Determinants of productivity change of crop and dairy farms in Germany, the Netherlands and Sweden in 1995-2004

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Abstract

We calculate the productivity change of the dairy and crop farms in three European countries in 1995-2004 using the Divisa index. We decompose the productivity change in the stochastic frontier framework into four components: technical efficiency change, technical change, scale change and allocative change.

The average annual productivity growth of the crop farms in 1995-2004 is 1.6%, 2.8% and 3.4% respectively in Germany, the Netherlands and Sweden. The main source of the productivity growth of the German and Dutch crop farms is the technical change. The main source of the growth in the Swedish crop farms is the technical efficiency change.

The average annual productivity growth of the *dairy farms* in Germany, the Netherlands and Sweden in 1995-2004 is 0.8%, 2.2% and 1.9% respectively. The main source of the productivity growth of the German and Swedish dairy farms is due to *technical change*. The main source of productivity growth of the Dutch dairy farms is *technical efficiency change.*

Keywords Productivity, Decomposition of TFP, Stochastic frontier models, crop farms, dairy farms

1 Introduction

The basic definition of productivity is the rate of transformation of total input into total output. There are two relevant questions: one is how to measure productivity growth; the other is how to decompose productivity growth. The first question is important because productivity growth is an important parameter for economic policy. The second question is also important because it is useful to understand what drives the economic growth, or explore explanations or sources for productivity growth.

An often-used measure for productivity (or the overall productivity) in presence of multiple outputs and inputs is the Total Factor Productivity or Multifactor Productivity (TFP or MFP) measurement, which is defined as the ratio of aggregated output to aggregated input at a certain point of time. Total factor productivity growth is *conventionally* defined as the growth of real output not explained by the growth of factor inputs and associated with changes in technology, i.e. Solow residual. Based on the methods of aggregation of inputs and outputs, there are different ways of measuring TFP growth (Coelli et al., 2005).

The conventional index number measures of TFP growth are defined as ratios of output and input indexes. Typical measures include the Divisia TFP index, the Malmquist TFP index, the Tornquist index, the Fisher index and the Luenberger index (Diewert and Nakamura, 2002). Among these conventional measures, the Divisia index is an appropriate index for the measurement of total factor productivity (Hulten, 1973; Star and Hall, 1976; Kumbhakar and Lovell, 2000).

Apart from the conventional measures of index numbers like Divisia index for TFP growth, the productivity change measurement has been extended from the standard calculation of TFP towards more refined decomposition methods. Among these, parametric frontier estimates of total factor productivity change link the productivity growth to the technical progress, technical efficiency change as well as scale components. Recent measures of productivity change seek to decompose the impact of scale effects of input changes (i.e. movements along the production function), technical change (i.e. operating on a new production frontier) and efficiency change (i.e. moving towards the production frontier) by a parametric method in a stochastic environment (Kumbhakar and Lovell, 2000). The decomposition of productivity change is mostly based on the primal approach (e.g.

production frontier framework), i.e. by estimation of a production function or a distance function (thus called *the parametric approach*).

In the last two decades, the Common Agricultural Policy (CAP) within the European Union (EU) intends to shift to a more market-oriented policy regime for agriculture and increase the competitiveness of agriculture. Productivity growth is one of the key component of competitiveness. In this study we would like to analyse the economic performance of some individual farms (e.g. specialist *crop farms* and *dairy farms*) in the period of 1995-2004, particularly in terms of productivity, which might provide some insights for the future policy reforms. We study the productivity performance of the crop farms and dairy farms, using the Divisia index and output distance function approach. Particularly, the productivity change is further decomposed into four main elements: technical change, technical efficiency change, allocative change and the scale change. For this purpose, we calculate the Divisia indexes for the specialist *crop farms* and *dairy farms* in Germany, the Netherlands and Sweden in the period of 1995-2004, and estimate their production frontiers, using the FADN data. The estimated frontier models allow for calculating the components of the productivity change. From the estimated output distance functions, we calculate the four components of the productivity index: technical change, technical efficiency change, scale change and allocative change. As such, we contribute to the literature on the empirical assessment of the EU CAP reform.

