DETERMINANTS OF PART-TIME FARMING AND ITS EFFECT ON FARM PRODUCTIVITY AND EFFICIENCY [1]

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Paper prepared for presentation at the 107th EAAE Seminar *"Modelling of Agricultural and Rural Development Policies"*. Sevilla, Spain, January 29th -February 1st, 2008

[1] Comments on a earlier version of the paper from Arne Henningsen and Øyvind Hoveid are gratefully acknowledged.

Abstract

Little attention has been given in the agricultural economics literature to the impact of off-farm work on farm productivity and efficiency. More knowledge about what determines part-time farming and whether farm productivity and efficiency are affected by part-time farming could help policy makers introduce better targeted rural development policies. This paper aims to fill the above-mentioned gaps by first analysing factors that influence the choice of off-farm work; and then examining how off-farm work influences productivity and technical efficiency at the farm level. An unbalanced panel data set from 1991 to 2005 from Norwegian grain farms is used for this purpose.

The results show that the likelihood of off-farm work and the share of time allocated to it increase with increasing age (up to 39 years), and with low relative yields (compared to others farms in the surrounding area/region). The level of support payments is not significantly associated with the extent of off-farm work. Large-scale farms and single farmers tend to have a lower likelihood of off-farm work.

Average technical efficiency was found to be 79%. Farmers with low variability in farm revenue were found to be more technically efficient than farmers with high revenue variability. We did not find any evidence of off-farm work share affecting farm productivity − the predicted off-farm work share was not statistically significant. In other words, we did not find any systematic difference in farm productivity and technical efficiency between part-time and full-time farmers.

Key words: off-farm work, productivity, efficiency, unobserved heterogeneity, panel data

1. Introduction

In Norway farm income represents, on average, a relatively small and decreasing part of the total income of farm-family households. In 2004, only 22 per cent of the average total household income (for holder and spouse/cohabitant) came from agriculture, forestry and fishing. By contrast, in 1992, the income from these primary industries amounted to 27 per cent of total household income (Statistics Norway, 2006). Similar developments are found in many developed countries (e.g. Hill, 2000; Andersson *et al.*, 2003). For example, when considering large and very large commercial farms in U.S. the share of farm income in total household income ranges from 50 to 75 per cent (Goodwin and Mishra, 2004).

Studies within a wide range of approaches and disciplines have examined characteristics and motivations that explain part-time and full-time farming. A number of studies examining time allocation by farm households have adapted theory from the "new household economics" (Becker, 1981) to the special case of the agricultural household model (e.g. Huffman, 2001). Aspects examined in these studies include:

a) the characteristics of those participating in off-farm employment and the factors affecting labour supply (hours worked) in off-farm activities (Weersink *et al.*, 1998; Woldehanna *et al.*, 2000);
b) the association between education and off-farm work (e.g. Huffman, 2001);

c) the effect of differences in and variability of incomes/wealth between agriculture and other occupations (e.g. Mishra and Goodwin, 1997; Andersson *et al.*, 2003; Fall and Magnac, 2004); and
d) whether part-time farming is a stable adjustment, a way to full-time farming or way out of agriculture (e.g. Kimhi, 2000).

Some attention has been given to the impact of off-farm work on production methods. Goodwin and Mishra (2004) provided support for the hypothesis by Smith (2002) that a greater involvement in off-farm labour markets decreases on-farm efficiency. Phimister and Roberts (2006) explored the extent to which farmer participation in off-farm work changes the intensity on fertiliser and crop protection use. Ahituv and Kimhi (2006) analysed the simultaneous determination and evaluation over time of work choices and the level of farm activity.

Little attention has been given to the impact of off-farm work on farm productivity and efficiency, even though Bateman *et al.* (1974) stressed that more knowledge was needed about extent to which productivity differs between part-time and full-time farmers. In one such study Bagi (1984) estimated a stochastic frontier production function and analysed differences in technical efficiency between full-time and part-time farms in west Tennessee. Brümmer (2001) investigated, among other things, how technical efficiency differed between part-time and full-time farmers in Slovenia. Chavas *et al.* (2005) investigated the economic efficiency (technical, allocative and scale efficiency) of farm households in a peri-urban area of Gambia, thus capturing the importance of off-farm activities. Other similar studies appear to be rare.

More knowledge about what determines part-time farming and whether farm productivity and efficiency are affected by part-time farming could help policy makers introduce better targeted rural development policies. This paper aims to fill part of the above mentioned gaps by:

1. analysing factors that influence the choice of off-farm work; and then
2. examining how off-farm work influences productivity and technical efficiency at the farm level.

The rest of this paper is divided into four additional sections. The next section presents the conceptual framework, followed by a description of the dataset and estimation method. The subsequent section presents and discusses the main results of the analysis while the last section provides some concluding remarks.

