INVESTMENT AND CREDIT IN THE U.S. AGRICULTURE: A FRAMEWORK FOR EMPIRICAL ANALYSIS

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Abstract

The present manuscript develops a theoretical model of investment for the proprietary that explicitly allows for the possibility of credit constraints altering investment. It is shown how to test the model empirically using Hansen's generalized method of moments using aggregate data available for the U.S. farm sector. The advocated model allows the researcher to calculate a point estimate (along with its standard deviation) of the average cost of credit constraints in relative terms.

Introduction

The present manuscript develops a theoretical model of investment for the proprietary firm based on the q-theory advanced by Tobin. It is shown that under suitable restrictions the advocated model yields models previously advanced in the literature, so that their validity can be tested in a straightforward manner. The model explicitly allows for the possibility of credit constraints altering investment. Second, it is shown how to test the model empirically using Hansen's generalized method of moments using aggregate data available for the U.S. farm sector. Third, the estimated model can be used to calculate a point estimate (along with its standard deviation) of the average cost of credit constraints to the sector under study.

Theoretical Model

Consider an agent with the utility function

$$(1.1) \quad U = \sum_{t=0}^{T} \beta^t u(c_t),$$

where β is a discount factor per period, $u(\cdot)$ is the one-period subutility or felicity function ($u' > 0$), c_t denotes consumption at date t, and T is her terminal period. Parameter β represents the individual's rate of time preference per period; the smaller (greater) β, the greater (smaller) the utility derived from current consumption relative to future consumption. In the context of expected utility, risk aversion (risk neutrality) is characterized by a strictly concave (linear) felicity function, i.e., $u'' < 0$ ($u'' = 0$).

At time t, the agent uses her labor income (y_t), production cash flows (π_t), wealth exclusive of production capital (W_t), and borrowings (B_t) to either consume (c_t), invest in various assets excluding production capital ($\iota' \mathbf{A}_t$) or change her holdings of production capital ($p_{I,t} I_t + a(I_t, K_{t-1})$). That is, the agent faces the budget constraint

$$(1.2) \quad c_t + \iota' \mathbf{A}_t - B_t + p_{I,t} I_t + a(I_t, K_{t-1}) = y_t + \pi_t + W_t,$$

where $\mathbf{A}_t$ is a vector of asset values, ι' is a conformable vector of ones, $p_{I,t}$ is the price of production capital, I_t is the physical investment in production capital, $a(\cdot)$ is the investment adjustment cost function, and K_{t-1} is the amount of production capital that can be used in production at time t.

Cash flows from production are defined as

$$(1.3) \quad \pi_t \equiv p_{Q,t} Q(K_{t-1}, L_{t-1}, \mathbf{N}_t) - \mathbf{p}_{N,t}' \mathbf{N}_t - l_t L_{t-1},$$

where $p_{Q,t}$ is the output price, $Q(\cdot)$ is a production function, $\mathbf{p}_{N,t}$ is a vector of variable input prices, $\mathbf{N}_t$ is a vector of variable inputs, l_t is the rental price of land, and L_{t-1} is the amount of land employed in production. Wealth exclusive of production capital is given by

$$(1.4) \quad W_{t+1} = \mathbf{r}_{t+1}' \mathbf{A}_t - (1 + i_{t+1}) B_t,$$

where $\mathbf{r}_{t+1}$ is the vector of gross returns from the various assets and i_{t+1} is the interest rate at which the agent is able to borrow. Finally, the evolution of production capital over time is given by

$$(1.5) \quad K_t = (1 - \delta) K_{t-1} + I_t,$$

where δ is the rate of depreciation of production capital.

Noting that W_t, L_{t-1}, and K_{t-1} are predetermined as of date t, at time t the agent is assumed to optimize with respect to consumption and other choice variables so as to maximize her expected utility subject to her budget constraint and to the equations of motion for wealth and production capital. That is,

$$(1.6) \quad V_t(K_{t-1}, W_t, L_{t-1}) = \max_{c_t, I_t, \mathbf{A}_t, B_t, L_t, N_t} E_t[\sum_{k=t}^{T} \beta^k u(c_k)]$$

$$\text{s.t.} \quad c_t + \iota' \mathbf{A}_t - B_t + p_{I,t} I_t + a(I_t, K_{t-1}) = y_t + \pi_t + W_t, \text{ (1.3), (1.4), and (1.5),}$$