2 Divisia index for productivity and its decomposition

2.1 Divisia index for productivity change

The basic definition of productivity (TFP) is the rate of transformation of total input into total output. The Divisia index of productivity change is defined as the difference between the rate of change of an output index ($\dot{Y}$) and the rate of change of an input index ($\dot{X}$), i.e.

$$\dot{TFP} = \dot{Y} - \dot{X} = \sum_m R_m \dot{y}_m - \sum_n S_n \dot{x}_n \,, \tag{1}$$

where $R_m = p_m y_m / R$ is the *observed revenue share* of output y_m, $R = \sum_m p_m y_m$ is the total revenue and $p = (p_1,..., p_M)$ is the output price vector, and $\dot{y}_m = (1/y_m)(dy_m/dt)$

is the change rate of output y_m. $S_n = w_n x_n / E$ is the *observed expenditure share* of input x_n, $E = \sum_n w_n x_n$ is the total expenditure, $\dot{x}_n = (1/x_n)(dx_n/dt)$ is the change rate of input x_n, and $w = (w_1,...,w_N) > 0$ is the input price vector (Kumbhakar and Lovell, 2000). Obviously, the Divisia index can be computed given observations on prices and quantities and thus is *nonparametric*.

2.2 Decomposition of Productivity in a Frontier Framework

Like other conventional measures of total factor productivity change, the Divisia index cannot distinguish between technological progress and changes in technical efficiency, yet the two may have quite different policy implications (Diewert and Nakamura, 2002). In the framework of *frontier production models*, the conventional measure of TFP change is decomposed into a measure of technical change and technical efficiency change (Nishimizu and Page, 1982). Kumbhakar and Lovell (2000) use *a production frontier model* to decompose the Divisia TFP growth rate into technical change component, scale component, a technical efficiency change component and an allocative inefficiency component. Brümmer et al. (2002) use *an output distance function* to decompose the Divisia TFP growth into the same four components. Karagiannis et al. (2004) use *an input distance function* to further decompose the *Divisia productivity index* into technical efficiency and allocative efficiency change in addition to the technological change and scale effects as well.

We follow the decomposition method of Brümmer et al. (2002) to decompose the *Divisia* index into four components (allocative efficiency change, technical change, technical efficiency change and scale component) by an output distance function. The Divisia index of productivity change is defined in equation (1). The output distance function, expressed as the output-orientated measure of technical efficiency, can be writes as:

$$\ln D_0(t, x, y) + u = 0, \qquad (2)$$

where D is the distance to the output frontier and u is the inefficiency error term.

Totally differentiating this expression and using the definition of the conventional Divisia index for productivity growth, we can obtain the decomposition of this TFP growth index (Brümmer et al., 2002):

$$\overset{\bullet}{TFP} = [\sum_{m=1}^{M}(R_m - \mu_m)\dot{y}_m + \sum_{k=1}^{N}(\lambda_k - S_k)\dot{x}_k] + (RTS-1)\sum_{k=1}^{N}\lambda_k \dot{x}_k - \frac{\partial \ln D_0(.)}{\partial t} - \frac{\partial u}{\partial t}, \quad (3)$$

where $\mu_m = \frac{\partial \ln D_0(.)}{\partial \ln y_m}$, $\lambda_k = -\frac{\partial \ln D_0(.)}{\partial \ln x_k} / RTS$, and $RTS = \sum_{n}^{N} \frac{\partial \ln D_0(.)}{\partial \ln x_n}$.

This relation decomposes the observable total factor productivity growth into an output price effect $\sum_{m=1}^{M}(R_m - \mu_m)\dot{y}_m$, an input price effect $\sum_{k=1}^{N}(\lambda_k - S_k)\dot{x}_k$, a scale effect $(RTS-1)\sum_{k=1}^{N}\lambda_k \overset{\bullet}{x}_k$, a technical change effect $-\frac{\partial \ln D_0(.)}{\partial t}$ and a technical inefficiency effect $-\frac{\partial u}{\partial t}$. Clearly, the price effects of inputs and outputs capture the allocative effects (*AEC*), and therefore the factor growth rate is a decomposition of four elements, i.e.:

$$\overset{\bullet}{TFP} = AEC + SC + TC + TEC, \quad (4)$$

where, $AEC = [\sum_{m=1}^{M}(R_m - \mu_m)\dot{y}_m + \sum_{k=1}^{N}(\lambda_k - S_k)\dot{x}_k]$,

$$SC = (RTS-1)\sum_{k=1}^{N}\lambda_k \overset{\bullet}{x}_k,$$

$$TC = -\frac{\partial \ln D_0(.)}{\partial t},$$

and

$$TEC = -\frac{\partial u}{\partial t}.$$

Equation (4) is equivalent to the decomposition of productivity change in the context of one output production technology given by Kumbhahar and Lovell (2000, p284).

