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The Food and Agricultural Policy Simulator

Estimation of Farm Production Expenses

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Abstract

This report details empirical estimation of farm production expenses, which make up one component of farm income accounts. The model of production expenses forms part of the Food and Agricultural Policy Simulator, a large-scale econometric model of the agricultural sector used to examine the effects of proposed policy changes. This econometric model makes multiyear projections of supply, demand, and prices for many U.S. crops and animal products. This bulletin presents the theoretical background for the estimated equations for expenses, discusses the reliability of estimates, defines variables, and explains the equations chosen for 15 expense categories.

Keywords: Farm income, agricultural production expenses, farm expenditure budgets, Food and Agricultural Policy Simulator, FAPSIM, econometric estimation, cost-of-production data, policy modeling

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Introduction

Farm income statistics reported by the U.S. Department of Agriculture (USDA) have long been used to measure the well-being of the farm sector. For this reason, it is important to have an empirical model of the farm income accounts that can be used to examine how the different components of these accounts change under various assumptions about the economic conditions affecting the sector.

This report focuses on empirical modeling of the production expense component of farm income accounts. The overriding consideration in constructing this model was practicality. USDA must routinely generate forecasts (or baseline estimates) that are used for budgetary purposes, based on the latest information available about the economic factors affecting the agricultural sector. Wherever possible, the empirical model presented here is tied to the forecasts used as input in this baseline estimation process.

USDA farm income projections ultimately must be consistent with the assumptions used to establish the baseline. Because the real focus of the baseline process is the Federal budget, the forecasts generated in this process may not be entirely ideal for estimating farm income. We therefore used an approach based on a number of simplifying assumptions that allow the user to forecast farm production expenses with the available baseline information.

The proposed model of farm production expenses is designed to be a component of a larger econometric model of the agricultural sector. This larger model, known as the Food and Agricultural Policy Simulator (FAPSIM), estimates many of the same agricultural economic indicators that are generated during the baseline process (Salathe, Price, and Gadson, 1982).[1] Once a baseline has been established, FAPSIM is routinely recalibrated to be consistent with the baseline estimates. Because FAPSIM is recalibrated to each new baseline, the model generates farm production expenses consistent with the baseline assumptions.

This report presents a theoretical framework for modeling the different components of expenses, describes the data, and outlines the estimation techniques used. Empirical estimates are discussed and validation statistics for the model equations are also presented.

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[1]References, denoted by last name of author and date of publication, are listed in the References section at the end of this report.

Theoretical Framework

Acreage planted and animal numbers are among the quantities that are endogenously estimated within the FAPSIM framework but are exogenous to the farm production expense model. These quantities are used to estimate input expenses. Purchased inputs are assumed to be used in constant proportions to acres planted and livestock produced. We describe below the theoretical model used to justify this approach.

If the aggregate production function for agricultural products can be characterized as a Leontief function, inputs are used in fixed proportions, regardless of input prices. Under this assumption, the estimates of input use generated by FAPSIM may be used to obtain estimates on the use of other inputs not directly estimated by the model. In addition, the Leontief function implies that inputs are used in fixed proportions to final production levels. Thus, estimates of production generated by the model may also be used to estimate input use.

The Leontief production function may be characterized formally as follows: Let

$$i \in I$$

where

$$I = \{1, \ldots, m\}$$

denotes the index set for the m distinct commodities produced, and let

$$j \in J$$

where

$$J = \{1, \ldots, n\}$$

denotes the index set for the n distinct inputs used in the production process. If we assume that the technical coefficients in the production function remain constant over time, then the Leontief production function is given by the equation:

$$q_{it} = \min(\alpha_{i1} \cdot x_{i1t}, \ldots, \alpha_{in} \cdot x_{int}), \tag{1}$$

where

q_{it} = production of commodity i at time t,

x_{ijt} = quantity of input j used to produce commodity i at time t, and

α_{ij} = fixed technical coefficient, equal to the number of units of commodity i produced per unit of input j.

Let $\mathbf{q}_t = (q_{1t}, \ldots, q_{mt})$, and let $\mathbf{w}_t = (w_{1t}, \ldots, w_{nt})$ where w_{jt} represents the per-unit input cost of input j at time t. Then, the cost-minimizing demand for input j in the production of commodity i is:

$$\begin{aligned} x_{ijt} &= f_{ij}(q_{it}, \mathbf{w}_t) \\ &= f_{ij}(q_{it}) \\ &= (1/\alpha_{ij}) \cdot q_{it}, \end{aligned} \tag{2}$$

which implies that x_{ij} is used in a fixed proportion to q_i for all values of $\mathbf{w}_t$. Furthermore, for any j, k $\in$ J, equation (2) implies that:

$$\begin{aligned} f_{ik}(q_{it}) &= (1/\alpha_{ik}) \cdot q_{it} \\ &= (\alpha_{ij}/\alpha_{ik}) \cdot (1/\alpha_{ij}) \cdot q_{it} \\ &= (\alpha_{ij}/\alpha_{ik}) \cdot f_{ij}(q_{it}), \end{aligned} \tag{3}$$

which indicates that x_{ik} is used in a fixed proportion to x_{ij} in the production of i.[2] By definition, total production expenses associated with input j at time t are given by the equation:

$$C_j(\mathbf{q}_t, \mathbf{w}_t) \quad = \quad \Sigma_{i \in I}\, w_{jt} \cdot f_{ij}(q_{it}). \tag{4}$$

Because of aggregation problems, the empirical model may not be based directly on equation (4). Cost information is not usually reported for every unique input used in the production process. For example, seed expenses are reported as a single aggregate cost number in the farm income accounts. Obviously, corn seed is not the same input as, say, cotton seed, although the input expense associated with each of these seed types affects the aggregate seed expense. Therefore, we need to be able to aggregate across inputs that are used for similar purposes. In addition, price information is not readily available on individual inputs, so we generally must rely on aggregate price indices in the empirical model.

If we let R denote a subset of J, then the aggregate expense associated with the inputs in set R is expressed as:

$$\begin{aligned} C_R(\mathbf{q}_t, \mathbf{w}_t) &= \Sigma_{j \in R}\, C_j(\mathbf{q}_t, \mathbf{w}_t) \\ &= \Sigma_{j \in R}\, \Sigma_{i \in I}\, w_{jt} \cdot f_{ij}(q_{it}). \end{aligned} \tag{5}$$

If we let t = 0 denote a particular base year, then:

$$C_R(\mathbf{q}_t, \mathbf{w}_t) \quad = \quad \Sigma_{j \in R}\, (w_{jt}/w_{j0}) \cdot [\Sigma_{i \in I}\, w_{j0} \cdot f_{ij}(q_{it})]. \tag{6}$$

For any fixed value of j, the term in brackets defines the total cost of the input j valued at the base year input prices. The price ratio, w_{jt}/w_{j0}, adjusts these costs to a current year basis. Since individual price indices of this type usually are not available, the empirical results are based on aggregate price indices. The Laspeyres price index for the inputs in the set R is:

$$W_{Rt} \; = \; \{\Sigma_{j \in R}\, w_{jt} \cdot [\Sigma_{i \in I}\, f_{ij}(q_{i0})]\} / \{\Sigma_{j \in R}\, w_{j0} \cdot [\Sigma_{i \in I}\, f_{ij}(q_{i0})]\}. \tag{7}$$

We will approximate the relationship in equation (6) by:

$$C_R(\mathbf{q}_t, \mathbf{w}_t) \quad = \quad W_{Rt} \cdot \{\Sigma_{j \in R}\, [\Sigma_{i \in I}\, w_{j0} \cdot f_{ij}(q_{it})]\}. \tag{8}$$

The term in braces is the cost of production associated with all of the inputs in the set R valued at the base year prices. Multiplying by the Laspeyres price index for the inputs in R results in an approximation of these production costs in terms of current year prices. Observe that if there is only one element in the set R, then equation (8) is identical to equation (6).

Notice, too, that the Laspeyres quantity index for the inputs in the set R is given by:

$$X_{Rt} \quad = \quad \{\Sigma_{j \in R}\, w_{j0} \cdot [\Sigma_{i \in I}\, f_{ij}(q_{it})]\} / \{\Sigma_{j \in R}\, w_{j0} \cdot [\Sigma_{i \in I}\, f_{ij}(q_{i0})]\}. \tag{9}$$

Then equation (8) implies that:

$$C_R(\mathbf{q}_t, \mathbf{w}_t) \quad = \quad W_{Rt} \cdot X_{Rt} \cdot \{\Sigma_{j \in R}\, [\Sigma_{i \in I}\, w_{j0} \cdot f_{ij}(q_{i0})]\}. \tag{10}$$

Thus, the specifications used in the empirical results are the product of the Laspeyres price and quantity indices for the inputs as well as the total production costs associated with the inputs in R for the base period.

