The Contribution of Productivity and Price Change to Farm-level Profitability: A Dual Approach Analysis of Crop Production in Norway

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Abstract Previous studies estimating TFP and its components can be criticized for not considering unobserved heterogeneity in their model. Moreover, the studies focused on the technical evaluation of a sector. However, the technical evaluation alone reveals how well farmers use the physical production process. There is a need to closely examine the cost efficiency of the farmers. In this study, we used a cost function (dual) approach to facilitating the decomposition and estimation of TFP components. Using a translog stochastic cost function, we estimated the level and source of productivity and profitability change for crop producing family firms in Norway. We used the true random effect to account for farm heterogeneity. The analysis is based on 23 years unbalanced panel data (1991–2013) from 455 only crop-producing firms with a total of 3885 observations. The result indicates that average annual productivity growth rate in grain and forage production was – 0.11% per annum during the period 1991–2013. The profit change was −0.14% per annum.

1 Introduction

Increasing agricultural productivity to feed the growing population is contemporary development challenge for developing and developed countries. Compared to other European countries, the total acreage of agricultural land in Norway is small and, because of the topography, many fields are scattered and often steep. These factors make agriculture costly. In recognition of these conditions,

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the Norwegian government has assigned relatively large subsidies to the agriculture sector compared with other countries. The main goal of the Norwegian government is sustainable agricultural production in all regions. Thus, livestock production is a common practice all over the country. However, eastern Norway and central regions are with geographical, soil and climatic conditions relatively favorable for grain and forage production.

Agricultural productivity growth in Norway is a topic of continuing interest to researchers and policy makers who aim to improve economic sustainability in the sector. The Norwegian government white paper report no. 9 (2011–2012) stated that the main goal of the Norwegian agriculture sector is to increase food production to keep up the present level self-sufficiency. There is a need to measure and evaluate the economic performance of farms to suggest possible improvements to achieve agricultural policies.

The economic performance of a firm can be measured by the efficiency and productivity measures. Efficiency estimation involves estimating the frontier based on production, cost or profit functions and measuring the performance of the farmers to the frontier (Coelli et al. 2005). The word productivity[1] in economics is a broad concept, but this study focused on total factor productivity (TFP) as an appropriate measure of productivity. TFP is the ratio of aggregate output to aggregate inputs, which shows how much output firms produce from a given quantity of inputs. The dynamics of TFP can be measured by the evolution of the TFP over time. TFP change is a widespread quantitative economic instrument used to evaluate the performance and sustainability of agricultural systems over time. It has proven valuable for policy measures geared towards fostering agricultural development (Melfou et al. 2007).

Few studies conducted on the performance of agricultural production in Norway particularly focused on a dairy farm. For instance (Koesling et al. 2008; Kumbhakar et al. 2012; Lien et al. 2010; Odeck 2007; Sipilainen et al. 2013). We still very little known about the performance of the Norwegian agricultural sector First, the previous studies ignored forage production in spite of it being major output in the Norwegian agriculture with, for instance, 2400 mill.kg of forage produced in the year 2013 (Statistics Norway 2016). Second, the analysis for this study is based on extensive farm-level panel data set for a long period of observations (1991–2013). The firms, in the long run, can change all inputs and allows choosing the combination of inputs that reduce the cost of production at a given output. Moreover, previous productivity studies failed to consider unobserved heterogeneity within the regions or groups. The efficiency estimated in the previous models didn't distinguish individual heterogeneity from the inefficiency. In these models, all the time-invariant heterogeneity is confounded into inefficiency. Thus, the inefficiency component might be picking up heterogeneity in addition to or even instead of inefficiency (Greene 2005).

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[1]Productivity is the ratio of output per unit of input(s) so that it can be measured in different forms. For instance a partial productivity measure uses only one input e.g. productivity of labor = aggregate output/labor.

The rest of the paper organized as follows. Section two presents the theoretical framework with a detailed derivation of productivity and profitability change components from the cost function. Section three describes the empirical model while section four discusses the data and definition of variables used in the cost function. Empirical estimation and results presented in section five. The final section encompasses a summary of our findings and conclusions.

2 Theoretical Framework

2.1 Theoretical Background

There are different approaches to measuring and decomposing the dynamics of TFP. It can be measured by the index numbers such as the Divisia, Malmquist, Tornquist, Luenberger, and Fisher TFP indexes depending on the aggregation of outputs and inputs. The most commonly used measure is the Malmquist index, but a conventional measure is the Divisia index (Zhu et al. 2012). A method first proposed by Kumbhakar (1996) and Kumbhakar and Lovell (2003) decomposes TFP into technical change, scale effects, technical efficiency, and a price component. Following this approach, different papers decompose TFP change commonly using either Malmquist or Divisia Indices. For instance, Balk (2001) using the Malmquist index identifies four components of TFP change.

