Dynamics of income, wealth and capital in Norwegian farm household accounts: A state-space model

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Abstract— **Feedbacks between on-farm and off-farm activities are analyzed with a state-space model over a panel of farm household accounts. We discover significant positive effects of farm capital both on farm income and on wage labor income. The latter effect is interpreted as wage labor partly paying the debt incurred by investments in farm capital. Significant positive effects on farm capital from wealth — indicating credit rationing or an immediate willingness to pay for farm investments — are also discovered. The wealth effect on farm income is also significantly positive. By and large — at least for the household for which the the results are estimated, and for the model applied — Fishers separation theorem is rejected.**

Keywords— **farm households, finance, investment**

I INTRODUCTION

Farm account surveys represent a unique source of information on the dynamic economic behavior of farm households. This is in particular the case in Denmark, the Netherlands and Norway which gather the complete household accounts, not only the part that relates directly to farming.

Modern farming households tend to run some off-farm activities: Off-farm business, off-farm labor supply and/or at least management of finance and risk. According to the ruling paradigm of separability or recursivity, based on the Fisher separation theorem or the Arrow-Debreu model [2] [7], this does not affect their farming. However, producer household theory shows that there are reasons why that presumption may be incorrect. Basically, absence or imperfectness of markets facilitates the combined management of on-farm activities on the one hand, and private, financial and off-farm activities on the other, [6], [22]. This has been considered immediately relevant for developing countries where product and factor markets may be imperfect or missing. However, the non-recursivity argument applies to all commodities in the Arrow-Debreu model, in particular to the Arrow-Debreu securities which tend to be without markets in every economy, and also to credit which tends to be rationed due to asymmetric information, [21]. Thus, even in developed countries one should expect some non-recursivity in the relationship between producers and their owners — both within farming and in other sectors as well. And this eventually non-recursive behavior is expected to affect the allocation of real and financial capital.

With respect to farming in developed economies there are also other market failures of relevance: (1) In the market of user rights to land, the marginal user value will depend on the distance between the land and the home of the user. The effective marginal cost then increases with the quantity demanded. An aspect of rationing is also present as land lots are available in the market in only a relatively short time-window. (2) Markets for sale of buildings and structures are highly imperfect. Either the user rights can be sold, and then the arguments for the land market applies, or they can be sold at scrap value. (3) Markets for amenities associated with owning and running a farm are absent. One cannot purchase the maintenance of family traditions, the hedging against a chaotic future, the life style of running and living on the farm, the love of tractor driving, independent work and the good life in the countryside. One simply has to purchase a farm and make the best out of it.

It is not easy to account for the consequences of each market imperfection and each market absence. Actually we will not even try to do that. Traces of the consequences are anyway found in the data records of the farms.

Empirical analysis supports also the idea of non-recursive farmer behavior. Evidence against profit-maximization pops up in many ways and are given many different names. Lee and Chambers (1986) [14] find cash-flow effects in aggregate U.S. agricultural data and interpret this as *expenditure constraints*. Some econometric analyzes find relationships between off-farm labor and the farming activity: [18], [10], [1]. Others find that the shadow price of household farm labor is significantly lower than the off-farm wage rate, [15], [8], [9].

The standard approach in analyzing farm panel data has mostly been to focus on the relationship between some parts of the data. For example, labor supply, supply of particular products, demand for particular factors, investments, credit etc. It is both tempting and relevant to ask, say, how the supply of barley in Norway is affected by the income and wealth of the farmers. However, barley is a detail while income and wealth are broad aggregates. As a first shot at the effects of income and wealth, it seems more convenient to relate these aggregates to other broad aggregates. Moreover, it is natural to exploit the fact that accounts actually are designed to measure income and wealth. Hence, we will investigate in broad terms the dynamics of the farmer household accounts to look for eventual feedbacks from off-farm to on-farm activities.

II THE RELEVANCE OF STATE-SPACE MODELS

A recent paper [19] points out that estimation results from farm survey data are highly dependent on the estimation method used. Our approach contributes with yet another estimation method based on the insight that there might be unobserved heterogeneity both between and within units [13]. Heterogeneity within units will arise when there are unobserved individual changes in the behavioral model of observed units over time. Basically, we deal with this problem by introducing latent variables which describe the "state" of the economic model for each unit at each point in time. Because, unobserved state variables are explicit parts of the model, such models are named "state-space models". Contrary to random individual effects which are independent between units, the state variables are dependent over time and develops in accordance with new observations as they become available. The technique that deals with this is the Kalman filter.

State-space modeling is commonly applied in time-series analysis. The basic tools are described by Harvey (1989) [11]. Applications are numerous within engineering and macroeconomics. Chavas (1985) [5] pioneered the technique in agricultural context. Applications for panel data are scant, due to lack of standard software.