$$(1.6') \quad = \max_{I_t, \mathbf{A}_t, B_t, L_t, N_t} \{\beta^t u(y_t + \pi_t + W_t - \iota' \mathbf{A}_t + B_t - p_{I,t} I_t - a(I_t, K_{t-1})) + E_t[V_{t+1}(K_t, W_{t+1}, L_t)]\},$$

$$(1.6'') \quad = \max_{I_t, \mathbf{A}_t, B_t, L_t, N_t} \{\beta^t u(y_t + \pi_t + W_t - \iota' \mathbf{A}_t + B_t - p_{I,t} I_t - a(I_t, K_{t-1})) + E_t[V_{t+1}((1 - \delta) K_{t-1} + I_t, \mathbf{r}_{t+1} \mathbf{A}_t - (1 + i_t) B_t, L_t)]\},$$

where $E_t(\cdot)$ represents the expectation operator conditional on information available at date t. Expression (1.6') is derived by recursive application of (1.6).

First order conditions (FOCs) corresponding to optimal physical investment and borrowings may be expressed as Euler equations (1.7) and (1.8), respectively (see Appendix A):[1]

[1]Only FOCs (1.7) and (1.8) are reported here in the interest of space; FOCs with respect to the other choice variables are assumed to hold as well, but they are omitted because they are not central to the present analysis.

$$(1.7)\quad E_t\{\beta \frac{u'(c_{t+1})}{u'(c_t)} [p_{Q,t+1} \frac{\partial Q(K_t, L_t, \mathbf{N}_{t+1})}{\partial K_t} - \frac{\partial a(I_{t+1}, K_t)}{\partial K_t} + (1-\delta)(p_{I,t+1} + \frac{\partial a(I_{t+1}, K_t)}{\partial I_{t+1}})]\}$$

$$- p_{I,t} - \frac{\partial a(I_t, K_{t-1})}{\partial I_t} = 0,$$

$$(1.8)\quad 1 - E_t[\beta \frac{u'(c_{t+1})}{u'(c_t)} (1 + i_{t+1})] = 0.$$

Credit Constraints

Objective function (1.6) must be modified if the agent faces borrowing constraints. To allow for such constraints, assume that the decision maker can borrow freely up to a certain level based on her collateral ($\iota' \mathbf{A}_t + p_{I,t} K_t$). That is, $B_t \leq \theta (\iota' \mathbf{A}_t + p_{I,t} K_t)$, where $\theta > 0$ is a constant. Then, the Euler equations analogous to (1.7) and (1.8) for the credit-constrained decision maker are (1.9) and (1.10), respectively:

$$(1.9)\quad E_t\{\beta \frac{u'(c_{t+1})}{u'(c_t)} [p_{Q,t+1} \frac{\partial Q(K_t, L_t, \mathbf{N}_{t+1})}{\partial K_t} - \frac{\partial a(I_{t+1}, K_t)}{\partial K_t} + (1-\delta)(p_{I,t+1} + \frac{\partial a(I_{t+1}, K_t)}{\partial I_{t+1}})]\}$$

$$- p_{I,t} - \frac{\partial a(I_t, K_{t-1})}{\partial I_t} + \frac{\lambda_t}{\beta^t u'(c_t)} \theta p_{I,t} = 0,$$

$$(1.10)\quad 1 - E_t[\beta \frac{u'(c_{t+1})}{u'(c_t)} (1 + i_{t+1})] - \frac{\lambda_t}{\beta^t u'(c_t)} = 0,$$

where $\lambda_t \geq 0$ is the Lagrange multiplier corresponding to the credit constraint. Hence, $\lambda_t [\theta (\iota' \mathbf{A}_t + p_{I,t} K_t) - B_t] = 0$ by the complementary slackness condition.