These allocative effects can be caused by market or behavioural conditions (e.g. there exists market imperfection or profit maximization does not hold), so allocative effects are called the '*connected to market*' part of TFP change that is not determined technologically. The other three components (technical change, technical efficiency change and scale change) of the TFP change are called the '*connected to technology*' part or the '*technological induced change*' of the TFP change, which can be derived by the presentation of production technology (Brümmer et al., 2002).

3 An Empirical Model

For an empirical study, we require knowledge on the growth rates of inputs and outputs, and the *observed* revenue (R_m) and cost shares (S_k) to calculate the TFP growth ($\dot{TFP}$) using equation (1).

For decomposing TFP growth according to equation (4), we need to estimate an output distance function representing the production technology with multiple-outputs and inputs first. Then we can calculate the scale change *SC* and technical change *TC* based on the estimated output distance function. This estimated distance function also provides a measure of technical efficiency *TE*. Technical efficiency change (*TEC*) is calculated as the change rate of the technical efficiency estimate over time.

Assume that a farm's production involves *M* outputs ($y_1, y_2, \ldots, y_M$) and *N* inputs ($x_1, x_2, \ldots, x_N$), we specify an output distance function for the *i*-th firm in time *t*:

$$\begin{aligned}\ln y_{1i}^t &= \beta_0 + \sum_{k=1}^{N}\beta_k \ln x_{ki}^t + \frac{1}{2}\sum_{k=1}^{N}\sum_{j=1}^{N}\beta_{kj}\ln x_{ki}^t \ln x_{ji}^t \\ &+ \sum_{m=2}^{M}\beta_m \ln\frac{y_{mi}^t}{y_{1i}^t} + \frac{1}{2}\sum_{m=2}^{M}\sum_{n=2}^{M}\beta_{mn}\ln\frac{y_{mi}^t}{y_{1i}^t}\ln\frac{y_{ni}^t}{y_{1i}^t} + \sum_{k=1}^{N}\sum_{m=2}^{M}\beta_{km}\ln x_{ki}^t \ln\frac{y_{mi}^t}{y_{1i}^t} \\ &+ \beta_t t + \frac{1}{2}\beta_{tt}t^2 + \sum_{k=1}^{N}\beta_{kt}\ln x_{ki}^t t + \sum_{m=2}^{N}\beta_{mt}\ln\frac{y_{mi}^t}{y_{1i}^t}t + v_{it} - u_{it},\end{aligned} \tag{5}$$

where u_{it} is defined by:

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

Technical efficiency is estimated as: $TE_{it} = \exp(-u_{it})$.

Further, we can calculate the *elasticity of output* (multiple outputs) with respect to each input ε_k, the *return to scale* of the production *RTS*, the ratio of elasticity of outputs with respect to input to RTS λ_k, scale change *SC, technical change TC,* and *technical efficiency change TEC*.

$$\varepsilon_k = \beta_k + \sum_j \beta_{kj}\ln x_{ji}^t + \sum_{m=2}^{M}\beta_{km}\ln\frac{y_{mi}^t}{y_{1i}^t} + \beta_{kt}t \tag{6}$$

$$RTS = \sum_k^N\{\beta_k + \sum_j \beta_{kj}\ln x_{ji}^t + \sum_{m=2}^{M}\beta_{km}\ln\frac{y_{mi}^t}{y_{1i}^t} + \beta_{kt}t\} = \sum_k^N \varepsilon_k \tag{7}$$

$$\lambda_k = \frac{\varepsilon_k}{RTS} \tag{8}$$

$$SC = (RTS - 1)\sum_{k=1}^{N} \lambda_k \dot{x}_k \tag{9}$$

$$TC = \beta_t + \beta_{tt}\, t + \sum_{k=1}^{N} \beta_{kt} \ln x_{ki}^t + \sum_{m=2}^{M} \beta_{mt} \ln \frac{y_{mi}^t}{y_{1i}^t} \tag{10}$$

$$TEC = \frac{TE_i^{t+1} - TE_i^{t}}{TE_i^{t}} = \frac{TE_i^{t+1}}{TE_i^{t}} - 1 \tag{11}$$

