# An Error-Components Three-Stage Least-Squares Model of Investment Allocation by Farm Households

Stephen P. Davies, Kenneth Erickson, Steve Vickner,
Dana Hoag, and Richard Nehring †

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† Stephen Davies and Dana Hoag are Professors, Department of Agricultural and Resource Economics, Colorado State University. Steven Vickner is Associate Professor, Department of Economics, Utah State University. Kenneth Erickson and Richard Nehring are economists at the U.S. Department of Agriculture, Economic Research Service, Resource Economics Division, and Charles Hallahan is an econometrician with the Information Services Division, Economic Research Service, Washington, D.C. The views expressed here are not necessarily those of the Economic Research Service or the U.S. Department of Agriculture.

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## INTRODUCTION

Farm households are faced with wide-ranging decisions about how to allocate limited resources among farm and non-farm activities, including employment, investment, and consumption (Mishra et al., 2002). The farm household controls a portfolio of resources/investments. To remain viable, the household's farm must cover the owner's financial obligations and be competitive with returns from alternative investments. If the farm is profitable, the wealth of its owners can increase over time. An unprofitable farm reduces owners' wealth. The fact that American agriculture is full of farms that routinely earn low or negative returns on equity from production operations complicates the evaluation of the farm production sector's well being. This suggests the need for a micro-level understanding of the relationship between farm profitability, off farm sources of income, return on other capital, and owner wealth (Blank et al. 2004, p. 1299, hereafter "BEMN").

One key insight into how farm and off farm income affect the overall well being of farm households is seen through farm households' allocation of income into assets. A key question is how farm households invest and how they vary this pattern with changing macroeconomic conditions and variations in relative rates of return. For instance, if government payments increase, does the farm household reinvest in agricultural assets, or in non-farm financial assets? Depending on this outcome, government payments may be a force for the development of farm assets, wealth and ultimately a growing agricultural sector, or they may hasten an exit from farming. Stock market gains and the potential for investment in non-farm real estate might well have the same possible range of effects. These effects certainly could vary by commodity, region and size of the household's farm.

Therefore, the topic of this paper is an assessment of patterns of investment by farm households via an econometric model adapted from a land allocation approach of Holt (1999). This analysis will shed light on the importance of different classes of assets to farm household well-being, and it will show the reaction of farm households to a variety of market, international and government effects.

## ECONOMIC MODEL DEVELOPMENT

This paper adapts a linear land allocation model to the allocation of investment funds by farm households into various asset types, assuming that there is a fixed level of investment in a given year. The model used is a levels version of earlier differential models by Barten and Vanloot (1996), which was developed by Holt (1999). Zilberman (2002) also notes that this model is an EV approach to economic behavior under risk. In effect, the model creates a system of equations whereby farm households maximize the certainty equivalent of profits from investment in various assets, subject to a constraint that total investment funds are fixed. In matrix terms, the Lagrangian related to the objective function is:

$$L(inv, \mu) = \left\{ inv^T r^e - .5 * \lambda\, inv^T \Omega\, inv - \mu \left[ inv_{tot} - i^T inv \right] \right\} \qquad (1)$$

where the farm household chooses *inv* that maximize these profits. The Lagrangian multiplier $\mu$ represents the "shadow price" of an additional dollar of investment in various assets (the change in profits with respect to a change in the level investment). $\lambda$ is the coefficient of risk aversion. In this equation, *inv* = a vector of investment in *n* asset types, $r^e$ is a vector of *n* expected returns on assets (defined to be net returns, above costs), $\Omega$ is a matrix of variances and covariances between the different returns to assets, and $inv_{tot}$ is the total investment funds available. After much algebra, Holt (1999) shows that this relation can be estimated as a set of equations, with a typical equation for the $i^{th}$ financial asset as:

$$\nu_i = \alpha_i + \sum_j s_{ij} r_j^e + \sum_k \beta_k z_{kt} \qquad (2)$$

where $\nu_i$ = the share of the $i^{th}$ investment in total investment ($inv_i / inv_{tot}$), $s_{ij}$ ends up as a coefficient on $r^e$, which can be interpreted as one of the elements of $\Omega$, the matrix of variances and covariances. $s_{ii}$ refers to one diagonal element of $\Omega$, $s_{ij}$ refers to an off-diagonal element, and ii goes from 1 … n, where there are n assets. There could also be a variety of region or farm-type specific characteristics, which are allowed for in the $z_{kt}$ variables. $k$ indexes the farm-type specific characteristics, and $t$ the year. It is clear that additional restrictions would make sense as well, such as those used to reflect the depreciation of real assets, or create distributed lag specifications to tie current investment to past asset values. "Safety" limits on investing heavily in one asset might be added restrictions. To the extent possible, we will add these equations in the system in the future.

For the purposes of this initial effort, we compute investible funds in a manner related to equations in BEMN. First, BEMN state that change in wealth equals $\Delta W_t = Finc_t + Ofinc_t + \psi\Delta K_t + GovP_t - C_t$, where ΔWt is the change in a farm household's wealth over a year, $Finc_t$ is farm income, $OFinc_t$ is off-farm income, $GovP_t$ is government payments during the year, $\psi\Delta K_t$ reflects capital gains, and $C_t$ is consumption. ΔWt includes changes in interest earnings on past wealth both through the change in asset values, and through $\psi\Delta K_t$, which reflects capital gains on those assets. Clearly, each term in this relation could be elaborated into further structural relations, but we leave this for later work. From $\Delta W_t$, we derive the value for $inv_t$, which is needed to examine the decision making process of farm households. Thus,

$$\Delta W_t = \sum_i (P_{it} - P_{it-1}) * A_{it-1} + inv_t \ ,or,$$
$$inv_t = \Delta W_t - \sum_i (P_{it} - P_{it-1}) * A_{it-1} \qquad (3)$$

The data series for $inv_t$ will be developed from the ARMS database as discussed below.

