect positive or negative effects of subsidies on TE under different conditions. On the one hand, subsidies can increase TE if they provide an incentive to innovate or switch to new technologies [8]. Subsidies may, on the other hand decrease technical efficiency if higher income from subsidies weakens the motivation in the form of slack or lack of effort [9]. Therefore, how much and in what direction the CAP subsidies affect farm-performance is an empirical question.

The literature provides empirical results on the effects of different support policies on TE in various agricultural sectors. First, a part of the literature studies the effects of participation in subsidized credit programs. Taylor et al. [10] investigated the impact of credit programs subsidized by the World Bank on TE of Brazilian traditional farmers and found no effect. In contrast, Brümmer and Loy [11] and Rezitis et al. [12] showed that an EU subsidized farm credit program led to lower TE in the case of German dairy farms and various Greek farms, respectively. Second, some studies investigate the effects of governmental direct subsidies. In the case of Russian farms, Sotnikov [13] found that farms that still face soft budget constraints are less efficient. For Canadian wheat farms, Giannakas et al. [14] showed that government payments were associated with lower efficiency scores, and similar results were obtained by Bojnec and Latruffe [15] in the case of Slovenian farms. On the contrary, no significant impact of state subsidies on TE of Russian corporate farms was found by Grazhdaninova and Lerman [16]. The third group of studies considers the impacts of CAP direct payments. A negative relation was found for Spanish beef farms [17], Hungarian mixed farms [18], several types of English and Welsh farms [19], and Spanish and German farms [20]. Hadley [19], however, also found a positive effect in the case of dairy and beef producers. The analysis of Guyomard et al. [21] indicated that CAP direct payments led to lower TE for crop, beef, and dairy farms in France; however, they also found that the subsidies positively influenced the technical efficiency change (TEC) over time.

The objective of this paper is twofold. First, we investigate the effects of different types of CAP subsidies together with other exogenous variables on technical efficiency and technical efficiency change. The empirical study focuses on unbalanced panel data from German, Dutch and Swedish specialized dairy farms over the period 1995-2004. Stochastic output distance function are estimated for each country in order to analyse TE and TEC and the impact of coupled and decoupled subsidies within countries Second, we compare the existing production technologies of the three countries by performing an analysis of their relative productivity. The applied approach is similar to the derivation of inter-firm catch-up component used by Oude Lansink et al. [22]. We calculate the ratios of predicted output of each country using its own production technology to the predicted output using the production technologies of the other countries. The ratios reveal a given country's performance over time relative to the "best practice frontier", thereby indicating the improvement potential that might be realized by adopting the theoretically best available technology in the three countries. In short, this paper provides comparable information on the performance of farms operating under a given technology in different EU countries. Productivity, which is implicitly related to technical efficiency, is a determinant of overall competitiveness [23]. Therefore, the analysis of farm efficiency and the comparison of production technologies across countries provide insights into the competitiveness of farms and their potential for improving productivity and resource use [24].

The paper proceeds as follows. In section 2, we present the theoretical framework of the stochastic frontier analysis in the form of output distance function and the inefficiency effects model. This is followed by a discussion of the empirical model specification for dairy farms in section 3. Section 4 describes the data and the statistics of the model variables and section 5 presents the results. Section 6 concludes.

II. THEORETICAL MODEL

A. Theoretical Background on the Effects of Subsidies

The 2003 CAP reforms entail a decoupling of subsidies from farm production, meaning that subsidies based on production quantity are transformed into lump sum payments. Decoupled payments are lump-sum income transfers to farm operators that do not depend on their current production but on their historic entitlements with obligations of keeping their land in good agricultural and environmental conditions. The actual effects of subsidies on a producer's performance are complex and have led to a large number of studies in the field.

A stream of literature hypothesises that coupled and decoupled subsidies have an income effect in the presence of uncertainty. If farmers are risk averse, any measures that reduce risk or increase income will have effects on production [25]. Hennessy [5] showed that decoupled policies affect the decisions of risk-averse producers in the presence of uncertainty. The impact of income support on farm's production decisions can be attributed to an income effect and an insurance effect. Due to the presence of risk and uncertainty in agricultural production, the income-stabilizing effect of income support policy against risk may affect optimal decisions, i.e. the insurance effect. Burfisher and Hopkins [26] found that decoupled payments improved the wellbeing of recipient farm households by enabling them to comfortably increase spending, savings, investments, and leisure with minimal distortions of agricultural production and trade.

Second, subsidies can affect production through the impact of income on off-farm and on-farm labour supply [27]. That is, the income from subsidies changes the time allocated to farming. Findeis [28] showed in a theoretical model that income transfers reduce total working time, caused by an increase in affordability of home time. Woldehanna et al. [29] found that decreased price support in combination with direct income support is most likely to increase off-farm employment of arable farm households in the Netherlands. El-Osta et al. [30] found a positive effect of decoupled payments on on-farm labour supply, and thus on production. Serra et al. [31] showed that the decoupling associated with the 1996 US agricultural policy reform reduced the likelihood of off-farm labour participation. Similarly, Ahearn et al. [32] found that government payments, whether coupled or decoupled, have a negative effect on off-farm labour participation. Ooms [33], however, does not find an effect of decoupled payments on on- and off-farm labour supplies and production.

Third, subsidies can affect performance through an effect on financial variables such as debt, solvability and liquidity. Those financial factors influence investment decisions, thereby affecting farms' production potential in the long run [33, 34, 35]. Gardebroek [36] found that capital adjustment costs are an important determinant in investments in buildings for Dutch pig farms. Bezlepkina et al. [37] found that subsidies affect the input-output mix and have a positive impact on the allocative efficiency and profit of Russian dairy farms. Zhengfei and Oude Lansink [38] studied the impacts of financial strategies and subsidies on the productivity of Dutch arable farms and found a positive effect of debt and a negative effect of subsidies on productivity growth.