2. Conceptual framework

Figure 1 outlines the hypothesised main causal relationships between farm and owner characteristics, support payments, share of owner's time off farm, use of other inputs, and the productivity and efficiency of the farm.

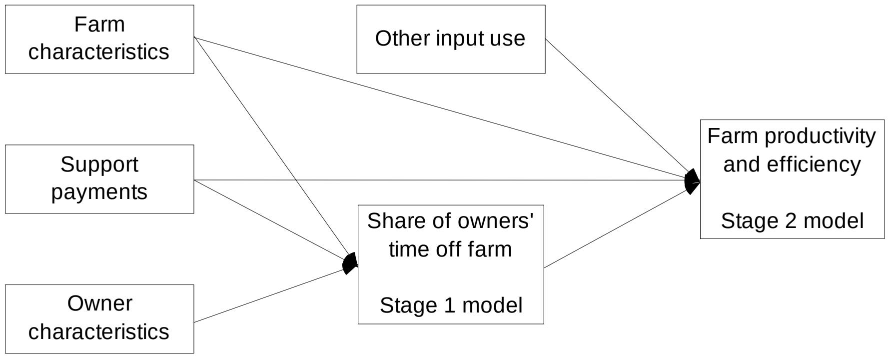

Figure 1. Assumed relationships between owner and farm characteristics, support payments, share of owner's time off farm, other input use, and the farm productivity and efficiency.

Earlier findings typically show that owner characteristics (such as farmer's age, experience, marital status, education) affects share of owner's time off farm (e.g. Huffman, 1980; Sumner, 1982; Serra *et al.*, 2004, 2005; Ahituv and Kimhi, 2006: Lien *et al.*, 2006). Previous studies also typically show a negative association between farm size and likelihood of off-farm work (e.g. Mishra and Goodwin, 1997; Ahituv and Kimhi, 2002; Serra *et al.*, 2005; Benjamin and Kimhi, 2006). Farm characteristics such as yields, region, and urbanization may also influence the household time allocation decision (e.g. Sumner, 1982; Mishra and Goodwin, 1997; Goodwin and Mishra, 2004; Serra *et al.*, 2005). In addition to these established factors, it was also assumed in this study that owner and farm characteristics will exogenously affect the extent of off-farm work. Moreover, since support payments may induce more or less off-farm work (e.g. Mishra and Goodwin, 1997; Ahearn *et al.*, 2006), this aspect was also taken into account. Hence, as shown in Figure 1, in stage 1 we assume that owner and farm characteristics and support payments affect the share of owners' time devoted to off-farm work.

Many studies of grain farmers have investigated the optimal way of converting inputs into outputs, i.e. raising technical efficiency (e.g. Heshmati and Kumbhakar, 1997; Seyoum *et al.*, 1998; Wilson *et al.*, 2001). Typically inputs included in the production function in these kinds of studies have been land, labour, materials and capital. Bagi (1984), Brümmer (2001) and Chavas *et al.* (2005) were, as far as we know, the only previous studies that has explicitly analysed whether off-farm work affects farm productivity and efficiency. In our study some of the farm characteristics, the support payments and other production input use were assumed to affect farm productivity and efficiency. In addition, an endogenous variable for the extent of off-farm work was also assumed to affect farm productivity and efficiency (Figure 1, stage 2).

No model of this kind can be completely specified – mainly for lack of data. It is to be expected that the true model contains unmeasured farm or farmer-specific characteristics so that the chosen model is incomplete or misspecified. Agricultural production is heterogeneous (in topology, soil type, weather, luck, etc.) and farms differ in many ways, making it important that this heterogeneity is accounted for in production analysis (e.g. Just, 2000; Just and Pope, 2002). In the case of off-farm work share, heterogeneity may also be present because attitudes towards farm and off-farm work are likely to vary across individuals. Pride in being a farm operator, a preference for outdoor work, a family tradition of farming, attitudes to the environment, or simply individual tastes, are examples of such unobserved variables that typically are not accounted for by explanatory variables (e.g. Corsi and Findeis, 2000;

Ahituv and Kimhi, 2002). In this study, using farm-level panel data, unobserved heterogeneity was accounted for in both stage 1 and stage 2 of the model outlined in Figure 1, as explained below.

3. Data description

The data source is the Norwegian Farm Accountancy Survey. This is an unbalanced set of farm-level panel data, collected by the Norwegian Agricultural Economics Research Institute (NILF). It includes farm production and economic data collected annually from about 1000 farms, divided between different regions, farm size classes, and types of farms. Participation in the survey is voluntary. There is no limit on the numbers of years a farm may be involved in the survey. Approximately 10 per cent of the survey farms are replaced per year. The farms are classified according to their main category of farming, defined in terms of the standard gross margins of the farm enterprises.