## DATA

This study uses farm-level data from the USDA's Agricultural Resource Management Survey (ARMS). We construct a unique pseudo-panel data set from pooled ARMS data for 1997-2002 over four homogenous states: Indiana, Illinois, Iowa and Ohio. The time periods include years 1997 to 2002. In each year, 13 cohorts (i.e., aggregations of individual farm households of similar size and characteristics, which are given in table 1 below) are tracked in each state. In some years and some states, data were not available for smaller cohorts giving rise to an unbalanced or incomplete panel data set. There will be one equation for each investment class, which includes at present just the aggregates of farm household and off farm wealth. Later, we can elaborate this model for farmland, buildings, machinery and equipment, inventories of commodities and livestock, some stocks and bonds, savings accounts and retirement accounts and non-farm real estate returns. As some of these accounts are not collected every year in ARMS interpolation is required at times. (Moss, Featherstone and Baker).

The expected returns can be created in several ways. Contemporaneous values of returns, given annual data, might make sense. Also, readily-available monthly data stock market returns, interest rates and bond yields have been collected and could be used to construct ARMA models as "rational expectations" to represent various expectations processes or use futures market prices where they exist. For this iteration, we simply use the levels in each year. We can construct returns to land, family labor and management using the ARMS data, and there are also published returns to farming available (Moss). Again, it is premature to include these variables beyond just the levels for a given year. Moreover, at present we have used national values of returns on stocks and bonds, and interest rates, but we have collected for later iterations the regional mortgage rates for examples, and some other location - specific variables.

This pseudo-panel data set contains 13 cohorts in each year. Cohorts are aggregations of individual farm households of similar size and characteristics and are tracked in each state. For empirical studies using such panel data, the temporal pattern of a given farm's production behavior must be established. In the absence of genuine panel data, repeated cross-sections of data across farm typologies may be used to construct pseudo panel data (see Deaton; Heshmati and Kumbhakar; Verbeek and Nijman). Such a panel is created by grouping the individual observations into homogeneous cohorts, distinguished according to time-invariant characteristics such as fixed assets, geographic location, or land quality or acreage. The empirical analysis is then based on the cohort means rather than the individual farm household-level observations.

We assigned the farm household-level data to cohorts based on the ERS farm typology (TYP) groups (Hoppe and MacDonald). The typologies and cohorts are summarized in table 1. The data in TYP1-3 (limited resource, retirement, and residential) are relatively limited compared to the traditional farm data. Therefore, they were further grouped into three cohorts by level of agricultural sales. Three cohorts each were similarly defined for TYP4 and 6, and two each were designated for TYP5 and TYP7&8. A cohort group is formed for each state in the sample. Thus, there are 13 cohorts per state and 4 states, resulting in a total of 52 cross-sectional entities per year. In general, the cohorts averaged close to 30 observations per cohort and formed an unbalanced panel.

The pseudo panel data we use are the weighted mean values of the variables to be analyzed, by cohort, state, and year.  For example, for the Corn Belt states we have 65 observations per year, for our 5-state sample.  To present our results below, we group these cohorts into (i) residential

**Table 1. The Farm Typology Groups and Cohort Definitions**

| *Typology* | *USDA definition* | *Sales ($)* |
|---|---|---|
| TYP1 | Limited resource | <100,000 (assets <150,000, income < 20,000) |
| TYP2 | Retirement | <250,000 |
| TYP3 | Residential (other major occupation) | <250,000 |
| TYP4 | Farm/lower sales | <100,000 |
| TYP5 | Farm/higher sales | <250,000 |
| TYP6 | Large family farms | 250,000-499,999 |
| TYP7 | Very large farms | 500,000+ |

| *Cohort* | *Typology* | *Gross Value of Sales* |
|---|---|---|
| COH1 | TYP1-3 | <2,499 |
| COH2 | TYP1-3 | 2,500-29,999 |
| COH3 | TYP1-3 | >30,000 |
| COH4 | TYP4 | <10,000 |
| COH5 | TYP4 | 10,000-29,999 |
| COH6 | TYP4 | 30,000-99,999 |
| COH7 | TYP5 | 100,000-174,999 |
| COH8 | TYP5 | 175,000-249,999 |
| COH9 | TYP6 | 250,000-329,999 |
| COH10 | TYP6 | 330-000-409,999 |
| COH11 | TYP6 | >500,000 |
| COH12 | TYP7 | <1000,000 |
| COH13 | TYP7 | >1000,000 |

farms (RES, COH1-3); (ii) small family farms (SM, COH4-6); (iii) larger family farms (LG, COH7-10); and (d) very large family and non-family farms (VLG, COH11-13).

Before turning to the results, we review some of the main data series that will be used in the subsequent regressions. First, the means of each series are presented for the entire data series in table 2. The average farm income was about $56,000 while nonfarm income averaged about $40,400. Land value comprised 21 percent of total net worth on average, at $163,000 compared to total net worth averaging $770,700. Net nonfarm wealth was only 11 percent of farm wealth, as it averaged about $84,500. Looking at the other descriptive statistics shows income to be the most variables, followed by land values.