State-space models are relevant to the analysis of farm survey data partly for econometric reasons. These panels are unbalanced. As pointed out by [3], standard fixed and random effects models are not consistent in this case. There are also economic reasons for their relevance. In an Arrow-Debreu economy each economic agent would have time-consistent economic strategies and there would never be a need to revise them. In economies with less strict structure, agents with forward-looking economic behavior will probably revise their strategies as new information becomes available. Such revision of strategies might in principle be mirrored by the state-space model.

With a structural approach one might formulate a state-space model the following way. Assume current economic actions y_{it} minimizes some objective $O(y, x_{it}, \alpha_{it}; \beta)$ depending on present economic conditions, x_{it}, unobserved state, α_{it} and global parameters β. The behavioral model can then be stated as:

$$y_{it} = \text{argmax}_y \left\{ O\left(y, x_{it}, \alpha_{it}; \beta\right) \right\} + \epsilon_{it}$$

and the autoregressive process of unobserved states can be specified as:

$$\alpha_{it} = T\alpha_{i,t-1} + \eta_{it}$$

where T is a matrix of autoregressive parameters. The econometric task is then to estimate all the unknown parameters of the model including the distributions of ϵ_{it}, α_{it} and η_{it}.

Due to our lack of experience with state-space models we will employ state-space models in the simplest possible way with a reduced form model where the behavioral functions are linear, with no reference to any quadratic objective from which they might be deduced. Nevertheless, the design of that model will to some extent reflect the nature of our data. A certain technique with respect to accounting data will be presented in the next section.

III INTERPRETING ECONOMETRIC MODELS OF ACCOUNTING DATA

Accounting data is potentially an important source of information with regard to the feedbacks between real and financial measures in an economy without separability. However, it is not straightforward to exploit all this information in econometric models. The present section shows how a considerable part of the information actually can be utilized.

From an accounting perspective are all variables informative. However, from a statistical perspective accounting data are collinear, due to the balances which accounting data satisfy. The econometric modeling of complete accounting data should respect this. On the one hand some variables need to be excluded from the econometric model to avoid collinearity. On the other hand can these variables be re-entered in the analysis after the econometric model is estimated. The effects of omitted variables, and eventually the impacts on omitted variables can be deduced from the linear dependencies. The issue is relevant to our analysis as we will utilize values from the asset balance as explanatory variables, and values from the flow balance as dependent variables.

The flow balance is in our context a balance of expenditures less revenues on the one hand and exogenous income on the other

$$I^F - R^F - M^W - R^O + C - \Delta D + \Delta S \equiv M^X$$

where

$I^F =$ gross investment in real farm capital
$R^F =$ net revenue from farming less I^F and the farming part of M^X
$M^W =$ wage labor income and compensatory social payments
$R^O =$ all net revenue from the non-farming sector
$C =$ private consumption
$\Delta D =$ additional money withdrawn as debt
$\Delta S =$ additional money deposited as savings
$M^X =$ net exogenous income independent of current trade, related to farming or not. This comprises direct farm payments, financial gains and losses, inheritance etc.

We will argue that the variables on the left hand side are dependent, and the variable on the right hand side is independent. Since the flow-balance is inherent in the data, one may skip one variable from the estimated model, and simply use the flow balance to predict it. A clear candidate in this respect is farm investments, I^F, which is expected to be distributed non-normally with a considerable number of zero observations and some very large. One might suspect that additional debt, ΔD, has a similar pattern, but the lumpiness of investments are at least not perfectly carried over to the debt.

In terms of the dependent variables of the econometric model, $Y' = (R^F, M^W, R^O, C, \Delta D, \Delta S)$, the full matrix of independent variables, Y^*, is given by:

$$Y^* = VY = \begin{pmatrix} \begin{pmatrix} 1 & 1 & 1 & -1 & 1 & -1 \end{pmatrix} \\ I \end{pmatrix} Y$$

The independent variables of the econometric model comprise opening stocks of various assets, all subscripted with $_{-1}$ to underline that these have been determined at the previous point in time:

$K^F_{-1} =$ opening stocks of all real capital of the farming sector
$K^O_{-1} =$ opening stocks of all other capital except savings, debt and equity
$S_{-1} =$ opening stocks of risk-free savings
$D_{-1} =$ opening stocks of debt
$E_{-1} =$ opening stocks of equity
$A_{-1} =$ opening stock of equity plus debt (total assets)

Of course, much more detail could be specified here, but the current paper will stick to this high level of aggregation. The total assets can be decomposed in two ways, as debt and equity, or distributed over various assets:

$$A_{-1} \equiv E_{-1} + D_{-1} \equiv K^F_{-1} + K^O_{-1} + S_{-1} \qquad (1)$$

The econometric model is based on opening stocks of farm capital, other capital, debt and total assets, $(K^F_{-1}, K^O_{-1}, D_{-1}, A_{-1})$, as independent variables. The effects of the omitted risk-free savings, S_{-1}, and equity, E_{-1}, can be deduced from (1). However, there is more to this model than the pure statistical analysis. Certain combinations of the independent variables are economically relevant. This relevance comes precisely from the dependencies in the data.