Another stream of literature links subsidies to the production decisions on farm growth and exit. A policy that has effects on farmers' income could affect entry and exit decisions and farm growth decisions, [33, 39, 40]. Ahearn et al. [39] found that commodity payments reduced the share of small farms, increased the share of large farms and increased farm exits in the period 1982-96 in US. By contrast, Pietola et al. [41] found that changes in income subsidy rates did not significantly affect farm closures in Finland. The study of Chau and de Gorter [42] found that the removal of decoupled payments can have a relatively large impact on exit decisions of low-profit farm units.

Yet another stream of literature link decoupled subsidies to market imperfections and input allocation. Moschini and Sckokai [43] found that a decoupling of subsidies is usually desirable even in a distorted economy in which lump-sum taxation is not feasible. Serra et al. [44] showed that partially decoupled compensatory payments introduced by the 1992 CAP reform intensified production practices by stimulating an increase in the use of inputs such as pesticides. Goodwin and Mishra [40] found that decoupled farm payments have only modest effects on the acreage allocation and the production decisions because payments tends to make producers less likely to idle or waste land.

B. Output Distance Function and Inefficiency Effects Model

Assume that production technology is defined by an output set $Y(x)$, representing the vector of outputs $y \in R_+^M$ that can be produced by an input vector $x \in R_+^N$, i.e. $Y(x) = \{y \in R_+^M : x \text{ can produce } y\}$. The output distance function is defined as $D_O(x, y) = \min\{\theta : y/\theta \in Y(x)\}$. $D_O(x, y)$, and is non-decreasing, positively linearly homogenous and convex in y, and decreasing in x [45]. The value of the distance function is less than or equal to one for all feasible output vectors. On the outer boundary of the production possibilities set, the value of $D_O(x, y)$ is one. Thus, the output distance function indicates the potential radial expansion of production to the frontier.

The output distance function is by definition linearly homogenous in outputs, which is imposed by dividing all outputs by one of the outputs. Technical change being represented by a time trend t, homogeneity in outputs implies that $D_0^t(x_i^t, y_i^t / y_{mi}^t; \beta) = D_0^t(x_i^t, y_i^t; \beta) / y_{mi}^t$. Taking the logarithms on both sides, adding a random error term (v_{it}) for the statistical 'noise' and using $u_{it} = -\ln D_0^t(x_i^t, y_i^t; \beta)$, we obtain the following relation [see 46, 47]:

$$-\ln y_{mi}^t = \ln D_0^t(x_i^t, y_i^t / y_{mi}^t; \beta) + u_{it} + v_{it} \quad (1)$$

where u_{it} is a non-negative random error term representing the time-varying technical inefficiency and independently distributed $N^+(z_{it}\delta, \sigma_u{}^2)$. The output-oriented technical efficiency is calculated as

$$TE_{it}^{O-O} = \exp(-u_{it}) = D_0^t(x_i^t, y_i^t; \beta). \quad (2)$$

There are different factors that can explain the technical efficiency differences amongst firms. These factors are exogenous variables, which are neither inputs to the production process nor outputs of the firm, but which nonetheless exert an influence on producer's performance. One of the approaches assumes that the exogenous factors influence the degree of technical inefficiency and hence these factors are modelled directly in the inefficiency term. The basic model is based on Kumbhakar et al. [48] and Battese and Coelli [49]. It is assumed that the u_{it}'s are non-negative random variables reflecting firm-specific and time-specific deviations from the frontier, associated with the technical inefficiency of production. In equation (1), u_{it} is specified as

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

where z_{it} is a vector of firm-specific time-varying *J* variables (called explanatory variables or exogenous factors) exogenous to the production process, and δ is an unknown vector of *J* parameters to be estimated. The error term w_{it} ~ N(0, σ_w^2) is truncated from below by the variable truncation point $-z_{it}\delta$. The frontier model (1) with inefficiency effects model (3) allows for a simultaneous estimation of the impact of different factors that determine technical efficiency. The technical efficiency (TE) corresponding to the production frontier model and inefficiency effects is defined as

$$TE_{it} = \exp(-u_{it}) = \exp\{-z_{it}\delta - w_{it}\}. \quad (4)$$

Technical efficiency change rate is defined as: $TEC = -\frac{\partial u_t}{\partial t}$. Taking the derivative of the definition of technical efficiency (i.e. $TE_{it} = \exp\{-u_{it}\}$) with respect to *t*, it is not difficult to obtain a general form of the technical efficiency change:

$$TEC = -\frac{\partial u_t}{\partial t} = \frac{dTE_{it}}{dt}\frac{1}{TE_{it}} = \dot{TE}_{it}. \quad (5)$$

Clearly, technical inefficiency or technical efficiency is explained by a set of specified exogenous variables (vector *z*) and the error term *w* captures the influences of the other unspecified factors in the stochastic frontier model (equation 4). In a dynamic environment these exogenous variables are also changing over time. Therefore, the technical efficiency change in (5) can also be explained by the change of z variables. We decompose technical efficiency change (TEC) into the change attributable to the *z* variables and the unspecified factors (*w*). From (4) and (5), we obtain

$$TEC = \dot{TE}_{it} = -\delta_1\frac{dz_{1it}}{dt} - \delta_2\frac{dz_{2it}}{dt} - ... - \frac{dw_{it}}{dt} \quad (6)$$

III. EMPIRICAL MODEL

A. Model Specification

This study employs a Translog specification of the output distance function. The Translog provides an attractive framework for estimating stochastic frontier models allows for a more flexible functional form representation of the technology than the Cobb-Douglas.