Because the on-farm work load on grain farms allows owners to combine farming with off-farm occupation to a large extent, this group was chosen for study. The data set used in the analysis was an unbalanced panel with 1491 observations on 178 grain farms from 1991 to 2005. Included in the analysis were those farms for which at least two years of data were available. In the sample used, the average duration of farms in the survey was 8 years. Grain farms usually have several grain production activities (wheat, barley, oats etc.). The total output is aggregated and measured in total produced feed units milk[2] (approximately equivalent to 1 kg barley) from crop production per year.

3.1. Econometric model

Following Figure 1, we chose the following system to analyse the off-farm work decision and farm production:

(1) $$y_{1it} = f\left(\mathbf{x}_{it}, \mathbf{z}_{it}^{p}; \boldsymbol{\beta}\right) + \phi y_{2it} + v_{it} - u_{it}$$

(2) $$y_{2it} = h\left(\mathbf{z}_{it}; \boldsymbol{\delta}\right) + c_i + \varepsilon_{it}$$

where y_{1it} = grain output for farm i at time t; $f\left(\mathbf{x}_{it}, \mathbf{z}_{it}^{p}; \boldsymbol{\beta}\right)$ is the production technology; $\mathbf{x}_{it}$ is the vector of inputs, $\mathbf{z}_{it}^{p}$ is a vector of control variables (farm characteristics affecting production) and $\boldsymbol{\beta}$ is the associated vector of technology parameters and parameters associated with the control variables to be estimated; y_{2it} is off-farm work share and φ is the associated parameter to be estimated; v_{it} is a random noise term (production shocks); and $u_{it} \geq 0$ is the inefficiency term. The inefficiency term is specified as $u_{it} = G_t \cdot u_i$, with $G_t = exp\left(\gamma \cdot \tilde{t}\right)$ where $\tilde{t}$ is a time-trend inefficiency index and γ is a parameter to be estimated; and $u_i \sim N^{+}\left(\mu, \sigma_u^2\right) = N^{+}\left(\mathbf{z}_{i\bullet}'^{e} \boldsymbol{\varsigma}, \sigma_u^2\right)$. The vector of inefficiency variables is denoted $\mathbf{z}_{it}^{e}$ and $\boldsymbol{\varsigma}$ is a vector of parameters to be estimated (Kumbhakar and Wang, 2005). In the second equation; $h\left(\mathbf{z}_{it}; \boldsymbol{\delta}\right)$ is a function of $\mathbf{z}_{it}$ variables which constitute farm, owner and support

[2] One feed unit milk (FUm) is defined as 6900 kJ of net energy.

payment characteristics and $\boldsymbol{\delta}$ is the associated vector of parameters to be estimated; $c_i = N(0, \sigma_c^2)$ represents the unobserved farm effect; and $\varepsilon_{it} = N(0, \sigma^2)$ is the random error component.

Thus we have a triangular system in which the first equation has two endogenous variables (y_1 and y_2) and the second equation has one endogenous variable (y_2). The model allows off-farm work to affect output but not vice-versa. One could expect that greater involvement of the farmer in the production process is likely to increase output (or that increase off-farm work is likely to decrease output). On the other hand, less time for the production process may force an increased efficiency. In other word, the sign of the φ coefficient is an empirical question.

In the off-farm work equation we controlled for unobserved farm- or owner-specific effects (c_i) which might be quite important. Some of these unobserved variables mentioned earlier are: preference for outdoor work and closeness to nature, family tradition, environmental values, etc. Such unobserved effects are also likely to affect output in (1). We viewed these effects as parts of management that is accommodated in the inefficiency term.

The system in (1) and (2) can be estimated jointly. However, consistent estimates can also be obtained through the equation-by-equation procedure in two-steps. We used the two-step approach. In stage 1 we modelled the decision about off-farm work. Factors that influence the choice of off-farm work were specified and estimated as a Tobit (Greene, 2008) because the dependant variable in equation (2) is specified as an intensity variable (ranging from 0 to 1) with the possibility that there might be many observations for which y_2 is zero (farmers not working off-farm). Then, in stage 2 a stochastic production function was specified and estimated to examine how off-farm work influences productivity and technical efficiency at the farm level. At this stage, we replaced off-farm work share by its predicted value for each farm, obtained from stage 1.

The $f(\mathbf{x}_{it}, \mathbf{z}_{it}^p; \boldsymbol{\beta})$ function in equation in (1) was specified with the following input variables: x_1 is log of productive farmland in hectares; x_2 is log of labour hours used on the farm, measured as total number of hours worked, including management, family and hired workers; x_3 is log of materials and machinery used in farm production (implicit quantity index). The broad machinery and materials variable[3] includes cash expenditures items for seeds, fertiliser, lime, pesticides, fuel, electricity, plus the maintenance costs of machinery, buildings, irrigation and land and the cost of hired machinery.[4] Fisher's implicit quantity index was used to specify the materials and machinery variable.[5] In addition

[3] At the outset, we tried to include an additional input variable, building capital. However, we found it difficult to derive a good measure of building capital from the data because no physical capital measure was recorded. Another problem is that monetary values of buildings in the data set are based on historical cost, which is a poor basis for deriving the economic value of the services provided from the buildings.