Technical change (TC) results from a shift in the cost frontier. TC captures the improvement in best practices through the adoption of new technologies. For instance, farmers using new crop varieties can produce more output at least cost. As a result, the best farms are getting better. TC can be positive or negative depending on whether the shift in the cost frontier down or up. The second component of TFP change is efficiency change (EC), the improvement in the firm's ability to use available technology. EC includes movement towards the cost frontier due to improved farm management, for example, or the wider adoption of better technology (Kumbhakar and Lovell 2003). The third component is the change in scale efficiency change (SC). SC shows movements along the cost function and a decrease in the average cost of production (Coelli et al. 2005). The fourth component is the input and the output mix effect (mixed-effect), which is very common in the multiple-input-multiple-output firm. The mix effect measures the effects of change in the composition of inputs and output vectors over time (Balk 2001).

Kumbhakar and Lozano-Vivas (2005) used the production frontier model to decompose the Divisia TFP growth into Technical efficiency change (TEC), technical change (TC), allocative efficiency change (AEC) and scale change (SC) components. On the other hand, Brümmer et al. (2002) decomposed the Divisa TFP change into TEC, TC, AEC and SC component using output distance function. Using input distance function Karagiannis et al. (2004) decompose Divisia TFP change into the same four components.

There have been several attempts to identify the relationship between profitability and productivity change. For instance, Miller and Rao (1989) decomposed profit

change into a productivity effect, an activity effect, and price effect. Grifell-Tatjé and Lovell (1999) developed an analytical framework in which profit change over time decomposed into price effect, an activity effect and productivity change effect. Activity effect includes resource mix, product mix, and scale effect. Productivity change effect includes operating efficiency and technical change effect. Kumbhakar and Lien (2009) decomposed the productivity effect further into technical efficiency and technological change effects while the activity effect subdivided into the scale, resource mix, and product mix effects see also (Sipilainen et al. 2013).

Our theoretical framework to a large extent follows the approach used by Kumbhakar and Lien (2009) and Sipilainen et al. (2013). In these studies, the dynamics of profitability change over time are measured as a change in profit based on the input distance function approach. These studies focused on the technical evaluation of dairy firms. However, the technical evaluation alone reveals how well farmers use the physical production process. There is a need to closely examine the cost efficiency of the farmers which will also address the management of financial resources. Moreover, Binswanger (1974) has shown that the dual approach is more desirable than the production function approach for economic analysis. The dual cost minimization framework is widely used in productivity literature to estimate and decompose productivity change through time (Kumbhakar and Lovell 2003). The theory of the cost function relies on the assumption that firms choose inputs to the production process that minimize the cost of producing output. The next sub-section discusses measuring the level of productivity and profitability change using the dual approach.

2.2 Application

2.2.1 Productivity (TFP) Change Decomposition

Suppose we have a dataset of N firms over T periods and let $x_{it}=(x_{1it},\ldots,x_{nit})$ be the input quantity vector for firm i in period t and $X_{it} \equiv X(x_{it})$ be the aggregate input function. $y_{it}= (y_{1it},\ldots,y_{mit})$ is the output quantity vector for firm i in period t and $Y_{it} \equiv Y(y_{it})$ is the aggregate output function. where X and Y are non-negative, non-decreasing and linearly homogenous aggregator functions. Output quantities are measures of quantities sold plus on-farm consumption and net changes in inventories. Input quantities are measures of purchasing inputs as well as farm production used on the farm. If a technology produces multiple outputs, TFP change ($T\dot{F}P$) 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 ($\dot{X}$) (Kumbhakar et al. 2014). For the development of expressions (1) to (6), we will suppress the firm subscript i.

$$T\dot{F}P = \dot{Y} - \dot{X} \equiv \sum_m R_m \dot{y}_m - \sum_j S_j \dot{x}_j \tag{1}$$

where a dot above a variable will denote the rate of change in the log of that variable; $R_m = p_m y_m / R$, $R = \sum_m P_m y_m$ in which R is total revenue and R_m is the observed revenue share of output y_m; p is the output price vector $(p = p_1, \ldots, p_m)$; y is the vector of output; and S_j is the observed expenditure share of input X_j $(S_j = w_j x_j / C)$. C is the total cost $(C = \sum_j w_j x_j)$; and w is the vector of input price $(w = w_1, \ldots, w_j)$. As shown by Kumbhakar and Lien (2009) and Sipiläinen et al. (2013) Eq. (1) can be re-written as:

$$T\dot{F}P = \text{TC} + \text{EC} + \left(1 - RTS^{-1}\right)\dot{y}_c + \left(\dot{y}_p - \dot{y}_c\right) \equiv TC + EC + Scale + Markup \tag{2}$$

where $\text{TC} = -\frac{\partial lnC}{\partial t}$; $RTS^{-1} = \sum_m \frac{\partial lnC}{\partial lny_m}$, $\dot{y}_c = RTS\left[\sum_m \frac{\partial lnC}{\partial lny_m}\dot{y}_m\right]$, $\dot{y}_p = \sum_m R_m \dot{y}_m$, and $\dot{y}_m$ is the rate of change in output y_m. EC (efficiency change) $= \frac{\partial TE}{\partial t}$; TE is the mean efficiency level of the firm at a given time. RTS is returns to scale of the firm. Using this concept we can decompose the profitability change in the next subsection.