Equation (8) is useful only if we have estimates of utilization for each input. Since FAPSIM does not generate this type of detailed information, we use equations (2) and (3) instead. We first partition the set I into two disjoint sets, S (for crops) and T (for livestock products). By equation (3), we may write:

$$f_{ij}(q_{it}) \quad = \quad (\alpha_{ij(i)}/\alpha_{ij}) \cdot f_{ij(i)}(q_{it}) \tag{11}$$

---

[2]See Chambers (1988) for a derivation of equations (3) and (4).

for any $i \in S$, where $j(i) \in J$. In practice, $j(i)$ typically is chosen to be acreage planted. Equation (2) similarly implies that:

$$f_{ij}(q_{it}) = (1/\alpha_{ij}) \cdot q_{it} \tag{12}$$

for any $i \in T$. Combining equations (8), (11), and (12), we obtain:

$$\begin{aligned} C_R(q_t, w_t) = \; & W_{Rt} \cdot \{\Sigma_{j \in R} [\Sigma_{i \in S} w_{j0} \cdot (\alpha_{ij(i)}/\alpha_{ij}) \cdot f_{ij(i)}(q_{it})]\} \\ & + W_{Rt} \cdot \{\Sigma_{j \in R} [\Sigma_{i \in T} w_{j0} \cdot (1/\alpha_{ij}) \cdot q_{it}]\}. \end{aligned} \tag{13}$$

If information were available on all of the variables included in equation (13), the equation could be used directly for estimating the farm production expenses associated with each category of inputs. This, unfortunately, is not the case. Equation (13) requires detailed cost-of-production data for every type of production enterprise in agriculture. USDA reports this type of information for only selected enterprises. The most notable omissions are poultry, fruits, and vegetables. For the empirical specification, expense information based on only a subset of the total commodities is used to create a proxy for total production expenses associated with each category of inputs ($S \cup T \neq I$ in equation (14)). The empirical model is represented by equation (14), where $\hat{\alpha}$ and $\hat{\beta}$ are parameter estimates. If the commodities omitted from equation (14) did not contribute to the production expenses associated with a particular input, then $\hat{\alpha}$ and $\hat{\beta}$ would approximately equal 0 and 1, respectively.

$$C_R(q_t, w_t) = \hat{\alpha} + \hat{\beta} \cdot \left[\begin{aligned} & W_{Rt} \cdot \{\Sigma_{j \in R} [\Sigma_{i \in S} w_{j0} \cdot (\alpha_{ij(i)}/\alpha_{ij}) \cdot f_{ij(i)}(q_{it})]\} \\ + & W_{Rt} \cdot \{\Sigma_{j \in R} [\Sigma_{i \in T} w_{j0} \cdot (1/\alpha_{ij}) \cdot q_{it}]\} \end{aligned} \right]. \tag{14}$$

Data Considerations

The model combines available data on unit costs, area and production levels, and prices paid indices to break out 15 expense categories. Table 1 presents the farm production expenses for calendar year 1989. It shows which components of the expense categories are most important in relative terms and how the different expense components are aggregated for the empirical model. Most of the categories are taken directly from USDA reports without additional aggregation. The only category that may cause some confusion is the one labeled "miscellaneous expenses" in table 1. This category includes not only miscellaneous expenses as reported by USDA (1991a), but marketing, storage, and transportation expenses as well.

Regarding data for the exogenous variables in the model, we will touch only on the data requirements for the model equations based on equation (14). Using the notation developed in the previous section, equation (14) implies that the farm production expenses for inputs in the set R can be based entirely on the following sets of variables:

(a) $w_{j0} \cdot (\alpha_{ij(i)}/\alpha_{ij})$ for $i \in S$, and
$w_{j0} \cdot (1/\alpha_{ij})$ for $i \in T$;

(b) $f_{ij(i)}(q_{it})$ for $i \in S$, and
q_{it} for $i \in T$; and

(c) W_{Rt}.

The variables in (a) have a simple interpretation. The term

$$w_{j0} \cdot (\alpha_{ij(i)}/\alpha_{ij})$$

is the cost of input j per unit of input j(i) used in the production of commodity i. Similarly, the term

$$w_{j0} \cdot (1/\alpha_{ij})$$

Table 1—Farm production expenses for calendar year 1989[1]

Item	Amount	Share
	Million dollars	*Percentage of total expenses*
Farm origin inputs:		
Feed purchases	22,722	15.9
Livestock purchases	12,983	9.1
Seed purchases	3,733	2.6
Total	39,438	27.7
Manufactured inputs:		
Fertilizer and lime	7,554	5.3
Pesticides	5,721	4.0
Fuel, oil, and electricity	7,421	5.2
Total	20,696	14.5
Interest:		
Non-real estate	7,480	5.2
Real estate	7,643	5.4
Total	15,123	10.6
Contract and hired labor	11,887	8.3
Other operating expenses:		
Repairs and maintenance	7,794	5.5
Machine hire and custom work	2,739	1.9
Miscellaneous expenses	14,070	9.9
Total	24,603	17.3
Other overhead expenses:		
Capital consumption	17,310	12.1
Property taxes	5,328	3.7
Net rent paid to NOLL[2]	8,181	5.7
Total	30,819	21.6
Total production expenses	142,566	100.0

[1]Reflects data that include operator dwellings.
[2]NOLL = Nonoperator landlords.
Source: USDA (1991a).

is the cost of input j per unit of commodity i produced. Both cost terms will prove to be important in the analysis. Cost-of-production data for crops are usually reported on the basis of cost per planted acre, whereas cost-of-production data for livestock are usually reported on the basis of cost per unit of production. Cost data were obtained from McElroy, Ali, Dismukes, and Clauson (1989), Betts (1987), and Shapouri, Bowe, Crawford, and Jessee (1990).

In the empirical results that follow, the variables in (b) represent data on planted acreage and data on animal numbers or production. All of these variables are generated endogenously within the FAPSIM framework.

For the most part, the prices paid indices (the variables in (c)) used in the empirical analysis are exogenous to FAPSIM. The historical data used for the empirical analysis were obtained from reports published by USDA (1990c). Forecast data also are routinely provided in the baseline process. Because prices paid are currently constructed with 1977 as the base year, the cost-of-production data for the variables in (a) also were based on 1977 data in the empirical model.

Estimation Methods

A pretest process was used to obtain the parameter estimates. The estimation procedure used annual data for 1965-89 unless data availability made this impossible. For each equation, ordinary least squares (OLS) initially was used to estimate the model parameters. In all but three equations, statistical tests indicated that first-order autocorrelation could not be rejected at the 5-percent significance level. Most of these equations were re-estimated using the maximum likelihood algorithm developed by Beach and MacKinnon (1978) to allow for an autoregressive error structure.[3]

We used the Durbin-Watson statistic to test for an autoregressive error structure in the equations (Durbin and Watson, 1950, 1951). For cases in which this statistic led to inconclusive test results, we computed the beta approximation (Durbin and Watson, 1971). In the regression results, the value reported for this statistic is the value of the distribution function evaluated at the test statistic. Finally, for cases in which the regression included a lagged dependent variable, we used Durbin's *h* statistic to test for autocorrelation in the error structure (Durbin, 1970).[4]

The following empirical results also give the t-statistics for the null hypothesis that the parameters are zero. They appear in parentheses below the parameter estimates. For cases in which the model was re-estimated to correct for autocorrelation, the asymptotic distributions used to derive the test statistics were based on the results derived by Hildreth (1969) and Dhrymes (1981).[5]

Empirical Results

We present in this section the relationships that were estimated, along with regression coefficients and test statistics.

Farm Origin Inputs

These inputs include purchased feed, livestock, and seed. Because these inputs are of farm origin, many of the determining prices and quantities are endogenous to the overall FAPSIM model.

Feed Purchases

Technically, equation (14) could be used as a basis for estimating this category of expenses. However, FAPSIM does not endogenously estimate changes in the index of prices paid by farmers for feed. If equation (14) were used to estimate feed costs, changes in feed costs would be reflected only through changes in the animal numbers when the model was used for simulation. Given this limitation, we adopted an alternative approach to model these costs.

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[3]Evidence by Judge and Bock (1978, chapter 7) indicates that this type of pretest procedure is justified.

[4]The values reported in the text for these test statistics are ones associated with the OLS regression results.

