Farmland Accumulation and Prices

Haim Shalit and Andrew Schmitz

A model of farmland accumulation is developed to study factors influencing U.S. farmland values. This model stresses the manner in which credit is allocated for land purchases. To secure necessary loans for additional land to expand farm size, the farmer provides as collateral his net accumulated wealth. Thus, land acquisitions are made to increase profits and to provide leverage for further land expansion. Besides income and consumption, the level of accumulated debt is one of the main determinants of farmland prices. Derived demand for farmland is developed, and the pricing equation for farmland is estimated as part of a structural equation model.

Key words: debt, farmland, land prices, wealth.

United States farmland was valued in 1979 at over one-half of a trillion dollars—a 50% real increase over 1969. Historically, farmland values more consistently linked to net farm income. This pattern existed from 1910 through 1950, supporting the Ricardian theory of a close relation between land rents and farm income. After the 1950s, the gap between the rise in land prices and the rise in net farm income widened. Moreover, since 1973, real net farm income consistently declined while farmland values continued to rise. The data show that, between 1973 and 1976, prices of U.S. farmland increased at an annual real rate of 9.1%, but real net farm income decreased at a 15% annual rate. The 1976 real net farm income was 6.4% lower than in 1972, while real land prices increased 36%. Considering only the residual income to farmland (net farm income less imputed returns to operators' labor and management) and ignoring capital gains from land price increases, the net return to farmland investment decreased even further between 1972 and 1976.

Professional interest in land prices, inflation, and farm income has been growing in recent years (Melichar, Reinsel and Reinsel, Barry). The motivation for such studies is that the econometric models of the 1960s for the behavior of farmland prices were inappropriate to explain the recent growing divergence between farm income and land values (Pope et al.). Melichar claimed that comparing farm income and farmland prices is incorrect. Instead, one should compare the real capital gains from farm assets with the current returns to these assets. However, Melichar argued, to justify present capital gains, these returns must grow by 5% annually, a rate not attained recently in U.S. agriculture. Reinsel and Reinsel asserted that although farmland prices can be explained by returns to land, "lenient credit terms . . . required to ease the entry of young people into farming . . . benefit only the earliest buyers. Cash flow and equity advantages are soon bid into the price of land" (p. 1096). Consequently, there is room for another theory of farmland demand.

This paper proposes an alternative theory to explain the phenomenal rise of farmland prices that has occurred in recent years. Our analysis focuses on the derived demand for farmland generated by agricultural production. Thus, we do not consider "speculative" motives. The speculative demand for farmland is generated by individuals who consider land as a store of value. Farmland attracts wealth owners who wish to diversify their asset portfolios. Feldstein further developed this notion by including changes in expected inflation. He showed (*a*) how an explicit portfolio choice framework can be used to derive land and capital price equations and (*b*) how increasing inflation causes a rise in the real value of land and a fall in the real value of corporate equities.

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Our analysis is at the level of the individual farm firm from which the aggregate demand for farmland is derived. The farmer maximizes utility over time rather than profit and is a price taker in all markets. The purchase of land is not a single event in the economic life of the farmer. Land purchases are long-term decisions and more than one purchase may be made by a farmer over a lifetime. Thus, one must look at a long-run, lifetime behavior model to derive the agricultural demand for farmland. Because the farmer maximizes utility of consumption over time, the propensity to consume is a decision variable, as are land purchases and other production decisions. For land purchases, it is assumed that credit is rationed and allocated on the basis of accumulated net wealth. The farmer obtains loans to purchase additional land by offering to the lending institutions his existing wealth as collateral. Thus, land acquisitions are made both to increase profits and to leverage further land expansion. This behavior explains farmland demand and the credit demand for land purchases. On the other hand, the supply of credit is provided by bankers who appraise farmers' assets as collateral. These lenders allocate credit according to their expectations of future farmland prices. We assume that any demand for credit to purchase land is satisfied if sufficient collateral is made available by the farmer.

The plan of the paper is as follows: First, we study individual farmer behavior in the land market, deriving his demand for farmland. Second, we develop the aggregate derived demand for farmland. Third, the land market model is empirically tested. Finally, some conclusions are brought forward.

A Life-Cycle Model of Land Accumulation

The model developed assumes that the producer knows, at the beginning of his economic life, the set of output and input prices that will prevail over his entire life span. Results under uncertainty are not derived in this paper. It is important to obtain results under highly simplified assumptions before such a model can be developed. As we show, even under uncertainty, with a realistic credit market, the model becomes complex.