The vector of outputs $y \in R_+^M$ and each output is indexed by *m* or *n*, *m* or *n*=1, 2, …, *M*. The vector of inputs $x \in R_+^N$ and each input is indexed by *j* or *k*, *j* or *k*=1, 2, …, *N*. The vector of exogenous variables $z \in R^J$ and each variable is indexed by *p*, *p*=1, 2, …, *J*. Homogeneity of output distance function in outputs is imposed by dividing all outputs by the quantity of a numeraire output [46]. This leads to the following specification for the *i*-th firm:

$$\ln y_{1i}^t = \beta_0 + \sum_{k=1}^{N} \beta_k \ln x_{ki}^t + \frac{1}{2}\sum_{k=1}^{N}\sum_{j=1}^{N} \beta_{kj} \ln x_{ki}^t \ln x_{ji}^t + \sum_{m=2}^{M} \beta_m \ln \frac{y_{mi}^t}{y_{1i}^t} + \frac{1}{2}\sum_{m=2}^{M}\sum_{n=2}^{M} \beta_{mn} \ln \frac{y_{mi}^t}{y_{1i}^t} \ln \frac{y_{ni}^t}{y_{1i}^t} + \sum_{k=1}^{N}\sum_{m=2}^{M} \beta_{km} \ln x_{ki}^t \ln \frac{y_{mi}^t}{y_{1i}^t} + \beta_t t + \frac{1}{2}\beta_{tt} t^2 + \sum_{k=1}^{N} \beta_{kt} \ln x_{ki}^t t + \sum_{m=2}^{N} \beta_{mt} \ln \frac{y_{mi}^t}{y_{1i}^t} t + v_{it} - u_{it}, \quad (7)$$

where u_{it} is defined by:

$$u_{it} = z_{it}\delta + w_{it} = \delta_0 + \sum_{p=1}^{J} \delta_p z_{pit} + w_{it}. \quad (8)$$

The distributions of the error terms in the above model have the assumptions: i.e. $v_{it} \sim iid\ N(0,\sigma_v^2)$, $u_{it} \sim N^+(z_{it}\delta, \sigma_u^2)$ and $w_{it} \sim N(0,\ \sigma_w^2)$. The output distance function (7) and the inefficiency effects model (8) account for both technical change and time-varying inefficiency effects. Using $\varepsilon_{it} = v_{it} - u_{it}$ in equation (7), the output-oriented technical efficiency is estimated as

$$TE_{it}^{O-O} = E[\exp(-u_{it})|\varepsilon_{it}]. \quad (9)$$

The marginal effect of each exogenous variable (z_p) on technical efficiency can be calculated from:

$$\partial TE_{it} / \partial z_{pit} = \partial E[\exp(-u_{it})|\varepsilon_{it}] / \partial z_{pit} = TE_{it}\Psi\delta_p, \quad (10)$$

where $\Psi = \sigma_w^{-1}[\sigma_w + \frac{\phi(\rho)}{1-\Phi(\rho)} - \frac{\phi(\sigma_w + \rho)}{1-\Phi(\sigma_w + \rho)}$ and $\rho = \sigma_w^{-1}[\delta_0 + \sum_{p=1}^{J} \delta_p z_{pit}]$ [50][1].

We use a slightly different expression for the technical efficiency change of (6) in a discrete time context (t=1, 2… T), i.e.

$$TEC' = \frac{TE_{it} - TE_{it-1}}{TE_{it-1}} = \frac{TE_{it}}{TE_{it-1}} - 1. \quad (11)$$

Technical efficiency change can be further decomposed into:

$$TEC'_{it} = (-\delta_1 \frac{dz_{1it}}{dt} - \delta_2 \frac{dz_{2it}}{dt} - \ldots - \frac{dw_{it}}{dt})\frac{TE_{it}}{TE_{it-1}}, \quad (12)$$
$$= tz_{1it} + tz_{2it} + \ldots tz_{Jit} + to_{it}$$

where $tz_{1it} = -\delta_1(z_{1it} - z_{1it-1})\frac{TE_{it}}{TE_{it-1}}$, …, and $tz_{Jit} = -\delta_J(z_{Jit} - z_{Jit-1})\frac{TE_{it}}{TE_{it-1}}$ indicate the contributions of explanatory variables and $to_{it} = \frac{dw_{it}}{dt}\frac{TE_{it}}{TE_{it-1}}$ the contribution of unspecified factors to the technical efficiency change.

B. Relative Productivity

The output distance function in (7) and (8) is estimated for the Netherlands, Sweden and Germany separately. The estimates of the output distance function can be used to make a comparison of the relative productivity of dairy farms in these countries. The output distance function can be written as

$$\ln y_{1it} = f(x_{it}, y_{it}/y_{1it}, \beta) + \ln D_o, \quad (13)$$

or,

$$\ln(\frac{y_{1it}}{D_o}) = f(x_{it}, y_{it}/y_{1it}, \beta). \quad (14)$$

Note that smaller values of D_o indicate closer proximities to the frontier and a higher value of $\ln(y_{1it}/D_o)$. The deterministic part of the output

1. We can also use the marginal effect of exogenous variables on the technical inefficiency $\frac{\partial E(u_{it})}{\partial z_{it}}$ (see equation 9 of [51]) to obtain the marginal effect on technical efficiency. Using the definition of technical efficiency: $TE_{it} = E[\exp(-u_{it})|\varepsilon_{it}] = \exp[-E(u_{it})]$, we obtain the marginal effects of the exogenous variables on technical efficiency as: $\frac{\partial TE_{it}}{\partial z_{it}} = \exp[-E(u_{it})]\cdot(-\frac{\partial E(u_{it})}{\partial z_{it}}) = -TE_{it}\frac{\partial E(u_{it})}{\partial z_{it}}$.

distance function, i.e. $f(x_{it}, y_{it}/y_{1it}, \beta)$, provides a measure of the production potential in each country. In the analysis of the relative productivity, the output can be predicted for each country using its own technology and the predicted outputs using the technologies of other countries. If the output under its own technology is higher than the outputs from technologies in other countries, this specific country is more productive than its counterparts.