Finally, the difference between the TFP index and the *technological induced change* ($TC + TEC + SC$) gives the allocative efficiency change:

$$AEC = \dot{TFP} - (TC + TEC + SC)\,. \tag{12}$$

4. Data and selection of outputs, inputs and explanatory variables

A consistent database for the estimation of the frontier models is the European Community's Farm Accounting Data Network (FADN). The FADN contains farm level panel data on revenues, expenses and farm characteristics (e.g. farm size, land use, labour use and capital stock). For this research, we selected specialised crop farms from three countries, i.e. Sweden, the Netherlands and Germany under the principal type of farming (PTF 13): *Specialist cereals, oilseeds and protein crops (COP crops)*. Data from specialised dairy farms over the period 1995-2004 are obtained under the principal type of farming*: Specialist dairying* (PTF41). In order to obtain the quantities of inputs and outputs, we use the price indexes for agricultural inputs and outputs from EUROSTAT with base year 2000 to calculate the Tornqvist price indexes. Next, we derive implicit quantities of inputs and outputs as the ratios of values to the Tornqvist price indexes.

4.1 Crop farms in Germany, the Netherlands and Sweden

According to the FADN database, farm total output consists of *three categories*: crops and crop products, livestock and livestock products and other output. For the specialist crop farms, the share of crops and crop products amounts to at least 70% of the total outputs in all three countries. Therefore, we distinguish cereals, root crops (aggregated by sugar beets and potatoes) and other crops in the category of *crops and crop products*. We aggregate *livestock and livestock products* and *other output* into "other products" and finally consider four outputs (cereals, root crops, other crops and other products) for total output. Furthermore, we categorise three variable inputs:

seeds, chemicals (aggregated by fertilisers and pesticides) and other variable inputs, and three factor inputs: capital, labour and land. Descriptive statistics of the data on outputs and inputs are shown in Table 1.

Table 1 Descriptive statistics of outputs and inputs of crop farms in three countries

	Mean	Std. Dev.	Minimum	Maximum
Germany[a]				
Cereals (€)	61861	152995	60	2716982
Root crops (€)	58536	84628	0	1310043
Other crops (€)	34897	81257	0	1000335
Other products (€)	92292	282268	0	4061872
Seeds (€)	14007	28447	0	611867
Chemicals (€)	31912	63852	0	883116
Other variable inputs (€)	106979	258700	4369	4002987
Capital stock (€)	405928	1094311	2606	20247558
Labour (hours)	7555	18207	2208	313599
Land (ha)	163	404	6	6263
Netherlands[b]				
Cereals (€)	19391	18651	61	142951
Root crops (€)	141662	142061	0	985566
Other crops (€)	42165	67572	0	999431
Other products (€)	29418	57534	0	775097
Seeds (€)	26841	26919	0	223202
Chemicals (€)	29372	22948	0	156765
Other variable inputs (€)	62760	54116	5905	562710
Capital stock (€)	418490	353046	6875	3629547
Labour (hours)	3805	2464	100	19527
Land (ha)	71	50	10	348
Sweden[c]				
Cereals (€)	33149	36301	5	272627
Root crops (€)	47203	66624	0	610558
Other crops (€)	15681	50968	0	687191
Other products (€)	39829	70641	0	693803
Seeds (€)	9200	12032	0	109546
Chemicals (€)	19032	19726	0	141428
Other variable inputs (€)	63579	76606	3385	660951
Capital stock (€)	295854	286988	17423	1909601
Labour (hours)	2808	2267	100	15000
Land (ha)	115	131	9	1523

[a] Based on 1182 farms and 4755 observations in 1995-2004
[b] Based on 424 farms and 1966 observations in 1995-2004
[c] Based on 333 farms and 1009 observations in 1995-2004

Explanatory variables (*z*-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) (Wilson et al., 2001; Iraizoz et al., 2005). Table 2 shows the list of FADN variables that was selected to represent the factors that may explain technical efficiency. Many variables potentially affecting management strategies, such as age, education level and family characteristics were not available in the FADN database.