[5]Because these test statistics are based on asymptotic results, no adjustment was made for the degrees of freedom in the test statistic.

FAPSIM generates estimates of total feed use and average farm prices on a marketing year basis for corn, sorghum, barley, oats, and wheat. For soybean meal, the model estimates total domestic use and market price on a marketing year basis. Total marketing year feed cost can then be estimated by multiplying the feed use quantity by price for each of these feed components. Based on this approach, changes in feed costs would be affected both by changes in prices and by changes in demand for the individual feed items.

This approach to estimating the actual cost associated with feed purchases has two problems. First, the feed use statistics for grain include grain that is used on-farm where it is produced as well as grain that is sold through market channels. Therefore, the statistic representing total feed use will always exceed the quantity of feed actually purchased. Second, marketing year data must be converted to a calendar year basis before estimating.

The regression results were based on the following assumptions. For commodity i, let:

α_i = proportion of total feed use marketed,

β_i = proportion of total feed use associated with marketing year t-1 occurring in calendar year t (years are defined such that calendar year 1990 and marketing year 1990/91 have t = 1990),

P_{it} = price in marketing year t, and

Q_{it} = total feed demand in marketing year t.

Then, if we define:

$$C_{it} = \alpha_i[\beta_i P_{i,t-1} Q_{i,t-1} + (1 - \beta_i) P_{it} Q_{it}], \qquad (15)$$

C_{it} should approximate the total cost of feed associated with commodity i in calendar year t.

To convert the marketing year data to a calendar year basis, we estimated the proportion of the total marketing year feed use associated with each calendar year based on data for the 1975/76-1989/90 period.[6] We then averaged the results to obtain estimates of β_i in the regression equation for each of the commodities.

For each of the grains, we assumed that:

$$\alpha = \alpha_i.$$

This assumption implies that we may aggregate equation (15) across all grains to create a single variable to act as a proxy for the corresponding feed costs in the regression analysis. The constant α may then be estimated as a parameter in the regression. We used this procedure to avoid problems with multicollinearity.

Although these assumptions are open to debate, the regression results seem plausible. The coefficient on aggregate feed costs associated with grains (0.804604) is positive and less than 1, indicating that a portion of the grain is used on-farm where it is produced.[7] The exact magnitude of the coefficient is difficult to interpret, because using farm-level prices to value the grain probably understates the actual price farmers must pay to purchase feed. Purchased feed costs include processing, additives, storage, marketing, and transportation, all of which would tend to inflate the estimate of the coefficient.

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[6]The estimates for grain were based on quarterly data obtained from USDA (1991b, 1991e), whereas the estimates for soybean meal were based on monthly data obtained from USDA (1991d).

[7]According to Van Meir (1987), the proportion of grain consumed on-farm is approximately 25 percent.

Soybean meal was treated as a separate variable in the regression because it is a manufactured feed product. The regression results are somewhat surprising. *A priori*, one would expect the coefficient on the proxy for meal costs to be close to 1, because virtually all domestic soybean meal is used for feed purposes. Instead, the regression results indicate the coefficient is approximately 2.3.

This result has two possible explanations. First, the market price used to value soybean meal use may underestimate the actual retail price that farmers must pay for this product. Second, in the regression, the soybean meal variable may also act as a proxy for the feed costs associated with other manufactured feed products and feed additives. Both factors would tend to increase the estimates of the coefficients associated with soybean meal.

Regression results for feed purchase are:[1]

$$
\begin{aligned}
&[\text{feed purchases}]_t \\
&\quad = \underset{(0.238)}{157.812986} \\
&\quad + \underset{(9.557)}{0.804604} \left\{
\begin{aligned}
&0.33\,[\text{wheat price}]_{t-1}\,[\text{wheat feed use}]_{t-1} \\
&+ 0.67\,[\text{wheat price}]_{t}\,[\text{wheat feed use}]_{t} \\
&+ 0.61\,[\text{corn price}]_{t-1}\,[\text{corn feed use}]_{t-1} \\
&+ 0.39\,[\text{corn price}]_{t}\,[\text{corn feed use}]_{t} \\
&+ 0.54\,[\text{sorghum price}]_{t-1}\,[\text{sorghum feed use}]_{t-1} \\
&+ 0.46\,[\text{sorghum price}]_{t}\,[\text{sorghum feed use}]_{t} \\
&+ 0.40\,[\text{barley price}]_{t-1}\,[\text{barley feed use}]_{t-1} \\
&+ 0.60\,[\text{barley price}]_{t}\,[\text{barley feed use}]_{t} \\
&+ 0.42\,[\text{oats price}]_{t-1}\,[\text{oats feed use}]_{t-1} \\
&+ 0.58\,[\text{oats price}]_{t}\,[\text{oats feed use}]_{t}
\end{aligned}
\right\} \\
&\quad + \underset{(9.196)}{2.304366}\ \{0.01\} \left\{
\begin{aligned}
&0.72\,[\text{soymeal price}]_{t-1}\,[\text{soymeal domestic demand}]_{t-1} \\
&+ 0.28\,[\text{soymeal price}]_{t}\,[\text{soymeal domestic demand}]_{t}
\end{aligned}
\right\}
\end{aligned}
$$

Autocorrelation coefficient: 0.536575
(3.115)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1965-88
R^2	=	0.988
Durbin-Watson	=	1.082

[1]Square brackets enclose the variable names; for example, [feed purchases]$_t$. The appendix lists variable definitions. The wheat$_{t-1}$ multiplier, 0.33, corresponds to β_i from equation (15). It is the fraction of wheat feeding in marketing year$_{t-1}$ occurring in calendar year$_t$. The soymeal term includes a multiplier {0.01} to convert units.

Livestock Purchases

These expenditures include the aggregate value of inshipments of cattle, calves, hogs, pigs, sheep, and lambs purchased across State lines for feeding and breeding, and the value of all purchases of poultry (USDA, 1988). Extracting this type of information from the cost-of-production data published for different livestock enterprises proved to be impractical. As a result, the model specification for this expense category was not based on equation (14).

Because FAPSIM does not directly estimate these types of livestock marketings, we used the specification suggested by Todd (1979, pp. 32-3) to approximate the expenses associated with these purchases. We used total fed steer and heifer slaughter weighted by the price of feeder steers as a proxy for the value of farm purchases of cattle and calves. We similarly used total barrow and gilt slaughter weighted by their market price to approximate the value of purchased hogs and pigs. We included the time trend in the regression to account for changes in marketing practices over the sample period.

One drawback to this specification is that it is impossible to assess the size of the regression coefficients based on other considerations as in the feed equation. However, the estimated coefficients on the variables used as proxies for the value of farm purchases of cattle and calves, and hogs and pigs do have the anticipated sign. Moreover, the equation seems to track the historical data reasonably well.[8]

Regression results for livestock purchases are:

$[\text{livestock purchases}]_t$

$$= -436.215359$$
(-1.073)

$$+ 6.571632\ [\text{feeder steer price}]_t\ [\text{fed steer and heifer slaughter}]_t$$
(15.967)

$$+ 0.278686\ [\text{barrow and gilt price}]_t\ [\text{barrow and gilt slaughter}]_t$$
(1.187)

$$- 78.304631\ [\text{time}]_t$$
(-2.066)

Autocorrelation coefficient: 0.341500
(1.817)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1965-89
R^2	=	0.988
Durbin-Watson	=	1.339
Durbin-Watson beta	=	0.011

[8]The coefficient associated with inshipments of hogs and pigs is not statistically significant at the 5-percent level, probably because these animals contribute relatively little to this expense category. However, it should be noted that the t-statistics reported for this equation are not theoretically justified. The inclusion of the time trend is inconsistent with the assumptions used by Hildreth (1969) to obtain the asymptotic covariance matrix of the estimator.

Seed Purchases

We estimated seed costs on the basis of equation (14). The input costs of seed per acre planted for 1977 were obtained from McElroy, Ali, Dismukes, and Clauson (1989). We then used these costs as weights for the expense variable used in the regression equation. This specification represents an improvement over an earlier specification used by Todd (1979, pp. 30-2) because it is simpler. Forecasts of seed costs based on Todd's specification would require forecasts of annual seeding rates for each of the crops. The current specification avoids this problem.

The regression results indicate that the coefficient on the proxy for seed costs in the equation is greater than 1. This result is typical of what we would expect to find for any expense equation based on equation (14). As indicated earlier, the commodity coverage in the construction of the proxy is incomplete. Because not all crops have been accounted for by the proxy, this variable will tend to account for a portion of the influence of the omitted variables in the regression equation. As a result, the coefficient will tend to exceed unity.

