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ESTIMATING THE ELASTICITY OF TRANSFORMATION BETWEEN ON-FARM WORK AND OFF-FARM WORK FOR NORWEGIAN DAIRY FARMERS

by

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Abstract

We have collected a sample of 2191 milk farm households. The sample contains information on incomes made off- and on-farm and working hours devoted into those two activities, during the years 1996-2004,. Based on a method developed by J. Thornton we estimate on-farm and off-farm labour supply functions, using both 2SLS and 3SLS. We find that the elasticity of transformation between on-farm and off-farm work is approximately -0.9.

1. Introduction

This paper is concerned with the analysis of labour supply and production decisions of households which also own and operate a farm. The distinctive features of these households are: (a) a significant proportion of the labour input used by the household farm is supplied by its proprietors, i.e. the household's members; (b) the household supplies a positive amount of off-farm work; and (c) the returns from farm work are substantially lower compared to the returns from off-farm work.

The objective of this paper is to estimate the elasticity of transformation between on-farm work and off-farm work for Norwegian dairy farmers. To be able to do this it is necessary to estimate labour supply and production responses of farm households in Norway considering the interdependence between utility and profit maximization decisions which may arise from features (a), (b) and (c).

Labour decisions of farm families are often studied using household models (Huffman, 1980). There is a considerable amount of literature discussing labour allocation decisions of farm families based on household models and cross-section data especially for the United States and developing countries, but also for Europe. However, estimates of on-farm labour supply elasticities are scarce. Most of the empirical studies on farm household labour decisions for Europe analyze the influence of specific characteristics of farm holders, their families, and their enterprises on off-farm labour participation in a bivariate way (e.g. Woldehanna et al., 2000). Only a few studies discuss the determinants of hours worked off-farm (e.g. Schulz-Greve, 1994).

Schulz-Greve (1994) is one of few articles also investigating the decisions behind the amount of on-farm work which is undertaken. He derives estimates of the effect of a change in standard gross margins on on-farm labour supply. Based on his estimates and the assumption that the ratio between standard gross margins per year and the hours worked on the farm represents the shadow wage rate of farm family labour, one can derive own-wage elasticities of on-farm labour supply. They range between *0.15* and *0.18* for men and between *0.07* and *0.10* for women for two distinct areas in Germany.

Only a few studies actually derive own-wage elasticities of on-farm labour supply based on farm household models (Thijssen, 1988; Elhorst, 1994; Kjeldahl, 1995; Woldehanna, 1996). All four authors derive very similar elasticities in the range of *0.17* to *0.28*.

Woldehanna (1996) differentiates between household heads and other family members. He not only derives own-wage elasticities for these two groups, but also cross-wage

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elasticities between them. According to Woldehanna (1996) a *one* percentage increase in the shadow wage rate of farm labour of the household's head decreases the on-farm labour supply of other family members by *0.63* percent. Conversely, a *one* percentage increase in the shadow wage rate of farm labour of other family members decreases the on-farm labour supply of the household's head by *0.23* percent. Hence, a *one* percentage increase of the shadow wage rate of farm labour of the household's head would decrease the on-farm labour supply of the hole family by *0.41* percent (*0.22 – 0.63*) implying a backward sloping labour supply curve. Woldehanna (1996) holds that even if the farm labour shadow wage rate of both groups would increase by one percent the net effect on on-farm work would be negative.

In Table 1 can be seen a reviewed representative sample of articles. The range of elasticities given in Table 1 for studies based on cross section data and household models (*0.09 – 0.28*) is confirmed by similar results for non European countries. Singh et al. (1986) report own-wage elasticities of on-farm labour supply between *0.01* and *0.45* for seven countries in Asia and Africa. Lopez (1984, 1986) estimates an own-wage elasticity of on-farm labour for Canadian farmers of *0.12*, and Thornton (1994) reports own-wage elasticities of on-farm labour supply for dairy farmers in Utah as *0.22*.