IV. DATA AND DESCRIPTIVE STATISTICS

Data from specialised dairy farms over the period 1995-2004 are obtained from the European Community's Farm Accounting Data Network (FADN). The FADN database contains mainly input expenditures and output revenues. Price indexes of agricultural products are obtained from EUROSTAT and are used to calculate Tornqvist price indexes for the aggregate inputs and outputs. Next, we compute implicit input and output quantities as the ratios of values to the price indexes.

We distinguish two outputs (milk and other outputs), one variable input and three factor inputs (capital, labour and land). Descriptive statistics for the data for each country are shown in Table 1. Information on livestock subsidies and total subsidies are found in Appendix 1.

Exogenous variables which may influence farm efficiency include management strategies (e.g. financial management), environmental factors (such as location and specialization), and socio-economic factors (e.g. public policies) [17, 52]. The list of the explanatory variables is shown in Table 2. The explanatory variables include different types of subsidies, farm size, management related variables (degree of specialization, labour use and land use) and financial management related variables. Furthermore, regional differences may play a role in explaining farmer's technical efficiency.

Table 1 Descriptive statistics of outputs and inputs of dairy farms in Germany, the Netherlands and Sweden

	Mean	Std. Dev.	Min	Max
Germany[a]				
Milk (€)	90888	58662	13252	413046
Other products (€)	32810	19991	4347	136177
Variable inputs (€)	73470	43791	6868	438746
Capital (€)	2825	4385	337	458499
Labour (hrs)	4036	1950	2186	31910
Land (ha)	58	37	8	364
Netherlands[b]				
Milk (€)	159668	87422	11563	525867
Other products (€)	42355	39276	3776	311657
Variable inputs (€)	102330	52922	16698	467700
Capital(€)	4168	2441	425	31308
Labour (hrs)	4362	1656	756	13149
Land (ha)	42	23	6	214
Sweden[c]				
Milk (€)	97128	106332	184	1407383
Other products (€)	36363	45217	150	501265
Variable inputs (€)	91446	95277	3876	1431048
Capital (€)	3238	2916	176	33010
Labour (hrs)	4468	2398	500	36756
Land (ha)	84	84	4	1119

[a] Based on 2845 farms and 12458 observations in 1995-2004
[b] Based on 696 farms and 3223 observations in 1995-2004
[c] Based on 597 farms and 3341 observations in 1995-2004

The available data on the period under investigation did not contain information on coupled and decoupled subsidies. Therefore, two explanatory variables were constructed to account for the impact of coupled and decoupled subsidies on technical efficiency. First, note that the data are on specialised dairy farms, so the share of livestock subsidies in total subsidies is assumed to mimic the impact of coupled subsidies. Livestock subsidies provided by the EU are directly related to production activities. Second, the share of total subsidies in total farm revenue is assumed to reflect the impact of decoupled subsidies. The impact of coupled subsidies is already controlled, so this variable captures the effect of those subsidies that are not directly related to production.

Table 2 Explanatory variables in the inefficiency effects model and their definitions

Variable name	Definition
Coupled subsidies	Livestock subsidies in total subsidies (%)
Total subsidies	Total subsidies in total revenue (%)
Farm size	Farm size in terms of European size units (ESU)
Degree of specialisation	Milk production in total production (%)
Family labour	Family labour in total labour (%)
Rented land	Rented land in total utilised land (%)
Long term debt	Long and intermediate run loans in total assets (%)
Short term debt	Short run loans to total assets (%)
Time trend	Time=1 for 1995, time=10 for 2004
Regional dummies	12 dummies for Germany and 2 dummies for Sweden

Farm size captures the impact of economies or (diseconomies) of scale which may partly materialise through a higher (lower) technical efficiency. Degree of specialisation captures any advantages related to specialisation such as economies of scale in a single production activity and knowledge. The share of family labour in total labour may positively affect technical efficiency if family labour is more motivated or better skilled. Rented land reflects the impact of ownership as an additional incentive to produce efficiently. Finally, long- and short-term debt may have a positive effect on technical efficiency if they provide a disciplinary role [38].

V. EMPIRICAL RESULTS

A. Technical efficiency

The estimations of output distance function and inefficiency effects model for dairy farms in three individual countries (Germany, Netherlands and Sweden) are shown in Appendix 2. Technical efficiency and technical efficiency change are shown in Table 3. Furthermore, the marginal effects of the exogenous variables on technical efficiency are presented in Table 4.

Table 3 Technical efficiency (TE) and technical efficiency change (TEC) of dairy farms

	Germany		Netherlands		Sweden	
Year	TE	TEC	TE	TEC	TE	TEC
1995	0.546	-	0.468	-	0.827	-
1996	0.544	0.002	0.469	0.015	0.838	-0.011
1997	0.574	0.051	0.508	0.062	0.798	-0.056
1998	0.583	0.014	0.533	0.050	0.800	-0.001
1999	0.615	0.030	0.578	0.082	0.771	-0.029
2000	0.638	0.025	0.557	-0.042	0.793	0.022
2001	0.604	-0.029	0.590	0.063	0.767	-0.032
2002	0.606	0.017	0.598	0.008	0.764	0.002
2003	0.610	0.000	0.627	0.042	0.782	0.032
2004	0.604	-0.003	0.614	-0.008	0.759	-0.036
Average	0.594	0.010	0.552	0.028	0.788	-0.011

The mean technical efficiency of the dairy farms in 1995-2004 is 59**%** in Germany, 55% in the Netherlands, and 79% in Sweden. The mean TE scores show an increasing trend for both Germany and the Netherlands, while average TE decreased in Sweden between 1995 and 2004. These trends are also indicated by the average technical efficiency change results.