Regression results for seed purchases are:[1]

$[\text{seed purchases}]_t$

$$= \underset{(1.988)}{266.141702}$$

$$+ \underset{(16.992)}{1.024651} \; [\text{seed price}]_t \, \{0.01\} \left\{ \begin{array}{l} \ 11.06 \; [\text{corn acreage planted}]_t \\ +\ 3.56 \; [\text{sorghum acreage planted}]_t \\ +\ 4.64 \; [\text{barley acreage planted}]_t \\ +\ 2.79 \; [\text{oats acreage planted}]_t \\ +\ 3.93 \; [\text{wheat acreage planted}]_t \\ +\ 19.72 \; [\text{rice acreage planted}]_t \\ +\ 9.48 \; [\text{soybean acreage planted}]_t \\ +\ 6.67 \; [\text{cotton acreage planted}]_t \end{array} \right\}$$

Autocorrelation coefficient: 0.604959
(3.799)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1965-89
R^2	=	0.981
Durbin-Watson	=	0.790

[1]The multiplier {0.01} converts units. The multiplier for corn acreage, 11.06, is the seed expense per acre of corn planted in the base period, 1977. It corresponds to $w_{j0} \cdot (\alpha_{ij(i)}/\alpha_{ij})$ in equation (14), and $[\text{corn acreage planted}]_t$ corresponds to $f_{ij(i)}(q_{it})$.

The fact that there are omitted variables in each of the equations based on equation (14) also has implications for the error structure of the model. To the extent that these omitted variables are serially correlated, the error structure of the disturbance term in the regression will also be serially correlated.[9] In addition, one would expect the disturbances to be positively correlated over time, because of the nature of these variables. Based on the Durbin-Watson statistic, we re-estimated the equation to allow for an autoregressive error structure.

Manufactured Inputs

Manufactured inputs include fertilizer and lime; pesticides; and fuel, oil, and electricity. The specification for the expenses in each of these three input categories is based on equation (14). As expected, the estimates of the coefficients associated with the proxy variables for production expenses are greater than unity in each of the regression equations. Also, we re-estimated each of the equations to correct for autocorrelation.

Regression results for fertilizer and lime expenses are:[1]

$$[\text{fertilizer and lime expenses}]_t$$

$$= \underset{(0.432)}{163.775378}$$

$$+ \underset{(15.780)}{1.266840} \; [\text{fertilizer and lime price}]_t \; \{0.01\} \left\{ \begin{array}{l} 35.35 \; [\text{corn acreage planted}]_t \\ + 12.36 \; [\text{sorghum acreage planted}]_t \\ + 6.82 \; [\text{barley acreage planted}]_t \\ + 5.83 \; [\text{oats acreage planted}]_t \\ + 9.41 \; [\text{wheat acreage planted}]_t \\ + 28.00 \; [\text{rice acreage planted}]_t \\ + 6.19 \; [\text{soybean acreage planted}]_t \\ + 17.80 \; [\text{cotton acreage planted}]_t \end{array} \right\}$$

Autocorrelation coefficient: 0.475832 (2.705)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1965-89
R^2	=	0.966
Durbin-Watson	=	1.157

[1]The multiplier {0.01} converts units. The multiplier for corn acreage, 35.35, is the fertilizer and lime expense per acre of corn planted in the base period, 1977.

[9]See, for example, Judge, Griffiths, Hill, and Lee (1980, p. 171) for a discussion of this issue.

Regression results for pesticide expenses are:[1]

$$
\begin{aligned}
&[\text{pesticide expenses}]_t \\
&\quad = \underset{(0.524)}{692.008845} \\
&\quad + \underset{(3.643)}{1.490517}\ [\text{chemical price}]_t\ \{0.01\} \left\{ \begin{array}{l} \ \ 8.95\ [\text{corn acreage planted}]_t \\ +\ \ 3.08\ [\text{sorghum acreage planted}]_t \\ +\ \ 1.62\ [\text{barley acreage planted}]_t \\ +\ \ 0.26\ [\text{oats acreage planted}]_t \\ +\ \ 1.14\ [\text{wheat acreage planted}]_t \\ +\ 22.20\ [\text{rice acreage planted}]_t \\ +\ \ 9.34\ [\text{soybean acreage planted}]_t \\ +\ 19.47\ [\text{cotton acreage planted}]_t \end{array} \right\}
\end{aligned}
$$

Autocorrelation coefficient: 0.965752
(18.610)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1965-89
R^2	=	0.949
Durbin-Watson	=	0.508

[1]The multiplier {0.01} converts units. The multiplier for corn acreage, 8.95, is the pesticide expense per acre of corn planted in the base period, 1977.

The equation for fuel, oil, and electricity merits special attention because this is the first instance in which the proxy variable for expenses includes a livestock component. The inclusion of livestock led to certain complications due to the existing variety of livestock operations and to the form in which the cost-of-production data were reported for these different enterprises. We used the procedure described below for each regression equation that included a livestock component in the expense variable.

Cost of production for fed cattle operations is reported on a live weight basis (Shapouri, Bowe, Crawford, and Jessee, 1990). FAPSIM endogenously estimates total fed beef production, but these estimates are on a carcass weight basis. Therefore, we used a conversion factor to convert the production data to a live weight basis.[10]

[10]The conversion factors of (1.0/0.62) for fed beef and (1.0/0.72) for pork used in the equation both were obtained from Bowe (1987).

Regression results for fuel, oil, and electricity expenses are:[1]

$$[\text{fuel, oil, and electricity expenses}]_t$$

$$= \underset{(1.773)}{1263.722556}$$

$$+ \underset{(10.248)}{1.208834} \; [\text{fuel and energy price}]_t \{0.01\}$$

$$\left\{ \begin{array}{l} \; 6.81 \; [\text{corn acreage planted}]_t \\ +\; 8.23 \; [\text{sorghum acreage planted}]_t \\ +\; 5.59 \; [\text{barley acreage planted}]_t \\ +\; 4.63 \; [\text{oats acreage planted}]_t \\ +\; 4.45 \; [\text{wheat acreage planted}]_t \\ +\; 21.97 \; [\text{rice acreage planted}]_t \\ +\; 5.61 \; [\text{soybean acreage planted}]_t \\ +\; 22.65 \; [\text{cotton acreage planted}]_t \\ +\; 0.38 \; [\text{fed beef production}]_t \{0.01/0.62\} \\ +\; 0.94 \; [\text{pork production}]_t \{0.01/0.72\} \\ +\; 10.23 \; [\text{beef cow breeding herd}]_t \\ +\; 0.20 \; [\text{milk production}]_t \{10.0\} \end{array} \right\}$$

Autocorrelation coefficient: 0.919307 (11.680)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1965-89
R^2	=	0.987
Durbin-Watson	=	1.007

[1]The multipliers in small braces, such as {0.01}, convert units. The constants 0.62 and 0.72 relate carcass weight to live weight, as discussed in the text. The multiplier for corn acreage, 6.81, is the petroleum fuel, oil, and electricity expense per acre of corn planted in the base period, 1977.

For pork, cost-of-production data are available for three types of enterprises (Shapouri, Bowe, Crawford, and Jessee, 1990). To simplify the analysis, we used only farrow-to-finish enterprise costs to construct the expense variable for pork, because this type of production enterprise is the most common. A conversion factor was needed to convert the pork production data to a live weight basis, as in the case of fed beef.

Data on cow-calf and dairy enterprises were obtained directly from Shapouri, Bowe, Crawford, and Jessee (1990) and Betts (1987), respectively. Expenses associated with poultry and egg production were ignored in constructing the proxy for expenses, because of a lack of detailed cost-of-production information for these commodities.

Interest

It proved to be impractical to use equation (14) as a basis for estimating the regression equations for interest expenses. USDA cost-of-production data for livestock enterprises do not break out both real estate and non-real estate interest payments. Rather than combine these two interest expense categories, we used an alternative specification to model these expenses.

Non-Real Estate Interest

Expenses on non-real estate interest are a function of the current and past debt that was incurred for production purposes and the terms of these loans. We adopted an ad hoc approach to model these expenses.

We included lagged interest expense as a variable in the regression equation to capture the effect of past loan activity. The corresponding regression coefficient indicates that the regression equation is dynamically stable.

Total farm cash receipts deflated by the consumer price index were included in the regression as a proxy for aggregate production in the sector. As production increases, investment should expand and producers will incur new debt to finance this increase in investment.[11] Therefore, real cash receipts were hypothesized to be positively related to interest expenses. The regression results bear out this relationship.