Table 1: *Studies on on-farm labour supply*

Study	Country	Farm type	Elasticity	Comment
Thijssen (1988)	Netherlands	Dairy	*0.17*	
Elhorst (1994)	Netherlands	Dairy	*0.21*	
Schulz-Greve (1994)	Germany	Agriculture	*0.16*	Men
			0.09	Women
Kjeldahl (1995, 1996)	Denmark	Agriculture	*0.28*	
Woldehanna (1996)	Netherlands	Arable	*0.22*	Household head
			0.27	Other family members
Cowling et al. (1970)	UK	Agriculture	*0.50*	

A low range of the own-wage elasticity of on-farm labour supply is to some degree also confirmed by estimates of the cross-wage elasticity of off-farm labour supply, i.e. the elasticity of hours worked off-farm with respect to the on-farm shadow wage rate. If it is assumed that leisure is a normal, inelastic good, an increase in hours worked on-farm must lead to a decrease in the hours worked off-farm by almost the same amount. Many studies report

cross-wage elasticities of off-farm labour supply to be in a similar though negative range as own-wage elasticities of on-farm labour supply. Thornton (1994) reports an estimate of *-0.05* for the US. For Europe Kjeldahl (1995, 1996) reports a cross-wage elasticity of *-0.03*. From Schulz-Greve (1994) one can derive a cross-wage elasticity for men between *-0.23* and *-0.07*, and between *-0.14* and *-0.09* for women.

The own-wage elasticities of on-farm labour supply derived from household models cover only the effect of a change in the wage rate on the hours worked and not the effect of labour force moving into the sector. Hence, the aggregated labour supply elasticity can be expected to be higher than the individual supply elasticities based on household models. Cowling, Metcalf and Rayner (1970) reports an estimate of the aggregated own-wage elasticity of labour supply as *0.50* for the UK.

2. Econometric method

The following model is taken from Thornton (1994). It is assumed that the farm household wishes to maximize a continuous, monotonic, quasi-concave utility function

$$(1) \qquad U = U\left(\mathbf{X}, T - L_g, T - L_p\right),$$

where $\mathbf{X}$ is an *n*-dimensional vector of consumption goods, T is farm household total time endowment, and L_g an L_p are on-farm and off-farm labour services. It is further assumed that the farm household does not consume its own output. Utility function (1) is maximized subject to time, technology, and budget constraints.

The household budget constraint is represented by

$$(2) \qquad \mathbf{P_X X} = \left(P_Q Q(\mathbf{V}, \mathbf{Z}, L_g) - \mathbf{W_V V} - \mathbf{W_Z Z}\right) + W_p L_p + M,$$

where $\mathbf{P_X}$ is an *n*-dimensional vector of consumption good prices, $\mathbf{W_V}$ is an *m*-dimensional vector of variable input prices, $\mathbf{W_Z}$ is a *k*-dimensional vector of fixed input prices, P_Q is farm output price, W_p is the off-farm wage rate, and M is pension. It is assumed that $\mathbf{P_X}$, $\mathbf{W_V}$, $\mathbf{W_Z}$, W_p, P_Q and M are exogenous.

The objective of the farm household is to maximize utility function (1) subject to budget constraint (2). Assuming interior solutions for all choices, the first-order necessary conditions for utility maximization are

(3a) $$\partial U/\partial X_i = \lambda P_{Xi}, \quad i = 1, \ldots, n,$$

(3b) $$\partial U/\partial(T - L_g) = \lambda P_Q \partial Q/\partial L_g,$$

(3c) $$\partial U/\partial(T - L_p) = \lambda W_p,$$

(3d) $$P_Q \partial Q/\partial V_j = W_{Vj}, \quad j = 1, \ldots, m.$$

The Lagrangian multiplier λ gives the marginal utility of income. Equations (3b) and (3c) indicate that the prices to which the farm household responds when making utility maximizing on-farm and off-farm work decisions differ. The price of on-farm work effort is an endogenous virtual price. This virtual price is given by the farm household's value of marginal product associated with on-farm input services.