Estimation

Unobservability of the Lagrange multiplier (λ_t) prevents us from estimating Euler equations (1.9) and (1.10) directly. However, assuming a strictly positive collateral value (i.e., $\iota' \mathbf{A}_t + p_{I,t} K_t > 0$), the complementary slackness condition ($\lambda_t [\theta (\iota' \mathbf{A}_t + p_{I,t} K_t) - B_t] = 0$) allows us to derive estimation equations (2.1) and (2.2) from (1.9) and (1.10), respectively:

$$(2.1)\quad (1 - \mu \frac{B_t}{\iota' \mathbf{A}_t + p_{I,t} K_t}) \{E_t[\beta \frac{u'(c_{t+1})}{u'(c_t)} (p_{Q,t+1} \frac{\partial Q(K_t, L_t, \mathbf{N}_{t+1})}{\partial K_t} - \frac{\partial a(I_{t+1}, K_t)}{\partial K_t}$$

$$+ (1 - \delta) (p_{I,t+1} + \frac{\partial a(I_{t+1}, K_t)}{\partial I_{t+1}}))] - p_{I,t} - \frac{\partial a(I_t, K_{t-1})}{\partial I_t} \} = 0,$$

$$(2.2)\quad (1 - \mu \frac{B_t}{\iota' \mathbf{A}_t + p_{I,t} K_t}) \{1 - E_t[\beta \frac{u'(c_{t+1})}{u'(c_t)} (1 + i_{t+1})]\} = 0,$$

where $\mu \equiv 1/\theta \geq 0$. All variables in (2.1) and (2.2) are observable. As well, (2.1) and (2.2) nest the unconstrained agent's Euler equations (1.7) and (1.8), as the latter can be obtained from the former by setting $\mu = 0$. This is to be expected, as $\mu = 0$ is equivalent to $\theta = \infty$, which implies no borrowing constraints.

Interestingly, one may obtain a point estimate (along with its standard deviation) of the average cost of the credit constraint normalized by the marginal utility by plugging in the estimated parameters back into Euler equations (1.9) and (1.10). The resulting figure provides the marginal increase in expected utility due to relaxing the credit constraint by one dollar relative to the marginal increase in expected utility obtained from an increasing consumption by one dollar. Therefore, one can easily assess the economic significance (as opposed to the statistical significance) of the credit constraint.

Functional Forms

To give empirical content to (2.1) and (2.2) it is necessary to be more specific about the functional forms of the felicity function u(·), the production function Q(·), and the adjustment cost function a(·). The specification of such functional forms is discussed next.

The felicity function chosen for estimation purposes is the power function, i.e., $u(c) = 1/(1-\gamma)\, c^{1-\gamma}$, where γ is the coefficient of relative risk aversion. The power form is the most popular felicity function in empirical finance. Power felicity greatly simplifies the estimation problem because the empirical methods used here require stationary variables (Ogaki). Power felicity allows us to work with consumption ratios c_{t+1}/c_t (which are stationary) instead of consumption levels c_t (which are nonstationary). Also, under certain conditions the power felicity allows for aggregation of power-felicity agents with different wealth levels and different levels of relative risk aversion into a single "representative" agent with power felicity (Altuğ and Labadie, p. 22). Finally and more importantly, power felicity is the best choice in terms of parsimony because its only parameter is the coefficient of relative risk aversion, and different felicity functions with the same relative risk aversion yield almost identical decisions (Kallberg and Ziemba).

Regarding the production function $Q(K_t, K_t, N_{t+1})$, besides standard regularity conditions we only assume that it is characterized by constant returns to scale. Hence, Euler's theorem (e.g., Chiang p. 417) implies that

$$(2.3)\quad p_{Q,t+1}\frac{\partial Q}{\partial K_t} = p_{Q,t+1}\frac{Q}{K_t} - p_{Q,t+1}\frac{\partial Q}{\partial L_t}\frac{L_t}{K_t} - p_{Q,t+1}\sum_j \frac{\partial Q}{\partial N_{i,t+1}}\frac{N_{j,t+1}}{K_t},$$

As well, under the maintained assumption of perfect competition the Euler equation for land is

$$(2.4)\quad E_t\{\beta \frac{u'(c_{t+1})}{u'(c_t)}[p_{Q,t+1}\frac{\partial Q}{\partial L_t} - l_{t+1}]\} = 0,$$

and the FOCs for variable inputs are $p_{Q,t+1}\, \partial Q/\partial N_{j,t+1} = p_{N_{j,t+1}}$ for all j. Using these results, it is straightforward to show that

$$(2.5)\quad E_t[\beta \frac{u'(c_{t+1})}{u'(c_t)} p_{Q,t+1} \frac{\partial Q}{\partial K_t}] = E_t[\beta \frac{u'(c_{t+1})}{u'(c_t)} (\frac{p_{Q,t+1} Q - \mathbf{l}_{t+1}\mathbf{L}_{t+1} - \mathbf{p}_{N,t+1}\mathbf{N}_{t+1}}{K_t})].$$

By substituting (2.5) into Euler equation (2.1) we obtain an alternative expression for the Euler equation nicely suited for estimation, as it involves no production function parameters.