[4] In calculating the aggregate measure machinery and materials, seed costs were deflated by the price index for seeds, fertiliser and lime costs were deflated by the price index for fertiliser, pesticide costs were deflated by the index for total variable costs, fuel costs were deflated by the fuel price index, electricity costs were deflated by the electricity price index, and maintenance costs of machinery, buildings, irrigation and land and the cost of hired machinery were all deflated by index for fixed costs.

[5] In general, when considering several inputs, we observe the vector of prices $\mathbf{w}_j$ and the vector of quantities, $\mathbf{x}_{jt}$ (the implicit quantities of the individual items) for $t = 1, \ldots, T$. Then the Fisher index (e.g. Diewert, 1992) for the quantity of inputs used in period t, using period s as a base, is: $\mathbf{x}_{jst} = \left[\left(\mathbf{w}'_{jt}\mathbf{x}'_{jt} / \mathbf{w}'_{js}\mathbf{x}'_{js}\right) \times \left(\mathbf{w}'_{js}\mathbf{x}'_{jt} / \mathbf{w}'_{jt}\mathbf{x}'_{js}\right)\right]^{0.5}$. The first term in the brackets is the cost

to these three 'traditional' input variables in a production function, x_4 representing total subsidies received (implicit quantity index)[6] and a time-trend index, t (1, …, 15), to account for neutral technical change in the production function, were added.

Variables in $\mathbf{z}_{it}^{p}$ consist of regional dummies. We define two regions, viz., (a) the region with most favourable production conditions – labelled "favourable" (including Eastern Norway - lowlands, Jæren, and Mid-Norway - lowlands), and (b) the region with average and least favourable production conditions – labelled "other" (Agder and Rogaland, Western Norway, Mid-Norway - other parts, Eastern Norway – other parts, and Northern Norway). Within each of the regions the growing conditions are quite similar. To allow for time-varying efficiency, the vector $\widetilde{t}$ in the function G_t in equation (1) is specified with $t = (1, \cdots, 15)$.

In the present analysis, we have chosen to define off-farm work share, y_2, in equation (2) as the owner's and spouse's (if not single) total hours worked off the farm. The $\mathbf{z}_{it}$ variables in equation (2) consist of: z_1 is age of farmer in years; z_1^2 is age of farmer squared (to allow for the expected nonlinear effect of age); z_2 is years of farming experience of the farmer; z_3 is a dummy variable that has value one if the holder is married/has cohabitant and zero if single; z_4 is the number of children in the household; z_5 is the farm specific (within farm) coefficient of variation (CV) in total farm revenue; z_6 is total subsidies received (implicit quantity index); z_7 is productive farmland in hectares; z_8 is mean normalised yields (average individual farm level yields / average regional yields); z_9 is centrality, with value 1 if the farm is located in the central municipalities and zero otherwise. This variable should account for the fact that the off-farm labour markets may be better in urban regions than in rural regions; z_{10} is a dummy for region equal to z_1^P described above. Also include in $\mathbf{z}_{it}$ was a time-trend index, $t = (1, \cdots, 15)$.

The variables in the inefficiency function consists of average (over time) values of: z_1^e which is farm-specific CV of farm revenue, chosen to represent variability in revenue at farm level (the same as variable z_5); z_2^e which is farm-specific subsidies received (the same as variable x_4); z_3^e which is farm-specific mean normalised yields; z_4^e which is farmer-specific farming experience; and z_5^e which is farm-specific predicted off-farm work share.

In Table 1 the summary statistics of variables for the off-farm work choice function and for the production function with the error component are listed. On the basis of a standardised yearly labour input from one labour unit of 1845 hours, the average off-farm work share, y_2, was 1.03. In other words, on average slightly more than one labour-unit (man-year) was spent on off-farm work per farm. The average farm size in the sample (30 ha) was higher than the average in Norway of 21 ha. On the

change between the two periods. The second term is the ratio of two values: period-*t* quantities valued at period-*s* prices; and period-*s* quantities valued at period-*t* prices. This formula was used to calculate the non-transitive implicit index for machinery and materials.

[6] Total subsidies received were deflated by the consumer price index (CPI).

other hand, the average age of farmer in the sample was 50 compared to 55 for Norway (Koesling *et al.*, 2004).

Prior to estimation, output and x-variables in the translog function were scaled to have unit means, so that the first-order coefficients in the model can be interpreted as elasticities of output evaluated at input means.