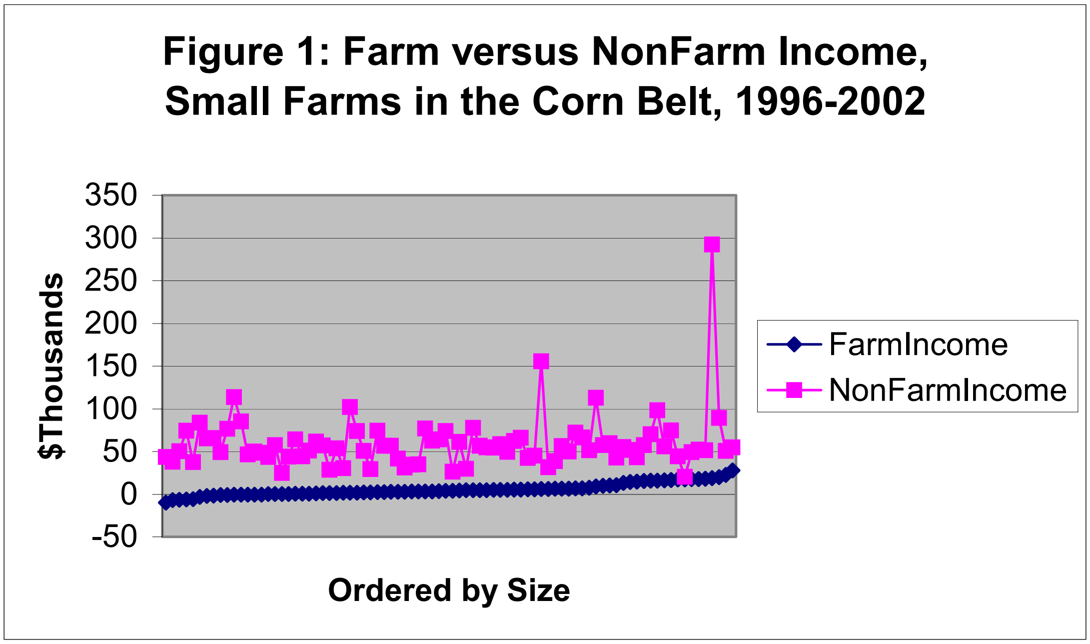
**Table 2: Descriptive Statistics for Key variables**
(All are in Thousand $)

| | Farm Income | Non Farm Income | LandValue | FarmNetWorth | NonFarm Net Worth |
|---|---|---|---|---|---|
| Average | 56.047 | 40.363 | 162.947 | 770.680 | 84.481 |
| Std. Dev. | 108.005 | 31.193 | 180.144 | 707.708 | 67.426 |
| Min | -34.114 | 1.026 | 3.981 | 65.313 | -62.678 |
| Max | 985.288 | 330.047 | 1167.146 | 5297.435 | 473.597 |

Next, some graphical results are given comparing the smallest farms (in cohorts 1,2 and 3) with the largest farms (in Cohorts 10,11,12 and 13). Figures 1 and 2, compare farm versus nonfarm income for the small and large farms. These data are plotted with $Thousands on the y-axis, and the cohorts ordered by size. The nonfarm income remains roughly the same for the small and large farms regardless of the size of farm operation. Clearly, farm income is much higher among the large farms (at $5,500 versus $143,000). However, as the farm operation grows in size, there is no real tendency for nonfarm income to change directly. However, the main values appear to be higher for small farms, and are clearly above farm income while the reverse is true for the large farms. (The mean farm income for small farms in figure 1 is $5,500 versus $60,000 in nonfarm income, while for the large farms in figure 2 it is $143,000 in farm income versus $33,000 in nonfarm income). Thus, as expected and, as well documented, farm households with small farm operations rely on off farm sources of income.

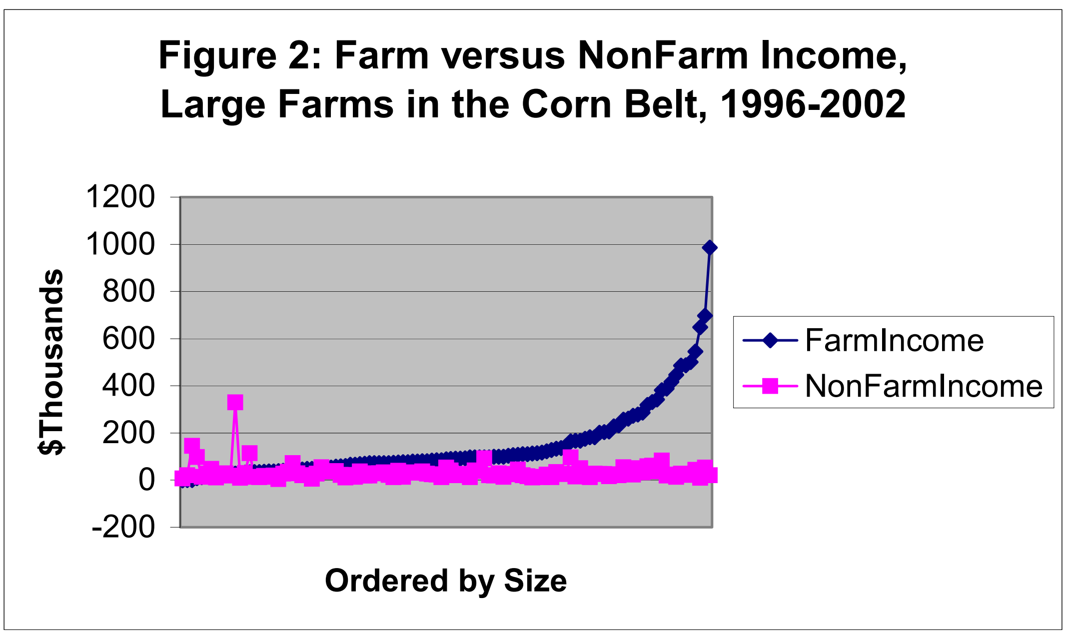
Figures 3 and 4 compare land values in the panel of farms with total farm net worth. Comparing the two figures shows that the total net worth of small farms is about three times the value of land, while that ratio is evidently smaller in the large farms. One supposition is that there are economies of size, so that larger farms spread barns, machinery and other fixed capital across a larger land base, and thus do not have as much extra fixed capital (and farm wealth as we define it) as do the smaller farms. The mean value for the small farms was $32,900 in land value versus $268,800 in total assets, which yields a higher ratio of total net worth to land value than in the large farms, which was at $344,500 in land value versus $1.428 million in total farm net worth. One interesting feature is that this ratio seems to jump at the largest levels of net worth, so there may be something systematically different in the capital-land ratios for the largest farms, and it appears that added investment in nonland capital is required at these higher levels.