Finally, following recent work by Hamermesh and Pfann (p. 1271), the adjustment cost function is specified as

$$(2.6)\quad a(I_t, K_{t-1}) = \{\exp[\alpha_1 (\frac{I_t}{K_{t-1}} - \alpha_0)] - \alpha_1 (\frac{I_t}{K_{t-1}} - \alpha_0) + \frac{\alpha_2}{2} (\frac{I_t}{K_{t-1}} - \alpha_0)^2 - 1\} K_{t-1},$$

where α_0 is the rate of investment that entails no adjustment costs, α_1 and $\alpha_2 \geq 0$ denote other parameters, and exp(·) is the exponential function. Adjustment cost function (2.6) is consistent with the basic assumption made by the literature on the q-theory of investment because it is linear homogeneous in I_t and K_{t-1} (Hayashi). However, unlike most of the previous studies, adjustment cost function (2.6) allows for asymmetric adjustment costs. Adjustment costs are symmetric if $\alpha_1 = 0$ and asymmetric if $\alpha_1 \neq 0$. If $\alpha_1 > (<) 0$, adjustment costs for a rate of investment I_t/K_{t-1} of $(1 + x)\alpha_0$ for some $x > 0$ are greater (smaller) than adjustment costs for a rate of investment of $(1 - x)\alpha_0$. For estimation purposes, the corresponding derivatives of (2.6) are plugged into Euler equation (2.1).

Estimation Method

Hansen's generalized method of moments (GMM) is used for estimation, as it is the typical choice to estimate Euler equations. Succinctly, using the aforementioned specifications for u(·), Q(·), and a(·), Euler equations (2.1) and (2.2) define errors $e_{1,t+1}$ and $e_{2,t+1}$, respectively:

$$(2.7)\quad e_{1,t+1} \equiv (1 - \mu \frac{B_t}{\iota' \mathbf{A}_t + p_{I,t} K_t}) \{\beta (\frac{c_{t+1}}{c_t})^{-\gamma} [\frac{p_{Q,t+1} Q - \mathbf{l}_{t+1}\mathbf{L}_{t+1} - \mathbf{p}_{N,t+1}\mathbf{N}_{t+1}}{K_t}$$

$$+ (\alpha_1 \frac{I_{t+1}}{K_t} - 1) \exp(\alpha_1 (\frac{I_{t+1}}{K_t} - \alpha_0)) + \frac{\alpha_2}{2} ((\frac{I_{t+1}}{K_t})^2 - \alpha_0^2) + 1 - \alpha_0 \alpha_1$$

$$+ (1 - \delta) (p_{I,t+1} + \alpha_1 (\exp(\alpha_1 (\frac{I_{t+1}}{K_t} - \alpha_0)) - 1) + \alpha_2 (\frac{I_{t+1}}{K_t} - \alpha_0))]$$

$$- p_{I,t} - \alpha_1 [\exp(\alpha_1 (\frac{I_t}{K_{t-1}} - \alpha_0)) - 1] - \alpha_2 (\frac{I_t}{K_{t-1}} - \alpha_0)\},$$

(2.8) $$e_{2,t+1} \equiv (1 - \mu \frac{B_t}{\iota' \mathbf{A}_t + p_{I,t} K_t}) [1 - \beta (\frac{c_{t+1}}{c_t})^{-\gamma} (1 + i_{t+1})],$$