Table 1. Descriptive statistic (N= 1491)

Variable	Label	Mean	Std.dev	Min	Max
y_1	Grain output (feed units)	116701	71126	10850	545103
y_2	Off-farm work share[a]	1.03	0.60	0.00	2.71
x_1	Land (ha)	29.2	14.4	4.2	78.5
x_2	Labour used on farm (hours)	1344	899	50	6200
x_3	Materials and machinery (index)	3.90	2.53	0.47	19.31
x_4	Total subsidies received (index)	6.27	4.26	0.25	32.71
z_1^p	Dummy for region, other = 1	0.30	0.46	0	1
z_1	Age of the farmer (years)	49.3	8.8	26	72
z_2	Years of farmer experience	17.76	9.58	0	46
z_3	Holder is single, no = 1, else = 0	0.85	0.36	0	1
z_4	Number of children	0.92	1.27	0	6
z_5	Farm-specific CV[b] in farm revenue	0.29	0.29	0.01	2.20
z_6	Total subsidies received (index)	6.27	4.26	0.25	32.71
z_7	Land (ha)	29.2	14.4	4.2	78.5
z_8	Mean normalised yields (individual yields / region yields)	1.01	0.52	0.17	3.36
z_9	Centrality, farm in central municipalities = 1, else = 0	0.73	0.44	0	1
z_{10}	Dummy for region, other = 1	0.30	0.46	0	1
z_1^e	Farm-specific CV[b] in farm revenue	0.29	0.29	0.01	2.20
z_2^e	Farm-specific (average of the sample period) subsidies received (index)	6.15	3.59	0.70	31.24
z_3^e	Farm-specific (average of the sample period) mean normalised yields	1.01	0.52	0.17	3.36

[a] Note, the predicted value of y_2 from equation (2) in stage 1 is used as a control variable in equation (1) in stage 2.
[b] CV = coefficient of variation, which expresses the standard deviation in farm revenue relative to the mean farm revenue.

4. Results

4.1. The off-farm work choice function

The censored equation (2) was estimated to assess the factors that influence the choice of off-farm work.[7] Parameter estimates for the model are presented in Table 2. The effect of farmers' age on off-

[7] Before ending up with these first and second stage regression models presented in this result section, several alternative models were tested to check robustness. For example, we dropped the insignificant variables in the Tobit regression, without any important change of the significant parameter estimates of the Tobit equation and frontier production equation. To check the importance of the off-farm work share as a input in the frontier production function we ran the second stage frontier

farm work had an inverted "U" shape, with the peak at around 39 (below the average age of the farmers), which is in accord with the life-cycle hypothesis for the farm household that has also been supported in earlier studies (e.g. Huffman, 1980; Sumner, 1982; Serra *et al.*, 2004, 2005; Ahituv and Kimhi, 2006). Contra to the finding of Mishra and Goodwin (1997) found that increasing experience decreases the share of off-farm work, the results in this study do not support the hypothesis that the experience of farmers influences the off-farm work share.

Table 2. Tobit regression estimates for the off-farm work share choice equation

Parameter	Label	Estimate	Std. Err.	
δ_1	Age of the farmer in years	0.097	(0.015)	***
δ_{1_sq}	Age of the farmer squared	-0.001	(0.000)	***
δ_2	Years of farming experience	-0.002	(0.003)	
δ_3	Dummy, the holder is not single = 1	0.366	(0.037)	***
δ_4	Number of children	-0.035	(0.012)	**
δ_5	CV of farm revenue	0.072	(0.177)	
δ_6	Total subsidies received	0.006	(0.005)	
δ_7	Farmland	-0.005	(0.002)	*
δ_8	Mean normalised yield	-0.222	(0.090)	*
δ_9	Dummy, centrality = 1	-0.027	(0.076)	
δ_{10}	Dummy for region, other = 1	-0.208	(0.090)	*
δ_{11}	Time-trend index	0.038	(0.003)	***
δ_0	Intercept	-0.860	(0.370)	***
σ_c^2	Random effect variance	0.193	-(0.022)	***
σ^2	Random error term variance	0.092	-(0.004)	***

Estimates significant at $*P<0.05$, $**P<0.01$ and $***P<0.001$.

As expected, farmers who are single generally worked less frequently off the property than non-single farmers. The presence of children in the farm household was found to have a significant negative effect on the off-farm activities of farmers and their spouses, supporting some earlier findings (e.g. Mishra and Goodwin, 1997; Goodwin and Mishra, 2004) but contradicting the results of Ahituv and Kimhi (2006) who found that the presence of children did not significantly affect the supply of off-farm labour.

Our results do not statistically support the findings in earlier research (e.g. Mishra and Goodwin, 1997; Serra *et al.*, 2005) that higher variability in farm revenues increases the likelihood of off-farm work among the farm households.

