Accumulation and Rental Behavior in the Market for Farmland

Robert G. Chambers and Tim T. Phipps

A farmer's choices of tenure and farm size result from a complex interplay of economic factors, technology, entrepreneurial ability, and personal preferences. This paper examines the qualitative effects of these factors on tenure and farm size in a dynamic optimization framework. One implication of the theoretical model is that changes in technology should cause systematic differences to be observed between rates of return on farmland and rates earned on comparable long-term assets. This implication is supported by an empirical test.

Key words: land accumulation, land rental, nonpecuniary benefits, technical change.

Many postwar structural changes in U.S. agriculture, such as the increase in average farm size and the decline in the agricultural labor force, are well understood and at least partially explained by technological change. A less noted, but nonetheless important, development has been the evolution of a farm tenure system characterized by two stylized facts: the full-owner operator has been displaced by the part-owner operator as the dominant tenure category for large commercial farms (table 1 and figure 1); and tenant farming, the traditional entry point on the agricultural ladder, has declined greatly in importance. While the breakdown of the tenant farming system has been attributed (particularly in the South) to the introduction of labor-saving technical innovation (Day), the switch from full-owner operator to part-owner operator is less understood.

Two bodies of literature are most relevant to this study: the literature on farmland price determination and that on tenure choice. Most farmland price studies have separated land price determination from the choices of farm size and tenure (Castle and Hoch, Herdt and Cochrane). Some studies have attempted to include farm size considerations as explanatory factors for land prices. Examples include average farm size (Klinefelter), the change in average farm size (Reynolds and Timmons), and the stock of machinery, a proxy for the demand for farm enlargement (Tweeten and Martin). All of these models were basically static in nature.

Three studies have examined farmland pricing in a dynamic framework (Burt, Phipps, Shalit and Schmitz). Burt assumed the stock of land was fixed, so prices were entirely demand determined. Choice of farm size and tenure were not considered in the theoretical or empirical models. In his theoretical model Phipps allowed the farmer to adjust land stock but assumed the stock of land was fixed in the empirical model. In addition, because the theoretical model allowed instantaneous adjustment, it was not capable of capturing truly dynamic behavior. Shalit and Schmitz considered optimal land accumulation when adjustment of land stocks was constrained by the flow of savings. Their empirical model focused on the effects of owner equity on farmland prices. None of these studies explored the joint choices of farm size and tenure.

Prior to World War II, much of the farm tenure literature involved study and testing of the agricultural ladder concept. The agricultural ladder was a hypothetical career path for farmers, from farm laborer to tenant and even-

Robert G. Chambers is a professor at the Department of Agricultural and Resource Economics, University of Maryland. Tim T. Phipps is a Fellow at the National Center for Food and Agricultural Policy, Resources for the Future.

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Table 1. Farm Tenure System

	Operated Land by Tenure					
	Full	Part owners				
Year	own-ers	Land owned	Land rented	Total	Ten-ants	Man-agers
	(% total acres)					
1935	37	13	12	25	32	6
1940	36	13	15	28	29	7
1945	36	17	16	33	22	9
1950	36	21	16	37	18	9
1954	34	23	18	41	16	9
1959	31	25	20	45	14	10
1964	29	26	22	48	13	10
1969	35	28	24	52	13	NA
1974	35	28	25	53	12	NA
1978	33	29	26	55	12	NA

Source: U.S. Census of Agriculture.

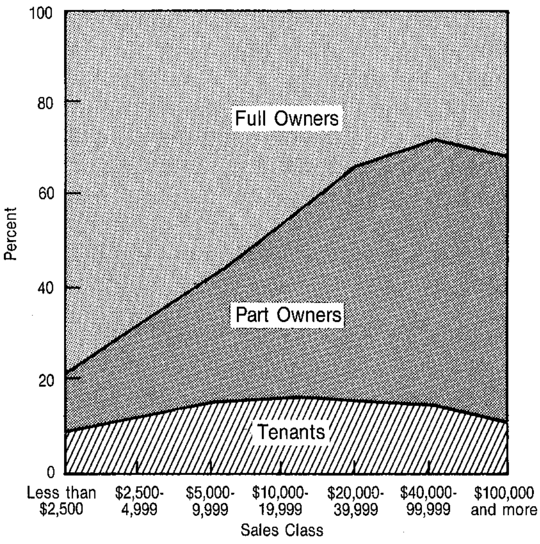

Figure 1. Tenure of operator, 1978

tually to full-owner operator. By 1950, the concept was discredited as being an unrealistic view of the farm tenure process (Barlowe and Timmons). The more recent literature has concentrated on the effects of tenure on efficiency, especially the relative efficiency of cash and share rental (Apland, Barnes, and Justus; Cheung; Stiglitz; Sutinen). Garcia, Sonka, and Yoo examined the joint effects of farm size and tenure on farm efficiency in Illinois. The authors did not address the choices by a farmer of farm size and tenure because land was assumed to be fixed and tenure was exogenous to the model.