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. In order to analyse the impacts of the CAP subsidies properly, we have investigated the composition of subsidies in the study period (1995-2004) in the FADN data source. The available data does not provide information on coupled and decoupled subsidies directly. Rather, the data distinguishes five categories of subsidies: 1) subsidies for crops (including *compensatory payment* to the producers of COP crops, *set aside premiums* paid to producers of COP crops and *other crop subsidies* on field, horticultural and permanent crops), 2) subsidies for livestock activities (subsidies dairying, other cattle, sheep & goats, and other livestock), 3) other subsidies (including environmental subsidies, LFA subsidies and other rural development payments), 4) subsidies on intermediate consumption, 5) subsidies for external factors (wages, rent and interests). The compensatory payment and other crop subsidies in the first group are linked to production activities of specialised crop farms and are considered to be directly coupled to production of crops. S*et aside premiums* are considered to be predominantly decoupled from production. In order to capture the effect of *coupled subsidies* on technical efficiency of specialised crop farms, we use the share of crop subsidies excluding set-aside premiums in total subsidies. This share indicates the extent to which subsidies are coupled to crop production, and is assumed to represent the *degree of coupling.* The impact of *decoupled subsidies* on technical efficiency is reflected by the share of total subsidies in total farm revenues (i.e. total output plus total subsidies). This variable is motivated by the fact that decoupled subsidies are given as a lump sum payment to farmers, thereby giving them a wealth signal. This wealth signal of decoupled payments is assumed to be reflected by the share of all subsidies in total revenues; the coupled impact of subsidies is controlled for by the share of crop subsidies in total subsidies.

Table 2 Explanatory variables (*z*-variables) in the inefficiency effects model and their definitions

Variable name	Definition
Degree of coupling	Share of coupled crop subsidies excluding set-aside premiums in total subsidies (%)
Decoupled payment	Share of total subsidies in total farm revenues (%)
Farm size	Farm size in terms of European size units (ESU)
Degree of specialisation	Share of crop production in total production (%)
Family labour	Share of family labour in total labour (%)
Rented land	Share of rented land in total utilised land (%)
Long term debt	Share of long- and intermediate-term loans in total assets (%)
Short term debt	Share of short-term loans in total assets (%)

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, the shares of long- and short-term debts in total assets account for the impact of financial risk and pressure on farmers. Farms that have relatively high debt ratios may not be able to keep up with technical/technological changes and new legislative environment (Paul et al., 2000). However, debts may have a positive effect on farm performance if they provide an incentive to farmers to produce efficiently (Zhengfei and Oude Lansink, 2006).

4.2 Dairy farms in Germany, the Netherlands and Sweden

For the specialist dairy farms, the dairy output (milk) amounts to at least 65% of the total outputs. Therefore, we categorize two outputs: milk and other outputs, which is the aggregate of the remaining part of the total output. For the total inputs, we distinguish one variable input and three factor inputs (capital, labour and land). Descriptive statistics for the data for each country are shown in Table 3.

Table 3 Descriptive statistics of outputs and inputs of dairy farms in Germany, the Netherlands and Sweden

	Mean	Std. Dev.	Minimum	Maximum
Germany[a]				
Milk (€)	90888	58662	13252	413046
Other products (€)	32810	19991	4347	136177
Variable inputs (€)	73470	43791	6868	438746
Capital stock (€)	2825	4385	337	458499
Labour (hours)	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 stock (€)	4168	2441	425	31308
Labour (hours)	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 stock (€)	3238	2916	176	33010
Labour (hours)	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 explanatory variables are similar to the crop farms, except for z1 and z5. In dairy farms, we use the share of livestock subsidy to the total subsidies for z1 and the share of dairy production to the total production for z5 for Table 2.