The marginal effects of exogenous variables (Table 4) show that the coupled livestock subsidies have negative impact on technical efficiency of dairy farms in Germany and Netherlands, but no significant impact in Sweden, while the decoupled subsidies have a significant negative impact on technical efficiency in each of the three countries. This suggests that the motivation of farmers to work efficiently is lower when farmers have extra income [9]. Furthermore, the results are in line with those of Iraizoz et al., Bakucs et al. and Guyomard et al. [17, 18, 21]. Moreover, as it can be seen in Table 4, that a 1% increase of the share of coupled subsidies in total subsidies causes a 0.03% and 0.02% decrease of TE in Germany and Netherlands, respectively. An increase of 1% of the share of total subsidies in total farm revenues leads to a 1.05%, 0.82% and 0.89% decrease of TE in Germany, Netherlands and Sweden, respectively. This implies that the composition of subsidies (i.e. the share of coupled subsidies) has a much smaller effect on TE than a change in the composition of total revenues (share of total subsidies). This result is of significant importance for the 2003 CAP reforms which entail a shift towards decoupled (direct) payments and are expected to increase the share of total subsidies in total farm revenues.

Table 4 Marginal effects of exogenous variables on Technical Efficiency

	Germany	Netherlands	Sweden
Coupled subsidies	-0.00027	-0.00024	0
Total subsidies	-0.01049	-0.00824	-0.00888
Farm size	0.00225	0.00161	0.00137
Specialization	0.0047	0.00473	0.00143
Family labour	-0.00045	0.00025	-0.0003
Rented land	0.00022	-0.00014	0.00037
Long term debt	-0.00005	0.00033	-0.00014
Short term debt	-0.00027	-0.00171	-0.00025
Time	0.00119	0.01801	-0.00161

Table 4 also shows that results for German and Swedish farms have a similar pattern, that is, larger size, a larger degree of specialization, a lower share of family labour and more rented land, and lower indebtedness increase technical efficiency. By contrast, on Dutch dairy farms, the share of family labour and long term debts increase technical efficiency whereas and the share of rented land decreases technical efficiency. The differences coincide with the fact that the studied samples of German and Swedish farms, relative to their Dutch counterparts, employ less family labour, utilize more rented land, and have lower proportion of long-term debts. Time trend shows positive effect in Germany and Netherlands but a negative effect in Sweden. This could be explained by the fact that Sweden joined to the EU in 1995, and the subsidies received after 1995 were more shocking to the production and had negative impact on TE over time.

Technical efficiency changes differently over time in the three countries. The mean annual TEC (Table 3) between 1995 and 2004 is 1.0%, 2.8% and -1.1% respectively for Germany, Netherlands and Sweden. That is, technical efficiency of dairy farms in Germany and the Netherlands on average improves, whereas technical efficiency of dairy farms in Sweden decreases.

The contributions of the specified exogenous variables and the other unspecified variables to the technical efficiency change are presented in Table 5. For Germany, the improvement of technical efficiency (1.0%) is, on average mainly attributable to the specified variables in the time period of 1995-2004. In Netherlands, the mean TEC (2.8%) is also mainly (3.3%) due to changes in the specified variables and -0.5% of the unspecified factors. In Sweden, the contribution of the specified variables to the average technical efficiency change (-1.1%) is -1.4%, whereas that of the unspecified factors is 0.3%.

Table 5 Contributions of specified variables and unspecified factors to Technical Efficiency Change

	Germany	Netherlands	Sweden
Specified variables			
Coupled subsidies	-0.002	-0.003	0
Total subsidies	-0.007	-0.007	-0.011
Farm size	0.013	0.004	0.006
Specialization	0.003	0.005	-0.005
Family labour	0	0	0
Rented land	0	0	0
Long term debt	0	-0.001	0
Short term debt	0	0	0
Time	0.002	0.035	-0.004
Total specified variables	0.010	0.033	-0.014
Unspecified factors	0	-0.005	0.003
TEC	0.010	0.028	-0.011

Considering the effects of the specified variables on technical efficiency change over time, similar results were found for Germany and the Netherlands. Both coupled livestock subsidies and total subsidies have contributed negatively to technical efficiency change, while farm size and specialization degree had positive effects. Moreover, in the case of the Dutch farms, the changes in long term debts decreased TE over the studied period. Furthermore, time contributes positively to the technical efficiency change in Germany and the Netherlands. In Sweden, the average decrease of TE is largely due to negative effects of an increased share of total subsidies in total farm revenues and to a decreasing degree of specialization and an autonomous technical efficiency change. These negative effects were slightly lowered by the positive effects of an increase in the average farm size.

In each of the three countries the share of livestock subsidies in total subsidies and the share of total subsidies in total farm revenue increased in the period 1995-2004. The increased shares of coupled and total subsidies had a negative impact on technical efficiency in each of the three countries. Our findings are not in line with those of Guyomard et al. [21], who found a positive contribution of CAP direct payments to the change of TE for various French farms.