This paper uses a growth-theoretic framework to examine the choices of tenure and size of operating unit. It is similar to the study of Shalit and Schmitz in that it assumes farmers solve an intertemporal utility maximization problem. However, unlike Shalit and Schmitz, the present approach recognizes explicitly that farmers receive nonpecuniary as well as pecuniary benefits from land ownership. In the Shalit and Schmitz study, utility was yielded only by consumption and the bequest of wealth at the end of the planning period (savings embodied in land).

Perhaps more importantly, the present study also integrates the rental decision into a dynamic optimization model. This development yields a central contribution of the paper: an interpretation of the land-rental market as a temporary equilibrium mechanism that permits farmers to make short-run adjustments in their farmed land size in much the same manner that active markets for commodity inventories facilitate short-run commodity adjustments.

One implication of the theoretical model is that changes in technology should cause systematic differences to be observed between rates of return on farmland and rates earned on comparable long-term assets. An empirical test, using time as a proxy for technical change, provides support for this implication.

The Model

Assume producers face a technology summarized by

$$\Upsilon(z, l_1, l_2, \Theta),$$

which is compact and convex. Here z is a vector of net outputs, l_1 is land owned by the farmer, l_2 is land rented (in or out) by the farmer ($l_2 < 0$ if the farmer rents out land and $l_2 > 0$ if the farmer rents in land), and Θ is a shift indicator that will be interpreted variously as an index of managerial ability and the state of technology. The specification of Υ recognizes that owned land and rented land need not be perfect substitutes in production. There are numerous reasons for this: for example, rented land may not be geographically adjacent to the farmer's operation, and its utilization may require different practices by the farmer. In addition, as hypothesized by Ciriacy-Wantrup, renters may be less inclined than owners to make long-term land improving or soil-conserving investments, such as leveling, tile drainage systems, or terracing. Ervin has provided empirical support for this hypothesis, although another study (Dillman and Carlson) was not supportive. At any point in time, the producer's income from a given level of owned and rented land committed to production is defined by

$$\pi(l_1, l_2, v, \Theta) = \max\{v \cdot z - \phi(l_1): z \epsilon \Upsilon(z, l_1, l_2, \Theta)\},$$

where v is an n-dimensional vector of net output prices and $\phi(\cdot)$ is a strictly convex function reflecting the cost of maintaining the quality of owned land. Π possesses the following properties: convex in v, non-decreasing in v and a generalized version of Hotelling's lemma (where the * indicates optimal choice):

$$z_i^* = \frac{\partial \Pi}{\partial vi} \qquad i = 1, 2, \ldots, n.$$

It is also assumed that Π is twice-continuously differentiable and exhibits strict concavity (diminishing marginal profitability) in both l_1 and l_2 while it is increasing in both l_1 and l_2.

Producers maximize the present value of utility, where instantaneous utility depends upon consumption (c). But at the same time we want to recognize that farmers may derive nonpecuniary benefits from owning land. Hence, instantaneous utility is expressed

$$u(c, l_1),$$

where $u(\cdot)$ is a twice-continuously differentiable and concave function of its arguments. We also assume land ownership and consumption are complementary goods ($\partial^2 u/\partial c \partial l_1 > 0$). In other words, farmers may derive utility from owning land in addition to the pecuniary remuneration they receive from renting the land or farming. To presume otherwise "does not do justice to the magnetic attraction of land" (Currie, p. 119). In many societies, land ownership obviously confers psychic or status-good benefits that are quite apart from the purely economic returns. This paper seeks to integrate this notion into a framework that permits scientific analysis of the tradeoff between psychic returns and returns that are purely market based. Hence, the incorporation of owned land into the utility function.[1]

In this model farmers have two alternative means of disbursing their flow income: consume it directly or save it. All saving takes place in the form of land accumulation. Hence, it is explicitly assumed that farmers do not have access to financial markets in what follows. This assumption is made to streamline the analysis. It is easy to demonstrate that the central qualitative results of the paper are preserved so long as the farmer does not face a perfect financial market, that is, the farmer cannot borrow as much as desired at a constant rate of interest.[2] If α is the acquisition price of land the total level of accumulated savings is αl_1. The rate of accumulation obeys the following intertemporal budget constraint:

$$\dot{l}_1 = [\Pi(l_1, l_2, v, \Theta) - wl_2 - c]/\alpha,$$

where dots over variables denote time derivatives and w is the rental price of land.