5 Empirical results

5.1 Productivity of crop farms

We use the maximum likelihood method to estimate the output distance functions of the crops farms and calculate their productivity change as well as the decomposition using the FADN data by software Stata/SE9.2. Table 4 is the summary of the productivity change of crop farms in each country and its decomposition into the allocative efficiency change, the technical efficiency change, the technical change and scale effects.

Table 4 Productivity change in crop farms and its decomposition 1995-2004

Time	AEC	TEC	TC	SC	TFP
Germany					
1995-1996	0.052	0.050	0.026	0	0.128
1996-1997	-0.001	-0.003	0.023	-0.001	0.019
1997-1998	-0.037	-0.037	0.021	0	-0.053
1998-1999	0.047	0.032	0.018	0.001	0.097
1999-2000	-0.016	0.031	0.015	-0.001	0.029
2000-2001	-0.033	-0.014	0.012	-0.002	-0.036
2001-2002	0.012	-0.042	0.010	-0.001	-0.022
2002-2003	-0.015	0.003	0.007	0	-0.005
2003-2004	0.042	0.025	0.004	-0.001	0.070
Average	0.002	0.001	0.014	-0.001	0.016
Netherlands					
1995-1996	0.179	0.006	0.025	-0.003	0.207
1996-1997	0.072	0.006	0.026	-0.004	0.100
1997-1998	-0.250	-0.017	0.026	0.004	-0.237
1998-1999	-0.210	0.006	0.026	0.007	-0.170
1999-2000	0.354	0.015	0.027	0.002	0.398
2000-2001	-0.051	-0.01	0.027	-0.002	-0.037
2001-2002	-0.203	0.062	0.028	0.006	-0.107
2002-2003	0.107	-0.017	0.028	0.007	0.125
2003-2004	-0.142	-0.019	0.028	0.009	-0.123
Average	-0.006	0.004	0.027	0.003	0.028
Sweden					
1995-1996	-0.022	0.107	0.004	0.009	0.099
1996-1997	0.089	0.014	0.007	0.001	0.111
1997-1998	-0.127	-0.040	0.010	-0.001	-0.158
1998-1999	0.062	-0.019	0.012	0.003	0.058
1999-2000	-0.019	0.179	0.015	-0.003	0.172
2000-2001	-0.032	-0.038	0.017	0	-0.053
2001-2002	0.006	-0.016	0.020	0.002	0.012
2002-2003	0.011	0.086	0.023	0	0.120
2003-2004	-0.005	-0.071	0.025	-0.001	-0.052
Average	-0.007	0.023	0.018	0	0.034

Table 4 shows that the annual productivity growth of the crop farms in Germany, the Netherlands and Sweden in 1995-2004 is 1.6%, 2.8% and 3.4%

respectively. Over time the productivity change rate of the crop farms in the countries are fluctuating. The fluctuation of the TFP change of the crop farms over time can be explained by the yields variations and price volatility.

Outputs and inputs of the crop production are largely dependent on the exogenous factors such as weather conditions and pest epidemics, as such the yields can change dramatically from year to year. In Germany there is a dramatic change of TFP growth from 1995-1996, 1998-1999 and 2003-2004. This can be explained by the record of annual yields of typical crops. For example, yields of cereals, wheat, potatoes and vegetables in Germany increased in 1995-1996, especially potato yields increased by 24%. In 2003 to 2004, cereal yield increased by 28%, potato by 28%, and sugar beets by 16% (EUROSTAT, 2008). Corresponding to the yield fluctuation, prices also fluctuate over time. In the Netherlands and in Sweden, the dramatic TFP changes in 1995-1996 and in 1997-1998 can also be explained by the yield variations and price volatility.

Further, we interpret the components of the TFP change. In Germany, 1.6% of the average annual productivity change is due to 0.2% of the allocative efficiency change, 0.1% of the technical efficiency change, 1.4% of the technical change and a marginal decrease of scale change (-0.1%).