Utility Maximization

At the beginning of his economic life, the farmer chooses a consumption plan, C, to maximize lifetime utility. The farmer does not derive utility from the possession of land. However, he gains satisfaction when he retires from the value of his bequest, which is the net value of land.[1] Assuming additivity, separability of the utility function, and a constant subjective time discount rate equal to the market rate of interest, r, instantaneous utility is written

$$(1) \qquad U[C(t)]e^{-rt},$$

where U is monotonically increasing, strictly concave, and twice differentiable with $\lim_{C(t)\to 0} U'[C(t)] = \infty$. If $V(\cdot)$ is the utility of bequest, the farmer's objective function is

$$(2) \qquad \int_0^T U[C(t)]e^{-rt}dt + V[W(T)]e^{-rT},$$

where T is the time horizon, and $W(T)$ is the value of net wealth accumulated at time T. The farmer's income is the profit, $\Pi[L(t)]$, defined as the revenue from farming less variable production costs. Land, $L(t)$, is owned as a means of production and as a store of wealth; it does not include buildings.

We assume that for a given land parcel, profit is constantly maximized with respect to available factors of production. The farmer decides upon a consumption level which maximizes his utility. The residual between the net income $\Pi[L(t)]$ and consumption is the farmer's net savings, S. We assume that S is used only for the purchase of additional land. This assumption, which seems restrictive, is based on the view that people invest in that which they know best. In a certain world, we also require that the returns on land be larger than the returns on any other prospect. Such an assumption implies that the rate of return on land (which we argue is based on the farm income and capital gains) is above the market interest rate. This condition, as we now argue, is consistent with credit rationing.

Access to Credit

In addition to using savings, the farmer also can borrow funds to purchase land. He is not required to borrow because land can be bought with cash savings. However, the rational farmer continues to borrow funds as long as farmland investment yields a positive

[1] This utility of bequest considers the farmer's utility of consumption between the time he retires and when he dies. This utility is a subjective evaluation of the net wealth accumulated during the farmer's active period.

net present value, implying that the internal rate of return on land is greater than or equal to the market rate of interest. We assume, however, that credit is rationed. This means that the farmer cannot borrow as much as he desires at market interest rates. Evidence of credit rationing in U.S. agriculture is reported by Dahl, Hesser and Schuh, and Schultz. The economic theory of credit rationing is discussed by Azzi and Cox, Freimer and Gordon, and Jaffee. These authors stress the notion of collateral that must be offered by the borrower to secure all loans. In our model, collateral is provided by accumulated net wealth, as defined by the current value of farmland less total debt at time t. Thus

$$(3) \qquad W(t) = P^L(t) \cdot L(t) - D(t),$$

where $W(t)$ is the net wealth of the farmer at time t, $D(t)$ is accumulated debt, $L(t)$ his land holdings, and $P^L(t)$ the going price of land at time t.

In a dynamic framework, the value of collateral that can be offered to secure a loan is equal to the change in wealth, since total wealth is already mortgaged for existing loans. The validity of this assumption depends on, among other things, the producer's age. The net wealth change includes the change in the value of the existing stock of land (the change in land prices and the value of additional land) less the change in the farmer's debt. This debt is then the sum of all past loans less reimbursements.

The farmer borrows as long as land purchases yield a positive net present value or as long as he has the necessary collateral to secure loans. Since credit is rationed, the farmer offers all his net wealth as collateral. Thus, the maximum loan that can be secured at time t is

$$B(t) \equiv B[P^L(t) \cdot L(t) - D(t)],$$

where $B(\cdot)$ is assumed to be a linear function of $W(t)$. For this relation, assume that a farmer purchases a parcel of land, $\tilde{L}$, and is required to pay P^L for it. He will be able to obtain an outright loan of size $\beta \cdot P^L\tilde{L}$ (where $0 < \beta < 1$). He must, however, supply $(1 - \beta) \cdot P^L \cdot \tilde{L}$ as a cash down payment from savings, S, or from loans based on his net worth which has increased because of price increases. On the other hand, if land prices decrease, the farmer wanting to buy land must allocate more of his savings to meet the cash down payment. Furthermore, he can sell parcels of land to meet consumption requirements if net income is insufficient.

A loan, $B[W(t)]$, granted at time t for the period $[t,T]$, is repaid by equal installments of size $\gamma(t) \cdot B[W(t)]$, where

$$(4) \quad \gamma(t) = r/\{1 - \exp[-r(T - t)]\} \qquad \text{for } (T - t) > 1,$$

and r is the interest rate on loans.