Finally, we compare the values for farm household versus nonfarm net worth for these two farm sizes. In both figures 5 and 6, the farm net worth grows in an S – shaped pattern, implying that there is considerable diversity in wealth for any size of farm. In contrast, there is only a small upward slope in the level of nonfarm wealth found in these figures, suggesting that nonfarm wealth is not where farm households really put resources in a correlated way with the level of farm wealth. Thus the tie between these two sources of wealth would not appear on the face of it to be managed jointly by most farm households. In term of averages within these two groups, the small farm households had $268,700 in farm assets versus $83,300 in non-farm assets, while the largest farm households had $1.429 million in farm wealth but only $99,700 in nonfarm wealth.



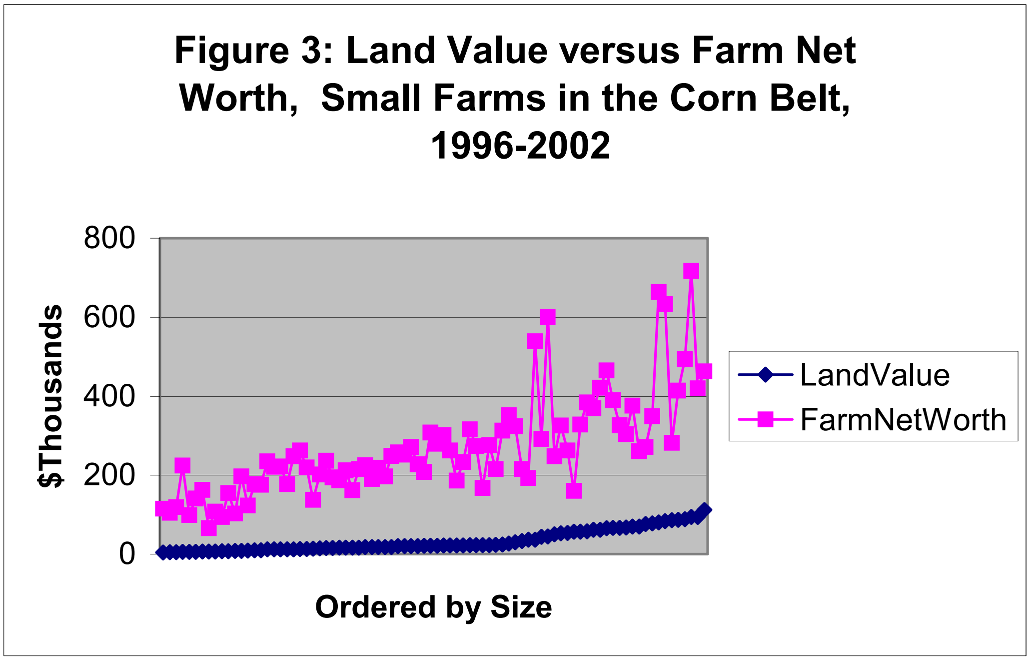

**Source: USDA-ARMS**

Farms refers to the definition in table 1.