Overall, the allocative efficiency change is quite volatile over time. This can again be explained by the price volatility of the product market, because allocative efficiency is a measurement of how good the firm choose their best combination of outputs and inputs to achieve the highest profit considering the prices of inputs and outputs. With fluctuations of prices (e.g. unforeseeable reason due to pest, weather conditions etc.), the allocative efficiency improvement (a positive change) is difficult to keep. Technical efficiency change over time is not stable due to the impacts of explanatory variables. Technical change in different countries exhibits different patterns: in Germany, it is decreasing, in the Netherlands, it is constant and in Sweden it is increasing over time. The scale change over time is very small in Germany and Sweden, while in the Netherlands on average it is increasing annually by 0.3%.

5.2. Productivity of dairy farms and its decomposition

Table 5 is the summary of the productivity change of the dairy farms in each country and its decomposition into the allocative efficiency change, the technical efficiency change, the technical change and scale effects based on the individual frontiers.

Table 5 Productivity change in dairy farms and its decomposition 1995-2004

Time	AEC	TEC	TC	SC	TFP
Germany					
1995-1996	-0.055	0.002	-0.004	-0.002	-0.059
1996-1997	-0.007	0.051	-0.001	0.003	0.046
1997-1998	0.055	0.014	0.002	-0.004	0.067
1998-1999	0.024	0.03	0.005	-0.003	0.057
1999-2000	-0.05	0.025	0.008	-0.007	-0.024
2000-2001	-0.05	-0.029	0.011	-0.007	-0.075
2001-2002	0.013	0.017	0.014	-0.001	0.044
2002-2003	-0.019	0	0.017	-0.004	-0.006
2003-2004	0.02	-0.003	0.020	0.001	0.039
Average	-0.008	0.010	0.008	-0.003	0.008
Netherlands					
1995-1996	-0.071	0.015	-0.007	0.008	-0.055
1996-1997	0.002	0.062	-0.004	0.009	0.070
1997-1998	0.05	0.05	-0.001	-0.005	0.094
1998-1999	0.009	0.082	0.002	-0.009	0.084
1999-2000	-0.054	-0.042	0.005	-0.002	-0.093
2000-2001	-0.036	0.063	0.008	-0.016	0.018
2001-2002	0.044	0.008	0.011	-0.011	0.051
2002-2003	-0.019	0.042	0.014	-0.008	0.029
2003-2004	0.008	-0.008	0.017	-0.005	0.012
Average	-0.007	0.028	0.003	-0.004	0.022
Sweden					
1995-1996	0.063	-0.011	0.019	0.006	0.078
1996-1997	0.002	-0.056	0.021	0.001	-0.033
1997-1998	-0.012	-0.001	0.023	0	0.009
1998-1999	0.006	-0.029	0.024	0.004	0.005
1999-2000	0.041	0.022	0.026	0.001	0.089
2000-2001	-0.054	-0.032	0.027	-0.001	-0.059
2001-2002	0.011	0.002	0.029	0.001	0.043
2002-2003	0.016	0.032	0.031	0.005	0.084
2003-2004	-0.028	-0.036	0.032	-0.001	-0.032
Average	0.002	-0.011	0.025	0.001	0.019

Table 5 shows that the annual productivity growth of the dairy farms in Germany, the Netherlands and Sweden in 1995-2004 is 0.8%, 2.2% and 1.9% respectively. In Germany, 0.8% of the average annual productivity change in the sample dairy farms is due to -0.8% of the allocative efficiency change, 1.0% of the technical efficiency change, 0.8 % of the technical change and -0.3% of the scale change. The main source of the productivity growth is due to *technical efficiency change*.

In the Netherlands, 2.2% of the average annual productivity change is due to 2.8% of the technical efficiency change, 0.3% of the technical change and -0.4% of the scale effect as well as a slight decrease of the allocative efficiency (-0.7%). The main source of productivity growth is the improvement of *technical efficiency change*.

In Sweden, the 1.9% of the productivity change is due to 0..2% of the allocative efficiency change, -1.1% of the technical efficiency change, 2.5% of the technical change, 0.1% of the scale effects. *Technical change* is the main source of the productivity growth for Swedish dairy farms.