Credit costs, $K(t)$, are composed of the payments towards interest, $I(t)$, and principal, $P_r(t)$. They increase by $\gamma(t) \cdot B[W(t)]$ each time the farmer takes a new loan. Thus,

$$(5) \qquad K(t) = P_r(t) + I(t), \text{ and}$$

$$(6) \qquad \dot{K}(t) = \gamma(t) \cdot B[W(t)].$$

Credit costs at time t are the sum of all the installment payments from past loans. However, interest payments are paid on outstanding debt $D(t)$. Hence,

$$(7) \qquad I(t) = rD(t),$$

and, from equation (5), principal payments are

$$(8) \qquad P_r(t) = K(t) - rD(t).$$

As outstanding debt increases with new loans and decreases with principal payments, the equation governing the debt change of the producer over time is

$$(9) \quad \dot{D}(t) = B[P^L(t) \cdot L(t) - D(t)] - K(t) + rD(t).$$

Land Accumulation and Budget Constraint

The farmer's purchase of additional land is constrained by the savings he decides upon and the loans he can obtain. The latter depends on the change in the producer's net wealth. Hence, the change in the farmer's land holding is

$$(10) \quad \dot{L}(t) = \frac{1}{P^L(t)} \{S(t) + B[P^L(t) \cdot L(t) - D(t)]\}.$$

This relation expresses the demand for farmland by farmers. Land can even be purchased $[\dot{L}(t) > 0]$ when farm income is declining but land prices are increasing. In that case savings decline, but the gain in net worth more than compensates for it. Furthermore, land can be sold when prices increase if the farmer wants to consume more than he earns from agriculture.

Credit costs including interest and principal must be deducted from the total revenue to reflect the farmer's instantaneous profit. By equation (5), this implies that loans are being repaid in equal installments and that the interest rate for loans is exogenous and constant. The instantaneous budget constraint is

$$(11)\quad C(t) + S(t) = \Pi[L(t)] - K(t);$$

thus, equation (10) becomes

$$(12)\quad \dot{L}(t) = \frac{1}{P^L(t)}\{\Pi[L(t)] - K(t) - C(t) + B[P^L(t)\cdot L(t) - D(t)]\}.$$

We assume that the funds available for credit repayment are always adequate. If land prices are increasing, the farmer can always sell land to help pay old debts if farm income is not sufficient since he can borrow funds on newly created equity. On the other hand, if land prices decrease and income is not large enough to service debt, $\dot{L}(t)$ will be negative. Thus, the farmer will have to sell all or part of his holdings.

The Optimal Consumption Plan

The farmer's basic objective is to maximize lifetime utility [equation (2)] subject to the land accumulation constraint [equation (12)], the debt management constraint [equation (9)], and the credit cost constraint [equation (6)]. Because the objective function is an integral over a finite interval $(0,T)$ and the constraints are differential equations, the solution used here is the maximum principle of optimal control. The solution is dynamic since we must determine the pattern of the farmer's optimal consumption over time, his subjective evaluation of the land constraint, the debt constraint, and the credit cost constraint.

The optimal consumption plan is found by maximizing the following Hamiltonian function with respect to $C(t)$:

$$(13)\quad H(\cdot) = e^{-rt}\{U(C) + \frac{\lambda}{P^L}[\Pi(L) - K - C + B(\cdot)] + \mu[B(\cdot) - K - rD] + \eta[\gamma(t)\cdot B(\cdot)]\},$$

where λ, μ, and η are the dual variables associated with the land constraint, the debt constraint, and the credit cost constraint, respectively. They are the dynamic equivalent of Lagrangean multipliers, representing the farmer's subjective (implicit) utility evaluation of the constraints.

If $C(t)$ is an optimal solution to the problem, there are three continuous functions $\lambda(t)$, $\mu(t)$, and $\eta(t)$ which satisfy the necessary conditions of the maximum principle of optimal control. They are

$$(14)\quad \frac{\partial H}{\partial C} = 0 \Rightarrow U'(C) = \frac{\lambda}{P^L},$$

$$(15)\quad \dot{\lambda} - \lambda r = -\frac{\partial H}{\partial L} \Rightarrow \dot{\lambda} = \lambda\left(r - \frac{\Pi_L}{P^L} - B_W\right) - B_W P^L[\mu + \eta\gamma(t)],$$

$$(16)\quad \dot{\mu} - \mu r = -\frac{\partial H}{\partial D} \Rightarrow \dot{\mu} = B_w\left[\frac{\lambda}{P^L} + \mu + \eta\gamma(t)\right],$$

$$(17)\quad \dot{\eta} - \eta r = -\frac{\partial H}{\partial K} \Rightarrow \dot{\eta} = \frac{\lambda}{P^L} + \mu + \eta r.$$