The necessary conditions (3) suggest a more useful way to reformulate the model and conceptualize the problem of the farm household. Equation (3d) implies that for any quantity of L_g chosen; amounts of variable inputs will be selected that maximize net farm income conditional on that value of L_g. This idea can be formalized by defining the net income function

(4) $$N(P_Q, \mathbf{W_V}, \mathbf{W_Z}, \mathbf{Z}; L_g) = G(P_Q, \mathbf{W_V}, \mathbf{Z}; L_g) - \mathbf{W_Z Z}.$$

The production side of the model is comprised of a set of output supply and input demand functions conditional on the amount of labour services supplied by the household to the farm operation. Application of Hotelling's lemma to the net income function (4) yields

(5a) $$Q^b = \partial N/\partial P_Q = Q^b(P_Q, \mathbf{W_V}, \mathbf{Z}; L_g),$$

(5b) $$V_j^b = -\partial N/\partial W_{Vj} = V_j^b(P_Q, \mathbf{W_V}, \mathbf{Z}; L_g), \quad j = 1, \ldots, m,$$

where Q^b and V_j^b are the conditional net income maximizing supply and demand choices, respectively.

To maximize net income for any given level of household on-farm work effort, it is both necessary and sufficient to maximize the function

(6) $$G(P_Q, \mathbf{W_V}, \mathbf{Z}; L_g) = \max\{P_Q Q(\mathbf{V}, \mathbf{Z}, L_g) - \mathbf{W_V V}\}.$$

Therefore, to estimate the production side of the model we estimate a variable profit function.

The production function for dairy farmers is given by the Cobb-Douglas specification

$$(7) \qquad Q = A'H^{\beta'}Z^{\phi'}L_g^{\delta'},$$

where Q is output, H is hired labour, Z is land, L_g is household labour, and $A', \alpha', \beta', \phi'$, and δ' are parameters. The variables Q, H, and L_g, are endogenous and chosen by the farm household in the process of maximizing utility.

The variable profit function dual to (7) is given by

$$(8) \qquad G = AW_H^{\beta}Z^{\phi}L_g^{\delta}P_Q^{(1-\beta)},$$

where W_H, and P_Q are the prices of hired labour, and output respectively and G is profit. Application of Hotelling's lemma to (8) yields the conditional net income maximizing output supply and variable input demand equations

$$(9a) \qquad Q = \partial G/\partial P_Q = (1-\beta)AW_H^{\beta}Z^{\phi}L_g^{\delta}P_Q^{-\beta},$$

$$(9b) \qquad H = -\partial G/\partial W_H = -\beta AW_H^{\beta-1}Z^{\phi}L_g^{\delta}P_Q^{(1-\beta)}.$$

Corresponding to (8) is the unit-output price variable profit function which when expressed in terms of natural logarithms is given by

$$(10) \qquad \ln(G/P_Q) = \ln A + \beta \ln(W_H/P_Q) + \phi \ln Z + \delta \ln L_g.$$

The associated variable input demand functions in share form are

$$(11) \qquad (W_H/P_Q)H/(G/P_Q) = W_H H/G = -\beta.$$

The estimating equations for the production side of the model in this study consist of equations (10) and (11).

Consumption side estimating equations are derived by maximization of the modified Stone-Geary utility function

(12) $$U = \Theta_x \ln(X - \gamma_x) + \Theta_g \ln(D_g - \gamma_g') + \Theta_p \ln(D_p - \gamma_p'),$$

where $D_g = T - L_g$, $D_p = T - L_p$ and Θ_x, Θ_g, Θ_p, γ_x, γ_g', γ_p' are parameters. It is assumed that consumption X is equal to the sum of net farm, wage and pension. This functional form is selected because it possesses desirable statistical properties.