Regression results for non-real estate interest expenses are:

$$[\text{non-real estate interest expenses}]_t$$

$$= \underset{(-3.924)}{-2621.977263}$$

$$+ \underset{(2.107)}{3.200513}\ [\text{total cash receipts}]_t \,/\, [\text{CPI}]_t$$

$$+ \underset{(5.377)}{273.272371}\ [\text{interest rate on commercial paper}]_t$$

$$+ \underset{(24.377)}{0.841222}\ [\text{non-real estate interest expenses}]_{t-1}$$

$$- \underset{(-2.300)}{1119.347935}\ [\text{1974 dummy}]_t$$

Summary statistics:

Estimation technique	=	ordinary least squares
Estimation period	=	1965-89
R^2	=	0.988
Durbin's *h*	=	1.066

[11]See the model for capital consumption expenses.

The effect of a change in the short-term interest rate may be mixed. As the interest rate rises, investment in agriculture is likely to fall. This would imply that farmers would accrue less debt with an increase in the interest rate. However, an interest rate increase would also increase the interest payments associated with any fixed loan amount. The empirical results indicate that the second effect dominates the first.

A dummy variable was included in the regression equation to account for an outlier in 1974. The 1972-74 period was unusual for agriculture. The year-to-year percentage changes in real cash receipts were 12.1 percent in 1972 and 33.9 percent in 1973. These types of changes in real cash receipts were unprecedented during the sample period. Real cash receipts peaked in 1973, then abruptly declined in 1974. This may justify the inclusion of the dummy variable.

Real Estate Interest

The specification used for interest expenses on farm mortgages is identical to the one used by Todd (1979, p. 35). The specification also has some similarities with the one used for non-real estate interest expense. For example, lagged mortgage interest expense was used as an explanatory variable to account for the influence of past mortgage transactions.

The short-term interest rate also appears as an explanatory variable in the equation for real estate interest expenses. Including a longer term interest rate in the equation would probably have been more appropriate, because of the type of debt being modeled. Interest rates, however, tend to be highly correlated, and substituting an alternative rate into the equation would probably have little effect on the regression results. As with the previous equation, the estimates indicate that the interest rate is positively related to mortgage interest expenses.

The final variable that appears in the equation is the nominal value of land per acre. If the supply of land is relatively fixed, an increase in land values implies an increase in the demand for land. As the demand for land increases, more debt will be assumed to acquire land. Therefore, any increase in land values translates into increased mortgage interest expenses.

Regression results for real estate interest expenses are:

$$[\text{real estate interest expenses}]_t$$

$$= \underset{(-6.085)}{-767.440293}$$

$$+ \underset{(8.333)}{2257.899884}\ [\text{farm real estate value}]_t$$

$$+ \underset{(2.621)}{66.558858}\ [\text{interest rate on commercial paper}]_t$$

$$+ \underset{(27.068)}{0.698500}\ [\text{real estate interest expenses}]_{t-1}$$

Summary statistics:

Estimation technique	= ordinary least squares
Estimation period	= 1965-89
R^2	= 0.997
Durbin's *h*	= 1.929

Contract and Hired Labor

The regression equation for labor expenses is based on equation (14). As in previous regression results based on this specification, the coefficient on the proxy variable for production expenses exceeds unity. In addition, we re-estimated the equation to correct for autocorrelation.

The regression results indicate some potential problems. The coefficient on the proxy variable for production expenses is high relative to the other regressions examined thus far based on the same general specification. The problem is that the production enterprises used to construct the proxy account for only a small portion of the sector's total labor costs. Based on equation (14), the value of the proxy variable in 1977 would be equal to the actual labor expenses for the sector in that same year if the proxy had been constructed to include every type of production enterprise. However, the proxy variable actually accounts for only 29 percent of the sector's total labor costs in that year. Nonetheless, the results indicate that the regression equation fits the historical data reasonably well.

Regression results for contract and hired labor expenses are:[1]

$$
\begin{aligned}
&[\text{contract and hired labor expenses}]_t \\
&= \underset{(5.403)}{1896.124611} \\
&+ \underset{(17.768)}{2.306426}\ [\text{wage rate paid by farmers}]_t\ \{0.01\}
\left\{
\begin{array}{l}
3.01\ [\text{corn acreage planted}]_t \\
+\ 2.33\ [\text{sorghum acreage planted}]_t \\
+\ 4.63\ [\text{barley acreage planted}]_t \\
+\ 0.78\ [\text{oats acreage planted}]_t \\
+\ 2.49\ [\text{wheat acreage planted}]_t \\
+\ 14.48\ [\text{rice acreage planted}]_t \\
+\ 2.25\ [\text{soybean acreage planted}]_t \\
+\ 17.06\ [\text{cotton acreage planted}]_t \\
+\ 0.44\ [\text{fed beef production}]_t\ \{0.01/0.62\} \\
+\ 0.67\ [\text{pork production}]_t\ \{0.01/0.72\} \\
+\ 7.92\ [\text{beef cow breeding herd}]_t \\
+\ 0.65\ [\text{milk production}]_t\ \{10.0\}
\end{array}
\right\}
\end{aligned}
$$

Autocorrelation coefficient: 0.588079
(3.635)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1965-89
R^2	=	0.983
Durbin-Watson	=	0.792

[1]The multipliers in small braces, such as {0.01}, convert units. The constants 0.62 and 0.72 relate carcass weight to live weight, as discussed in the text. The multiplier for corn acreage, 3.01, is the contract and hired labor expense per acre of corn planted in the base period, 1977.

Other Operating Expenses

Other operating expenses include repairs and maintenance, machine hire and custom work, and miscellaneous expenses. Because these regression equations are all based on equation (14), we will discuss only some of their unique aspects.

Repair and maintenance expenses include labor costs associated with the repair and maintenance of farm machinery as well as the replacement costs for machinery parts (USDA, 1988). Because this expense category contains these different types of costs, it was difficult to determine an appropriate prices paid index to use in the construction of the proxy for repair and maintenance expenses.

We tried a weighted average of the prices paid for labor and for farm and motor supplies in the equation, but the estimated coefficient on the prices paid for farm and motor supplies was negative. Therefore, this price index was dropped from the final equation.

Regression results for repair and maintenance expenses are:[1]

$$[\text{repair and maintenance expenses}]_t$$

$$= \underset{(3.190)}{1330.775228}$$

$$+ \underset{(10.431)}{1.134558}\ [\text{wage rate paid by farmers}]_t\ \{0.01\} \left\{ \begin{array}{l} 6.29\ [\text{corn acreage planted}]_t \\ +\ 7.65\ [\text{sorghum acreage planted}]_t \\ +\ 6.07\ [\text{barley acreage planted}]_t \\ +\ 5.76\ [\text{oats acreage planted}]_t \\ +\ 5.10\ [\text{wheat acreage planted}]_t \\ +12.89\ [\text{rice acreage planted}]_t \\ +\ 6.02\ [\text{soybean acreage planted}]_t \\ +27.07\ [\text{cotton acreage planted}]_t \\ +\ 0.46\ [\text{fed beef production}]_t\ \{0.01/0.62\} \\ +\ 1.54\ [\text{pork production}]_t\ \{0.01/0.72\} \\ +13.54\ [\text{beef cow breeding herd}]_t \\ +\ 0.27\ [\text{milk production}]_t\ \{10.0\} \end{array} \right\}$$

Autocorrelation coefficient: 0.788100
(6.402)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1965-89
R^2	=	0.980
Durbin-Watson	=	0.384

[1]The multipliers in small braces, such as {0.01}, convert units. The constants 0.62 and 0.72 relate carcass weight to live weight, as discussed in the text. The multiplier for corn acreage, 6.29, is the repair and maintenance expense per acre of corn planted in the base period, 1977.

The equations for machine hire and custom work and for miscellaneous expenses both were estimated over a shorter sample period. Both proxy variables used for expenses in these equations were based on the prices paid index for farm services and cash rent. This series was unavailable before 1971.

The relatively small coefficients on the proxy for expenses in both of these equations indicate that there may be some problems with the specification. The main problem is the lack of an entirely satisfactory prices paid index to use in constructing the proxy for expenses in either regression.

The index of prices paid for farm services and cash rent includes cash rent, custom work, insurance, piece rate labor, telephone, and transportation. The relative weight of custom work in this index is only 23.2 percent of the total.

Miscellaneous expenses, as defined here, include marketing, storage, and transportation; livestock services, supplies and products; livestock feeding; production fees; general production expenses; and general management expenses (USDA, 1988). However, the relative weight of insurance, telephone, and transportation is only 33.2 percent of the total index for farm services and cash rent.