Technical change in three countries shows an increasing pattern. Technical efficiency change is linked to the change of explanatory variables. Allocative efficiency change is fluctuating over time to respond to the price change because the allocative efficiency change is the connected-to-market part of TFP change, which includes the output and the input price effects. In both Germany and the Netherlands, the scale effects are usually negative due to the decreasing returns to scale, but positive in Sweden due to its increasing return to scale. The overall productivity growth is mainly attributed to the technical change, technical efficiency change and the allocative efficiency change. The variation of allocative efficiency change over time is caused by the volatility of the price change over time. In order to cooperate with the volatile price change over time, firms have to adjust their allocation of inputs and outputs properly to achieve their cost minimization or profit maximization, which results in the volatile allocative efficiency change.

6 Concluding remarks

We apply the stochastic frontier framework and the FADN data of the crop farms and dairy farms in three EU countries to estimate the output distance functions and inefficiency effects model in the period 1995-2004. We calculate the Divisia index for the productivity change and decompose it into allocative efficiency change, technical efficiency change, technical change and scale change as the determinants of the productivity change.

The annual productivity growth of the crop farms in Germany, the Netherlands and Sweden in 1995-2004 is 1.6%, 2.8% and 3.4% respectively. The main source of productivity growth in Germany and Dutch crop farms is due to the *technical change*. The main source of the productivity growth in the Swedish crop farms is *technical efficiency change*.

The annual productivity growth of the dairy farms in Germany, the Netherlands and Sweden in 1995-2004 is 0.8%, 2.2% and 1.9% respectively. The main source of the productivity growth of the Germany dairy farms and Dutch dairy farms is due to *technical efficiency change*. The main source of productivity growth in the Swedish dairy farms is *technical change*.

The study implies that the productivity change in Germany and the Netherlands is mainly caused by the technical change in the crop farms but technical efficiency change in dairy farms, while in Sweden technical efficiency change in crop farms and technical change in dairy farms is the main reason of productivity change. The CAP reform in the form of income support in the period has different impacts on the technical efficiency change in different countries and different farming sectors. Overall the technical efficiency change due to all the exogenous factors is on average positive in the crop farms in three countries and dairy farms in Germany and the Netherlands, but negative in Swedish dairy farms.

References

Brümmer B. (2001). “Estimating confidence intervals for technical efficiency: the case of private farms in Slovenia.” *European Review of Agricultural Economics* 28: 285-306.

Brümmer B., T. Glauben and G. Thijssen. (2002). “Decomposition of productivity growth using distance functions: the case of dairy farms in three European countries.” *American Journal of Agricultural Economics* 84: 628-644.

Coelli, T.J., D.S. P. Rao, C.J. O’Donnell and G.E. Battese (2005). “*An introduction to Efficiency and productivity analysis*.” Springer, USA.

Diewert, W. E. and A. O. Nakamura (2002). The measurement of aggregate total factor productivity growth. University of British Columbia and University of Alberta.

Hulten, C. R. (1973). Divisia index numbers, Econometrica 41: 1017-1025.

Iráizoz, B., M. Rapún and I. Zabaleta (2003). “Assessing the technical efficiency of horticultural production in Navarra, Spain.” *Agriculture System* 78:387-403.

Karaginnis, G., P., Midmore, and V. Tzouvelekas (2004). “Parametric decomposition of output growth using a stochastic input distance function.” *American Journal of Agricultural Economics* 86: 1044-1057.

Kumbhakar, S. C. and C. Lovell (2000), *Stochastic Frontier Analysis,* Cambridge University Press, Cambridge.

Nishimizu, M. and J.M. Page (1982). “Total factor productivity growth, technological progress and technical efficiency change: dimensions of productivity change in Yugoslavia, 1965-78.” *The Economic Journal* 92: 920-936.

Paul, C. J. M., W. E. Johnston, and G. A. G. Frengley. 2000. Efficiency in New Zealand Sheep and Beef Farming: The Impacts of Regulatory Reform. Review of Economics and Statistics. 82(2):325-337.

Star S. and R. E. Hall (1976). An Approximate Divisia index of total factor productivity. Econemetrica 44: 257-263.

Wilson, P.. Hadley, D. Asby, C., 2001. The influence of management characteristics on the technical efficiency of wheat farmers in Eastern England. Agricultural Economics 24: 329-338.

Zhengfei, G. and A. Oude Lansink. 2006. The Source of Productivity Growth in Dutch Agriculture: A Perspective from Finance. American Journal of Agricultural Economics. 88(3):644-656.