2.2.2 Profitability Change Decomposition

A profit of a firm $(\pi) = Revenue\ (R) - cost\ (C) = \sum_m p_m y_m - \sum_j w_j x_j$ and change in profit using Eq. 2 is expressed as:

$$\frac{d\pi}{dt} = \left(\sum_m p_m \frac{\partial y_m}{\partial t} + \sum_m y_m \frac{\partial p_m}{\partial t}\right) - \left(\sum_j w_j \frac{\partial x_j}{\partial t} + \sum_j x_j \frac{\partial w_j}{\partial t}\right)$$

$$= \left(\sum_m p_m y_m \frac{\partial lny_m}{\partial t} + \sum_m y_m p_m \frac{\partial lnP_m}{\partial t}\right) - \left(\sum_j w_j x_j \frac{\partial lnx_j}{\partial t} + \sum_j x_j w_j \frac{\partial lnw_j}{\partial t}\right)$$

$$= R\left(\sum_m R_m \dot{y}_m + \sum_m R_m \dot{P}_m\right) - C\left(\sum_j S_j \dot{x}_j + \sum_j S_j \dot{w}_j\right) \tag{3}$$

Divide Eq. (3) by total cost

$$\frac{1}{C}\frac{d\pi}{dt} = \frac{R}{C}\left(\sum_m R_m \dot{y}_m + \sum_m R_m \dot{P}_m\right) - \left(\sum_j S_j \dot{x}_j + \sum_j S_j \dot{w}_j\right) \tag{4}$$

From Eq. (1) and (2) we can get

$$-\sum_j S_j \dot{x}_j = TC + EC + \left(1 - RTS^{-1}\right)\dot{y}_c + \left(\dot{y}_p - \dot{y}_c\right) - \sum_m R_m \dot{y}_m \tag{5}$$

Substituting (5) into (4)

$$\frac{1}{C}\frac{d\pi}{dt} = \frac{R}{C}\left[\sum_m R_m \dot{y}_m + \sum_m R_m \dot{p}_m\right] - \sum_j S_j \dot{w}_j + \ TC + EC +$$

$$\left(1 - \sum_m \frac{\partial lnC}{\partial lny_m}\right)\dot{y}_c + (\dot{y}_p - \dot{y}_c) - \sum_m R_m \dot{y}_m$$

$$\frac{1}{C}\frac{d\pi}{dt} = \left(\frac{R}{C} - 1\right)\dot{y}_p + \left(\frac{R}{C}\right)\dot{p} - \dot{w} + TC + EC + \left(1 - RTS^{-1}\right)\dot{y}_c + \left(\dot{y}_p - \dot{y}_c\right)$$

$$(6)$$

$$\frac{1}{C}\frac{d\pi}{dt} \equiv \left(\frac{R}{C} - 1\right)\dot{y}_p + \left(\frac{R}{C}\right)\dot{p} - \dot{w} + T\dot{F}P$$

where $\dot{p} = \sum_m R_m \dot{p}_m$ and $\dot{w} = \sum_j S_j \dot{w}_j$. Equation (6) is of primary interest for this study, which decomposes the change in profit as a percentage of total cost into several components. Following Kumbhakar et al. (2009) and Sipilainen et al. (2013), we can give an interpretation of each component in (6) as follows:

(a) TC is the technical change component $\left(-\frac{\partial lnC}{\partial t}\right)$, which will affect profitability positively if there is technical progress;
(b) $\left(1 - RTS^{-1}\right)\dot{y}_c$ is the scale component and measures the effect scale economies. It will increase profit if RTS >1 and the aggregate output cost ($\dot{y}_c$) is small.
(c) $\dot{y}_p - \dot{y}_c$ is the markup component. It will increase profitability of the farm if the markup change is positive.
(d) EC is the efficiency change component (EC $= \frac{\partial u}{\partial t}$), which will affect profit positively if efficiency improves over time;
(e) $\dot{y}_p\left(\frac{R}{C} - 1\right)$ is the output growth component, which will increase profitability if the output growth rate is positive.
(f) $\left(\frac{R}{C}\right)\dot{p}$ is the output price change component; which will affect profit positively if output price increase overtime;
(g) $\dot{w}$ is input price change component; which will affect profit positively if input price change is negative

Output change, input and output price change components can be computed simply from the data, while TC, scale, markup, and EC require econometric estimation.

3 The Econometric Model

A cost function gives the minimum[2] cost of producing a given level of output given input prices and technology. That is, we assume that a firm i ($i=1,\ldots,N$) is a cost-minimizing entity that produces output Y subject to a production constraint $F=(Y,X)$. The mathematical expression as follows:

$$\text{Min } C = \sum_{j=1}^{n} W_j X_j (Y, W) \tag{7}$$

Subject to

$$F(Y,X) = 0$$

The true cost function is unknown. Thus, consistent with most of the firm efficiency literature (Christensen and Greene 1976), we can estimate a Transcendental Logarithmic (TL) cost function. It is continuous and non-negative, as well as positively linearly homogenous, non-decreasing, and concave on price; non-decreasing, and quasi-convex on output. Our specification of a multi-product TL cost function C for $j=1,\ldots,J$ inputs and $m=1,\ldots,M$ outputs can be specified in log form as:

$$lnc = \alpha_0 + \sum_{j=2}^{4} \beta_j \ln\check{w}_j + \sum_{m=1}^{3} \propto_m \ln y_m + \sum_{l=1}^{3} \propto_{mt} \ln y_m t + \sum_{j=2}^{4} \beta_{jt} \ln\check{w}_j t +$$