Over time market prices (v) as well as the rental and the acquisition price of land will vary. Most likely, it is unreasonable to believe that any farmer will know the complete trajectory of all such prices. Therefore, it is necessary to ignore this problem or to confront it by making some expectational assumption. Two assumptions that are particularly tractable and popular in dynamic models are static expectations and a constant rate of growth in all prices. In dynamic models, static expectations are often combined with the assumption of continual updating as new information is acquired (Epstein). In such cases, although an individual plans an entire control trajectory, he only implements that part of the trajectory corresponding to the current period. After new information becomes available, the optimal trajectory is revised subject to the constraint that the new initial state value equals that implied by previous decisions. A constant rate of growth in prices means that $v(t) = v(o)e^{bt}$ is the vector of market prices in time t where b is the growth rate. If this is the case, an individual still gains by reformulating his optimal plan if

[1] An anonymous reviewer suggested that rental land may also confer psychic benefits by providing access to a farming lifestyle. While this would present an interesting extension of our model, we have chosen in this paper to restrict our attention to the nonpencuniary benefits associated exclusively with land ownership.

[2] The assertion that our basic qualitative results would not change with imperfect credit markets can be justified formally. Suppose that the rate at which an individual farmer borrows and the amount that he borrows depend upon his net equity. If we denote all equity in units of owned land, then instantaneous profits—now defined as farm income less debt service—can still be expressed as a general function of l_1. Although not the same as the current $\pi(l_1, l_2, v, \Theta)$, this new instantaneous profit function would have almost identical properties and the analysis would proceed accordingly.

experience teaches him that all prices do not grow at this constant rate.

For the sake of clarify and ease of exposition, we employ the static expectations assumption with continual revision. The farmer's intertemporal optimization problem can now be stated as

$$\text{(1)} \qquad \operatorname*{Max}_{c,l_2} \int_0^\infty e^{-rt} u(c, l_1)\, dt$$

subject to

$$\dot{l}_1 = [\Pi(l_1, l_2, v, \Theta) - wl_2 - c]/\alpha;$$
$$l_1 + l_2 \geq 0;$$
$$l_1(0) = \bar{l}_1;$$

where r is the intertemporal discount rate; $l_1 + l_2 \geq 0$ reflects the fact that an individual at any point in time can never rent out more land than he already owns. It is assumed l_1 is always nonnegative and finite.

Optimal Acquisition and Rental Behavior

From (1), form the constrained current value hamiltonian:

$$\text{(2)} \quad H = u(c, l_1) + q[\Pi(l_1, l_2, v, \Theta) - wl_2 - c]/\alpha + \lambda(l_1 + l_2),$$

where q is the current value co-state variable and λ is a lagrangian multiplier associated with the rental constraint. Conditions for an interior solution include

$$\text{(3)} \qquad \frac{\partial H}{\partial c} = \frac{\partial u}{\partial c} - \frac{q}{\alpha} = 0;$$

$$\text{(4)} \qquad \frac{\partial H}{\partial l_2} = \frac{q}{\alpha}\left[\frac{\partial \Pi}{\partial l_2} - w\right] + \lambda = 0;$$

$$\text{(5)} \qquad \frac{\alpha \partial H}{\partial q} = \Pi(l_1, l_2, v, \Theta) - wl_2 - c = \alpha \dot{l}_1;$$

$$\text{(6)} \qquad \frac{\partial H}{\partial l_1} = \frac{\partial u}{\partial l_1} + \frac{q}{\alpha}\frac{\partial \Pi}{\partial l_1} + \lambda = rq - \dot{q}; \text{ and}$$

$$\text{(7)} \qquad \lim_{T\to\infty} e^{-rT} q(T) = 0.$$

Equations (5) and (6) portray the dynamic properties of the optimal response system. The concavity of the hamiltonian in c and l_1 and the transversality condition (7) guarantee that if the associated $q(t)$ and $l_1(t)$ converge to a steady-state equilibrium, the convergent path is optimal (Arrow and Kurz, p. 51). In the case of continuously nonbinding constraints (6) can be written

$$\dot{q} + q\left(\frac{\partial \Pi}{\partial l_1}\alpha^{-1} - r\right) = -\frac{\partial u}{\partial l_1},$$

and direct integration assuming $\lim_{t\to\infty} q(t) = \bar{q} < \infty$ and $r > \frac{l\partial \Pi}{\alpha \partial l_1}$ (see below) gives

$$q(t) = \int_t^\infty \exp\left[\int_t^\gamma \left(\alpha\frac{-l\partial \Pi}{\partial l_1} - r\right) d\eta\right]\frac{\partial u}{\partial l_1}\, dt.$$

Thus q is positive and can be interpreted as the marginal utility of one unit of land discounted to the present. In turn, this implies that the ratio q/α can be interpreted much like Tobin's Q, i.e., the ratio of the discounted stream of future benefits of an asset relative to its acquisition price.