such that $E_t(e_{j,t+1}) = 0$ ($j = 1, 2$). Letting $z_{h,t}$ ($h = 1, \ldots, H$) be an instrumental variable known at time t and $E(\cdot)$ be the unconditional expectation operator, the "Law of Iterated Expectations" implies that $E(e_{j,t+1}\, z_{h,t}) = 0$ because $E(e_{j,t+1}\, z_{h,t}) = E[E_t(e_{j,t+1}\, z_{h,t})] = E[E_t(e_{j,t+1})\, z_{h,t}] = E(0\, z_{h,t})$. Given n sample observations, the sample estimate of the orthogonality condition $E(e_{j,t+1}\, z_{h,t})$ is $(\Sigma_t\, \hat{e}_{j,t+1}\, z_{h,t})/n$. Stacking such sample estimates into a 2 H column vector g_n and denoting a corresponding consistent covariance matrix by S_n, the GMM parameter estimates are obtained by minimizing the quadratic form $J_n \equiv g_n'\, S_n^{-1}\, g_n$ with respect to the unknown parameters β, γ, μ, α_0, α_1, and α_2. That is, the GMM estimators are found by setting the sample orthogonality conditions as close to zero as possible.

If the number of orthogonality conditions (2 H) exceeds the number of parameters to estimate (# parameters), there are (2 H – # parameters) linearly independent remaining orthogonality conditions that are not set to zero during GMM estimation but should be close to zero if the restrictions of the model are true. This fact provides the basis for the "test of overidentifying restrictions," n J_n, which tests the model under the null hypothesis that all (2 H) orthogonality conditions are equal to zero. Under the null, the (n J_n) test statistic converges in distribution to a chi-square random variable with (2 H – # parameters) degrees of freedom.

If the model is true, the error term $e_{j,t+1}$ should be unpredictable given information at time t. Hence, a necessary condition for the model to hold is that the $e_{j,t+1}$ series not be autocorrelated (i.e., that $e_{j,t-1}$ cannot be predicted using $e_{j,t}$). This provides an additional test for the proposed model, which consists of testing whether the error estimates $\hat{e}_{j,t+1}$ are autocorrelated.

Besides allowing us to estimate Euler equations without unduly restrictive assumptions about the distribution of random variables, a nice feature of GMM for the present application is that it is an instrumental variable method. This assertion is true because consumption growth and other variables involved in the estimation equations (2.7) and (2.8) are most likely measured with error, and one of the recommended solutions to the problem of estimation in the presence of measurement errors is the use of instrumental variable methods such as GMM (e.g., Greene).

Data

The proposed method may be applied using either individual firm data (e.g., Saha, Shumway, and Talpaz) or sectoral data (e.g., Hubbard and Kashyap). The former has the advantage of being more consistent with the theoretical model. However, as pointed out by Griliches and Mairesse, individual firm data exacerbates misspecification problems. For this reason, in this section we describe a data set corresponding to the U.S. sector that may be suitable for the present analysis (a detailed description of the data set construction is provided in Appendix B).

The advocated data span the period 1934 (when data collection about farm operators' off-farm income began) through 1994, for a total of 61 annual observations. The consumption series (c_t) used here is real withdrawals per farm operator ($RWFO_t$). The basic data used to construct the RWFO series are the farm sector's income statements and balance sheets published by the U.S. Department of Agriculture (USDA). The method employed follows the basic concepts introduced by Penson et al. and used recently by Erickson, but with some modifications to yield a series corresponding to farm operators only. Such modifications are needed because the farm sector's income statements refer to operator data, whereas the farm sector's balance sheets incorporate data for both operators and landlords (Penson).

GMM requires the use of instrumental variable. The most obvious instruments are the lagged values of consumption growth and returns. However, measurement errors and other data problems may lead to spurious results when using such instruments (Ferson and Constantinides).

For this reason, it is useful to use instruments other than lagged values. To provide powerful tests of the Euler equation restrictions, instruments should be "predetermined" (i.e., known at time t), highly correlated with date t + 1 consumption growth and returns, and not too numerous (Davidson and Mackinnon, Ch. 17).

Concluding Remarks

The present manuscript develops a theoretical model of investment for the proprietary that explicitly allows for the possibility of credit constraints altering investment. The manuscript shows how to test the model empirically using Hansen's generalized method of moments using aggregate data available for the U.S. farm sector. In addition to other advantages of the advocated model to analyze actual investment behavior, it allows the researcher to calculate a point estimate (along with its standard deviation) of the average cost of credit constraints in relative terms. That is, with the advocated model it is possible to analyze the economic (as opposed to statistical) significance of the credit constraints faced by the firm.