$$+ \frac{1}{2}\left[\sum_{m=1}^{3}\sum_{m=1}^{3} \gamma_{mm} \ln y_m \ln y_m + \sum_{j=2}^{4}\sum_{j=2}^{4} \delta_{jj} \ln\check{w}_l \ln\check{w}_j + \rho t^2 \right] +$$

$$\sum_{j=2}^{3}\sum_{m=1}^{3} \varnothing_{jm} \ln y_m \ln\check{w}_j + dt + \mu_i + V_{it} + U_{it} \tag{8}$$

where lnc represents log form of total cost, w_j represent the price of inputs j, and y_i is the quantity of output i. $\ln\check{w}_j = \ln w_j - \ln w_1$ ($\forall j$) discussed in the next paragraph. All Greek letters are parameters to be estimated and the white noise error term (V_{it}) is added to allow for random measurement error in Eq. (8). μ_i capture latent heterogeneity (farm-effect). U_{it} is the non-negative variable representing technical inefficiency. We assumed V_{it} is symmetric and to satisfy the classical assumptions, i.e. $v_{it}^{iid} \sim N\left(0, \sigma_v^2\right)$, $V_{it} \perp U_{it}$. The trend variable, t, include

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[2]In a cost minimization setup the output(y) is treated as exogenous and the inputs (x) are treated as endogenous.

to capture Hicks-neutral technology change starts with T=91 for 1991 and increases by one annually. Economic theory imposes homogenous and symmetry restrictions on the parameters. Any sensible cost function must be homogenous of degree 1 in input prices; thus the restrictions in input prices $\sum_j^k \beta_j = 1$, $\sum_j^k \gamma_{jl} = \sum_j^k \delta_{jl} = 0$; and the symmetry restriction $\gamma_{lj} = \gamma_{ji}$. From Eq. (8) we can derive the cost share function (S_j) using Shephard's lemma as follows:

$$s_j = \frac{\partial lnc}{\partial \ln w_j} = \frac{w_j x_j}{c} = \beta_j + \sum_{j=2}^{l} \delta_{jj} \ln \breve{w}_l + \sum_{l=1}^{m} \varnothing_{jm} \ln y_m + \beta_{jt} t \qquad (9)$$

Since $\sum_{j=1}^{j} s_j = 1$, the cost share Eq. (9) must satisfy the adding-up property. However, this property implies the same restrictions as linear homogeneity in the cost function, so we imposed both properties by dividing the quantity of all inputs by the quantity of one of the inputs. Then, in Eq.(9) we imposed homogenous restriction by re-defining both the left- and right-hand sides of the equations as follows: $\ln \breve{w}_j = \ln w_j - \ln w_1$ $(\forall j)$ and $lnc = \ln \left({}^c\!/_{w_1} \right)$. This approach also implies that one of the share equations has to be dropped. The parameters of the dropped equation can be recovered from the homogeneity restrictions discussed above. Using Eqs. (8) and (9), we computed the seven components of profitability change shown in Eq. (6). We used Greene (2005) model to estimate parameters in Eq. (8). The next section discusses data source and variables.

4   Data and Definition of Variables

The data used in this analysis is an unbalanced panel with 3885 observations from farmers involved only in the production of crops (grain and forage) for the year 1991–2013. The data include production and economic data collected annually by the Norwegian Institute of Bioeconomy Research (NIBIO) from about[3] 1000 farms in all regions of Norway. Participation in the survey is voluntary. There is no limit on the number of years a farm included in the study. Some of the farmers participated more than 20 years, and others have started participating for the first time. To accommodate panel features in estimation, we included only those farms for which at least three consecutive years of data are available.

The output measure at our disposal in the data set is the grain output in 1000 FU[4] (y_1), forage output in 1000 FU (y_2), and other crop outputs in 1000 in Norwegian

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[3]The number of participants varies from year to year. For example in 1991 data has been collected from 1049 firms but in 2013 it was 924 firms. Approximately 10% of the survey farms are replaced per year to incorporate changes in the population of farms in Norway.

[4]FU stands for feed units, which adjust the quality difference in output. 1 FU = 1 kg of grain with the 15% water content. Thus the output is quality-adjusted yield in kilograms per year.

Kroner (NOK) (y_3). Grain output is an aggregate of four main species: barley, wheat, oats, and oilseed species. The aggregate is quality adjusted and is measured in FU (feed units) as defined by NIBIO. Thus, the natural output to use is the quality-adjusted crop output in kilograms per decare (daa).[5]

To assess the efficiency and productivity growth, we need to be sure that farmers under consideration are comparable. Forage and grain output can be an input for livestock production so that it can be an intermediate product. To avoid double counting, we have selected only 455 farmers who are involved producing grain, forage and other crop products (potatoes, tomatoes, vegetables, etc.). These firms are located in the eastern and central (Trøndlag) regions of Norway. Moreover, we exclude government intervention like a subsidy in the main output because the main task of the research is to know how the farmers allocate resources to produce crop production. Several studies conducted on the effect of subsidizing conclude that government farm support distorts efficiency (for instance Kleinhanß et al. 2007; Kumbhakar and Lien, 2009). Output prices (P_m) corresponding to the output variables are estimated from the survey data. Implicit output prices are calculated from output revenue for each kind of crop divided by the output quantity for each crop type. Prices for other outputs are aggregated as a Fisher index (Diewert 1998).