By (3), the farmer consumes up to the point where the instantaneous marginal utility from consumption exactly equals the gain that can be made by delaying consumption through the acquisition of land. Moreover, the concavity of u in c implies that as ($Q = q/\alpha$) rises, with the level of l_1 fixed, consumption must fall. But, of course, this is quite intuitive since Q can always be interpreted as the effective marginal opportunity cost of consumption. Any funds invested at time t in owned land priced at α will effect a return of q. Therefore, if the marginal utility per dollar of consumption is less than Q, the farmer is better off diverting funds to the accumulation of land. Similarly, an increase in l_1, keeping Q constant, will encourage current consumption since as l_1 increases the marginal utility derived from holding land decreases.

From (4), the optimal rental decision requires

$$\frac{\partial \Pi}{\partial l_2} - w = \frac{\alpha\lambda}{q} = -\frac{\lambda}{Q}.$$

The difference between the marginal profitability of hired land and its rental rate will always be nonpositive and equal to the shadow price of the rental constraint divided by the marginal benefit of another unit of owned land. However, as long as the constraint is not binding, i.e., the farmer does not rent out all his land,

$$\frac{\partial \Pi}{\partial l_2} = w, \tag{8}$$

i.e., the marginal profitability of rental land equals the rental price. Perhaps the most important thing about (8) is that it defines an implicit equation for rental demand. As long as Π is twice differentiable and strictly concave in l_2 one can solve (8) to obtain

$$l_2^* = l_2(w, v, \Theta, l_1). \tag{9}$$

Equations (8) and (9) may be used to determine the effect of changes in w, v, Θ and l_1 on rental land. By (8)

$$\frac{\partial l_2^*}{\partial w} = \frac{\partial^2 \Pi^{-1}}{\partial l_2^2} \leq 0.$$

Quite naturally, as the rental price of land rises, the farmer tends either to rent in less land or to rent out more land. Moreover, for a sufficiently large rise in w, the farmer could switch from being a farm operator to a landlord. Other factors that affect the net rental position are discussed in more detail below.

Similar arguments establish

$$\frac{\partial l_2^*}{\partial l_1} = -\frac{\partial^2 \Pi / \partial l_2 \delta l_1}{\partial^2 \Pi / \partial l_2^2}, \tag{10}$$

which, in general, has an ambiguous sign. However, the numerator of (10) can be interpreted as $(\partial p_t / \partial l_2)$, where p_t is the marginal profitability of owned land in the farming operation. If, as one usually expects, owned and rented land are close substitutes, this expression would be negative, which implies (10) is negative. We assume this is the case. Expressions (9) and (10) are also interesting because they provide an empirical basis for testing whether or not owned and rented land are perfect substitutes. If owned and rented land are perfect substitutes, expression (10) equals minus one. Accordingly, one can test the hypothesis of perfect subsitutability by specifying an appropriate form for (9) and then restricting it in a manner such that expression (10) equals minus one. Standard hypothesis testing procedures are then available. It also follows that

$$\frac{\partial l_2^*}{\partial \Theta_2} = \frac{\partial^2 \Pi / \partial l_2 \delta \Theta}{\partial^2 \Pi / \partial l_2^2}, \text{ and} \tag{11}$$

$$\frac{\partial_2^*}{\partial v_i} = \frac{\partial^2 \Pi / \partial l_2 \partial v_i}{\partial^2 \Pi / \partial l_2^2}. \tag{12}$$

If expression (11) is positive (negative) and Θ is taken as an index of technical change, we shall refer to technical change as being rental land using (saving).

There are instances where the farmer will exit from farming although he may still own land. The farmer will rent out all his land if his technology is such that

$$\frac{\partial \Pi(l_1, -l_1, v, \Theta)}{\partial l_2} < w;$$

i.e., the farmer can earn more by renting out all of his land than he can earn by devoting the same land to farming. Such seems likely to be the case for farmers who operate in regions where land has a high opportunity cost, e.g., on the periphery of a large city or the classic case of the retired farmer who can earn more by renting out all of his or her land to more productive farmers.