Government support payments may lessen the need for off-farm work by providing farm households with an alternative source of incomes, and this is empirically supported by, e.g. Mishra and Goodwin (1997) and Ahearn *et al.* (2006). However, our results indicate that support payments were not significantly associated with more off-farm work. In Norway, with generally a high standard of living,

production model adding (i) interaction of the predicted off-farm share with x_2 (log of farm labor), and (ii) adding interactions of the predicted off-farm share with x_1, x_2, x_3, and x_4. These specifications did not change the statistical significance of the predicted off-farm share, and our result that off-farm share in the frontier production function is not important seem robust.

good welfare support and high overall wealth level, it is not surprising that the level of support payments tends to be independent off-farm work choices.

The coefficient representing the effect of farm size was negative and statistically significant, suggesting that large-scale farms tend to have a lower likelihood of off-farm work. This last result is consistent with previous findings (e.g. Lass, Findeis and Hallberg, 1989; Mishra and Goodwin, 1997; Ahituv and Kimhi, 2002; Serra *et al.*, 2005; Benjamin and Kimhi, 2006).

A farm's productivity relative to other farms (average level of individual farm yields / average region yields) significantly influences the household time allocation decision. Our results support the expectation that more productive cropping farms would have higher relative returns to farm labour and thus supply less labour to off-farm activities. This result is also consistent with the findings of, e.g. Mishra and Goodwin (1997) and Serra *et al.* (2005).

The probability for off-farm work was found to be higher in the most favourable region, compared to the region including farming conditions classed as favourable and least favourable. One explanation could be the better off-farm job opportunities in the most favourable region. But our results showed that distance to the nearest town (centrality) not statistically significant influence on farmers' off-farm work share, which again was consistent with some earlier studies (e.g. Mishra and Goodwin, 1997; Goodwin and Mishra, 2004). The time-trend index show that the off-farm work share has increased on average at 3.8% per year from 1991 to 2005.

4.2. The production function estimates

In the second step of the analysis the general translog stochastic frontier production function model for grain output with the technical inefficiency effects specified in equation (1) was statistically tested against more restricted and parsimonious models. The first hypothesis specified was that the farmers are fully technically efficient or equivalently that the mean production function is adequate. This hypothesis was rejected at 0.001 significance level. The second hypothesis that a Cobb-Douglas frontier was an adequate representation of efficient production was also rejected. The null hypotheses, that the time-variant and time-invariant inefficiency variables in the model have zero coefficients, were also rejected by the data. The preferred model was therefore the stochastic frontier translog production function with the technical inefficiency module specified in equation (1). The parameters for this model are reported in Table 3 and discussed below.

Estimated output elasticities with respect to the inputs of land, farm labour, and subsidies all differed from zero at the 0.1% significance level (5% for material and machinery). The elasticity for land was the largest, being more than 5 times the elasticities with respect to labour and machinery and materials. As expected, the total grain yield depended strongly on the area of land used. In line with our estimate of 0.81, Wilson *et al.* (2001) found an elasticity for land of 0.76 among wheat farmers in eastern England for the crop year 1992, and Wilson *et al.* (1998) found an elasticity for land of 0.87 in UK potato production.

Table 3. Estimates of the parameters in the translog stochastic frontier production function for grain yield

Parameter	Label	Estimate	Std. Err.	
Stochastic frontier				
β_1	x_1 (Log of land)	0.806	(0.077)	***
β_2	x_2 (Log of farm labour)	0.146	(0.037)	***
β_3	x_3 (Log of materials and machinery)	0.126	(0.053)	*
β_4	x_4 (Log of subsidies)	-0.241	(0.043)	***
β_t	t (Time-trend index)	0.080	(0.010)	***
β_{11}	$x_1^{\ 2}$	-0.285	(0.126)	*
β_{12}	$x_1 * x_2$	-0.037	(0.045)	
β_{13}	$x_1 * x_3$	0.190	(0.080)	*
β_{14}	$x_1 * x_4$	0.082	(0.065)	
β_{1t}	$x_1 * t$	-0.012	(0.009)	
β_{22}	$x_2^{\ 2}$	-0.010	(0.038)	
β_{23}	$x_2 * x_3$	0.024	(0.034)	
β_{24}	$x_2 * x_4$	0.093	(0.033)	**
β_{2t}	$x_2 * t$	-0.012	(0.004)	**
β_{33}	$x_3^{\ 2}$	-0.033	(0.070)	
β_{34}	$x_3 * x_4$	-0.143	(0.047)	**
β_{3t}	$x_3 * t$	0.001	(0.006)	
β_{44}	$x_4^{\ 2}$	-0.015	(0.038)	
β_{4t}	$x_4 * t$	0.024	(0.005)	***
β_{tt}	t^2	-0.004	(0.001)	***
β_{C1}	Dummy for region, others = 1	-0.111	(0.026)	***
φ	Predicted off-farm work share	-0.006	(0.027)	
β_0	Intercept	-0.079	(0.059)	
Inefficiency model[a]				
ς_1	Farm-specific CV of farm revenues	0.260	(0.093)	**
ς_2	Farm-specific subsidies received	0.031	(0.007)	***
ς_3	Farm-specific mean normalised yields	-0.688	(0.122)	***
ς_4	Farmer-specific faming experience	0.000	(0.001)	
ς_5	Farm-specific predicted off-farm work share	-0.015	(0.034)	
ς_0	Intercept	0.578	(0.091)	***
Time-variant inefficiency				
γ	Time-trend index	0.022	(0.012)	*
Variance parameters				
σ_u	Standard deviation inefficiency model	-4.751	(0.335)	***
σ_v	Standard deviation error term	-3.110	(0.039)	***

Estimates significant at *P<0.05, **P<0.01 and ***P<0.001.