To derive demand equations, it appears necessary to maximize utility function (12) subject to the budget constraint in the form of (2). This yields the following consumption demand and labour supply equations in expenditures and earnings form

(13a) $$X = \gamma_x + \Theta_x\left(M + N_g\gamma_g + W_p\gamma_p - \gamma_x\right),$$

(13b) $$N_g L_g = N_g\gamma_g - \Theta_g\left(M + N_g\gamma_g + W_p\gamma_p - \gamma_x\right),$$

(13c) $$W_p L_p = W_p\gamma_p - \Theta_p\left(M + N_g\gamma_g + W_p\gamma_p - \gamma_x\right),$$

where $\gamma_g = T - \gamma_g'$ and $\gamma_p = T - \gamma_p'$. The estimating equations for consumption side of the model consist of (13).

The system of equations in both the production side and the consumption side of the model is first estimated using the method of *two stage least squares* (2SLS). The systems will then be re-estimated via the method of *three stage least squares* (3SLS).

3. Data

Sources

The data are obtained from a set of annual surveys of Norwegian farm households collected by the Norwegian Agricultural Economics Research Institute (NILF). The surveys are one of the more comprehensive sources of farm statistics in Norway, and dates back to the beginning of the 20th century. Since 1950, the survey has included approximately *1 000* farm households representing different regions and agricultural products, e.g. grain, dairy, livestock, etc. Participation in the survey is voluntary, but restricted to farmers younger than the age of *67* (retirement age) and to farm households working at least *400* on-farm hours a year.

Farms producing both grain and swine products and dairy farms have the highest representation both in absolute numbers and relative to the total population. Most farm households in the survey report between *1 800* and *6 000* on-farm work hours yearly, while a standard man-labour year in the agricultural sector is set to *1 875* hours. The survey consists of

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management accounts drawn from tax accounts and additional information about the use of farmland, yields obtained and labour input. Approximately *20* percent of the farm units are also involved in a separate survey of accounts for farm forestry.

This panel data set is rotating. Between five and ten percent of the panel is replaced each year, most commonly because of refusal to continue participation. The data collectors follow no specific guidelines when including replacement households. A primary aim is to enter respondents who hold more or less the same characteristics (with respect to region, size, and production) as those exiting.

This survey is the most elaborate source of information on Norwegian farm households' financial matters, both in a regional and a production context. Daily or weekly labour hours are reported for all household members, family members, and hired help, and in all kinds of employment. On-farm labour compensation, corrected for holiday allowances and social security payments, is calculated from the cost of hired help. Off-farm income is divided into wage income and other income. The survey also includes data on the total area of cultivated land and the division of land into different uses and the yield of and income from different agricultural crops, fruit, garden berries, and vegetables. The data required for the variables in this study are prices and quantities of labour and output, quantities of land, net farm earnings, off-farm wage income, pension, off-farm and on-farm wage rates, and hours worked by the farm household.

Definitions

Production output is measured in pounds of milk per year. Hired labour and land inputs are measured in terms of hours per year and acres respectively. The wage rate for hired labour is set as the ratio between net yearly costs associated with hired labour and hours of hired work. On-farm labour services provided by the household consist of hours worked on the farm by husband, wife and other family members. Profit is defined as restitution from on-farm work and equity minus costs related to hired labour, and is given by the operating profit minus the farms share of debt interest and circumstances. The operating profit is the compensation the household obtain from on-farm work and borrowed capital.

An estimate of consumption is generated by summing the net income from on-farm work (the product of the virtual wage and the amount of hours worked on-farm), off-farm work and pension. This implies that the household saves nothing as long as the actual wage rate equals the virtual wage rate. This does not occur in the sample. The mean values for on-farm wage rate and the virtual wage is *50* NOK and *10* NOK respectively. The off-farm wage

rate is the ratio between off-farm income of the household and total hours worked off the farm. The on-farm virtual wage is given by the predicted value of marginal product of on-farm work of the household and is obtained subsequent to estimation of the production side parameters.

All prices, wage rates, incomes and pension are deflated by the consumer price index with 1998 as base year.