Changing total assets keeping debt and real assets fixed, means that equity and savings increase in equal amounts. Changing debt keeping various capital and total assets fixed means that equity and debt are substituted in equal amounts. Changing farm capital keeping other capital, debt and total assets fixed, means this change is financed by reduced savings. Statistically, this is mirrored by the change in one single variable, K^F_{-1}, but economically, it need to be acknowledged that two variables, K^F_{-1} and S_{-1}, are substituted one for one.

Thus, even for these single-variable effects there is a discrepancy between the name of the single variable, and an appropriate economic interpretation of what is going on when the variable is changed. Obviously, one may find other interpretations of impacts by combining two or three independent variables: The impact of real assets financed by debt can be found by increasing total assets, real capital and debt in equal amounts. A liquidity impact is found by increasing debt and total assets in equal amounts keeping real assets fixed.

In our case, for each measure of capital there are four different measures that can covary and finance the change. Farm capital, say, can be financed by savings, debt, other real capital and equity. A given increment to farm capital with different financing may have different impacts on dependent variables.

Table 1 summarizes possible combinations and their economic interpretations. Each line of the table represents a simultaneous change of one unit for the pair of measures mentioned in the column dX^*. In some cases both measures are augmented by one unit, in remaining cases the first measure is augmented and the second reduced. The text and the context makes it clear which is which. This change is associated with a simultaneous change of one unit in the exogenous variables. The content of the table makes it clear which variables and which direction. The first line of the table has been commented above. A more complex case is the second line of the table which says that a change of one unit in farm capital and debt is associated in a change of one unit in the three independent variables dK^F_{-1}, dD_{-1} and dA_{-1} while dK^O_{-1} is kept constant. The association is represented as an equation:

$$dX^*_2 \begin{pmatrix} 1 & 0 & 1 & 1 \end{pmatrix} = \begin{pmatrix} dK^F_{-1} & dK^O_{-1} & dD_{-1} & dA_{-1} \end{pmatrix}$$

Dealing with five different measures of capital (debt, equity, farm capital,other real capital and savings) and one asset balance, there are $\binom{5}{2} = 10$, different paired combinations, dX^*, where two measures are varied simultaneously (one for one, or one for minus one) and the rest are kept constant. Hence, table 1 is indeed complete.

Clearly can several pairs of measures be changed simultaneously in different amounts. However, there are only four independent variables available and possible changes are constrained by the equations:

$$dX^*_k \, U_k = \begin{pmatrix} dK^F_{-1} & dK^O_{-1} & dD_{-1} & dA_{-1} \end{pmatrix} \text{ for all } k$$

where U_k represents the k-th row of the table. But this can also be stated as a vector equation:

$$U' dX^* = dX$$

where the matrix U is the whole content of the table, and the independent variables are represented with the column vector X. Then for any response matrix β so that

$$dY = \beta dX$$

for some vector of dependent variables, Y, we can deduce the complete set of responses to paired shocks by

$$dY = \beta U' dX^*$$

A variance-covariance matrix of the elements of $\beta U'$ can be computed from the corresponding matrix of the elements of β. Since β is a matrix, we have to apply the Vec-operator to β in order to deal with the all the covariances which arise under simultaneous equations estimation. The complete variance-covariance matrix is then stated as $\mathrm{Var}\,(\mathrm{Vec}\,(\beta))$. As $\mathrm{Vec}\,(\beta U') = (U \otimes I)\mathrm{Vec}\,(\beta)$, the variance-covariance matrix of $\mathrm{Vec}\,(\beta U')$ is found as:

$$\mathrm{Var}(\mathrm{Vec}\,(\beta U')) = (U \otimes I)\mathrm{Var}\,(\mathrm{Vec}\,(\beta))\,(U \otimes I)' \quad (2)$$

The variances are then found on the diagonal of this matrix.

IV THE DATA

The data source is the Norwegian farm accounting surveys 1991-2006 [16]. This is a rotating unbalanced panel of almost 1000 household farms with a main holder below the age of retiring and a scale of production exceeding 8 European Size Units (ESU). Farms are allowed to stay in the survey sample as long as they like while belonging to the target group. Approximately 10 percent of the farmers drop out of the

Table 1: Interpretations of effects from independent variables and combinations thereof