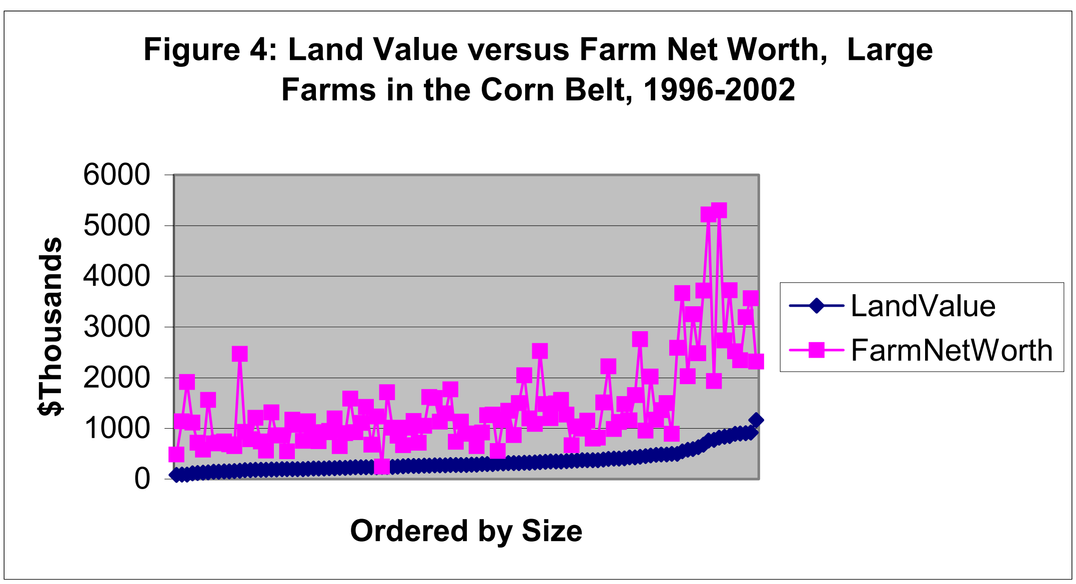



**Source: USDA-ARMS**

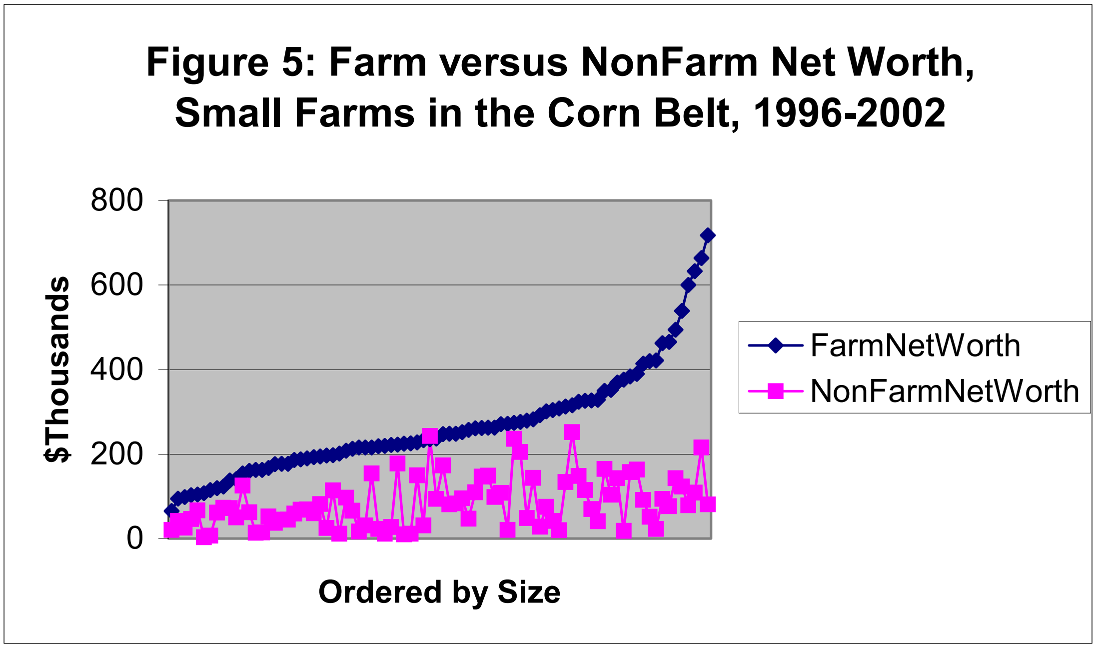
Farms refers to the definition in table 1.



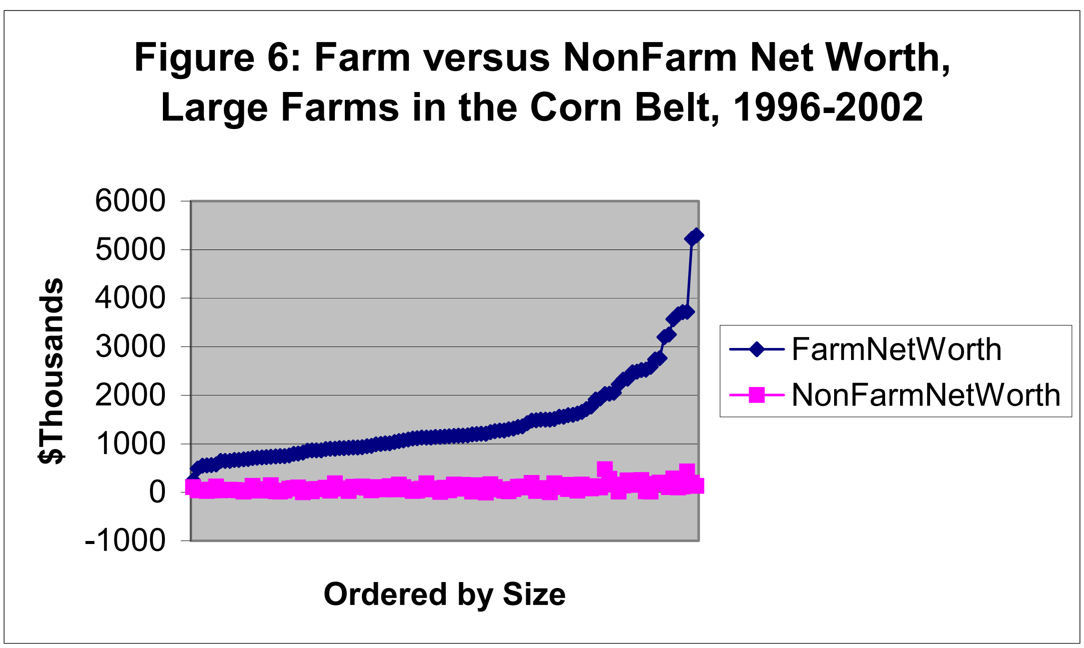

**Source: USDA-ARMS**
Farms refers to the definition in table 1.




**Source: USDA-ARMS**
Farms refers to the definition in table 1.




**Source: USDA-ARMS**
Farms refers to the definition in table 1.




**Source: USDA-ARMS**
Farms refers to the definition in table 1.

## MODEL SPECIFICATION

The estimation strategy at this point is to estimate a five-equation system consisting of equations for farm and nonfarm income, farm household and nonfarm wealth, and also land value. This system is listed without elaboration in the Appendix. We view in detail the two equations related to the determinants of farm household net worth, which that are listed below. To make these equations truly investment equations as indicated in the literature review, we would need to take differences, make some adjustments for depreciation and also incorporate restrictions on dynamic investment behavior from the literature. These are topics for future research. This acts a first approximation to the investment model that we will specify.

$$\begin{aligned}(off\ farm\,wealth)_{it} = \beta_{10} + \beta_{11}(land\,value)_{it} + \beta_{12}(non\ farm\,income)_{it} + \\ \beta_{13}(on\ farm\,income)_{it} + \beta_{14}(returns\ on\ stocks)_{it} \\ \beta_{15}(returns\ on\ bonds)_{it} + \beta_{16}(credit\ card\ rates)_{it} + \\ + \beta_{17}(Dotcom)_{it} + \beta_{18}(Small\ farms)_{it} + \varepsilon_{1it}\end{aligned} \tag{4}$$

$$\begin{aligned}(on\,farm\,wealth)_{it} = \beta_{20} + \beta_{21}(non\,farm\,income)_{it} + \\ \beta_{22}(on\,farm\,income)_{it} + \beta_{23}(returns\,on\,stocks)_{it} \\ \beta_{24}(returns\,on\,bonds)_{it} + \beta_{25}(credit\,card\,rates)_{it} + \\ + \beta_{26}(Dotcom)_{it} + \beta_{27}(Small\,farms)_{it} + \varepsilon_{1it}\end{aligned} \tag{5}$$

The first equation we examine (Eq. 5) explores the determinants of farm household net worth, and includes a series of explanatory variables related to cash flow, such as farm income and nonfarm income, which can enhance net worth if retained and not consumed. Additionally, land value is included as a proxy for a main component of farm net worth. It is hypothesized in our model that farm household net worth should grow through additional investment and through higher yields from returns on assets in place, so a series of rates of return from the general economy are added. (These are also the types of returns we will use to observe how investment is directed). We also add a dummy variable for small farm households to account for possible structural differences in a very simplified way, and one that attempts to account for the abrupt reversal of fortunes in investments after the technology boom in the late 1990s. The second equation essentially explores the same possibilities as those thought to determine the level of nonfarm income, but leaves out land value, as that is mainly related to farm income.