Regression results for machine hire and custom work expenses are:[1]

$$
\begin{aligned}
&[\text{machine hire and custom work expenses}]_t \\
&= \underset{(3.503)}{1443.698216} \\
&\quad + \underset{(1.597)}{0.479014}\ [\text{services and cash rent price}]_t \{0.01\} \left\{
\begin{aligned}
&3.43\ [\text{corn acreage planted}]_t \\
&+ 2.38\ [\text{sorghum acreage planted}]_t \\
&+ 1.11\ [\text{barley acreage planted}]_t \\
&+ 2.84\ [\text{oats acreage planted}]_t \\
&+ 2.04\ [\text{wheat acreage planted}]_t \\
&+ 21.70\ [\text{rice acreage planted}]_t \\
&+ 2.34\ [\text{soybean acreage planted}]_t \\
&+ 10.18\ [\text{cotton acreage planted}]_t
\end{aligned}
\right\}
\end{aligned}
$$

Autocorrelation coefficient: 0.885339
(8.300)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1971-89
R^2	=	0.803
Durbin-Watson	=	0.879

[1]The multiplier {0.01} converts units. The multiplier for corn acreage, 3.43, is the machine hire and custom work expense per acre of corn planted in the base period, 1977.

Regression results for miscellaneous expenses are:[1]

$$\left\{\begin{array}{l}\text{[miscellaneous expenses]}_t \\ \text{-[milk production]}_t \text{ [dairy assessment]}_t \ \{10.0\} \\ \text{-[milk production]}_t \text{ [dairy promotion program payment rate]}_t \ \{10.0\}\end{array}\right\}$$

$$\begin{array}{ll} = & \underset{(1.664)}{5882.434281} \\ + & \underset{(1.426)}{0.854548} \text{ [services and cash rent price]}_t \ \{0.01\} \end{array}$$

$$\left\{\begin{array}{l} \quad 5.19 \text{ [corn acreage planted]}_t \\ + \ 0.90 \text{ [sorghum acreage planted]}_t \\ + \ 0.83 \text{ [barley acreage planted]}_t \\ + \ 0.67 \text{ [oats acreage planted]}_t \\ + \ 0.28 \text{ [wheat acreage planted]}_t \\ + 30.10 \text{ [rice acreage planted]}_t \\ + \ 0.00 \text{ [soybean acreage planted]}_t \\ + 35.59 \text{ [cotton acreage planted]}_t \\ + \ 1.12 \text{ [fed beef production]}_t \ \{0.01/0.62\} \\ + \ 1.00 \text{ [pork production]}_t \ \{0.01/0.72\} \\ + \ 7.85 \text{ [beef cow breeding herd]}_t \\ + \ 0.76 \text{ [milk production]}_t \ \{10.0\} \end{array}\right\}$$

Autocorrelation coefficient: 0.956093
(14.220)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1971-89
R^2	=	0.924
Durbin-Watson	=	1.191
Durbin-Watson beta	=	0.016

[1]The multipliers in small braces, such as {0.01}, convert units. The constants 0.62 and 0.72 relate carcass weight to live weight, as discussed in the text. The multiplier for corn acreage, 5.19, is the miscellaneous expense per acre of corn planted in the base period, 1977.

Dairy assessments and payments under the dairy promotion program were included as proxies to account for production fees in the regression for miscellaneous expenses. The coefficient for each of these proxy variables was constrained to be 1.

Other Overhead Expenses

These other expenses include capital consumption, property taxes, and net rent paid to nonoperator landlords.

Capital Consumption

Capital consumption is the sum of depreciation and accidental damages to capital (USDA, 1988). Because cost-of-production data for individual commodities do not include estimates for this expense category, it proved to be impractical to base the specification of capital consumption expenses on equation (14). Instead, we based the specification on a simple accelerator model for the demand for capital.

According to the model developed by Koyck (1954), the demand for capital is specified as a distributed lag of past production. This yields the following equation:

$$K_t = \alpha \sum_{i=0}^{\infty} \beta^i Y_{t-i}, \quad (16)$$

where

K_t = stock of capital at time t,

Y_t = production at time t, and

α and β are constants with $0 \leq \beta \leq 1$. Equation (16) implies that:

$$K_t = \alpha Y_t + \beta K_{t-1}. \quad (17)$$

If the depreciation rate, δ, is constant over time, then equation (17) implies that:

$$\delta K_t = (\delta\alpha) Y_t + \beta(\delta K_{t-1}), \quad (18)$$

or

$$D_t = \alpha' Y_t + \beta D_{t-1}, \quad (19)$$

where

D_t = total depreciation of the capital stock at time t, and

α' = $\delta\alpha$.

If we interpret the depreciation rate as also capturing accidental damages, then equation (19) may be used as a basis for estimating total capital consumption expenses. In the regression, capital expenses were deflated by the general consumer price index to convert the variable to real terms. Total farm cash receipts deflated by the general consumer price index were used as a proxy for total aggregate production in the estimation. The dummy variable was included in the regression to account for an outlier in 1973.[12] Beginning in 1984, USDA implemented a new procedure to calculate capital consumption expenses. The remaining dummy variable that appears in the regression is included to account for this discontinuity in the historical data.

Property Taxes

Cost-of-production data for farm enterprises report only combined data on taxes and insurance. Because of this data limitation, equation (14) was not used to specify an equation for tax expenses. Instead, property taxes were specified as a function of land values on a per-acre basis weighted by the tax rate per acre. This specification ignores the fact that the total quantity of land devoted to agricultural production can change. However, if the supply of land in agriculture is relatively fixed, this specification will capture most of the variability in property taxes.

[12]See the section on non-real estate interest for a justification for this dummy variable.

Regression results for capital consumption expenses are:

[capital consumption expenses]$_t$ / [CPI]$_t$

$$= \underset{(-1.095)}{-3.442803}$$

$$+ \underset{(5.054)}{0.041267} \text{ [total cash receipts]}_t \text{ / [CPI]}_t$$

$$- \underset{(-2.248)}{5.235920} \text{ [1973 dummy]}_t$$

$$- \underset{(-6.853)}{6.444066} \text{ [1984 and later dummy]}_t$$

$$+ \underset{(20.963)}{0.775546} \text{ [capital consumption expenses]}_{t-1} \text{ / [CPI]}_{t-1}$$

Summary statistics:

Estimation technique	=	ordinary least squares
Estimation period	=	1965-89
R^2	=	0.987
Durbin's *h*	=	0.890

Regression results for property taxes are:

[property taxes]$_t$

$$= \underset{(1.750)}{924.782239}$$

$$+ \underset{(6.362)}{4503.807918} \text{ [farm real estate tax rate]}_t \text{ [farm real estate value]}_t$$

Autocorrelation coefficient: 0.946186
(14.619)

Summary statistics:

Estimation technique	=	maximum likelihood
Estimation period	=	1965-89
R^2	=	0.980
Durbin-Watson	=	0.536

Net Rent Paid to Nonoperator Landlords

Net rent received by nonoperator landlords includes both cash rent and share rent. Cash rental rates for land should be highly correlated with land values per acre. The same economic forces determine both of these variables. If land is in fixed supply, any increase in rental rates (or land values) should translate directly into increased rents. The regression results support this hypothesis.

Under a share rent agreement, landlords generally receive a fixed proportion of the total crop production in kind, and they also are entitled to a fixed proportion of the Government payments made

Regression results for net rent paid to nonoperator landlords are:

$$
\begin{aligned}
&[\text{rent to nonoperator landlords}]_t \\
&= \underset{(2.244)}{1146.006138} \\
&+ \underset{(2.155)}{0.097709} \left\{ [\text{cash receipts for crops}]_t + [\text{receipts from government}]_t \right\} \\
&- \underset{(-1.416)}{0.088048} \left\{ \begin{aligned} &[\text{feed purchases}]_t \\ &+ [\text{seed purchases}]_t \\ &+ [\text{fertilizer and lime expenses}]_t \\ &+ [\text{pesticide expenses}]_t \\ &+ [\text{fuel, oil, and electricity expenses}]_t \\ &+ [\text{real estate interest expenses}]_t \\ &+ [\text{contract and hired labor expenses}]_t \\ &+ [\text{repair and maintenance expenses}]_t \\ &+ [\text{capital consumption expenses}]_t \\ &+ [\text{property taxes}]_t \end{aligned} \right\} \\
&+ \underset{(1.740)}{4350.846458} [\text{farm real estate value}]_t \\
&+ \underset{(1.068)}{714.514790} [\text{1979 to 1983 dummy}]_t \\
&+ \underset{(3.580)}{2664.247299} [\text{1984 and later dummy}]_t
\end{aligned}
$$

Summary statistics:

Estimation technique	=	ordinary least squares
Estimation period	=	1965-89
R^2	=	0.939
Durbin-Watson	=	1.819

to the renters. Therefore, any increase in the value of production or in Government support payments should translate into increased rents received by landlords. The sum of total cash receipts for crops and total Government payments is included in the regression as a proxy variable to capture this effect.