Interpreted impact	dX^*	dK^F_{-1}	dK^O_{-1}	dD_{-1}	dA_{-1}
Farm capital replaces savings	$K^F_{-1}\backslash S_{-1}$	1			
Farm capital financed by debt	$K^F_{-1}\backslash D_{-1}$	1		1	1
Farm capital financed by equity	$K^F_{-1}\backslash E_{-1}$	1			1
Farm capt. replaces other capt.	$K^F_{-1}\backslash K^O_{-1}$	1	-1		
Other capital replaces savings	$K^O_{-1}\backslash S_{-1}$		1		
Other capital financed by debt	$K^O_{-1}\backslash D_{-1}$		1	1	1
Other capital financed by equity	$K^O_{-1}\backslash E_{-1}$		1		1
Savings financed by debt	$S_{-1}\backslash D_{-1}$			1	1
Savings financed by equity	$S_{-1}\backslash E_{-1}$				1
Debt replaces equity	$D_{-1}\backslash E_{-1}$			1	

survey every year and are replaced by others. No clear statistical design is imposed on the survey, hence it is not precisely clear what the average surveyed farm represents. Nevertheless, one might assert that the survey contains typical household farms of intermediate size. Farms of small and large scales are less well represented in the survey.

The surveyed farm accounts are in principle balanced and divided into sectors: agriculture, forestry, other business, finance and private. Since 1998 other business is in turn divided into business supplementary to agriculture and business independent of agriculture. The distinction is based on the type of capital which is employed. Activities using mainly real assets also used by agriculture are defined as supplementary. Activities using mainly other types of assets are independent. Our analysis is based on only two sectors: The farming sector comprising agriculture and its supplementary activities — when accounted for — and the non-farming sector comprising the rest.

The accounting of the total economy of the household has been conducted since the start of the survey in 1913. This is at odds with the general requirements of farm accounting surveys within the European Union, Farm Accountancy Data Network (FADN), but has been continued for national reasons in some countries (Denmark, the Netherlands and Norway). It is precisely this complete accounting of the household which make the Norwegian farm survey a relevant data source for our analysis.

The accounting data are basically values in nominal currency from the balance sheet and from the tax and the management accounts. The survey recognizes that tax accounts contain neither the complete nor the correct information needed to calculate yearly income. Much effort is hence directed at a conversion of the raw data of tax accounts into management accounts on which the results of the survey are based. Some measures of volumes (number of livestock, harvested crops) are included in the data to guide this conversion, but these are not utilized in this paper.

A statistical analysis of accounting data can be true to the dynamics of accounting. After all, accounting data are truly dynamic with a sequence of stocks changing according to the sum effect of investment, appreciation and depreciation. As such, accounting data might represent a natural starting point for dynamic modeling of the accounted enterprize. However, the policy relevance of the model is associated with trade and in particular on investments, credit and savings, recognizing that these are the control variables of the economic unit in a dynamic economy. These are also the response variables which interact in markets to form market prices, and consequently what temporary policy analysis should be based on.

In principle, the accounts consist of the following elements for each of the three types of assets K^F, S and K^O: opening balance, k_{-1}, net market demand, x, closing balance, k, and accounted net income, i. These variables are related by the identity:

$$k_{-1} + x - k + i \equiv 0 \tag{3}$$

so that the accounted net income is identical to net sales adjusted for the change of capital stocks due to depreciation and appreciation[1]. For the two types of

[1]Appreciation is not accounted for in the Norwegian farm survey, except in relation to livestock, savings and debt.

tangible assets, K^F and K^O, x is acquisitions less sales of capital (gross investments) while i is depreciation. For financial assets (savings), the net income i is the interest received less interest payed. As opening and closing stocks are measured according to bank statements, the term x is the net amount of money deposited in the accounts during the year. Whereas the accounts focus on the flow variables of net income, i, in relation to stocks, k_{-1} and k, our interest is directed at the flows of net demand, x, in relation to stocks. Although these figures tend to be absent in the accounting database, they can be reconstructed using (3).

A concise description of our utilized data can now be given. First, eventual missing recordings of net demands are calculated using (3). Then the aggregates of net demands over commodities, I^F, R^F, M^W, R^O, C, ΔD, ΔS and M^X are formed as described in section III and above. And the aggregate stocks, K^F_{-1}, K^O_{-1}, D_{-1} and A_{-1} are formed as described in section III.

Descriptive statistics for the variables employed in the various samples (after trimming) are given in table 1. Other net revenue, R^O, has a rather small mean as it can be positive or negative, but its variance is considerable. The pseudo-panel are formed by averaging the farms over NUTS4-regions[2] [17]. The age variable which refer to the stated manager of the farm is scaled to have mean 0 and variance 1 in the total sample.

V ESTIMATED MODEL AND RESULTS

With the data described in the previous section we estimate versions of the following linear simultaneous equations model, consisting of different types of observed and unobserved variables:

$$y_{it} = \beta x_{it} + \lambda d_{it} + \nu_i + \Gamma\alpha_{it} + e_{it}. \quad (4)$$

Let us first describe the observed variables: The (column-) vector of dependent variables, y_{it}, is:

$$y_{it} = \frac{1}{A_{-1}{}_{it}}\left(R^F_{it} \quad M^W_{it} \quad R^O_{it} \quad C_{it} \quad \Delta D_{it} \quad \Delta S_{it}\right)', \quad (5)$$

while x_{it} is the vector of the lagged balance sheet variables described in section III divided by A_{it}:

$$x_{it} = \left(\frac{K_{-1}{}^F_{it}}{A_{-1}{}_{it}} \quad \frac{K_{-1}{}^O_{it}}{A_{-1}{}_{it}} \quad \frac{D_{-1}{}_{it}}{A_{-1}{}_{it}} \quad 1 \right)'. \quad (6)$$

[2]NUTS (Nomenclature des Units Territoriales Statistiques) is a system of multilevel regions within the European Union.