## ECONOMETRIC METHODS AND RESULTS

Because of unobservable individual cohort effects, the need to make inferences beyond the sample of cohorts in the study, and the presence of time invariant regressors, we use the error-components 3SLS estimator, an extension of the much under-utilized but powerful Hausman-Taylor approach. (Later we will compare FE3SLS and EC2SLS, and a balanced version of the data). The empirical system is estimated using the approach outlined by Baltagi and Chang (2000, *Econometric Theory*, Vol. 16, pp. 269-279). Based on their Monte Carlo experiments, they concluded that the GLS-based error-components 3SLS estimator "performs quite well with incomplete panels and are recommended in practice." (p. 269) Moreover, they cautioned applied economists to avoid 'balancing' data as the "loss in root mean squared error can be huge." (p. 278).

The residuals of each $j^{\text{th}}$ equation are taken to be the form $\varepsilon_{jit} = \eta_{ji} + \theta_{jit}$, where the subscript *i* represents cohort and *t* represents year. This error-components structure is also called a one-way random effects model where the random, unobservable individual cohort effects are represented by the component $\eta_{ji}$ in the $j^{\text{th}}$ equation. Because of the need to make inferences beyond the sample of cohorts in the study and due to the cross-equation contemporaneous correlation among the $\varepsilon_{jit}$ terms, an error-components three-stage least-squares (EC3SLS) estimator is adopted for the empirical system (Cornwell et al., 1992). Since data from the ARMS survey were missing for various cohorts in the sample period from 1996 to 2002, the pseudo-panel data set is necessarily incomplete or unbalanced (i.e., a different length of time series data for each cohort such that $T_i \neq T \;\; \forall i = 1,...,52$ ). If the data were balanced, $\sum_{i=1}^{52} T_i = NT = 364$ , but for our case study $\sum_{i=1}^{52} T_i = 352$ . Thus, the approach outlined by Baltagi and Chang (2000) to obtain the EC3SLS estimator for the case of unbalanced panel data is implemented. Based on their Monte Carlo experiments, Baltagi and Chang (2000) concluded that GLS-based error-components 2SLS and 3SLS estimators "perform quite well with incomplete panels and are recommended in practice." (p. 269) Moreover, they cautioned applied economists to avoid 'balancing' data as the "loss in root mean squared error can be huge." (p. 278) It is noted this structural model is identified with respect to order and rank conditions (Bhargava). It is noted that all non-endogenous variables are used as the instruments in each of the three equations. Feasible estimation will follow Baltagi (1980, 1981, 2001), Hsiao (2002), Kinal and Lahiri (1993) and Vickner and Davies (1998).

The results are given in table 3. The first equation shown in that table (Farmland value) contains mostly the expected responses. Higher land values are associated with higher farm household net worth on farms, as is higher farm income. However, the larger the nonfarm income, the lower the value of farm household assets. As this value includes off farm labor income, this may simply be an association of small farms and the choice to undertake off farm work. If not, then this is clearly an interesting result, in that farm households that have larger amounts of nonfarm income clearly are related to less net worth in farming.

One of the most interesting parts of this model is that the rates of return in the nonfarm sector seem to have little effect on the level of farm household wealth, and none of the values for rates of return are significant at all. This suggests that increased performance in the general capital markets has little impact on the development of farm wealth (table 3). The positive value on the small farm dummy variable is somewhat surprising in that it suggests that small farms, conditioned on all other effects, have a higher farm household net worth than do the larger farms. One interpretation of this value that makes sense is that land value is already netted out in the regression and was significant, so that small farms have more non-land assets on their operations, perhaps actually leading to less efficient use of capital. This was seen quite clearly in the earlier section describing the data.

Some values of the coefficients are informative as well. First, a one-dollar change in land value is associated with an increase in farm household net worth of $2.64. This seems high, as the literature suggests that land is 65-70% of total farm household assets, but our results show a much lower average level of land value, even though we are comparing to household net worth and not assets. Nonetheless, the incremental contribution of land to net worth suggests that a one-dollar increase in land is associated with a net worth 2.64 times higher, or that land accounts for only about twenty percent of on-farm net worth, which is different than the conventional wisdom but it is consistent with our data. The farm income coefficient is nearly 6.0, suggesting that, other things being equal, farm income could completely double the level of farm household assets in six years, as one dollar of farm income is associated with six dollars of farm household net worth. This also implies about a 16.7% return on net worth. Thus, this sector's returns are very compatible with return on equity in the general economy.

The second equation (Eq. 4) is nearly the opposite of the farm household wealth model (Eq. 5). Both nonfarm income and farm income have positive and significant effects on the level of nonfarm income, although the amounts are far smaller than their contribution to farm household wealth, as each dollar of increased farm or nonfarm income adds less than a dollar to nonfarm assets.  This suggests mostly, as we have explored earlier in the data, that the level of nonfarm assets is much smaller than the level of farm assets.