Major inputs include labor, measured as the total labor hours used in the farm, including hired labor, owners' labor, and family labor; farmland, defined as productive land (both owned and rented); material which includes inputs such as fertilizer, seed, and pesticide, registered by their costs of purchase in NOK; and capital is measured as the sum maintenance and running (hiring) costs, depreciation and interest costs on the total capital stock (3%) deflated by an index for fixed cost items figure from NIBIO and calculated at 2013 price levels.

The cost function (8) is specified with the following four input prices (w_j). Land prices are derived from the market prices for rental of farmland, in the area of each farm. The price of labor is the wage of hiring labor. The price of other variable inputs and capital costs were constructed as Laspeyres indices based on figures provided by NIBIO. All prices are deflated to 2013 levels using the agricultural price index figures also provided by NIBIO. Descriptive statistics of data are summarized in Table 1. Norwegian farmers are small. The annual average output was about 61,000 FU of grain and 77,000 FU of forage. The average farm received on the output grain price of 1.86 Norwegian kroner (NOK) per FU and 0.33 NOK per FU for forage. Figure 1 shows crop output per year was increasing in all three agricultural outputs and follows an almost similar trend.

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[5]A decare (daa) is equal to 0.1 hectare (ha).

Table 1 Descriptive statics of model variables in cost function

| Variables	Label	Unit	Mean	Std. Dev.
Output (y_i) y_1	Grain output	1000 FU	60.829	65.715
y_2	Forage output	1000 FU	76.657	54.278
y_3	Other	1000 NOK	9.305	7.546
Inputs (x_i) x_1	Labor	1000 h	3.492	1.238
x_2	Land	1000 daa	0.346	0.202
x_3	Material cost	1000 NOK	217.639	133.380
x_4	Capital cost	1000 NOK	352.743	343.190
Inputs (p_i) p_1	Grain price	NOK/FU	1.855	0.559
p_2	Forage price	NOK/FU	0.324	0.477
p_3	Other crop prices	index	62.836	11.921
Inputs price (wj) w_1	Wage	NOK/h	144.496	31.926
w_2	Rent	NOK/daa	237.053	154.551
w_3	material price	index	67.187	15.590
w_4	capital price	index	80.741	10.359
T	Trend (1=year 1991)			
N	Sample size		3885	

NOK Norwegian Kroner and *FU* Feed Units
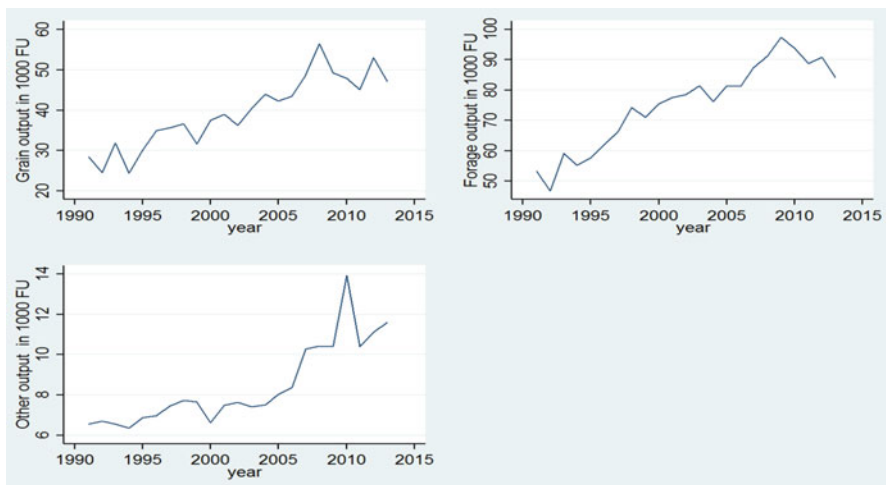
Fig. 1 Annual mean crop output from 1991–2013

5 Estimation and Results

5.1 Testing Model Specification

The cost function is estimated using STATA® version14. The trend variable is normalized to be zero in the year 2013. All other variables normalized before taking the logarithms by dividing each variable by its mean value so that the first-order parameters can be interpreted as elasticities at geometric mean. The estimated parameters and associated standard errors are reported in Table 3. The results show that the estimated variable cost function is not decreasing on each input price and output quantity at any reasonable level of significance. Various specification tests were conducted to obtain the best model and functional form for the data under analysis (Table 2).

Before estimating the production function, the skewness of the data tested based on Schmidt & Lin (1984). The test return of skewness with a P value less than 0.001 shows that the null hypothesis of no skewness confidently rejected. The null hypothesis that there are no technical efficiency effect in the models was tested. The null hypothesis rejected, in which the LR is greater than the (mixed) chi-square value of 5.412. A generalized likelihood ratio test using a mixed chi-squared distribution is consistent technical inefficiency constituting the largest share of total error variance, suggesting the appropriateness of the stochastic frontier analysis (SF) approach as opposed to ordinary least squares (OLS). Moreover, likelihood function expressed in terms of the two variance parameters as $\gamma = \sigma_u^2 / \sigma_u^2 + \sigma_v^2$ ($\gamma = 0.34$ in Table 3) shows that technical inefficiency consist the largest share of total error variance supports the appropriateness using SF approach. An LR tests reject a simplification of the TL to CD rejected. The goodness of fit measured by the log of likelihood function is statistically significant.