Temporary Equilibrium in the Land Rental Market

The discussion surrounding equations (8)–(12) suggests an interesting graphical interpretation of the land-rental decision. Figure 2 represents the short-run demand for rental land (9), given an existing stock of owned land that cannot be instantaneously augmented (i.e., it requires the investment of savings) and the other parameters of the decision problem. As long as the equality of (8) holds, land rental demand is a decreasing function of the rental price of land. Once the equality does not hold, there is a corner solution and the farmer rents out the entire land holding; land rented out becomes perfectly inelastic no matter what rental rate prevails.

Figure 2 provides an easy method of visualizing short-run tenure arrangements. For the individual depicted by the demand curve labeled LL_1L_2, the decision to rent in land requires that the market rental rate be less than w_o, while renting out land requires w to exceed w_o. In the region w_o to w^* the farmer farms part of his land and rents the rest out; for rental rates w^* and larger, the farmer reverts to a pure landlord and rents out his entire land holding. U.S. Department of Agriculture (USDA) data reveal that the bulk of large farmers perceive themselves as operating in markets with rental rates less than w_o, where they farm all of their own land and rent in more land to augment their owned land (see figure 1). This suggests that the inability to accumulate (decumulate) owned land instantaneously leaves them in a situation where the owned land base does not allow them to operate as they would prefer in the long run. The existence of a land rental market permits them to alleviate their short-run problem. It facilitates short-term adjustments necessitated by the fact that farmers cannot instantaneously augment land stock. This function of the rental market is important and should be emphasized because it is the existence of an active rental market for land (temporary trade in land inventories) that differentiates the land accumulation problem (and other problems where capital rental is possible) from the standard capital accumulation model.

Beyond explaining rental behavior relative to the price of rental land, figure 2 also offers insight as to why certain farmers faced with a given w will rent in land while other farmers will rent out land. In terms of our model there are two natural explanations for such behavior: the first revolves around the existing stock of land owned by the farmer; and the second involves technological and entrepreneurial differences as summarized by the parameter Θ. Let us start with differences in land endowment and consider a farmer identical to the one whose demand curve is given by LL_1L_2 in all respects except that he has a lower endowment of land ($\tilde{l}_1$). Assuming owned and rental land are relatively close substitutes in the production process, this individual's demand curve can be depicted by something like $\bar{L}\bar{L}_1\bar{L}_2$. Accordingly, at any rental rate this farmer will always tend to rent in (rent out) more (less) land than the original farmers considered. Again the intuition is fairly obvious. Both farmers are identical in all respects except their owned land endowment. The farmer with the lower land endowment tends to compensate for the inability to adjust owned land stocks instantaneously by renting more land. It is also interesting to note that differences in land endowment can be a key determinant of whether a farmer rents in or rents out land. For in the region $w_o\bar{w}$ the original farmer is renting out land while the second farmer is still renting in land.

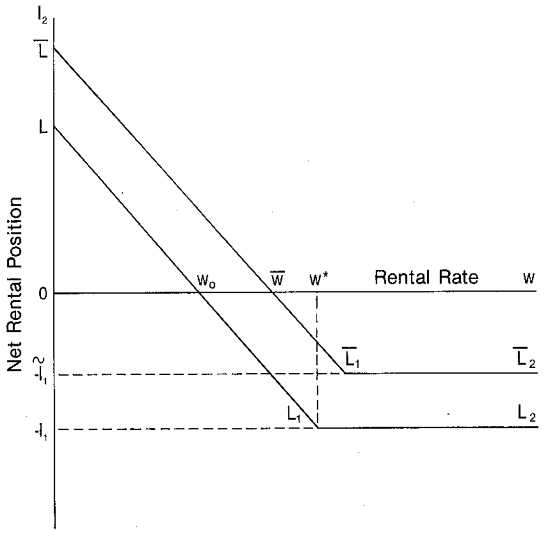

Figure 2. Individual rental land demands

Similar arguments apply to the parameter Θ introduced earlier. At this point it is convenient to identify it with entrepreneurial ability; later we shall use it as an index of technical change. Interpreting Θ as an index of entrepreneurial ability it is plausible to believe that, *ceteris paribus,* farmers with a high Θ will be able to earn a higher return on the margin from a unit of rental land than a farmer with a low Θ. Again the analytic argument is very similar to that developed above. Considering two farmers who are identical in all respects except for entrepreneurial ability, the farmer with the greater ability could have a demand curve like $\bar{L}\bar{L}_1\bar{L}_2$ while the one with lower ability would be something like LL_1L_2. Thus, at any rental price the farmer with greater entrepreneurial ability will tend to rent in more land than the farmer with the lower entrepreneurial ability.

The tendency to rent in more land as entrepreneurial ability rises is easily explained and likely provides a key determinant of tenure choice. Farmers with a given stock of land have two alternatives in the short run: farm it directly or rent it out. In the long run they can sell off any undesired land holding as their preference structure dictates. The opportunity cost of farming the land is the going rental rate, and farmers with a low degree of entrepreneurial ability will see this opportunity cost as relatively high, thus encouraging them to rent out the land.