[a] A negative sign on a parameter indicates a positive impact on efficiency.

The non-product-specific subsidy payments (almost all subsidies in Norway are now of this kind) showed a negative elasticity sign. This may partly be explained by increased non-product specific support that are paid to promote rural viability, maintaining cultural landscapes, more environmentally friendly production (such as organic farming) and ensuring food security for times of crisis (Prestegard, 2004), which may all induce lower productivity (e.g. Oude Lansink *et al.*, 2002; Ball *et al.*, 2004).

Scale economies were computed as the sum of all elasticities of input variables. On average, the scale elasticity was equal to 1.08 if subsidies were not included as a variable in the sum of elasticities of input variables, indicating that the production function exhibited increasing returns to scale at the means of the data. For crop farms in Sweden for the period 1976 to 1988 the estimated returns to scale was 1.25 on average, but declined gradually during the period analysed (Heshmati and Kumbhakar, 1997). When subsidies were included as an input to calculate the returns to scale the scale elasticity was equal 0.84. This implies that subsidy payments reduce the scale economies, suggesting that subsides contribute to conserving the current farm structure in Norwegian grain farming.

Yearly estimated technological change was statistical significant and positive at 8% per year, indicating reasonable growth in productivity over time. As expected, the region with average and least favourable production conditions had lower productivity than the region with most favourable production conditions. But the most important finding for the research objective was that the off-farm work share was not found to have any statistically significant influence on farm productivity.

4.3. Technically efficiency level

For the prediction of technical inefficiency effects, it is common to use an output-oriented measure defined as the ratio of observed output to the corresponding stochastic frontier output:

$$(3) \qquad TE_{it} = \frac{\exp(f(\mathbf{x}_{it}, \mathbf{z}_{it}^{p}; \boldsymbol{\beta}) + \phi y_{2it} + v_{it} - u_{it})}{\exp(f(\mathbf{x}_{it}, \mathbf{z}_{it}^{p}; \boldsymbol{\beta}) + \phi y_{2it} + v_{it})} = \exp(-u_{it})$$

This expression relies upon the value of the unobservable u_{it} being predicted, which is achieved by deriving the expression for the expectation of $exp(-u_{it})$ conditional on the observed value of $(v_{it} - u_{it})$. In practice we replace the 'true' parameter values by their estimates and 'true' residuals $(v_{it} - u_{it})$ by their predicted values. The exact formula for the conditional mean is given in Battese and Coelli (1988).

The average technical efficiency for the sample, estimated with the full flexible model, was estimated to be 0.79. The implication is that, for the average farmer, crop production could have been 21% higher, without requiring more input. However, behind the mean there may be large variation between farms, as illustrated in the histogram in Figure 2. Almost 25% of the farmers have a technical efficiency levels less than 0.7, suggesting that they have a large potential for improvement. On the other hand, about 30% were (almost) technical efficient, with a technical efficiency score of 0.9 or higher.

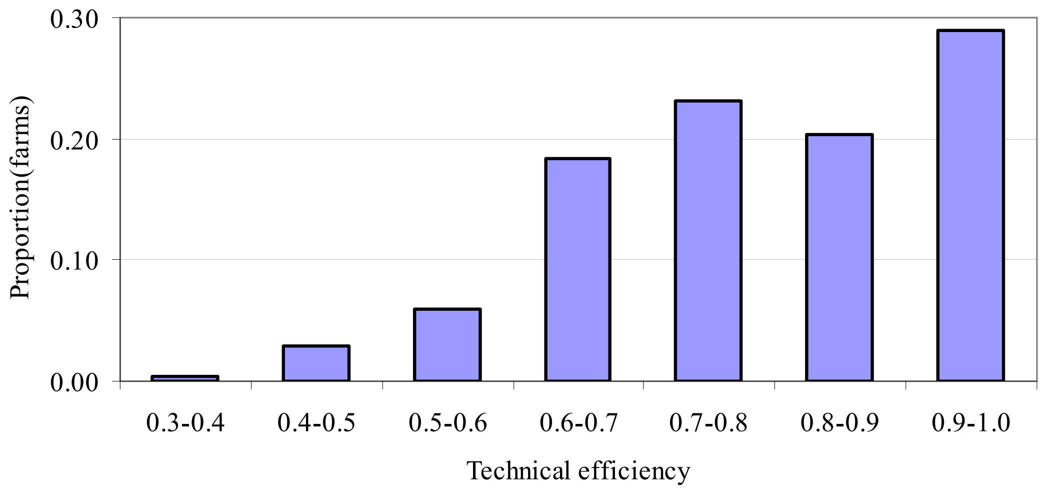

Figure 2. Distribution of the sample of grain farmers in Norway by technical efficiency.