Table 2 Properties of grain and forage production technology

Restrictions	Parametric restrictions	chi2	_p-value_
Cobb-Douglas technology	H_0: All interaction terms are zero	1285	0.000
Scale technology effects in output	H_0: $\propto_{mt} = 0$	12.31	0.006
Hicks technology effects in inputs	H_0: $\beta_{jt} = 0$	50.63	0.000
Schmidt & Lin (1984)	H_0: no skewness	445.8	0.000
Generalized LR ratio test	Test for one-sided error	61.02 [a]	0000

[a]Denotes significant at 1% level of significance using mixed chi-square distribution with 1 degree of freedom and a critical value of 5.412

Table 3 Estimates of the parameters of the translog stochastic frontier model

Variable	First orders	$\ln\check{w}_2$	$\ln\check{w}_3$	$\ln\check{w}_4$	$\ln y_1$	$\ln y_2$	$\ln y_3$	t
Constant	−0.21***(0.02)							
$\ln\check{w}_2$	0.04***(0.01)	0.02*(0.01)						
$\ln\check{w}_3$	0.35*** (0.14)	0.01(0.11)	9.70**(3.71)					
$\ln\check{w}_4$	0.54***(0.14)	−0.07(0.12)	0.07(0.05)	−15.95*(7.95)				
$\ln y_1$	0.14***(0.01)	0.01(0.01)	0.05(0.01)	0.02*(0.01)	0.04***(0.01)			
$\ln y_2$	0.13***(0.01)	0.01(0.01)	−0.18*(0.09)	0.19*(0.09)	0.01(0.01)	0.03***(0.01)		
$\ln y_3$	0.23***(0.01)	−0.01(0.01)	0.13(0.09)	−0.12(0.10)	−0.03***(0.01)	0.002(0.00)	0.05***(0.01)	
t	0.03***(0.00)	0.00*(0.00)	−0.32*(0.13)	0.31*(0.13)	0.00***(0.00)	0.00***(0.00)	0.00***(0.00)	0.008***(0.00)

Log. L.= 1040*** $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_i^2} = 0.34$ N=3885   (0.00)

Note: Standard errors in parentheses, * $p<0.05$, ** $p<0.01$, *** $p<0.001$; and $\check{w}_2$=land/labour, $\check{w}_3$=var.cost/labor, $\check{w}_4$=fixed.cost/labour, y_1= grain, y_2=forage, and y_3=other, all in log form
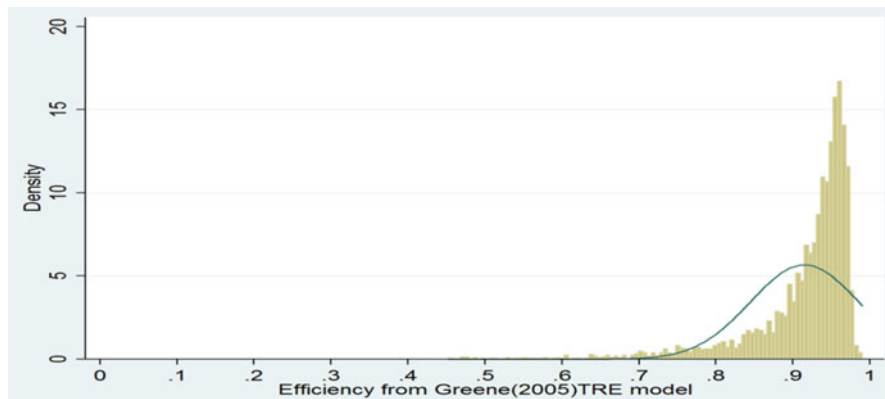
Fig. 2 Histogram of the efficiency index from the Greene (2005) model (The solid line is the fitted value for the model)

5.2 Inefficiency Score

We plot a histogram of efficiency index using the Greene (2005) true random-effects model (TRE) model (Fig. 2). The estimated efficiency score across the years of observation is 0.91. The estimated efficiency index implies that the minimum cost is about 91% of the actual expenditure. Alternatively, the actual cost can be reduced without reducing the output by 10% (1/0.91–1) if we remove inefficiency in crop production in Norway.

5.3 Price and Output Elasticities

Table 3 shows the parameters of stochastic frontier model estimation. The models exhibit positive and highly significant first-order parameters, fulfilling the monotonicity condition as expected for a well-behaved cost function. The elasticity of cost on the price of land, other variable input costs and capital costs were 0.04, 0.35 and 0.54, respectively. If one percent increases the price of land, costs will increase by an estimated 0.04%, ceteris paribus. If the price of other variable inputs increases by 1%, costs will increase by an estimated 0.35%. The coefficient for the capital (fixed input) price (0.54) is the largest among other partial elasticities and statistically significant (p < 0.001). The result implies that crop production in Norway more of capital intensive and the percentage change in the capital price has a larger influence on crop production compared to other inputs. Thus, any intervention to improve the crop sector needs to prioritize on these inputs. We can recover and estimate the elasticity of cost on the price of labor, i.e., If the price of labor increases by 1%, costs will increase by an estimated 0.07, i.e. 1− (0.04+0.35+0.54). The elasticity

of cost on grain, forage, and other outputs were 0.14, 0.13 and 0.23, respectively. This means for instance, if grain output increases by 1%, costs increased by an estimated 0.14%, ceteris paribus.