Appendix A: Derivation of Euler Equations (1.7) and (1.8)

The FOC corresponding to optimal physical investment is:

$$\text{(A1)} \quad -\beta^t u'(c_t)\,[p_{I,t} + \frac{\partial a(I_t, K_{t-1})}{\partial I_t}] + E_t[\frac{\partial V_{t+1}(K_t,\ W_{t+1},\ L_t)}{\partial K_t}\ \frac{\partial K_t}{\partial I_t}] = 0,$$

However, (1.6") yields the following result:

$$\text{(A2)} \quad \frac{\partial V_t(K_{t-1},\ W_t,\ L_{t-1})}{\partial K_{t-1}} = \beta^t u'(c_t)\,[p_{Q,t}\ \frac{\partial Q(K_{t-1},\ L_{t-1},\ N_t)}{\partial K_{t-1}} - \frac{\partial a(I_t, K_{t-1})}{\partial K_{t-1}}]$$

$$+ E_t[\frac{\partial V_{t+1}(K_t,\ W_{t+1},\ L_t)}{\partial K_t}\ \frac{\partial K_t}{\partial K_{t-1}}],$$

Furthermore, noting from (1.5) that $\partial K_t/\partial I_t = 1$ and $\partial K_t/\partial K_{t-1} = 1 - \delta$, (A1) may be used to rewrite (A2) alternatively as (A3):

$$\text{(A3)} \quad \frac{\partial V_t(K_{t-1},\ W_t,\ L_{t-1})}{\partial K_{t-1}} = \beta^t u'(c_t)\,\{p_{Q,t}\ \frac{\partial Q(K_{t-1},\ L_{t-1},\ N_t)}{\partial K_{t-1}} - \frac{\partial a(I_t, K_{t-1})}{\partial K_{t-1}}$$

$$+ (1-\delta)\,[p_{I,t} + \frac{\partial a(I_t, K_{t-1})}{\partial I_t}]\}.$$

Expression (1.7) is then obtained by moving (A3) forward one period, plugging the resulting expression into FOC (A1), and using the assumption that $u'(\cdot) > 0$.

The FOC for optimal borrowing is given by (A4):

$$\text{(A4)} \quad \beta^t u'(c_t) + E_t[\frac{\partial V_{t+1}(K_t,\ W_{t+1},\ L_t)}{\partial W_{t+1}}\ \frac{\partial W_{t+1}}{\partial B_t}] = 0.$$

Euler equation (1.8) is then obtained from (A4) by noting that (1.4) yields $\partial W_{t+1}/\partial B_t = -(1 + i_{t-1})$ and that the derivative $\partial V_{t+1}(K_t, W_{t+1}, L_t)/\partial W_{t+1}$ in (A4) can be obtained from (1.6") as follows:

$$\text{(A5)} \quad \frac{\partial V_t(K_{t-1}, W_t, L_{t-1})}{\partial W_t} = \beta^t u'(c_t).$$

Appendix B: Data

<u>Consumption (c)</u>: The consumption series used is real withdrawals per farm operator (RWFO):

$$\text{(B1)} \quad RWFO_t \equiv NWFO_t/IPFL_t,$$

$$\text{(B2)} \quad NWFO_t \equiv [(GCI_t + VHC_t + OFI_t)/NF_t + \Delta DO_t]$$

$$- \{[(TPE - CC_t) + GCEM_t + PREO_t \times GCEB_t]/NF_t + ARE_t + AFA_t\},$$

$$\text{(B3)} \quad \Delta DO_t \equiv (NRED_t + PREO_t \times RED_t)/NF_t - (NRED_{t-1} + PREO_{t-1} \times RED_{t-1})/NF_{t-1},$$

$$\text{(B4)} \quad PREO_t \equiv LOFO_t/(LOFO_t + LRFO_t),$$

$$\text{(B5)} \quad ARE_t \equiv \left(\frac{RE_t / LF_t + RE_{t-1} / LF_{t-1}}{2}\right) \times \left(\frac{PREO_t \times LF_t}{NF_t} - \frac{PREO_{t-1} \times LF_{t-1}}{NF_{t-1}}\right),$$

$$\text{(B6)} \quad AFA_t \equiv \left(\frac{IPFL_t + IPFL_{t-1}}{2}\right) \times \left(\frac{FA_t / IPFL_t}{NF_t} - \frac{FA_{t-1} / IPFL_{t-1}}{NF_{t-1}}\right),$$