The first condition states that the Hamiltonian is maximized by the control variable, C, at each point along the optimal path. The necessary conditions (15), (16), and (17) are differential equations for the dual variables defining the optimal path of the shadow prices of the state variables (land, debt, and credit cost). These conditions and the constraints (6), (9), and (12) plus the following boundary and initial conditions form the equations that determine the optimal path of the farmer behavior. The boundary conditions are given by

$$(18)\quad \lambda(T) = P^L V_W(P^L\cdot L - D),$$

$$(19)\quad \mu(T) = V_W(P^L\cdot L - D) = \frac{\lambda(T)}{P^L},$$

$$(20)\quad \eta(T) = 0;$$

and the initial conditions by

$$(21)\quad L(0) = L_0,\ D(0) = 0,\ K(0) = 0.$$

The optimal conditions show the behavior of the shadow prices of land and debt accumulation over time. The shadow price of land, λ, expresses in utility terms the subjective value of the land constraint. For the individual farmer, the rate of change of λ depends on the following factor. First, it is positively related to the actual price of land, P^L, from the first-order condition (14). Furthermore, as land prices increase, land accumulation is more expensive, and $\dot{\lambda} > 0$. Second, it is negatively related to the marginal product of land. As more profit is expected for the same amount of land, less land is required to sustain the same utility level. Third, λ will increase as the interest rate increases because farmers will postpone land purchases in favor of present consumption. And, finally, the impact of the net wealth effect B_W on $\dot{\lambda}$ is composed of a negative element $-\lambda$ and a positive element $-P^L[\mu + \eta\gamma(t)]$. The first expresses the farmer's ability to acquire more land when credit terms are eased (larger B_W). The second term illustrates the burden of debt and accumulated credit costs on the future availability of credit. These relations do not conform closely with statistic production theory. However they perfectly reflect the conclusions of optimal growth theory (Intriligator, chap. 16). For example, the imputed value of land accumulation (equal to marginal utility of consumption) rises with the interest rate and decreases with the marginal productivity of land. Furthermore, as we will see in equation (29), below, these conditions enable us to derive as a special case the static land valuation theorem.

The imputed value of debt, μ, and the imputed value of credit costs, η, are negative because their increase limits the farmer's future ability to borrow funds—the first by reducing net wealth and the second by reducing profit. Hence, loans increase the farmer's welfare because they allow him to acquire land. However, outstanding debt and credit costs do not. The rate of change in μ and the rate of change in η are negatively related to r since the farmer preferring more present consumption will not purchase additional land by debt financing. Thus, land accumulation expands whenever credit becomes available, but credit is available only when sufficient wealth is accumulated. Similarly, land accumulation increases with profit, but profit can only increase through a reduction in credit costs or by land expansion.

The system of equations (6), (9), (12), and (14)–(20) can be solved for specific functions and for a given set of initial conditions [equation (21)]. This solution is a system of equations that determine the time path of the consumption level, the holdings of land, the size of debt, and credit costs. Since equation (14) holds for every t, the consumption equation is derived by

$$(22) \qquad \dot{\lambda} = P^L\left(U''\dot{C} + U'\frac{\dot{P}^L}{P^L}\right).$$

Condition (16) can be rewritten as

$$(23) \qquad \dot{\mu} - \frac{\lambda}{P^L}B_W = B_W[\mu + \eta\gamma(t)],$$

which, inserted in (15), gives

$$(24) \qquad \dot{\lambda} = \lambda\left(r - \frac{\Pi_L}{P^L}\right) - \dot{\mu}P^L.$$

Equation (24) implies that the rate of change in λ does not depend on η or μ but on the change in the subjective price of debt. The farmer does not have to evaluate the subjective price of credit to determine his imputed value of land. The value $\dot{\mu}$ enters the equation only as a reference point for obtaining future loans. The net wealth effect B_W does not appear in the equation but affects $\dot{\mu}$ by (16). Equate equation (22) with (24) to obtain the dynamic equation of consumption as

$$(25) \qquad \frac{\dot{C}}{C} = \left(\frac{\Pi_L}{P^L} + \frac{\dot{P}^L}{P^L} - r\right)/\sigma(C) + \dot{\mu}/U'(C)\sigma(C),$$

where

$$(26) \qquad \sigma(C) = -\frac{U''(C)}{U'(C)} \cdot C$$

is the elasticity of marginal utility. In a land accumulation model without credit restrictions, it can be shown that the rate of consumption change over time is

$$(27) \qquad \frac{\dot{C}}{C} = \left(\frac{\Pi_L}{P^L} + \frac{\dot{P}^L}{P^L} - r\right)/\sigma(C).$$