An obvious, but important, implication of

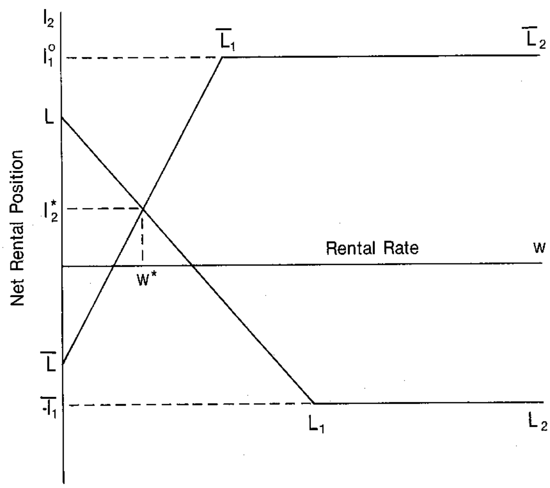

Figure 3. Temporary equilibrium rental price determination

this discussion is that at any time the individual's land holdings (l_1) are determined by the initial land endowment ($\bar{l}_1$) and expressions (5) and (6). Thus, the individual's land holding depends upon preferences. This finding highlights the central role preferences and entrepreneurial ability play in determining an individual's tenure position. To see this point, consider the simple example of two individuals starting with the same initial land endowment but with different preference structures and differing entrepreneurial abilities. Moreover, assume that the individual with the greater entrepreneurial ability derives fewer nonpecuniary benefits from land ownership than the other individual. Then, it seems likely that at any point in time the individual with the lower degree of entrepreneurial ability will have accumulated more land than the other individual simply because his preference structure dictates such an accumulation pattern. But previous results also suggest that this individual will rent out more land than the other because he owns more land but has a lower degree of entrepreneurial ability. Hence, the individual's preferences drive this person to accumulate land, but his ability (inability) as a farmer forces him into the position of a landlord.

The foregoing arguments suggest a natural mechanism for determing and interpreting the rental price of land. The market rental rate can be interpreted as that rate which clears the market for temporary trades in land inventories given other market prices, the distribution of entrepreneurial ability, and the distribution of the current stock of land. Pictorially, it can be depicted as in figure 3, where the curve LL_1L_2 represents an appropriately aggregated demand curve for individuals whose aggregate endowment is $\bar{l}_1$, while $\bar{L}\bar{L}_1\bar{L}_2$ is the negative of an appropriately aggregated demand curve for individuals whose aggregate endowment is l_1^0. Market equilibrium is given by the rental rate w^*, and individuals aggregated in LL_1L_2 tend to rent in land rented out by individuals aggregated in $\bar{L}\bar{L}_1\bar{L}_2$.

From the above, it should be apparent that the general form of an equilibrium rental price equation must be

$$w^* = w^*(\bar{l}_1, l_1^0, v, \bar{\Theta}, \Theta^0),$$

where $\bar{\Theta}$ and Θ^0 are parameters reflecting the entrepreneurial abilities of individuals aggregated in LL_1L_2 and $\bar{L}\bar{L}_1\bar{L}_2$. Hence, to portray accurately rental price behavior in the short run, one must know the way in which the current stock of farmland is distributed, the distribution of entrepreneurial abilities, and product prices (which in any case are likely jointly dependent).

Consumption and Rental Dynamics

The dynamic behavior of the system is effectively characterized by expressions (5) and (6). However, earlier developments show that the level of consumption depends upon the shadow price of land and the current stock of owned land. Hence, dynamic changes in either q or l_1 are associated with intertemporal adjustments in c. From (3), it follows for constant α that

$$(13) \qquad \dot{c} = [\dot{q} - \alpha(\partial^2 u/\partial c \partial l_1)\dot{l}_1]/\alpha(\partial^2 u/\partial c^2).$$

By our assumptions on $u(c, l_1)$, increases in the growth of the shadow price of land slow down the pace of consumption, while increases in land accumulation enhance consumption. The intuition is again simple. As q rises, land becomes more attractive to the farmer as an asset; hence, he tends to shift his income stream toward greater land accumulation and less consumption. On the other hand, increases in l_1 are associated with income growth and declining marginal utility of owned land which tends to increase consumption.