5.4 TFP and Profitability Change

The components of TFP and profitability change are plotted in Figs. 3 and 4, respectively. The estimated average TFP and profitability change are reported in Table 4. The result indicates that the overall average annual change in the TFP growth rate in grain and forage production during the period 1991–2013 was −0.11% per annum. This result is consistent with the results from previous studies. For instance, a survey conducted for Polish Agriculture reported TFP decreased by 2% over the period 1996 to 2000 (Latruffe et al. 2008) Moreover, Baráth and Fertő (2017) reported a decline in TFP for European agriculture from 2004 to 2013. TFP decline was mainly due to negative contributions from the markup change component. There are no similar studies conducted for multiple output technology in forage and grain production for comparison. The estimated result shows that technological change (TC) was – 0.03% per annum. Moreover, Wang and Ho (2010) stated that the first order coefficients of the time trend variable show estimates of the
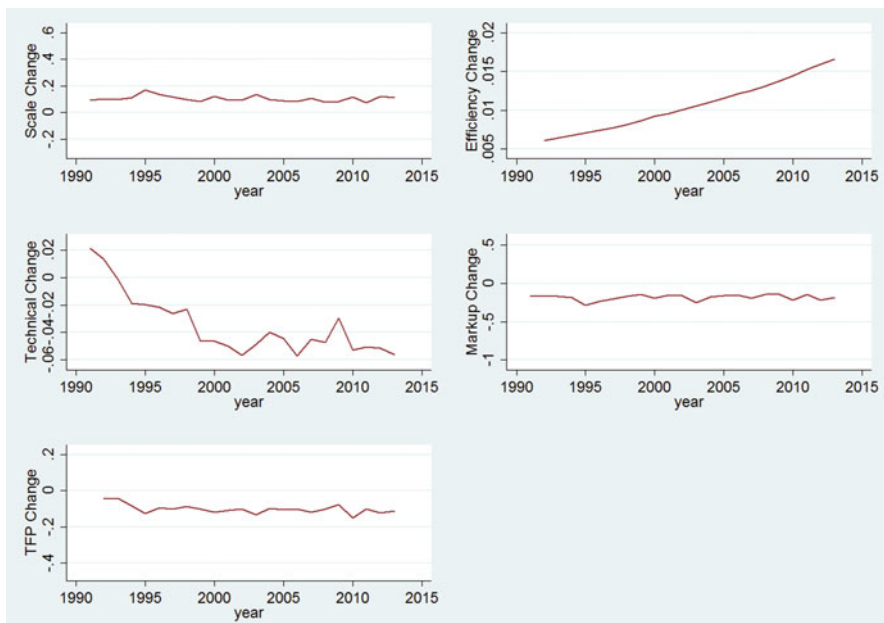

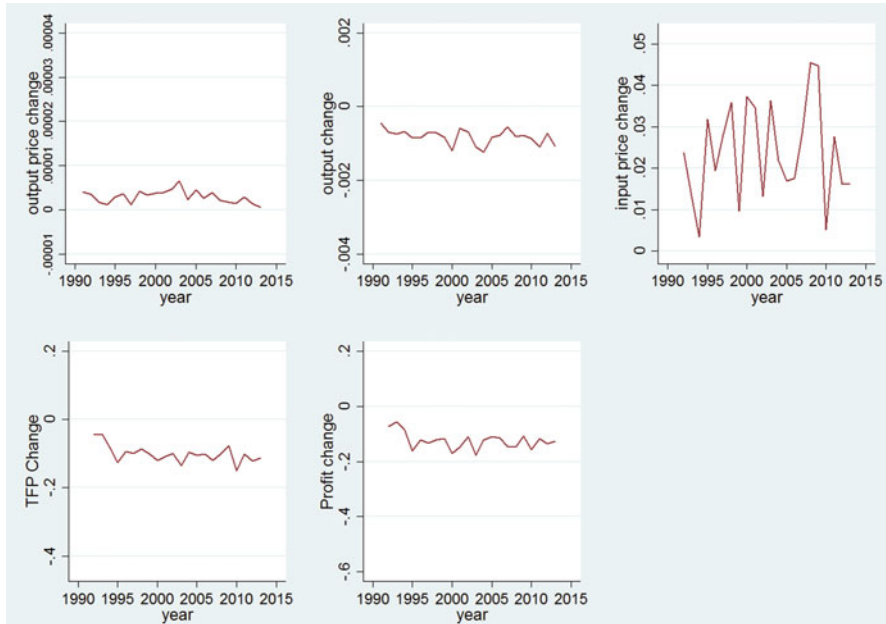**Fig. 3** Mean TFP change components estimated from cost function for the year 1991–2013