Equation (27) is the classical solution of wealth accumulation in a growth model. It states that the consumption growth rate decreases with the interest rate and increases with marginal income—the marginal profit from agriculture per dollar spent on land $\left(\frac{\Pi_L}{P^L}\right)$ plus the expected capital gains on farmland $\left(\frac{\dot{P}^L}{P^L}\right)$. Similarly, in a world without credit restrictions, the land accumulation constraint (12) becomes

$$(28) \qquad \dot{L} = \frac{1}{P^L}[\Pi(L) - C].$$

Solution of the system of differential equations (27) and (28) provides the optimal path of consumption and land accumulation in a world without credit restrictions. One possible solution is a steady-state one in which no individual land accumulation takes place and consumption remains constant, $\dot{L} = 0$ and $\dot{C} = 0$. In that case, $C = \Pi(L)$, implying that farmers, willing to maximize utility of consumption, indeed maximize income from farming. From (27) and $\dot{C} = 0$, one obtains

$$r = \frac{\Pi_L}{P^L} + \frac{\dot{P}^L}{P^L}. \tag{29}$$

This is the basic land valuation theorem including capital gains. Condition (29) shows that the classical land valuation holds for a world without credit restrictions and for a steady-state growth pattern. Hence, the traditional land valuation relation is only a special and restrictive case of our general model. However this standard relation is hardly representative of U.S. agriculture.

We now analyze equation (25) which expresses the individual consumption rate in a dynamic economy with credit restrictions. In that case, the consumption growth rate is equal to its value in the absence of credit plus the rate of change of the subjective utility price of debt. This relation implies that, *ceteris paribus*, the rate of consumption growth will decline if $\dot{\mu}$ is negative. By equation (16), μ is expected to be positive at the beginning of the planning period. As time passes and land accumulation continues, λ, μ, and η are decreasing. Thus $\dot{\mu}$ will be negative and will never be positive again because μ and η are negative. Hence, credit allocated on the basis of wealth induces the farmer to postpone consumption.

On the other hand, the land holdings will be larger in the present model than in one without credit restrictions, because from the beginning of the planning period, the farmer accumulates land at a faster pace [equation (12)]. This is because the credit costs, K, are smaller than the loan, $B(P^L \cdot L - D)$. Second, as time passes and consumption increases at a decreasing rate [equation (25)], land accumulation continues to increase. Moreover, as land prices increase, so does $\dot{L}$, since

$$\frac{\partial \dot{L}}{\partial P^L} \geqq 0 \qquad \text{for linear } B(\cdot).$$

The Aggregate Derived Demand for Farmland

Since the total supply of land can be considered as fixed and finite, the aggregate excess demand is the sum of the derived demands of buyers and sellers. In the aggregate, the equilibrium land price is that at which no more land transfers take place because both sellers and buyers are satisfied and the aggregate excess demand is zero. This is essentially a Walras equilibrium since the farmers consider the price of land as predetermined. They make their decisions independently of each other.

Consider an economy of farmers who are identical in the sense (a) that they have similar subjective discount rates equal to the market interest rate, (b) they have identical time horizons T, and (c) at the beginning of the planning period they are endowed with equal quantities of land L_0 and debt D_0. They are, however, different in their economic age, $0 \leqq a \leqq T$, which is distributed according to the density function $h_t(a)$ such that

$$\int_0^T h_t(a)\, da = N_t, \tag{30}$$

where $h_t(a)$ is the density function of economic age at time t, and N_t is the total number of farmers at time t. The differentiation by economic age is important since the consumption level, the demand for farmland, and the debt are time- and, thus, age-dependent. When the farmer is "young" (a is near 0), he tends to acquire more land than when he is "old" (a is near T). At T, the farmer retires from agriculture and sells his land or bequeaths it to an heir (whose economic age is zero).

Since consumption, the demand for land, and debt are time-dependent, they are also age-dependent. At $t = 0$, the farmer whose economic age is zero owns L_0 land. However, because of past history, the stock of land held at $t = 0$ by farmers of different economic age is distributed according to their ages.