The discussion on the technical efficiency change and the decomposition so far is based on the 10-year average rate of the technical efficiency change. Technical efficiency change is fluctuating over time, being positive in some years but negative in other years. That is, there is positive technical efficiency change in some years but negative in some other years due to the fact that values of exogenous variables, e.g. the subsidies received are changing over time under the different CAP reforms, and the farm size and specialization degree in dairy farms are also changing. We may explain this trend of technical efficiency change with the change of subsidies received. For example, the total subsidies in 1999 and 2000 in Germany are the lowest (see Appendix 1), which results in the highest technical efficiency (0.615 and 0.638) and technical efficiency change (0.030 and 0.025). This again confirms the negative impacts of the total subsidies on the technical efficiency and technical efficiency change.

B. Relative productivity

In Table 6, we present the average relative productivity indicators. The indicators in Table 6 are computed by inserting the inputs used in one country in the production frontier of each of the three countries. The value obtained in this way is divided by the value of the frontier output obtained from the own technology. Table 6 reports average values for the period 1995-2004.

Table 6 Mean values of the relative productivity ratios

	German	Dutch	Swedish
German farms	1.000	1.042	0.872
Dutch farms	0.973	1.000	0.849
Swedish farms	1.158	1.207	1.000

In contrast to the technical efficiency results, the three countries rank opposite in terms of the relative productivity. That is, on average for a given set of total inputs the Dutch production technology resulted in the highest total output, followed by the German and Swedish technologies. More specifically, the productivity of German dairy farms would be, on average, 4.2% higher if these farms would use the production technology of dairy farms in the Netherlands. Output of German dairy farms would decrease by 12.8% if they had used the Swedish production technology. Regarding the Dutch farms, the output using their own technology is on average higher than using the alternative technologies available in the other countries. In Sweden, dairy farms are relatively less productive than their counterparts in both Germany and the Netherlands. Swedish productivity could be improved by 15.8% or 20.7% when using the German or the Dutch production technology, respectively.

Therefore, competitiveness can be improved in different ways in the three countries. For German dairy farmers, there is a theoretical scope to increase their productivity by improving their production technology. In addition, it is also important in Germany to improve technical efficiency as the average farms are technically not very efficient (59.4%) relative to the best-practiced farm (98.3%) within the country. In the Netherlands, competitiveness can be primarily increased by improving technical efficiency with the available production technology. Among the countries, the average TE in the Netherlands scored the lowest (55.2%) relative to the country’s own potential output. In the case of Sweden, the actual production technology is utilized efficiently (78.8%) relative to the other countries; however, there is certainly a potential for improving the productivity.

VI. CONCLUSION

The objective of this empirical study was to investigate the impact of coupled and decoupled subsidies on the competitiveness of dairy farms operating in three EU member countries. Furthermore, a comparison of production technologies across countries was made. The empirical framework was applied to panel data of German, Swedish and Dutch dairy farms over the period 1995-2004.

In the period 1995-2004, average technical efficiency is 59**%** in Germany, 55% in the Netherlands, and 79% in Sweden. These results indicate the countries' potential in improving resource use relative to the optimum of their own production technology. Investigating the effects of exogenous variables on technical efficiency suggests that coupled livestock subsidies have negative impacts on technical efficiency of dairy farms in both Germany and the Netherlands, but no significant impacts in Sweden. Decoupled subsidies negatively affect technical efficiency in each country. Importantly, an increase in the share of decoupled subsidies has a much larger negative effect on technical efficiency than an increase in the share of coupled subsidies in total subsidies. Results also show that average annual change of technical efficiency is 1.0%, 2.8% and -1.1% respectively for Germany, the Netherlands and Sweden, respectively. The shares of coupled and decoupled subsidies increased in the period under investigation and caused a substantial negative effect on the change in technical efficiency in each of the three countries. The 2003 CAP reforms are expected to increase the share of decoupled subsidies and to decrease the share of coupled subsidies. The results of this study suggest a negative impact from the increase of total subsidies in total revenues (decoupled subsides) and a small positive impact from the decrease of the share of livestock subsidies (coupled subsidies).

The results of the comparison of different production technologies indicate that on average the Dutch production technology leads to the highest total output from a given set of total inputs, followed by production technologies in Germany and Sweden. Therefore, the overall competitiveness of dairy farms in the Netherlands can be improved by operating more efficiently under the given technology. For the German and Swedish counterparts, however, in principle there is a potential to improve productivity, in addition to improving their technical efficiency. Future empirical research is needed to gain insight to the effects of CAP subsidies on the productivity of farms.

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Appendix 1 Livestock subsidies and total subsidies in three countries in 1995-2004

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Average
GE	Livestock	1181	2218	1270	1094	902	1785	2592	3363	3537	7371	2662
	Total	13695	14728	14329	14249	12194	13159	14211	18095	19159	22504	15877
NL	Livestock	442	521	995	450	327	990	1709	2595	2741	8824	1925
	Total	3394	3130	3011	2970	3191	4001	6489	7752	8240	13791	5520
SW	Livestock	0	2401	7529	6515	7158	2083	3006	3424	3210	9594	4622
	Total	10046	10159	19742	20146	21547	26753	28449	29707	28204	29363	23090