Landlords also typically pay a portion of the production expenses under a share rent agreement. As these expenses increase, landlords receive less net rent. The sum of all the expense categories used by USDA in computing net rent (USDA, 1988) was used to capture this effect on net rents.

Finally, two dummy variables were included in the regression. The data for the periods 1965-78, 1979-83, and 1984-89 were computed using different methods. As a result, the data series are not consistent between these periods (USDA, 1991a). The dummy variables were used to account for this discontinuity in the historical data.

Model Validation

The information presented above provides some detail on the performance of the equations over the sample period. This section presents further summary statistics for the sample period and provides some evidence on how these equations would behave beyond the sample period.

Table 2 presents the mean absolute relative error (MARE), Theil's U_2 statistic, the relative turning point error (RTPE), and the forecast error (FE) for each of the equations described earlier.[13] The MARE is similar to the R^2 statistic reported for the regressions in that it measures how well the predicted values of the regression fit the historical data (Pindyck and Rubinfeld, 1981). By definition,

$$\text{MARE} = (1/T) \sum_{t=1}^{T} |(y_t - \hat{y}_t)/y_t|,$$

where

y_t = actual value of the endogenous variable at time t,

$\hat{y}_t$ = predicted value of the endogenous variable at time t, and

T = the sample size.

Theil's U_2 statistic measures the performance of the model in relation to a naive model where the estimated value of y_t is the value of y_t from the previous period (Theil, 1966). For the purposes of this report, the statistic is defined as:

$$U_2 = [\sum_{t=2}^{T} (y_t - \hat{y}_t)^2]^{1/2} / [\sum_{t=2}^{T} (y_t - y_{t-1})^2]^{1/2}.$$

With the naive model,

$$\hat{y}_t = y_{t-1}$$

for t = 2, ..., T. As a result, U_2 equals 1 in this case. If the value of U_2 is less than unity, the competing model is superior to this naive model.

The third measure presented in the table is the relative turning point error (Theil, 1966). For this report, the statistic is defined as:

$$\text{RTPE} = (1/(T-1)) \sum_{t=2}^{T} \text{TPE}_t,$$

[13]The validation statistics pertain to equations exactly as they were estimated. So, for example, the validation statistics presented for capital consumption expenses are actually for the regression equation for capital consumption expenses deflated by the consumer price index.

where

$$TPE_t = \begin{cases} 1 & \text{if } (\hat{y}_t - y_{t-1})(y_t - y_{t-1}) < 0, \\ 0 & \text{otherwise.} \end{cases}$$

This statistic measures how well the model tracks directional changes in the historical data.

The fourth measure is the forecast error (FE), which is defined as the absolute relative error for the forecast year. The most recent data available were used to estimate each of the model equations. Therefore, it is impossible to assess the performance of the equations beyond the sample period. To obtain some evidence about how well the equations will forecast, each equation was re-estimated using the same specification described earlier, excluding the final year from the sample period. These equations then were used to forecast the final, excluded year.

The MARE is less than 0.10 in most cases. The only notable exception is pesticide expenses. For this category of expenses, assuming constant application rates per acre is highly questionable. According to Eichers and Szmedra (1990), total pesticide use nearly doubled between 1966 and 1976.

Table 2—Validation statistics

Item	Measures			
	MARE[1]	Theil U_2	RTPE[2]	FE[3]
Farm origin inputs:				
Feed purchases	0.033	0.339	0.087	0.042
Livestock purchases	.036	.251	.125	.027
Seed purchases	.050	.520	.208	.032
Manufactured inputs:				
Fertilizer and lime	.072	.461	.167	.007
Pesticides	.210	.821	.125	.200
Fuel, oil, and electricity	.063	.454	.042	.036
Interest:				
Non-real estate	.102	.458	.167	.029
Real estate	.040	.257	0	.030
Contract and hired labor	.038	.702	.083	.005
Other operating expenses:				
Repair and maintenance	.044	.680	.208	.043
Machine hire and custom work	.107	.952	.167	.177
Miscellaneous expenses	.139	.962	.167	.105
Other overhead expenses:				
Capital consumption	.019	.388	.042	.064
Property taxes	.033	.707	.125	.040
Net rent paid to NOLL[4]	.094	.504	.208	.233

[1]MARE = Mean absolute relative error.
[2]RTPE = Relative turning point error.
[3]FE = Absolute relative forecast error.
[4]NOLL = Nonoperator landlords.

Since that time, total use has leveled off somewhat. Because of these production practice changes over the historical period, a Leontief production function may not be entirely adequate to model this category of expenses. It should be kept in mind, however, that pesticides represent one of the smaller expense categories in relative terms (see table 1). Hence, errors introduced by this equation will have a negligible effect on total production expenses for the sector.

In terms of Theil's U_2 statistic, all of the equations perform better than a naive model. The variables that had relatively high U_2 statistics were pesticides, machine hire and custom work, and miscellaneous expenses. Problems with the pesticide equation were just discussed. For the remaining two expense categories, readers should recall from the previous section of this report that there is a problem with the prices paid index used to construct the exogenous variables in the regressions. This might account for the relatively high U_2 statistics associated with these variables.

The RTPE was less than 0.25 for all variables. Given the large fluctuations in economic conditions that occurred over the sample period used in the analysis, this value is not unreasonably large.

Compared with the MARE, the forecast errors for the equations all seem reasonable except net rent paid to nonoperator landlords. However, 1989 may be a poor year to assess the out-of-sample forecast properties of this equation. Based on the "studentized residual" associated with 1989, this observation appears to be an outlier in the data (Cook and Weisberg, 1982).

Conclusions

Farm income has been mentioned in virtually every *Economic Report of the President* over the past two decades. Despite this concern with farm income, surprisingly few descriptions of empirical models have been published dealing with aggregate farm income accounts. The model presented here deals with the expense side of these accounts.

We selected our modeling approach on the basis of practical considerations stemming from data requirements. Every empirical economic model is a simplification of a complex set of processes and relationships. The real test of a model is how well it forecasts economic phenomena. With the exceptions noted in the text, the validation results indicate that the model fits the historical data reasonably well and forecasts fairly accurately.

Two important assumptions are used in constructing farm production expenses within FAPSIM. First, Leontief production functions are taken to describe the relationships between inputs and outputs. This means that inputs are used in fixed proportions to generate each output. Therefore, input levels generated endogenously within FAPSIM may be used to indirectly determine the levels of other inputs used. Second, the aggregate costs for any group of inputs may be approximated as the product of the Laspeyres price and quantity indices for these inputs, weighted by base period production costs.

We derived a cost function based on the assumptions above for most of the expense categories. The cost associated with a selected set of inputs equals the current period weight for the selected input group times the sum (across the selected inputs and across outputs) of the product of the base period weight for each input and the quantity of the input used. The quantity of each input may be in a known proportion to the level of output, as for livestock. Other input levels are assumed to be proportional to known input levels. For crops, an expense such as fertilizer purchase is taken to be proportional to acreage. This intermediate step is needed, because crop input data are typically published on a per-acre basis and because acreage levels are explicitly calculated in the FAPSIM model.

Data requirements for the model of farm expenses may appear imposing (see appendix). The model requires forecasts of 48 exogenous variables to generate forecasts for only 15 endogenous variables. However, only 14 of these exogenous variables are actually exogenous to the overall FAPSIM system, and 5 of these variables are either dummy variables or a time trend. Furthermore, virtually all of the 48 exogenous variables are routinely forecast in the USDA baseline process.

Finally, the model presented here provides a highly practical framework for simulating farm production expenses over both historical and future periods. Although the current model bears a number of similarities to Todd's (1979) earlier research, it also represents an improvement over this earlier work. Because the specifications used in the current model are in many respects similar to Todd's, the forecast properties of the two models also should be similar. However, Todd's model aggregated the expense categories into fewer subcategories.[14] Hence, the current model is able to provide more detailed information on movements in the individual expense categories in simulation.

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[14]Todd (1979) aggregated repairs and maintenance with petroleum fuels and oil to create a single expense category. Todd also included pesticides, machine hire and custom work, non-real estate interest, and electricity in the miscellaneous expense category. However, this report estimates these expenses more explicitly.