Using (8) and (10) yields, under static expectations,

(14) $$\dot{l}_2 = \frac{\partial l_2^*}{\partial l_1}\dot{l}_1 + \frac{\partial l_2^*}{\partial \Theta}\dot{\Theta},$$

which implies that growth of rentals is negatively associated with growth in ownership of land. Again the intuition is simple: if owned and rented land are close substitutes, the growth of land ownership tends to reduce the production opportunities for rental land. If we let $L = l_1 + l_2$, i.e., total farm size, we obtain when $\dot{\Theta} = 0$,

(15) $$\dot{L} = \left(1 + \frac{\partial l_2^*}{\partial l_1}\right)\dot{l}_1,$$

and by previous arguments we see that $L \leq l_1$ so long as there is no change in Θ. Because changes in Θ can be identified with either changes in entrepreneurial ability or technology and our model has no way of predicting such changes, we shall presume that the individual farmer perceives $\Theta = 0$ and confine our analysis of Θ to the comparative dynamic experiment that is carried out at the end of the paper. Total farm size has to grow slower than outright land acquisition if owned and rental land are close enough substitutes. In fact, if owned and rented land are perfect substitutes, expression (15) equals zero. This follows since any accumulation of owned land leads to an exact opposite movement in rental land when owned and rental land are perfect substitutes because their marginal profitabilities must be identical and equal to the rental price of land. Acquisition of owned land, then, forces down the marginal profitability of all land so that the farmer must rent in less land to restore equilibrium.

An interesting aspect of (15) is that it says the system does not need to be a steady state for overall farm size (L) to stop growing. Of course, if the system is in a steady state farm size growth is zero since $\dot{l}_1 = 0$ in the steady state. But farm size growth is also zero if

(16) $$\frac{\partial l_2^*}{\partial l_1} = -1,$$

which implies that owned and rental land are locally perfect substitutes for one another.

Expression (14) can be rewritten

$$\dot{l}_2/\dot{l}_1 = \frac{\partial l_2^*}{\partial l_1} = \xi(l_1, v, w, \Theta),$$

where ξ is the partial adjustment coefficient of rented land to owned land. It is particularly interesting to see what happens to ξ when technology changes or when the other parameters of the system change. In general, however, this requires explicit knowledge about the third derivatives of the farmer's income function. Because such information is hard to come by in most economic instances, attention is restricted to the case where ξ is a constant. Such would be the case if Π were quadratic in l_1 and l_2, i.e.,

(17) $$\Pi = \Pi^*(v, \Theta) + Q(l_1, l_2, v),$$

where Π^* is a general numeric function and Q is the general quadratic function. Technical change as represented in (17) is particularly tractable analytically because it does not affect the rate at which l_2 is utilized since expression (8) can now be written $\partial Q/\partial l_2 = w$.

The Steady State

One of the key questions this paper seeks to address is, what makes the farmer stop accumulating land for ownership? This can be rephrased as asking when the dynamic system depicted by (5) and (6) will be at rest. By (5) and (6) the steady state is characterized by (where H^o refers to the optimized current value hamiltonian)

(18) $$\alpha\frac{\partial H^o}{\partial q} = \Pi(l_1, l_2, v, \Theta) - wl_2 - c = 0, \text{ and}$$

(19) $$rq - \frac{\partial H^o}{\partial l_1} = rq - \frac{\partial u}{\partial l_1} - \frac{q}{\alpha}\frac{\partial \Pi}{\partial l_1} = 0$$

when the rental constraint is not binding.

In what follows it is assumed that there exists a unique solution to (18) and (19) which we denote by (l_1^∞, q^∞). As stated earlier, under the assumption of a unique state, the assumptions guarantee that a stable path converging to (l_1^∞, q^∞) and consistent with (3)–(7) will be optimal. From (18) and (19), the farmer will stop acquiring new land when his preferences are such that consumption exactly equals income, and when

$$Q\left(r\alpha - \frac{\partial \Pi}{\partial l_1}\right) = \frac{\partial u}{\partial l_1},$$

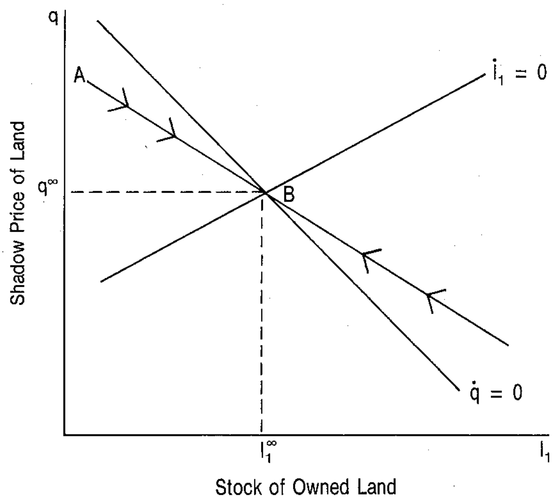

Figure 4. Adjustment to the steady state

which in turn implies that in the steady state,

$$r > \frac{l}{\alpha}\frac{\partial \pi}{\partial l_1},$$

i.e., the discount rate is greater than the instantaneous rate of return on funds invested in land. Normally, one might expect the discount rate to be equal to the instantaneous rate of return on funds invested in land