Since the total supply of land is fixed and finite at $\bar{L}$, the holding of land is attainable for the whole economy if for every $t \epsilon (0, \infty)$,

$$\int_0^T L_t(a)\, h_t(a)\, da \leqq \bar{L}. \tag{31}$$

Because of the private ownership of land and nonsatiety in the utility function, attainability implies

$$\int_0^T L_t(a)\, h_t(a)\, da = \bar{L} \tag{31a}$$

for every $t \epsilon (0, \infty)$. Therefore,

$$\int_0^T l_t(a)\, h_t(a)\, da = 0 \tag{32}$$

for all t, where

$$l_t(a) = \dot{L}_t(a),$$

since $\partial h_t(a)/\partial t = 0$ almost everywhere for a uniform distribution function $h_t(a)$.

Because each farmer maximizes his lifetime utility subject to $L_0(a)$ and a land price function, the derived land demand by farmers of economic age a, obtained from the optimum conditions (6), (9), (12), and (14)–(20), is

$$(33)\quad l_t(a, P^L) = \frac{1}{P^L}\{\Pi[L(a)] - K(a, P^L) - C(a, P^L) + B[P^L \cdot L(a) - D(a, P^L)]\},$$

where $D(\cdot)$, $B(\cdot)$, $K(\cdot)$, and $C(\cdot)$ are optimally derived from

$$(34)\quad \frac{\dot{C}(a, P^L)}{C(a, P^L)} = \left(\frac{\Pi_L}{P^L} + \frac{\dot{P}^L}{P^L} - r\right)\Big/\sigma(C) + \dot{\mu}/U'(C) \cdot \sigma(C),$$

$$(35)\quad \dot{D}(a, P^L) = B[P^L \cdot L(a) - D(a, P^L)] - K(a) + rD(a, P^L), \text{ and}$$

$$(36)\quad K(a) = \int_0^a \gamma(\tau)\, B[P^L \cdot L(\tau) - D(\tau, P^L)]d\tau.$$

Since $l(a, P^L)$ is optimally derived by each farmer and condition (32) holds for all the farmers, an equilibrium exists in the land market.

For specific values of T and r, the equilibrium land price for every t is found by solving the equation

$$(37)\quad \int_0^T h_t\,(a)\frac{1}{P^L}\{\Pi[L(a)] - \int_0^a B[W(\tau)]\gamma(\tau)\,d\tau - C(a, P^L) + B[P^L \cdot L(a) - D(a, P^L)]\}\,da = 0,$$

where $C(a, P^L)$ solves the differential equation (34). Individual consumption is a function of marginal net income, farmland price change rate, interest rate, and the change rate of accumulated debt. Hence,

$$(38)\quad C(a, P^L) = g^1[\dot{\Pi}(a)/\Pi(a), \dot{P}^L/P^L, r, \dot{D}(a)/D(a)].$$

Similarly, the solution of (35) provides the level of debt as a function of farmland price, interest rate, and the size of current land holdings;

$$(39)\quad D(a, P^L) = g^2[P^L, r, L(a)].$$

By aggregating the consumption level and the debt level over the entire agricultural sector, for each time period t we obtain

$$\bar{C}_t(P^L) = \int_0^T g^1[\dot{\Pi}(a)/\Pi(a), \dot{P}^L/P^L, r, \dot{D}(a)/D(a)]h_t(a)da, \text{ and}$$

$$\bar{D}_t(P^L) = \int_0^T g^2[P^L, r, L(a)]h_t(a)da.$$

Because the total land holdings are fixed and equal to $\bar{L}$, these functions become

$$(40)\quad \frac{\bar{C}_t}{\bar{L}} = G^1(\dot{\bar{\Pi}}_t/\bar{\Pi}_t, \dot{P}_t^L/P_t^L, r, \dot{\bar{D}}_t/\bar{D}_t) \text{ and}$$

$$(41)\quad \frac{\bar{D}_t}{\bar{L}} = G^2(P_t^L, r, N_t),$$

where N_t is the number of farmers and $\bar{\Pi}_t$ is the net income of the agricultural sector defined by

$$\bar{\Pi}_t = \int_0^T h_t(a)\{\Pi_t[L(a)] - K(a)\}\,da.$$

Since $B(\cdot)$ is linear in net wealth [i.e., $B(\cdot) = B_W(P^L \cdot L - D)$], equation (37) can be rewritten as

$$(42)\quad \bar{\Pi}_t - \bar{C}_t + B_W P_t^L \bar{L} - B_W \bar{D}_t = 0.$$

This is the fundamental equation for estimating the price of farmland from aggregate data. Hence,

$$(43)\quad P_t^L = \frac{1}{B_W}\left[\frac{\bar{C}_t(\cdot)}{\bar{L}} - \frac{\bar{\Pi}_t}{\bar{L}}\right] + \frac{\bar{D}_t(\cdot)}{\bar{L}}.$$

However, since $\bar{C}_t(\cdot)$ and $\bar{D}_t(\cdot)$ are endogenous variables, equation (43) must be estimated simultaneously with equations (40), (41), and (43). Aggregate net income per acre is assumed exogenous since credit costs depend on past land prices.