Appendix 2 Estimation results

Germany

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Ln (*milk*)						
Ln (*variable inputs*)	0.83216	0.11108	7.49	0	0.61444	1.04988
Ln (*capital*)	0.56635	0.08737	6.48	0	0.39509	0.73760
Ln (*labour*)	0.51810	0.13329	3.89	0	0.25685	0.77935
Ln (*land*)	0.58154	0.10759	5.41	0	0.37067	0.79241
Ln (*other products/milk*)	0.10838	0.05837	1.86	0.063	-0.00602	0.22279
Time	0.04888	0.01523	3.21	0.001	0.01903	0.07874
Ln (*variable inputs*)**2	0.02588	0.00825	3.14	0.002	0.00972	0.04204
Ln (*variable inputs*)*Ln (*capital*)	0.00000	0.01086	0	1	-0.02129	0.02128
Ln (*variable inputs*)*Ln (l*abour*)	-0.07503	0.01405	-5.34	0	-0.10258	-0.04749
Ln (*variable inputs*)* Ln (*land*)	-0.03688	0.01277	-2.89	0.004	-0.06191	-0.01185
Ln (*variable inputs*)* Ln (*other products/milk*)	-0.04983	0.00646	-7.72	0	-0.06248	-0.03717
Ln (*capital*)**2	-0.02104	0.00442	-4.76	0	-0.02971	-0.01237
Ln (*capital*)* Ln (*labour*)	0.00083	0.01181	0.07	0.944	-0.02232	0.02397
Ln (*capital*)* Ln (*land*)	-0.00972	0.01099	-0.88	0.377	-0.03125	0.01182
Ln (*capital*)* Ln (*other products/milk*)	0.00598	0.00554	1.08	0.28	-0.00487	0.01683
Ln (*labour*)**2	-0.00208	0.00915	-0.23	0.82	-0.02001	0.01585
Ln (*labour*)* Ln (*land*)	0.01172	0.01394	0.84	0.4	-0.01561	0.03905
Ln (*labour*)* Ln (*other products/milk*)	-0.01503	0.00667	-2.25	0.024	-0.02810	-0.00197
Ln (*land*)**2	-0.02462	0.00814	-3.02	0.002	-0.04057	-0.00866
Ln (land)* Ln (*other products/milk*)	0.02442	0.00601	4.06	0	0.01264	0.03619
Ln (*other products/milk*)**2	-0.04372	0.00333	-13.12	0	-0.05026	-0.03719
Time* Ln (variable inputs)	0.00341	0.00152	2.24	0.025	0.00042	0.00639
Time* Ln (*capital*)	-0.00610	0.00129	-4.72	0	-0.00863	-0.00356
Time* Ln (*labour*)	-0.00094	0.00160	-0.59	0.556	-0.00408	0.00219
Time*Ln (*land*)	-0.00676	0.00139	-4.86	0	-0.00948	-0.00404
Time* Ln (*other products/milk*)	-0.00089	0.00074	-1.2	0.228	-0.00235	0.00056
Time_square	0.00151	0.00024	6.18	0	0.00103	0.00199
Constant	-3.73514	0.59236	-6.31	0	-4.89614	-2.57414
u						
Livestock subsidy	0.00048	0.00008	6.4	0	0.00034	0.00063
Decoupled subsidy	0.01866	0.00028	65.66	0	0.01811	0.01922
Farm size	-0.00400	0.00012	-34.05	0	-0.00423	-0.00377
Specialization degree	-0.00836	0.00066	-12.73	0	-0.00965	-0.00707
Family labour	0.00081	0.00011	7.41	0	0.00059	0.00102
Rented land	-0.00039	0.00006	-6.88	0	-0.00051	-0.00028
Long-term debt	0.00010	0.00009	1.1	0.273	-0.00008	0.00027
Short-term debt	0.00048	0.00012	4.11	0	0.00025	0.00071
time	-0.00212	0.00451	-0.47	0.638	-0.01095	0.00671
Constant	1.13919	0.07107	16.03	0	0.99989	1.27850

Netherlands

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Ln (*milk*)						
Ln (*variable inputs*)	1.68688	0.19079	8.84	0	1.31294	2.06081
Ln (*capital*)	0.66136	0.16778	3.94	0	0.33251	0.99021
Ln (*labour*)	0.60772	0.24773	2.45	0.014	0.12219	1.09325
Ln (*land*)	0.43404	0.18717	2.32	0.02	0.06720	0.80089
Ln (*other products/milk*)	-0.32923	0.07946	-4.14	0	-0.48496	-0.17350
Time	-0.03163	0.02548	-1.24	0.215	-0.08158	0.01831
Ln (*variable inputs*)**2	0.03642	0.01757	2.07	0.038	0.00197	0.07086
Ln (*variable inputs*)*Ln (*capital*)	-0.06748	0.02556	-2.64	0.008	-0.11758	-0.01739
Ln (*variable inputs*)*Ln (l*abour*)	-0.07754	0.03010	-2.58	0.01	-0.13653	-0.01856
Ln (*variable inputs*)* Ln (*land*)	-0.15350	0.02307	-6.65	0	-0.19871	-0.10829
Ln (*variable inputs*)* Ln (*other products/milk*)	-0.00210	0.01057	-0.2	0.842	-0.02281	0.01861
Ln (*capital*)**2	-0.00789	0.01237	-0.64	0.524	-0.03214	0.01637
Ln (*capital*)* Ln (*labour*)	-0.01158	0.02553	-0.45	0.65	-0.06162	0.03847
Ln (*capital*)* Ln (*land*)	0.04667	0.02236	2.09	0.037	0.00284	0.09050
Ln (*capital*)* Ln (*other products/milk*)	-0.00640	0.00988	-0.65	0.517	-0.02576	0.01296
Ln (*labour*)**2	-0.01243	0.01826	-0.68	0.496	-0.04822	0.02335
Ln (*labour*)* Ln (*land*)	0.09172	0.02689	3.41	0.001	0.03901	0.14442
Ln (*labour*)* Ln (*other products/milk*)	0.02336	0.01182	1.98	0.048	0.00019	0.04653
Ln (*land*)**2	-0.07072	0.01430	-4.95	0	-0.09875	-0.04269
Ln (land)* Ln (*other products/milk*)	0.00040	0.00963	0.04	0.967	-0.01849	0.01928
Ln (*other products/milk*)**2	-0.03846	0.00420	-9.16	0	-0.04669	-0.03023
Time* Ln (variable inputs)	0.00244	0.00301	0.81	0.418	-0.00346	0.00834
Time* Ln (*capital*)	0.00028	0.00286	0.1	0.923	-0.00534	0.00589
Time* Ln (*labour*)	-0.00340	0.00334	-1.02	0.31	-0.00995	0.00316
Time*Ln (*land*)	0.00899	0.00266	3.38	0.001	0.00378	0.01421
Time* Ln (*other products/milk*)	0.00257	0.00120	2.15	0.032	0.00022	0.00491
Time_square	0.00144	0.00036	4	0	0.00073	0.00215
Constant	-6.57220	1.02803	-6.39	0	-8.58711	-4.55730
u						
Livestock subsidy	0.00046	0.00008	6.08	0	0.00031	0.00060
Decoupled subsidy	0.01561	0.00098	15.87	0	0.01368	0.01754
Farm size	-0.00305	0.00012	-26.12	0	-0.00328	-0.00282
Specialization degree	-0.00895	0.00071	-12.67	0	-0.01034	-0.00757
Family labour	-0.00046	0.00023	-2	0.046	-0.00092	-0.00001
Rented land	0.00027	0.00008	3.31	0.001	0.00011	0.00042
Long-term debt	-0.00063	0.00014	-4.46	0	-0.00090	-0.00035
Short-term debt	0.00323	0.00066	4.9	0	0.00194	0.00453
time	-0.03412	0.00706	-4.83	0	-0.04796	-0.02028
Constant	1.89565	0.09057	20.93	0	1.71814	2.07316