Finally d_{it} is a column vector of deterministic variables:

$$d_{it} = (\ Age_{it} \quad [I(t=s)]_{s=1}^T \ )',$$

where Age_{it} is the age of the main person of the household in year t and $I(t=s)$ is one if $t=s$ and zero else, i.e., a dummy variables indicating calendar year. Thus

$$\lambda d_{it} = \lambda_0 Age_{it} + \sum_{s=1}^{T} \lambda_s I(t=s).$$

Since a constant term is included in x_{it}, we impose the identifying restriction $\sum_{s=1}^T \lambda_s = 0$.

Using the notation Y_{it} and X_{it} of section III, we have

$$\begin{aligned} Y_{it} &= A_{-1}{}_{it} y_{it} \\ X_{it} &= A_{-1}{}_{it} x_{it} \end{aligned} \quad (7)$$

The scaling by A_{it} in the definition of y_{it} and x_{it} is chosen to reduce the problem of heteroscedasticity, which is very large for the nominal variables in Y_{it} and X_{it}. From (4) and (7),

$$dY_{it} = d(A_{-1}{}_{it} y_{it}) = \beta d(A_{-1}{}_{it} x_{it}) = \beta dX_{it},$$

which makes it straightforward to calculate partial effects as described in section III from the estimated coefficient matrix β.

Let us now turn to the unobserved variables. The model (4) contains three types of latent components. First,

$$\nu_i \sim \mathcal{IN}(0, \Theta)$$

is a farm-specific random effect. Second $\alpha_{it} = (\alpha_{1,it}, ..., \alpha_{r,it})'$ is an $r \times 1$ vector ($r \leq \dim(y_{it})$) of independent dynamic factors, distributed as Gaussian random walks:

$$\alpha_{it} = \alpha_{i,t-1} + \eta_{it};\ \eta_{it} \sim \mathcal{IN}(0, I);\ t = 2, ..., T_i \quad (8)$$

where 0 and I to denote, respectively, a matrix of zeros and an identity matrix of appropriate dimension. Finally, $e_{it} \sim \mathcal{IN}(0, \Sigma)$ is a vector of idiosyncratic error terms.

The covariance matrix Θ of the random effect v_i characterizes the permanent part of the cross-sectional heterogeneity across farms in their first observation year, in contrast to the transitory part e_{it}. Heterogeneity between farms in any later year also depends on *cumulated innovations*

$$\alpha_{it} = \left\{ \begin{array}{cc} 0 & t = 1 \\ \sum_{s=2}^t \eta_{is} & t \geq 2 \end{array} \right\}.$$

In order to obtain identification, the initial value is $\alpha_{i1} = 0$, while the subsequent innovations η_{it} have zero mean (since any non-zero mean will be captured by the term λd_{it} in (4)). Moreover, in order to identify the loading matrix Γ, we require that the covariance matrix of η_{it} is equal to the identity matrix, while $\Gamma = \{\gamma_{ij}\}_{6\times r}$ has a lower triangular structure: $\gamma_{ij} = 0$ if $j > i$.

It is possible to extend the random walk assumption in (8) by allowing instead an AR(1) structure: $\alpha_{it} = \Psi\alpha_{i,t-1} + \eta_{it}$. The assumption of a random walk, which is consistent with Gibrat's law that firms' growth rates are independent of firm size[3], is retained throughout this paper as a simplifying assumption.

The above model can now be cast in a familiar state space form where the state vector is

$$f_{it} = \left[\ \nu_i', \quad \alpha_{it}'\ \right]'.$$

That is:

$$\begin{aligned} y_{it} &= \beta x_{it} + \lambda d_{it} + Z f_{it} + e_{it} \\ f_{i,t+1} &= f_{it} + \left[\ 0', \quad \eta_{i,t+1}'\ \right]' \qquad t = 1, ..., T_i, \\ f_{i1} &= \left[\ \nu_i{}' \quad 0'\ \right]'; \end{aligned} \tag{9}$$

and

$$Z = \left[\ I \quad \Gamma\ \right] \tag{10}$$

Random effects and white noise are standard in panel data models, but the dynamic factor α_{it} is not. In effect this should capture the effects of all omitted farm-specific variables which change over time, such as e.g. productivity, preferences, expectations and the like. The state space model can be estimated with maximum likelihood using Kalman filter techniques (see e.g. [20]).