Empirical Results

The model represented by equations (40), (41), (43) is estimated for U.S. agriculture using annual data for the 1950–78 period. Farmland price is measured by the index of farm real estate value. This series is compiled by the Department of Agriculture's (USDA) Economic Research Service from estimates provided by regional crop reporters. The data is adjusted with information obtained from farm real estate brokers, local bankers, and county officials. Total net income is obtained from the series compiled by Hottel and Evans. The series consists of residual income to real estate equity obtained by deducting imputed returns to labor, management, and dwellings from the operator's total net farm income. The data on farm real estate debt, total land, and farm numbers are contained in USDA's *Agricultural Statistics*. The interest rate used is the average rate of interest on new loans. All figures are deflated to constant 1969 values using the consumer price index. Because consumption in the agricultural sector is unobservable and the theoretical model uses continuous time, compromises are necessary in order to estimate the structural equations. First, an exponential solution to the differential equation governing consumption is obtained by assuming that there is a constant rate-of-consumption change which is equal to the right-hand-side variables of equation (34). In that case, (34) becomes

$$\frac{C}{L}(t) = C_0\, e^{zt},$$

where z is a linear function of the independent variables in G^1 of equation (40). The consumption level is therefore

$$(44)\quad c_t = \exp[\delta_0 + \delta_1\phi_t + \delta_2\rho_t + \delta_3 r_t + \delta_4\psi_t],$$

where c_t is consumption per acre $(\bar{C}_t/\bar{L}_t)$; ϕ_t, net income change rate $(\dot{\Pi}_t/\bar{\Pi}_t)$; ρ_t, land price change rate $(\dot{P}_t^L/P_t^L)$; r_t, interest rate; and ψ_t, debt change rate $(\dot{D}_t/\bar{D}_t)$.

The theoretical model shows that the land price is a function of accumulated debt and savings. Assuming that land usually is sold at the end of the season after income from farming is obtained, the price of land is a function of present debt and lagged savings. Thus,

$$(45)\quad P_t^L = g(d_t, \pi_{t-1}, c_{t-1}),$$

where d_t is debt per acre, and π_t is income per acre. The functional form chosen for estimating (45) is a log-linear relationship. Hence, the empirical pricing function is

$$(46)\quad P_t^L = \gamma_0 d_t^{\gamma_1}\, \pi_{t-1}^{\gamma_2}\, c_{t-1}^{\gamma_3},$$

where γ_1, γ_2, γ_3 are elasticities to be estimated. Since the right-hand-side variables of equation (44) are predetermined, c_{t-1} is replaced by its equation. Thus, the price of land is estimated as a function of the debt per acre, the prior year's net income, and all factors affecting last year's consumption. From (46) and (44),

$$(47)\quad P_t^L = e^{\alpha_0}\, d_t^{\alpha_1}\, \pi_{t-1}^{\alpha_2} \exp(\alpha_3\phi_{t-1} + \alpha_4\rho_{t-1} + \alpha_5 r_{t-1} + \alpha_6\psi_{t-1}).$$

Finally, a log-linear relationship is used for the debt equation, which is estimated as

$$(48)\quad d_t = e^{\beta_0}\, P_t^{L\beta_1}\, N_t^{\beta_2}\, r_t^{\beta_3}.$$

The structural system to be estimated has been reduced to equations (47) and (48). The exponential form for these two equations was used principally because of the solution assumed for the consumption function (44). Furthermore, we hypothesize that the error terms of the estimated equations are serially correlated. This is based on the speculative demand theory that farmland serves as an inflation hedge. Thus, residuals may contain omitted variables, such as expected inflation, which are serially correlated. This hypothesis is tested using Fair's two-stage least-squares Cochrane-Orcutt procedure (2SLS-CORC).