Fig. 4 Mean profit change components for the year 1991–2013

Table 4 Annual TFP, profitability change and its components (in percent)

Variable	Mean	Std. Dev.
Efficiency change (EC)	0.0102	0.0031
Scale change(SC)	0.1001	0.4775
Technical change (TC)	−0.0327	0.0228
Markup	−0.1859	0.7348
TFP change	−0.1122	0.2829
Output price change	0.00002	0.00005
Input price change	0.0259	0.0195
Output change	−0.0011	0.0035
Profit change	−0.1379	0.2867
Sample size (N)	3885	

average annual rate of technical change (TC). The estimated parameter of the trend variable is positive and statically different from zero at the 1% level of significance, which suggests technical regress for Norwegian crop production during the study period. A similar result reported in other studies, for instance, in the Latruffe et al. (2008) study cited above for Poland for the period 1996–2000. The quadratic term in Table 3 is positive (coefficient of t^2), indicating that the technical regress is getting stronger over time.

Technical regress may be explained by several factors as discussed in Kumbhakar and Heshmati (1995) and Kumbhaker et al. (2008). First, they argue that changes in the regulations concerning input use, for instance, government controls on the use

of pesticides and fertilizers. Second, there might be increased technical inefficiency over time due to lack of external competition and restrictions on the transfer of farms between generations. Finally, a larger real increase in input prices than output prices may lead to results that look like technical regress. In another study Atsbeha et al. (2015) proposed that such apparent technical regress can occur if the sector under consideration is subject to scale restrictions, results in the scale of production that is sub-optimal to the latest technologies. The later reason is relevant for the Norwegian crop producing farms, in which the sector is based on small scale family farms and the land is fragmented. Thus, if there are economies of scale in the production of crop-producing technologies, this development may result in a shift in the long-run average cost of crop producing farms that leave small farms worse off over time.

As shown in Table 4 in the appendix, technical regress has been neither scale nor Hicks neutral. Moreover, Hicks non-neutrality of technology regress is exhibited as a significant interaction parameter with time (t) for cost share of variable inputs ($\check{w}_3$) and fixed input ($\check{w}_4$) (Table 2). Technological change exhibits a positive effect on the cost share of fixed inputs and a negative effect for cost share of variable inputs. Thus TC was non-neutral over the last 23 years. With respect to scale, the interaction parameter with time (t) for grain production (tlny_1) is negative and statically significant, which suggests that the cost increasing effects of technical regress get weaker as grain production increase. However, the interaction parameter with time (t) for other output (tlny_3) is positive and statistically significant, which suggests that the cost increasing effects of technical regress have become stronger for the other output production increase. These suggest that the technical regress was more important for small scale grain production and big scale other output production.

Efficiency change, which measures the change from observed cost towards the best practice farmers, was positive (0.01) % per annum. The estimated result of a decline in TC and an improvement in efficiency shows farmers are able to adopt the prevailing technology and hence lie, on average, closer to the frontier (Latruffe et al. 2008). The scale component (SC) was positively contributed to the total productivity change (0.10) % per annum. The contribution of the markup for the period 1991–2013 was −0.19% per annum. A markup effect could show firms have some market power and price above their marginal cost. However, a negative markup implies that market power through price-making does not give effect on firms' performance. A non-zero markup effect on TFP means that output prices diverge from the marginal cost of production, i.e. the output market is non-competitive (Sipiläinen et al. 2013). The contribution markup effects are shown in Fig. 1, which is fluctuating considerably over time and has almost the same movement as that of TFP change.

Figure 4 and Table 4 shows the estimated results of annual profitability change component (in percent). The profit change component was −0.14, suggesting that profit has declined by 0.14% per annum. This is mainly because of the negative TFP change of 0.11% per year with some contributions from an input price annual change of 0.03%. The contributions from output change and output price change, which might have a positive effect on the profitability change, are almost zero.

6 Discussion and Conclusion

The economic performance of a farm is commonly measured by the efficiency and productivity measures. We used farm level unbalanced panel data for the year 1991–2013. We have selected only crop producing specialized 455 farms located in the eastern and central (Trøndlag) regions of Norway. We have estimated the profitability and productivity of the Norwegian crop producing specialized farms using a translog cost function. The result indicates that average annual TFP growth rate in grain and forage production declined by 0.11% per annum during the period 1991–2013. The contributions of the technological change and markup change were − 0.03% and −0.19% per annum, respectively. Efficiency change, which measures the change from observed cost towards the best practice farmers, was positive (0.01% per annum). Moreover, the scale component has positively contributed to the total productivity change (0.04% per annum). The profit change declining by 0.14% and this was mainly because of the negative TFP change with some contributions from an input price change component increase by 0.03% per year.

Technical change captures the shift in technology and is the key driver of profitability and productivity growth. Policy makers have to give priority to investing in agricultural research and development, which can help in the innovation of new technologies and improvement in TC. Investment in research and development support for innovation of new technology and improves TC (O'Donnell 2010). The study also shows that there was a small efficiency change for the last 23 years. Thus, farmers continue to be lagging behind the best-practice farmers. Therefore, there is a need for intensive work on agricultural extension and dissemination to help farmers adopt the existing technologies.

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