Several versions of this model are estimated, with varying number of observations and varying rank of Θ and Γ. A general problem is identification. The larger the sum of the ranks of Γ and Θ, the more difficult it is to make the estimation algorithm converge. We are therefore unable to provide estimated models of all desirable combinations of ranks. The problem is somewhat relieved when extreme observations are eliminated. Such elimination is undertaken by dropping farm households which has some variable in the upper or lower 2.5 percent quantile in some year. This might seem innocent, but approximately half of the farms drop out of the sample in this way.

[3] See [23] and [4] for discussion.

In tables 3 and 4 we display the results for the partial effects

$$dY_{it} = \beta U dX_{it}^*$$

for the trimmed sample of single farms and for the pseudo-panel averaged farms according to the technique explained and the notation introduced in section III.

A general impression common to both models is a high level of statistical significance. Most of the parameters are significant at the 95 percent level. The results are very similar in both models indicating that the loss of information, neither by trimming the single farm sample nor by averaging single farms into pseudo-panels, is acceptable.

More detailed discussion of the results refers only to the trimmed single-farm sample. We consider first the effects of farm capital with various finance.

- Farm capital favors farm investment. This indicates that investments primarily take place on farms that are growing. If investment primarily was a response to shortage of capital on farms of constant size, the opposite effect would have appeared.
- Farm capital favors net farm revenue as expected. The effect differs somewhat according to finance with claim financing significantly lower than the others
- Farm capital financed with savings or other capital has a clearly significant negative impact on wage labor income. This corresponds to the idea that households with a larger scale of farms production have less time for wage labor. However, when farm capital is financed with debt or equity, the impact is significantly positive. The positive impact of farm capital and debt suggests that wage labor is required to pay for farm debt. The positive impact of farm capital and equity suggests that wealthier farmers take more wage labor indicating that wage labor is part of the behavioral strategy of farming households, not only a resort when farm income fails. We will return to further discussion of this finding later.
- Other revenue is not positively effected by farm capital. This is the expected result, indicating that a larger scale of farm production favors a lower scale of other production.
- With consumption we have again challenging results. The pattern is exactly as with wage labor

income indicating that in some sense is consumption complementary to wage labor income. That consumption is boosted with farm capital and debt/equity can be seen as a response to farm income which is expected to arise later. But that consumption grows more with debt than equity finance is difficult to understand.

- The change of debt is negatively affected by previous debt finance. This is a natural response reflecting repayment of debt.
- The change of savings is positively affected by previous finance from savings. Again the response is natural reflecting the restoration of savings.

The remaining columns are interpreted more roughly:

- Other capital financed with equity has a small positive impact of other capital on farm investment. This is consistent with a diversification effect. The farmer with other capital that diversifies farming risk, will invest more if he is more wealthy. Farm revenue is lowered by other capital as expected when two branches of production competes for resources. Remaining effects of other capital are similar as those of farm capital and need not further comment.
- Savings has no significant effect on farm investment while the impact on farm revenue is positive. The latter is a clear sign of a short-run liquidity constraint, while there is no sign here of a borrowing constraint. Savings has a positive impact on wage labor income. This is not immediately easy to explain, as the naive expected effect is negative. Remaining effects are as expected.
- The effects of debt at the expense of equity can by switching sign be interpreted as effects of wealth. This is positive on farm investments. This is a pure financial effect which should not have been present with separability. This is most likely an effect of a borrowing constraint. If the more wealthy farmer tended to invest more of sheer optimism there would have been an effect in the previous column as well. The effect of wealth on farm revenue is negative. Again a sign of non-separability. The sign might reflect laziness or pursuit of other goals than profit from farm production.
- At last the exogenous income has effects almost as expected. Investments are affected positively contrary to the case of separability. Sources of endogenous income are all affected negatively. Consumption and savings is increased, while debt is reduced.

To evaluate the importance of the state-space approach we have estimated a model without state variables, but full rank of the random effects. The log likelihood came out as 75696. Compared to the log likelihood value of 77288 for the state space model, the conventional model is clearly rejected.

VI DISCUSSION

With the models estimated above, we have found statistically significant and economically relevant cross-effects between the farming and the non-farming sectors of farm households. On the one hand finance positively affects both the short-run revenue of the farm and farm investments. On the other hand equity- and debt-financed farm capital affects wage labor income positively. Hence, our results support non-separability of farming from other activities of the household.

We have no decisive conclusion with respect to the reason of this non-separability. Both borrowing constraints, liquidity constraints and household production interfering with farming is suggested by the results.

There is a wide-spread belief that mingling of activities is relevant in particular for smaller farms which have a higher proportion of other sources of income. Models (not reported here) over sub-samples of farmers divided according to income sources show that finance matters almost as much for the smaller as the larger farms.