In the presence of serial correlation, least squares estimates remain unbiased, unless the omitted variables also are correlated with the explanatory variables. We estimated the serial correlation coefficient for each equation and corrected the standard errors accordingly. The regression results are reported in table 1. For each equation, single equation two-stage least squares (2SLS), ordinary Cochrane-Orcutt (CORC) method, and 2SLS-CORC procedure are presented. Using Godfrey test for serial correlation, one can reject the null hypothesis ($\rho = 0$) for the debt equation but not for the price equation. The CORC method reveals evidence of positive serial correlation for the two equations. The price equation estimates confirm the hypothesis that farmland price is determined principally by accumulated debt and less strongly by farm income. The relative size of the elasticities is interesting. The debt elasticity is not far from unity in the two Cochrane-Orcutt estimates. This suggests that most of the debt on farm real estate is translated into land price increases, whereas farm income increases have a much smaller impact. On the other hand, the factors affecting past consumption (ψ_{t-1}, r_{t-1}, ρ_{t-1}, ϕ_{t-1}) are not statistically significant, so that we were unable to measure the possible impact of consumption on land accumulation. Perhaps we could estimate the system more accurately if data on aggregate consumption in the agricultural sector were available.

For the debt equation, we see that debt per acre increases with land prices and declines as farm numbers increase. The declining number

Table 1. Regression Estimates of the Price and Debt Equations

Price Equation (P_t^L)				Debt Equation (d_t)			
Variables	CORC	2SLS	2SLS-CORC	Variables	CORC	2SLS	2SLS-CORC
Constant	1.99	3.11	2.14	Constant	3.44	4.09	3.47
	(3.42)	(31.63)	(3.19)		(5.56)	(6.92)	(4.83)
π_{t-1}	.051	.034	.039	P_t^L	.32	.23	.32
	(1.37)	(.60)	(.87)		(3.78)	(2.33)	(3.13)
d_t	.83	.49	.79	N_t	−1.72	−1.89	−1.73
	(4.78)	(12.45)	(3.98)		(−6.59)	(−15.89)	(−6.20)
ϕ_{t-1}	−.01	−.02	.003	r_t	−.002	.0003	.002
	(−.42)	(−.47)	(.09)		(.95)	(.05)	(.93)
ρ_{t-1}	.17	1.43	.15				
	(.65)	(2.67)	(.47)				
r_{t-1}	.50	−.01	.15				
	(.96)	(−.01)	(.22)				
ψ_{t-1}	−.26	−.91	.085				
	(−.63)	(1.42)	(.14)				
R^2	.98	.95	.98	R^2	.99	.99	.99
$S^{2(a)}$	.021	.094	.022	S^2	.016	.030	.016
$\rho^{(b)}$	.90	—	.89	ρ	.89	—	.89
$\pi^{(c)}$	—	.10	3.22	π	—	2.63	3.12

Note: t-values in parentheses, (a) sum of squared residuals, (b) serial correlation estimator, (c) Godfrey's π. The measurement units are. income/acre: U.S.$ per acre deflated by the consumer price index (1967 = 100); debt/acre: U.S.$ per acre deflated by CPI; price of acre: index of farm real estate value (1967 = $100) deflated by CPI; number of farms: in millions of farms.

of farms and the increase in land area per farm is related to the rise in urban income, which is an incentive to leave agriculture (Kislev and Peterson). We argue that this process, through our modelling of the credit market, causes an increase in the debt per acre for the remaining farmers who buy land. In addition, the interest elasticity in the debt equation is not significantly different from zero. This is certainly plausible when the supply of funds from the general banking sector made available for land purchases is at least as great as the demand for credit for farms. As we emphasize, the supply of credit is influenced by bankers' perceptions of future real-estate values.

Conclusion

A model of farmland accumulation, emphasizing the factors affecting farmland prices, was proposed and empirically tested. It was shown that savings (the difference between farm income and consumption) and accumulated real estate debt are the main determinants of high farmland prices. This conclusion was derived from a model which is a more general and dynamic extension of the standard asset valuation theory. We have demonstrated that the price of farmland is determined not only by the profit it generates (agricultural income and capital gains) but also by the debt it can carry. The latter depends critically on the extent to which the banks are willing to lend farmers money to purchase farmland. This depends on bankers' expectations about the future real value of farmland.

We have shown that as the banking system increases the supply of credit to farmers with land as collateral, land values rise at a faster rate than if no credit were available. Hence, the expansion and contraction of credit importantly affects the pace at which land prices increase or decrease.

While this paper deals only with derived demand for land generated from agricultural production, there is ample room for explicitly including the speculative demand for land. The latter has been developed by Feldstein and by Barry, who explain farm real estate returns in a portfolio context. The link between these two demands depends on the formation of expectations which controls credit extension by bankers.

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