The relationship between the returns to different asset classes is also quite interesting and informative in the second equation.  All are significant, and give quite different outcomes depending on asset class.  The returns on stocks have a strong positive effect on the value of nonfarm assets (and presumably would lead to more investment as well).  Negative values occurred with the increased returns on bonds and credit cards, perhaps suggesting mostly that higher interest rates led to periods where nonfarm assets performed poorly. (These are in proportional units, so that a one-unit increase is a 100 percent increase in the returns of one of these assets.)

To further determine the general pattern of returns across the economy, we added a "dotcom" variable that was zero before 2000 and one thereafter, in an attempt to show the rise and fall of the technology boom.  This showed a positive value for the post-dotcom era, suggesting that nonfarm wealth was in assets other than the stock markets, which grew despite the retrenchment in that market.  Again, we added a small farm dummy variable to see if behavior was systematically different for the small farms, and the value was nearly significant and positive, but the magnitude was very small.

## CONCLUSIONS

We stress here once again, as we have throughout the paper, this analysis is not exactly compatible at present with an investment model, which would look more precisely at the changes in wealth, account for depreciation and perhaps include restrictions from investment theory.

Nonetheless, if the relationships hold up when we make these changes, we expect to see a somewhat separated farm investment process, which is less tied to the performance of financial assets in the general economy than might be expected, but is highly related to the ability to leverage wealth from farm income and land values. Farmers thus do not appear to use their wealth from off farm sources to finance farm operations to a significant degree. Also, it may be that higher values of farm income and land values are associated with farms that perform better over the long run. Consequently, higher farm income and land values during one era (1996-2002) might be good indicators of longer-run performance and perhaps identify those farms households that are more efficient. The behavior of the smaller class of assets, those that are nonfarm, seems to be reasonably rational but it may well be that they are not managed very aggressively.

## REFERENCES


Bruce L. Ahrendsen, Robert N. Collender, and Bruce L. Dixon. "An Empirical Analysis of Optimal Farm Capital Structure Decisions." *Agricultural Finance Review*, Vol. 54, 1994, pp. 108-119.

Hans Andersson, S. Ramamurtie, and Bharat Ramaswami, "Labor income and risky investments: can part-time farmers compete*?" Journal of Economic Behavior & Organization* Vol. 50, (2003) 477-493.

Baltagi, B.H. and Y.J. Chang. "Simultaneous Equations with Incomplete Panels." *Econometric Theory*. 16(2000):269-279.

Baltagi, B.H. "On Seemingly Unrelated Regression with Error Components." *Econometrica*. 48(1980):1547-1551.

____, "Simultaneous Equations with Error Components." *Journal of Econometrics*. 17(1981):189-200.

____, *Econometric Analysis of Panel Data*. 2nd Edition. New York, NY: John Wiley & Sons, Ltd., 2001.

Barten, A.P., and C. Vanloot. "Price Dynamics in Agriculture: An Exercise in Historical Econometrics." *Economic Modelling* 13(July 1996):315-331.

Bhargava, A. "Identification and Panel Data Models with Endogenous Regressors." *Review of Economic Studies*. 58(1991):129-140.

Blank, Steven C., Kenneth W. Erickson, Charles B. Moss, and Richard Nehring. "Agricultural Profits and Farm Household Wealth." *American Journal of Agricultural Economics* 86 (Number 5, 2004):1299-1307.

Chambers, R.G. and U. Vasavada. "Testing Asset Fixity Theory and the Overproduction Trap: Comment." *American Journal of Agricultural Economics* 69(May 1987):392-94.

Chavas, J.-P., and M.T. Holt. "Economic Behavior Under Uncertainty: A Joint Analysis of Risk Preferences and Technology." *Review of Economics and Statistics* 78(May 1996):329-335.

Chavas, Jean-Paul. "Production and Investment under Sunk Cost and Temporal Uncertainty." *American Journal of Agricultural Economics* 76 (February 1994): 114-127.

Cornwell, C., P. Schmidt and D. Wyhowski. "Simultaneous Equations and Panel Data." *Journal of Econometrics*. 51(1992):151-181.

Deaton, Angus. "Panel Data from Time Series Cross-Sections," *Journal of Econometrics*. 30 (1985): 109-126.

Deaton, Angus. "Saving and Liquidity Constraints." *Econometrica*, Vol. 59, No. 5 (Sep., 1991), 1221-1248.

Guiso, Luigi, Tullio Japelli, and Daniele Terlizzese. "Income Risk, Borrowing Constraints, and Portfolio Choice." *The American Economic Review*. Vol. 86, No.1, March 1996, pp. 158-172.

Gutierrez, Luciano. "Borrowing Constraints and the Agricultural Investment Decision Process." *Agribusiness*, Vol. 18 (1) 101-114 (2002).

Heshmati A. and S. Kumbhakar. "Estimation of Technical Efficiency in Swedish Crop Farms: A Pseudo-Panel Data Approach," *Journal of Agricultural Economics* 48, 1 (1992): 22-37.

Hochguertel, Rob Alesse and Arthur van Soest. "Saving Accounts versus Stocks and Bonds in Household Portfolio Allocation." *Scandinavian Journal of Agricultural Economics* 99(1), 81-97, 1997.

M.T. Holt. "A Linear Approximate Acreage Allocation Model." *Journal of Agricultural and Resource Economics*. 24(1999):383-397.

Holt, Matthew T. and Jean-Paul Chavas. "The Econometrics of Risk under Incomplete Markets" in *A Comprehensive Assessment of the Role of Risk in U.S. Agriculture*. Richard E. Just and Rulon D. Pope, Editors, Kluwer Academic Publishers, Boston (2002): 143-166.

Hoppe, R. and J. MacDonald. *America's Diverse Family farms: Assorted Sizes, Types, and Situations*. Economic Research Service Agriculture Information Bulletin No. 769, http://www.ers.usda.gov/publications/aib769/, May 2001.

Hsiao, C. *Analysis of Panel Data*. 2nd Edition. Cambridge: Cambridge University Press, 2002.