where NWFO denotes nominal withdrawals per farm operator, IPFL is the index of prices paid by farmers for family living, GCI equals gross cash income, VHC is the value of home consumption, OFI represents off-farm income, NF is the number of farms, ΔDO equals the change in farm debt per operator, TPE are total production expenses, CC denotes capital consumption (including operator's dwellings), GCEM (GCEB) are farm gross capital expenditures in motor vehicles and other machinery and equipment (buildings and land improvements), PREO is the proportion of farm real estate owned by farm operators, ARE (AFA) is the value of the acquisitions of farm real estate (financial assets) per operator, RED (NRED) equals real estate (non-real estate) debt including dwellings, LOFO is the land owned by farm operators, LRFO equals the land rented from others, RE denotes farm real estate value including dwellings, LF represents land in farms, and FA is the total value of farm financial assets.

The sources for the (original series) used in (B1) through (B6) are as follows: *Economic Indicators of the Farm Sector: National Financial Summary* (GCI, VHC, TPE, CC, GCEM, GCEB, NF, LF, RE, FA, NRED, RED, and OFI), Johnson (GCI, VHC, TPE, CC, GCEM, and GCEB), Census of Agriculture (LOFO and LRFO), Melichar (FA, NRED, and RED), USDA (1973) (NF and LF), U.S. Department of Commerce (RE), and *Agricultural Statistics* (NRED, RED, OFI, and IPFL).

Capital Stock (K): Sum of stocks of autos, trucks, tractors, and other farm machinery. Stocks of autos and trucks (tractors and other farm machinery) are calculated by dividing the value of stocks of autos and trucks (tractors and other farm machinery) reported in *Economic Indicators of the Farm Sector: National Financial Summary* by the index of prices paid by farmers for autos and trucks (farm machinery) reported in *Agricultural Statistics*. Before 1939, stock values were calculated from the series for capital expenditures and depreciation reported in that publication using the method described by McGath and Strickland).

Depreciation rate (δ): Assumed to be 14.8% per year. This is a weighted average of the depreciation rates for autos, trucks, tractors, and other farm machinery used by the USDA (McGath and Strickland).

Price of Capital (p_I): Laspeyres price index constructed using the values of stocks of autos, trucks, tractors, and other farm machinery (from *Economic Indicators of the Farm Sector: National Financial Summary*) and the indices of prices paid by farmers for autos and trucks and for farm machinery (from *Agricultural Statistics*).

Investment (I): Sum of investments in autos, trucks, tractors, and other farm machinery. Investments in autos and trucks (tractors and other farm machinery) are obtained by dividing gross capital expenditures in autos and trucks (tractors and other farm machinery) reported in

Economic Indicators of the Farm Sector: National Financial Summary by the index of prices paid by farmers for autos and trucks (farm machinery) reported in *Agricultural Statistics*.

Interest Rate (i): Interest rate charged by the Farm Credit System's Production Credit Associations on nonreal estate loans, as reported in *Agricultural Statistics* and in *Agricultural Income and Finance*.

<u>Revenue (p_Q Q)</u>: Gross farm income reported in *Economic Indicators of the Farm Sector: National Financial Summary*.

<u>Land Costs (l L)</u>: Land costs are calculated as the product of the rate of return to farmland times the value of farm real estate. The rate of return to farmland is calculated as the sum of appreciation and rent as a percentage of the initial value of farm real estate. The rent to farmland is calculated by multiplying the value of farm real estate by the weighted (by value) average of the state cash-rent-to-value ratios reported by the USDA. The value of farm real estate is taken from Melichar and from *Economic Indicators of the Farm Sector: National Financial Summary*.

<u>Factor costs (p_N N)</u>: Total production expenses plus imputed return to operator's labor and managerial minus interest, net rent to nonoperator landlords, and capital consumption of autos, trucks, tractors, and other farm machinery. All these series are reported in *Economic Indicators of the Farm Sector: National Financial Summary*.

<u>Debt (B)</u>: Nonreal estate debt series (NRED).

<u>Asset values (A)</u>: Farmers' net worth series published in Melichar, *Economic Indicators of the Farm Sector: National Financial Summary*, and *Agricultural Statistics*.

Whenever applicable, data are expressed on a per farm basis by dividing by the number of farms.

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