Sample selection

We have extracted a sample containing farm households whose main production is dairy products. Analyzing all the different production forms at the same time, could potentially be a problem due to the heterogeneous nature of the production price. The production price is expected to vary quite a bit over the different productions, e.g. a meat producing farm anticipates a far higher production price compared to a grain farm. Another feature worth mentioning is the differences in the work hours demanded from the different production forms, e.g. a dairy farmer is expected to face a substantially larger workload than a grain farmer. Dairy cows need attention at regular hours several times per day, and dairy farming may therefore be particularly difficult to combine with an off-farm job. In addition to the natural attrition mentioned above, farm units that do not have a positive demand for off-farm work, and farm units that do not have a positive demand for hired labour, is disregarded. A last, but not as comprehensive, requirement is that the hour's pay from off-farm work is within the range of *50* and *1 000* NOK. The selectivity criteria leave *2 191* observations to be included in the analysis. The remaining sample is, however, representative of the survey farms with respect to factors such as location, and farm size.

Descriptive statistics

The empirical definitions of the variables and summary statistics are reported in Table 2. Observe that due to a substantially larger workload on-farm the mean value of the off-farm restitution is about *50 000* NOK higher than the average earnings from on-farm work.

The average age of operators is *51* years. The youngest participator is *28* years old and the oldest is *75* years. The mean values of the *ERFARING*-variable and the *EIERAR*-variable are approximately *21* years. Farm sizes ranges from *36* to *1 013* acres with average farm size equal to *216* acres. Farm size is a variable that frequently indicates something about the labour input required on the farm, but the relation is ambiguous. *A priori*, we assume a positive correlation between farm size and labour input, but large farms are often grain producing and

thus not very labour intensive throughout the year. According to Biørn and Bjørnsen (2006) a substantial proportion of all grain farms are located near medium sized or large cities. Additionally, these grain farmers often work off the farm. On the other hand, large farms often generate high incomes and consequently high reservation wages.

When looking at the regional spread, one finds that most of the farms in the sample are located in the south-eastern part of Norway, while Agder and Rogaland are more sparsely represented. *23* percent of the sample are located in the western region, while Trøndelag and Nord-Norge represents *18* and *13* percent respectively.

Table 2: *Means and standard deviation of variables. Farm and off-farm work*

Variables	Symbol	Mean	Standard Deviation
Human capital characteristics			
Age – years	*ALDER*	51.04	8.69
Experience – years	*ERFARING*	21.48	14.17
Years as owner	*EIERAR*	21.78	8.75
Farm characteristics			
Tillable acre	*AREAL*	216.27	115.72
Financial condition			
Pension	*PENSJON*	6961.16	25205.28
On-farm work restitution	*JARB_L*	105687.10	51246.90
Off-farm work restitution	*AARB_L*	148570.30	106073.10
Off-farm hour's pay	*AARB_TL*	115.01	33.32
On-farm virtual wage	*VIRTUELL*	9.71	0.36
Distribution of the workload			
On-farm work – hours	*JARB_T*	2653.85	715.73
Off-farm work – hours	*AARB_T*	1266.42	789.78
Regional/Labour market characteristics. Dummies			
Østlandet	*EAST*	0.28	0.45
Agder/Rogaland	*SOUTH*	0.18	0.38
Vestlandet	*WEST*	0.23	0.42
Trøndelag	*MID*	0.18	0.38
Nord-Norge	*NORTH*	0.13	0.33

The farm households average more than *2 600* working hours on-farm per year. The farm operators often work more than a standard man labour year on the farm which was 1 875 annual hours during the observation period. Approximately *70* percent of the farm household's total workload is allocated to this sector. The average farm household works nearly *1 300* hours off-farm yearly.

4. Results

Table 3 present production side estimates obtained from the estimation methods mentioned above. Standard errors are given in brackets directly below the coefficients. Instruments included in the estimation are the exogenous variables of age, experience and years as owner.