Sweden

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Ln (*milk*)						
Ln (*variable inputs*)	0.63563	0.18278	3.48	0.001	0.27738	0.99388
Ln (*capital*)	-0.26957	0.15853	-1.7	0.089	-0.58028	0.04113
Ln (*labour*)	0.78832	0.21295	3.7	0	0.37094	1.20570
Ln (*land*)	0.20980	0.13987	1.5	0.134	-0.06435	0.48394
Ln (*other products/milk*)	-0.38626	0.09671	-3.99	0	-0.57581	-0.19672
Time	0.05475	0.02873	1.91	0.057	-0.00156	0.11107
Ln (*variable inputs*)**2	0.02655	0.01721	1.54	0.123	-0.00718	0.06029
Ln (*variable inputs*)*Ln (*capital*)	-0.07614	0.02343	-3.25	0.001	-0.12206	-0.03022
Ln (*variable inputs*)*Ln (l*abour*)	0.05969	0.02758	2.16	0.03	0.00564	0.11374
Ln (*variable inputs*)* Ln (*land*)	-0.02775	0.01774	-1.56	0.118	-0.06253	0.00703
Ln (*variable inputs*)* Ln (*other products/milk*)	-0.00974	0.01200	-0.81	0.417	-0.03326	0.01377
Ln (*capital*)**2	0.08031	0.01371	5.86	0	0.05343	0.10718
Ln (*capital*)* Ln (*labour*)	-0.03534	0.02357	-1.5	0.134	-0.08153	0.01086
Ln (*capital*)* Ln (*land*)	-0.03515	0.01696	-2.07	0.038	-0.06839	-0.00191
Ln (*capital*)* Ln (*other products/milk*)	-0.01479	0.00984	-1.5	0.133	-0.03407	0.00448
Ln (*labour*)**2	-0.06222	0.01620	-3.84	0	-0.09398	-0.03046
Ln (*labour*)* Ln (*land*)	0.07629	0.02176	3.51	0	0.03364	0.11894
Ln (*labour*)* Ln (*other products/milk*)	0.01269	0.01408	0.9	0.367	-0.01490	0.04029
Ln (*land*)**2	-0.03721	0.00731	-5.09	0	-0.05154	-0.02288
Ln (land)* Ln (*other products/milk*)	0.03010	0.00821	3.67	0	0.01401	0.04620
Ln (*other products/milk*)**2	-0.06582	0.00299	-22	0	-0.07169	-0.05996
Time* Ln (variable inputs)	-0.01413	0.00403	-3.5	0	-0.02203	-0.00622
Time* Ln (*capital*)	0.00890	0.00293	3.03	0.002	0.00315	0.01465
Time* Ln (*labour*)	-0.00921	0.00386	-2.39	0.017	-0.01676	-0.00165
Time*Ln (*land*)	0.01224	0.00295	4.14	0	0.00645	0.01802
Time* Ln (*other products/milk*)	-0.00745	0.00181	-4.11	0	-0.01100	-0.00390
Time_square	0.00082	0.00052	1.58	0.114	-0.00020	0.00184
Constant	-1.92086	0.85691	-2.24	0.025	-3.60037	-0.24134
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Livestock subsidy	0.00001	0.00025	0.02	0.984	-0.00048	0.00049
Decoupled subsidy	0.02062	0.00081	25.51	0	0.01904	0.02221
Farm size	-0.00318	0.00043	-7.33	0	-0.00404	-0.00233
Specialization degree	-0.00331	0.00105	-3.17	0.002	-0.00536	-0.00126
Family labour	0.00070	0.00054	1.3	0.195	-0.00036	0.00175
Rented land	-0.00086	0.00017	-5.06	0	-0.00120	-0.00053
Long-term debt	0.00032	0.00031	1.03	0.302	-0.00029	0.00093
Short-term debt	0.00057	0.00068	0.83	0.406	-0.00077	0.00191
time	0.00373	0.00495	0.75	0.451	-0.00597	0.01344
Slattbygdslan	0.14270	0.01920	7.43	0	0.10507	0.18032
Sachsen-Anhalt	0.07536	0.01757	4.29	0	0.04093	0.10979
Constant	0.14146	0.10593	1.34	0.182	-0.06617	0.34908