We have also estimated a model for a pseudo-panel by averaging farms over NUTS4 regions. There is obviously some loss of information by this aggregation, but also a reduction of errors. Largely, similar results appear for the pseudo-panel as the panel. This is comforting with regard to the part of the sample which was trimmed away in the panel models. Anyway, linear relationships should be preserved under additive aggregation.

State-space models seem to be an appropriate choice for temporary models. They can capture both unobserved expectations and other unobserved variables which change over time.

There are some weaknesses with our implemented models. First, we have a problem with the interpretation of the clearly positive effect of savings on wage labor income. The only explanation we can think of is a life-cycle effect which is not properly captured by the state variables and the independent age variable. This result might indicate some weakness of the model. Secondly, there is possibly some weakness in the estimation algorithm which prevents us from using all single farm observations and all possible combinations of state variables and unit specific random effects.

With respect to the policy relevance of our results we admit that the results are short run and contingent on unobserved expectations. Results from longer runs have not yet been developed. The model does not utilize information on prices. This should also be added to get a more complete picture of the dynamic behavior of farming households.

Despite these weaknesses we have established that the farm household can — and perhaps should — be modeled as a unit making simultaneous decisions with respect to investments, farm production, other production, wage labor and finance.

Norwegian farmers comply with the broad picture provided by Hill (2000) [12]: In particular part-time farmers tend to have negative profits from their farming activity, and this is largely compensated with income from other sources. The farm income is too small to give a decent return both to reported household labor in farming and to employed capital. Our results support this picture by showing that debt incurred by farm capital to a considerable extent is paid with wage labor, and that wealth which is invested in the farm likewise gives rise to increased wage labor income.

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Table 2: Descriptive statistics of utilized farm survey sample variables. Numbers relative to total opening assets

		Farms		Pseudo-panel farms	
		Mean	Stdv	Mean	Stdv
Net farm revenue	R^F/A_{-1}	0.0576	0.0519	0.0524	0.0314
Wage labor income	M^W/A_{-1}	0.0907	0.0796	0.0881	0.0363
Other net revenue	R^O/A_{-1}	0.0031	0.0485	0.0062	0.0330
Consumption	C/A_{-1}	0.1413	0.0695	0.1301	0.0378
Debt	$\Delta D/A_{-1}$	−0.0280	0.0579	−0.0141	0.0427
Savings	$\Delta S/A_{-1}$	0.0029	0.0437	0.0054	0.0267
Exogenous income	M^X/A_{-1}	0.0545	0.0540	0.0469	0.0365
Opening debt	D_{-1}/A_{-1}	0.3874	0.2372	0.3868	0.1194
Opening farm capital	K^F_{-1}/A_{-1}	0.5730	0.1350	0.5520	0.0784
Opening other capt.	K^O_{-1}/A_{-1}	0.2711	0.1191	0.2709	0.0604
Age		−0.0078	1.0733	0.0000	1.0004
Number of firms		859		73	
Number of obs.		6588		402	

Table 3: Effects on all single farms of trimmed sample. Four-dimensional dynamic factors. Five-dimensional farm specific random effects. Log likelihood = 77288.7181

	$K^F_{-1}\backslash S_{-1}$	$K^F_{-1}\backslash D_{-1}$	$K^F_{-1}\backslash E_{-1}$	$K^F_{-1}\backslash K^O_{-1}$	$K^O_{-1}\backslash S_{-1}$	$K^O_{-1}\backslash D_{-1}$	$K^O_{-1}\backslash E_{-1}$	$S_{-1}\backslash D_{-1}$	$S_{-1}\backslash E_{-1}$	$D_{-1}\backslash E_{-1}$	M^X
I^F	**0.0447**	**0.0320**	**0.0522**	**0.0375**	0.0071	−0.0056	**0.0147**	−0.0127	0.0076	**−0.0203**	**0.0899**
	(0.0110)	(0.0045)	(0.0048)	(0.0095)	(0.0115)	(0.0070)	(0.0069)	(0.0107)	(0.0080)	(0.0049)	(0.0206)
R^F	**0.0440**	**0.1058**	**0.0922**	**0.0975**	**−0.0536**	0.0083	−0.0053	**0.0618**	**0.0482**	**0.0136**	**−0.2005**
	(0.0100)	(0.0044)	(0.0044)	(0.0084)	(0.0104)	(0.0063)	(0.0061)	(0.0098)	(0.0074)	(0.0048)	(0.0154)
M^W	**−0.0251**	**0.1039**	**0.0590**	**−0.0937**	**0.0686**	**0.1976**	**0.1527**	**0.1290**	**0.0841**	**0.0449**	**−0.1643**
	(0.0143)	(0.0070)	(0.0070)	(0.0131)	(0.0150)	(0.0105)	(0.0097)	(0.0139)	(0.0111)	(0.0081)	(0.0138)
R^O	**−0.0270**	−0.0047	**−0.0124**	**−0.0499**	**0.0229**	**0.0452**	**0.0375**	**0.0223**	0.0146	0.0076	**−0.1484**
	(0.0107)	(0.0046)	(0.0048)	(0.0096)	(0.0115)	(0.0072)	(0.0070)	(0.0104)	(0.0078)	(0.0052)	(0.0176)
C	**−0.0937**	**0.1366**	**0.0890**	**−0.0623**	**−0.0314**	**0.1988**	**0.1513**	**0.2302**	**0.1827**	**0.0475**	**0.0471**
	(0.0142)	(0.0067)	(0.0067)	(0.0129)	(0.0151)	(0.0101)	(0.0095)	(0.0138)	(0.0107)	(0.0077)	(0.0166)
ΔD	0.0143	**−0.0521**	**0.0175**	**0.0214**	−0.0071	**−0.0735**	−0.0039	**−0.0664**	0.0032	**−0.0696**	**−0.1576**
	(0.0106)	(0.0045)	(0.0047)	(0.0093)	(0.0111)	(0.0069)	(0.0067)	(0.0101)	(0.0076)	(0.0048)	(0.0201)
ΔS	**0.0551**	**−0.0156**	**0.0151**	0.0001	**0.0551**	**−0.0157**	**0.0151**	**−0.0708**	**−0.0400**	**−0.0308**	**0.1922**
	(0.0093)	(0.0038)	(0.0038)	(0.0077)	(0.0100)	(0.0057)	(0.0056)	(0.0093)	(0.0070)	(0.0042)	(0.0165)