The profit function is well-behaved if it is decreasing and convex in input prices and increasing in land and household on-farm labour. These properties are satisfied if $\beta < 0$, $\phi, \delta > 0$ and $G/P_Q > 0$ for all observations. Table 3 reveals that for both methods of estimation the coefficients exhibit correct signs. Thus, all the regularity conditions are fulfilled so that the estimated profit function is consistent with economic theory.

Table 3: *Cobb-Douglas Profit Function Estimates (standard errors in parentheses)*

Parameter	2SLS	3SLS
$\ln A$	22,6582 (18,4405)	5,5155 (17,3197)
β	-5,9217** (3,2341)	-1,7639 (3,1011)
ϕ	0,1976 (0,3899)	0,0938 (0,3662)
δ	0,8916 (1,7323)	1,2668 (1,6037)

** Significant at 10 % level

The estimates chosen for further analysis is given by the values in the final column of Table 3.

Two methods are used to obtain consumption side parameter estimates, *two stage least squares* and *three stage least squares*. Instruments incorporated here include age and years as

owner of the farm. The results of the Stone-Geary preference estimates are presented in Table 4.

Table 4: *Stone-Geary Utility Function Estimates (standard errors in parentheses)*

Parameter	2SLS	3SLS
Θ_g	0,0114 (0,01475)	0,0114 (0,01475)
Θ_p	0,1446 (0,1749)	0,1446 (0,1749)
Θ_x	0,4914* (0,1848)	0,4914* (0,1848)

* Significant at 1 % level

Both methods generate equal estimates. This tells us that there is no correlation between the error terms in the consumption part of the model. All estimates are consistent with *a priori* economic theory.

Table 5 presents on-farm and off-farm labour supply elasticities with respect to the virtual wage, off-farm wage, and pension evaluated at sample means. These elasticities are easily calculated by taking the partial derivatives of the natural logarithms of equations (13) and using the parameter estimates reported in the final column of Table 4.

Table 5: *Labour Supply Elasticities*

	On-Farm Labour Supply	Off-Farm Labour Supply
Virtual Wage	0,1293	-0,0186
Off-Farm Wage	-0,1325	0,0141
Pension	-0,0018	-0,0027

From Table 5 we can see that a *one* percent increase in the off-farm wage results in a *0.014* percent increase in hours employed off the farm while a *one* percent increase in the virtual wage results in a *0.13* percent increase in hours of farm work.

Cross-wage elasticity estimates from Table 5 reveal that self-employment decisions are much more responsive to changes in the off-farm wage (*-0.13*) than wage employment choices are to changes in the market wage (*-0.02*). Moreover, pension effects are stronger for off-farm work (*-0.0027*) than for on-farm work (*-0.0018*).

Based on the following relationship one can now calculate the elasticity of transformation between on-farm and off-farm work:

$$(14) \qquad \sigma = \frac{\varepsilon}{\theta - 1},$$

where ε is the own wage elasticity, and θ is the share of labour allocated to agriculture. Accordingly, the elasticity of transformation for the sample takes on an average value of *-0.9*.

5. Conclusion

This paper has been concerned with investigating the supply and production decisions of Norwegian dairy farmers who engage in outside employment and face an imperfect labour market. Major empirical finding include the following. The hypothesis of constant returns to scale technology cannot be rejected for Norwegian dairy farmers. On-farm labour supply decisions are more responsive to changes in prices than off-farm labour supply decisions; and changes in pension have a small but noticeable impact on the scale of dairy farm operations. The results suggest that any policy action that decreases pension will increase milk production. Alternatively, policy action that decrease output price and/or increase input prices will lower production. The main objective of this paper is to estimate the elasticity of transformation between on-farm and off-farm work for Norwegian dairy farmers. The results obtained suggest that a *one* percent increase in the off-farm wage implies that farm households will reallocate their labour supply in a way that constitutes a *0.9* percent increase in off-farm work on average.

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