Kinal, T. and K. Lahiri. "On the Estimation of Simultaneous-Equations Error-Components Models with an Application to a Model of Developing Country Foreign Trade." *Journal of Applied Econometrics*. 8(1993):81-92.

Lagerkvist, Carl Johan. "Agricultural policy uncertainty and farm level adjustments-the case of direct payments and incentives for farmland investment." *European Review of Agricultural Economics* Vol. 32 (1) pp. 1-23.

Mishra, Ashok K. et al. *Income, Wealth, and the Economic Well-Being of Farm Households*. USDA-Economic Research Service, Agricultural Economic Report Number 812. July 2002.

Mishra,Ashok K. and Mitchell J. Morehart. "Off-Farm Investment of Farm Households: A Logit Analysis. " *Agricultural Finance Review*, Vol. 61, No. 1, 2001, pp. 87-101.

Charles B. Moss, Allen M. Featherstone and Timothy Baker. "Agricultural Assets in an Efficient Multiperiod Investment Portfolfio." *Agricultural Finance Review*, Vol. 47, 1987, pp. 82-94.

Vasavada, A. and R. Chambers. "Investment in U.S. Agriculture*." American Journal of Agricultural Economics* 72(November 1990):924-34.

Verbeek, M. and T. Nijman. "Can Cohort Data Be Treated as Genuine Panel Data*"" Empirical Economics* 17 (1992): 9-23.

Weersink, A. and L.W. Tauer. "Regional and Temporal Impacts of Technical Change in the U.S. Dairy Sector." American Journal of Agricultural Economics 72(November 1990):924-34.

Vickner, S.S. and S.P. Davies. "Comment: On the Estimation of Simultaneous-Equations Error-Components Models with an Application to a Model of Developing Country Foreign Trade." *Journal of Applied Econometrics*. 13(1998):671.

Wilcox, Walter W. "Capital in Agriculture." *Quarterly Journal of Economics*, Volume 58, Issue 1 (Nov.,1943), 49-64.

Zilberman, David. "Risk Aversion" Chapter 5, lecture notes. 2002. Department of Agricultural and Resource Economics, University of California-Berkeley.

| Table 3. EC3SLS Estimators for Equations 1-5: Farmland value, FarmIncome, FarmNetWorth, NonFarmIncome, and NonFarmNetWorth | | | | |
|---|---|---|---|---|
| Farmland value equation | | | | |
| Variable | Estimate | Std. Deviation | *t*-Value | Pr>\|t\| |
| Interest rate | 170.7554 | 26.4999 | 6.4436*** | 0.0000 |
| Productivity | 12.4578 | 7.7783 | 1.6016 | 0.1102 |
| GovernmentPayments | 2.2402 | 0.2230 | 10.0451*** | 0.0000 |
| PopDen | 0.3028 | 0.0835 | 3.6283** | 0.0003 |
| SmallFarm | -178.9288 | 19.4868 | -9.1821*** | 0.0000 |
| FarmIncome equation | | | | |
| Interest rate | 54.6191 | 14.8129 | 3.6873** | 0.0003 |
| FarmNetWorth | -0.0732 | 0.0328 | -2.2309 | 0.0263 |
| GovernmentPayments | -1.1450 | 0.1486 | -7.7057*** | 0.0000 |
| HumanCapitaEduc | 476.2953 | 79.3831 | 6.0000*** | 0.0000 |
| SmallFarm | -54.8815 | 13.3398 | -4.1141*** | 0.0000 |
| | | | | |
| FarmNetWorth (Eq. 5) | | | | |
| Interest rate | -471.0953 | 903.5948 | -0.5214 | 0.6025 |
| FarmlandValue | 2.6425 | 0.2626 | 10.0617*** | 0.0000 |
| NonFarmIncome | -1.7535 | 0.5642 | -3.1078* | 0.0020 |
| FarmIncome | 5.9351 | 0.3200 | 18.5495*** | 0.0000 |
| ReturnStocks | 1036.1908 | 1111.5286 | 0.9322 | 0.3519 |
| ReturnBonds | -687.8473 | 687.0669 | -1.0011 | 0.3175 |
| CreditCard | -208.3659 | 7234.8458 | -0.0288 | 0.9770 |
| DotCom | 495.5060 | 415.3504 | 1.1930 | 0.2337 |
| SmallFarm | 501.4240 | 103.8651 | 4.8276*** | 0.0000 |
| NonFarmIncome | | | | |
| Interest rate | 9.4194 | 4.0934 | 2.3011 | 0.0220 |
| Wages & Salaries | 1.0357 | 0.0696 | 14.8794*** | 0.0000 |
| Consumption | 0.0004 | 0.0862 | 0.0043 | 0.9965 |
| PopDen | 0.0007 | 0.0132 | 0.0563 | 0.9552 |
| HumanCapitalEduc | 3.4254 | 5.3636 | 0.6387 | 0.5235 |
| SmallFarm | 6.0599 | 3.1690 | 1.9122 | 0.0567 |
| NonFarmNetWorth (Eq. 4) | | | | |
| Interest rate | 984.4757 | 197.9416 | 4.9736*** | 0.0000 |
| NonFarmIncome | 0.5044 | 0.1124 | 4.4875*** | 0.0000 |
| FarmIncome | 0.3324 | 0.0390 | 8.5127*** | 0.0000 |
| ReturnStocks | 1135.9247 | 205.2982 | 5.5330*** | 0.0000 |
| ReturnBonds | -956.8056 | 106.9157 | -8.9492*** | 0.0000 |
| CreditCard | -7652.5388 | 1552.8557 | -4.9280*** | 0.0000 |
| DotCom | 431.1902 | 71.1956 | 6.0564*** | 0.0000 |
| SmallFarm | 12.6965 | 8.4601 | 1.5008 | 0.1343 |

$R^2 = 0.7830$

Source: U.S. Department of Agriculture, Economic Research Service, “BEMN” ARMS dataset.