Table 4: Effects on pseudo-panel farms. Four-dimensional dynamic factors. Five-dimensional farm specific random effects. Log likelihood = 21545.835

	$K^F_{-1} \backslash S_{-1}$	$K^F_{-1} \backslash D_{-1}$	$K^F_{-1} \backslash E_{-1}$	$K^F_{-1} \backslash K^O_{-1}$	$K^O_{-1} \backslash S_{-1}$	$K^O_{-1} \backslash D_{-1}$	$K^O_{-1} \backslash E_{-1}$	$S_{-1} \backslash D_{-1}$	$S_{-1} \backslash E_{-1}$	$D_{-1} \backslash E_{-1}$	M^X
I^F	0.0152	**0.0494**	**0.0401**	0.0206	−0.0054	0.0288	0.0194	0.0342	0.0249	0.0093	**0.1865**
	(0.0324)	(0.0128)	(0.0163)	(0.0280)	(0.0320)	(0.0216)	(0.0191)	(0.0320)	(0.0204)	(0.0174)	(0.0536)
R^F	**0.0770**	**0.1021**	**0.1043**	**0.1058**	−0.0288	−0.0037	−0.0015	0.0251	**0.0273**	−0.0023	**−0.2535**
	(0.0175)	(0.0082)	(0.0090)	(0.0161)	(0.0187)	(0.0132)	(0.0117)	(0.0173)	(0.0125)	(0.0103)	(0.0315)
M^W	**−0.0456**	**0.0809**	**0.0491**	**−0.0936**	**0.0480**	**0.1746**	**0.1427**	**0.1266**	**0.0947**	**0.0319**	**−0.1027**
	(0.0195)	(0.0102)	(0.0106)	(0.0191)	(0.0216)	(0.0156)	(0.0145)	(0.0198)	(0.0145)	(0.0120)	(0.0279)
R^O	**−0.0604**	0.0129	**−0.0541**	**−0.1355**	**0.0751**	**0.1484**	**0.0814**	**0.0733**	0.0063	0.0670	**−0.2673**
	(0.0269)	(0.0119)	(0.0131)	(0.0238)	(0.0285)	(0.0184)	(0.0171)	(0.0272)	(0.0180)	(0.0152)	(0.0485)
C	**−0.1039**	**0.1128**	**0.0591**	**−0.0987**	−0.0052	**0.2114**	**0.1578**	**0.2167**	**0.1630**	**0.0537**	**0.1134**
	(0.0250)	(0.0118)	(0.0129)	(0.0228)	(0.0268)	(0.0184)	(0.0168)	(0.0252)	(0.0179)	(0.0148)	(0.0430)
ΔD	0.0449	**−0.0362**	**0.0357**	0.0381	0.0068	**−0.0744**	−0.0025	**−0.0811**	−0.0093	**−0.0719**	−0.0365
	(0.0301)	(0.0126)	(0.0151)	(0.0264)	(0.0305)	(0.0210)	(0.0181)	(0.0297)	(0.0196)	(0.0169)	(0.0520)
ΔS	**0.1046**	−0.0025	**0.0358**	−0.0071	**0.1118**	0.0047	**0.0430**	**−0.1071**	**−0.0688**	**−0.0383**	0.0401
	(0.0209)	(0.0086)	(0.0102)	(0.0175)	(0.0211)	(0.0134)	(0.0123)	(0.0212)	(0.0135)	(0.0115)	(0.0360)