4.4. Factors explaining the technically efficiency levels

In the lower part of Table 3 above the determinants for variations in the efficiency score between farms are examined. The parameters indicate the direction of the effects these variables have upon inefficiency levels (where a negative parameters estimates shows that the variable has a positive effects on efficiency).

The parameter for CV of farm revenues was positive, which indicates that farmers with low variability of revenue were more technically efficient than farmers with high variability (but the causation could also be the other way around). The same applied for subsidies − farmers with a low level of subsides were more technically efficient than farmers with higher subsidies, although the effect was small. Subsidies can be distorting, causing inefficiency, mainly in resource allocation and levels of input use (e.g. Lachaal, 1994; Barnes, 2006). One possible further explanation of the adverse effect of subsidies on efficiency is that larger scale farmers may strategically chose more extensive production while receiving a relatively large amount of non-product-specific subsidies because of their large farm areas.

Unsurprisingly, farmers within a given region with relatively high crop yields were more technically efficient than farmers in that region with low crop yields. Wilson *et al.* (1998) and Wilson *et al.* (2001) found that managers with more experience are likely to be more efficient than those with fewer years of experience, which contrasts with our failure to find any significant difference in technical efficiency of non-experienced and experienced farmers.

As for the stochastic frontier function, the predicted off-farm work share had no statistically significant influence on technical efficiency. These results are at variance with the work of Goodwin and Mishra (2004) who found for U.S. family farms that a greater involvement in off-farm labour markets decreases on-farm efficiency. Brümmer (2001) also found that full-time farmers were more technically efficient than others in Slovenia. However, our finding supports an earlier study of west Tennessee farmers, where Bagi (1984) concluded that the technical efficiency of part-time farms was not systematically lower than that of full-time farms. Singh and Williamson (1981) also concluded that Tennessee part-time farmers were not more inefficient in production than full-time farmers in the same area. Chavas *et al.* (2005) found that off-farm earnings had a significant effect on allocative efficiency but no significant effect on technical efficiency on farms in Gambia.

4.5. Model limitations and possible extensions

There are some limitations to this study. The model outlined in Figure 1 might not represent the relationships in the real world. Two main limitations come to mind.

First, when investigating determinants of part-time farming and its effect on farm productivity and efficiency, it is reasonable to assume (or test) that the extent of off-farm work affects productivity and efficiency, as done in this study. But, it is also reasonable to assume that high farm productivity affects the extent of off-farm work. That is, the relationship is simultaneous not necessarily triangular. In other words, productivity may depend on off-farm work share and off-farm work share may depend on productivity. However, preliminary results of simultaneous estimation without inefficiency show that such simultaneity does not exit, i.e., we find that off-farm work share is not significant in determining output.[8] Thus, our results do not suffer from simultaneity bias.

Second, we did not account for the possibility that support payments could affect the levels of the other inputs used as explanatory variables in the frontier production function. One option could be to treat subsidies as a facilitating input, so that the productivity function coefficients of other inputs are affected by the level of subsidy (in total or perhaps for specific targeted subsidies). We leave this for a future study.

5. Conclusions

A priori, there are no obvious relationships between share of the owner's and spouse's hours worked off the farm and farm productivity and efficiency. A part-time farmer will have a different livelihood strategy to a full-time farmer, with less time for farm work and less financial dependence on farming income. These factors may contribute to reduced productivity and technical efficiency. On the other hand, less time for farming may induce a need for more effective production and more intensive labour and capital use.

Agricultural policy in Norway does not distinguish between part-time and full-time farms in the payment support programs, although it is sometimes argued that full-time farmers should be prioritised. But on the other side of the argument, part-time farming may better promote rural viability etc. As a contribution to such policy debates and to help policy makers introduce better targeted agricultural policies, there is a need for more knowledge about what determines part-time farming and what its effects are on farm productivity and efficiency.

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[8] The model with inefficiency is more involved from econometric point of view and we are working on this. However, our preliminary results still support the notion that off-farm work share does not affect productivity.

The above analysis is a contribution towards meeting this need. Our results show what factors influence decisions by this sample of Norwegian farm households to undertake off- farm work. Moreover, and importantly, our analysis did not reveal any systematic differences in either farm productivity or technical efficiency between part-time and full-time farmers. On this evidence there appear to be no productivity or efficiency reasons for policy makers to discourage part-time farming in Norway.

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