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Appendix

Appendix table 1—Variable definitions

Name[1]	Description	Source[2]
Endogenous variables:		
[capital consumption expenses]$_t$	Farm expenses, capital consumption, calendar year (million $)	USDA (1991a)
[contract and hired labor expenses]$_t$	Farm expenses, contract and hired labor, calendar year (million $)	USDA (1991a)
[feed purchases]$_t$	Farm expenses, feed purchases, calendar year (million $)	USDA (1991a)
[fertilizer and lime expenses]$_t$	Farm expenses, fertilizer and lime, calendar year (million $)	USDA (1991a)
[fuel, oil, and electricity expenses]$_t$	Farm expenses, fuel, oil, and electricity, calendar year (million $)	USDA (1991a)
[livestock purchases]$_t$	Farm expenses, livestock purchases, calendar year (million $)	USDA (1991a)
[machine hire and custom work expenses]$_t$	Farm expenses, machine hire and custom work, calendar year (million $)	USDA (1991a)
[miscellaneous expenses]$_t$	Farm expenses, miscellaneous expenses, calendar year (million $)	USDA (1991a)
[non-real estate interest expenses]$_t$	Farm expenses, non-real estate interest, calendar year (million $)	USDA (1991a)
[pesticide expenses]$_t$	Farm expenses, pesticides, calendar year (million $)	USDA (1991a)
[property taxes]$_t$	Farm expenses, property taxes, calendar year (million $)	USDA (1991a)
[real estate interest expenses]$_t$	Farm expenses, real estate interest, calendar year (million $)	USDA (1991a)
[rent to nonoperator landlords]$_t$	Farm expenses, net rent paid to nonoperator landlords, calendar year (million $)	USDA (1991a)
[repair and maintenance expenses]$_t$	Farm expenses, repairs and maintenance, calendar year (million $)	USDA (1991a)
[seed purchases]$_t$	Farm expenses, seed purchases, calendar year (million $)	USDA (1991a)

See footnotes at end of table.

Continued—

Appendix table 1—Variable definitions—Continued

Name[1]	Description	Source[2]
Exogenous variables:		
[barley acreage planted]$_t$ [3]	Barley, planted acreage, dated by year of harvest (million acres)	USDA (1991h)
[barley feed use]$_t$ [3]	Barley, feed use, June-May year (million bushels)	USDA (1991b)
[barley price]$_t$ [3]	Barley, average market price, June-May year ($/bushel)	USDA (1990c)
[barrow and gilt price]$_t$ [3]	Barrows and gilts, market price, seven markets, calendar year ($/cwt live weight)	USDA (1991c)
[barrow and gilt slaughter]$_t$ [3]	Barrows and gilts, slaughter, Dec.-Nov. year (million head)	USDA (1991c)
[beef cow breeding herd]$_t$ [3]	Beef cows, breeding herd, Jan. 1 (million head)	USDA (1991f)
[cash receipts for crops]$_t$ [3]	Cash receipts for farm marketings of crops, calendar year (million $)	USDA (1991a)
[chemical price]$_t$	Prices paid by farmers, chemicals, calendar year (1977 = 100)	USDA (1990c)
[corn acreage planted]$_t$ [3]	Corn, planted acreage, dated by year of harvest (million acres)	USDA (1991h)
[corn feed use]$_t$ [3]	Corn, feed use, Sept.-Aug. year (million bushels)	USDA (1991b)
[corn price]$_t$ [3]	Corn, average market price, Sept.-Aug. year ($/bushel)	USDA (1990c)
[cotton acreage planted]$_t$ [3]	Cotton, planted acreage, dated by year of harvest (million acres)	USDA (1991h)
[CPI]$_t$ [3]	Consumer price index, all items, calendar year	USDL (1991)
[dairy assessment]$_t$	Milk, dairy assessment, calendar year ($/cwt)	USDA (1990a)
[dairy promotion program payment rate]$_t$	Milk, dairy promotion program payment rate, calendar year ($/cwt)	Green (1991)
[farm real estate tax rate]$_t$	Farm real estate tax rate, calendar year ($/$100 value)	USDA (1990b)

See footnotes at end of table.

Continued—

Appendix table 1—Variable definitions—Continued

Name[1]	Description	Source[2]
[farm real estate value]$_t$ [3]	Farm real estate values per acre, calendar year (1977 = 1)	USDA (1990b)
[fed beef production]$_t$ [3]	Beef, fed production, calendar year (million lbs carcass weight)	Gustafson (1990)
[fed steer and heifer slaughter]$_t$ [3]	Fed steer and heifer slaughter, calendar year (million head)	USDA (1991c)
[feeder steer price]$_t$ [3]	Price of choice feeder steers, all weights and grades, Kansas City, calendar year ($/cwt live weight)	USDA (1991c)
[fertilizer and lime price]$_t$	Prices paid by farmers, fertilizer and lime, calendar year (1977 = 100)	USDA (1990c)
[fuel and energy price]$_t$	Prices paid by farmers, fuel and energy, calendar year (1977 = 100)	USDA (1990c)
[interest rate on commercial paper]$_t$	Interest rate on prime commercial paper, 4-6 months (percentage)	ERP (1991)
[milk production]$_t$ [3]	Milk, production, calendar year (billion lbs)	USDA (1991g)
[oats acreage planted]$_t$ [3]	Oats, planted acreage, dated by year of harvest (million acres)	USDA (1991h)
[oats feed use]$_t$ [3]	Oats, feed use, June-May year (million bushels)	USDA (1991b)
[oats price]$_t$ [3]	Oats, average market price, June-May year ($/bushel)	USDA (1990c)
[pork production]$_t$ [3]	Pork, production, calendar year (million lbs carcass weight)	USDA (1991c)
[receipts from government]$_t$ [3]	Government payments to farmers, calendar year (million $)	USDA (1991a)
[rice acreage planted]$_t$ [3]	Rice, planted acreage, dated by year of harvest (million acres)	USDA (1991h)
[seed price]$_t$ [3]	Prices paid by farmers, seed, calendar year (1977 = 100)	USDA (1990c)
[services and cash rent price]$_t$	Prices paid by farmers, services and cash rent, calendar year (1977 = 100)	USDA (1990c)

See footnotes at end of table.

Continued—

Appendix table 1—Variable definitions—Continued

Name[1]	Description	Source[2]
[sorghum acreage planted]$_t$ [3]	Sorghum, planted acreage, dated by year of harvest (million acres)	USDA (1991h)
[sorghum feed use]$_t$ [3]	Sorghum, feed use, Sept.-Aug. year (million bushels)	USDA (1991b)
[sorghum price]$_t$ [3]	Sorghum, average market price, Sept.-Aug. year ($/bushel)	USDA (1990c)
[soybean acreage planted]$_t$ [3]	Soybeans, planted acreage, dated by year of harvest (million acres)	USDA (1991h)
[soymeal domestic demand]$_t$ [3]	Soybean meal, domestic demand, Oct.-Sept. year (million lbs)	USDA (1991d)
[soymeal price]$_t$ [3]	Soybean meal, average wholesale price of 44% protein at Decatur, Oct.-Sept. year ($/cwt)	USDA (1991d)
[time]$_t$	Linear time trend (1965 = 1)	none
[total cash receipts]$_t$ [3]	Cash receipts, total received for farm marketings, calendar year (million $)	USDA (1991a)
[wage rate paid by farmers]$_t$	Prices paid by farmers, wages, calendar year (1977 = 100)	USDA (1990c)
[wheat acreage planted]$_t$ [3]	Wheat, planted acreage, dated by year of harvest (million acres)	USDA (1991h)
[wheat feed use]$_t$ [3]	Wheat, feed use, June-May year (million bushels)	USDA (1991e)
[wheat price]$_t$ [3]	Wheat, average market price, June-May year ($/bushel)	USDA (1990c)
[1973 dummy]$_t$	Dummy variable, 1973 = 1	none
[1974 dummy]$_t$	Dummy variable, 1974 = 1	none
[1979 to 1983 dummy]$_t$	Dummy variable, 1979-83 = 1	none
[1984 and later dummy]$_t$	Dummy variable, ≥ 1984 = 1	none

[1]Years are aligned such that both calendar year 1990 and marketing year 1990/91 correspond to t = 1990.
[2]The following abbreviations are used: U.S. Department of Agriculture (USDA), U.S. Department of Labor (USDL), and *Economic Report of the President* (ERP).
[3]Denotes variables which are exogenous to the farm production expense model, but which are endogenous to the overall FAPSIM model.

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