$$\left(\frac{l}{\alpha}\frac{\partial \pi}{\partial l_1}\right).$$

But this only takes into account the pecuniary returns from owning land. Since the farmer derives psychic as well as pecuniary returns, it makes sense that there should be a gap between the discount rate and the rate of return on funds invested in land. Put rather imprecisely, this implies that the farmer accumulates land past the point where his opportunity cost and instantaneous rate of return are equal. Hence, we can say that the farmer continues to accumulate land until he reaches a point where his marginal pecuniary losses from holding land are proportional to his marginal psychic gains from owning land. This implication is tested in the empirical section of this paper by comparing rates of return on farmland to rates earned on comparable long-term investments.

Typically, we will be interested in characterizing the dynamic behavior of the model in the neighborhood of the steady state. The most appropriate conceptual tool for this is a phase

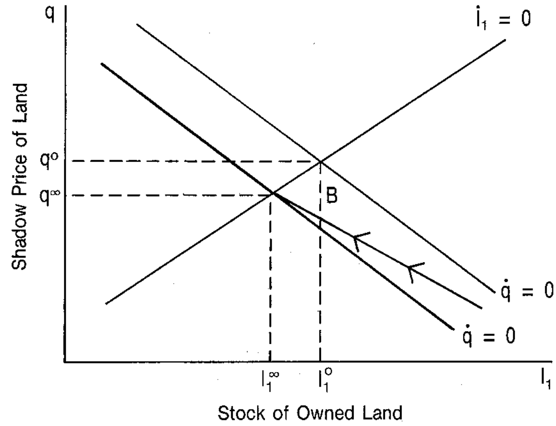

Figure 5. Dynamic effects of changes in the discount rate

diagram. To start we need to know how q and l_1 interact along the locus of points $\dot{q} = l_1 = 0$. By (18),

$$\text{(20)} \qquad \left.\frac{\partial q}{\partial l_1}\right|_{l_1=0} = -\frac{\partial^2 H^o/\partial q \partial l_1}{\partial^2 H^o/\partial q^2}.$$

H^o is convex in q and concave in l_1 by usual results in optimization theory (from the sufficiency conditions). Hence, minus the denominator in (20) is negative. Direct calculation establishes

$$\text{(21)} \qquad \frac{\partial^2 H^o}{\partial q \partial l_1} = \frac{l}{\alpha}\left[\frac{\partial \pi}{\partial l_1} + \frac{\partial \pi}{\partial l_2}\frac{\partial l_2^*}{\partial l_1} - w\frac{\partial l_2^*}{\partial l} - \frac{\partial c^*}{\partial l_1}\right] = \frac{l}{\alpha}\left[\frac{\partial \pi}{\partial l_1} - \frac{\partial c^*}{\partial l_1}\right].$$

Expression (21) is ambiguous in sign, but a moment's reflection will establish that it is plausible to think of (21) as negative. To see this, approximate the optimal adjustment in owned land linearly around the steady state l_1^∞ to obtain

$$\text{(22)} \qquad l_1 \simeq \frac{l}{\alpha}\left[\frac{\partial \pi}{\partial l_1} - \frac{\partial c^*}{\partial l_1} - \frac{\partial c^*}{\partial q}\frac{\partial q}{\partial l_1}\right] \cdot [l_1 - l_{1*}^\infty],$$

where l_{1*}^∞ represents the steady-state value. A set of sufficient conditions for (22) to be stable is

$$\text{(23)} \qquad \frac{\partial \pi}{\partial l_1} - \frac{\partial c^*}{\partial l_1} \leq 0, \text{ and}$$

$$(24) \qquad \frac{\partial q}{\partial l_1} \leq 0.$$

We assume both (23) and (24) hold. Direct calculation yields

$$(25) \qquad \left.\frac{\partial q}{\partial l_1}\right|_{\dot{q}=0} = \frac{\partial^2 H^o/\partial l_1^2}{r - \partial^2 H^o/\partial l_1 \partial q} = \frac{\partial^2 H^o/\partial l_1^2}{r - \delta^2 H^o/\partial q \partial l_1}.$$

If H^o is twice continuously differentiable, our assumptions imply (20) is positive and (25) is negative, so the phase system is as depicted in figure 4.

Changes in the Discount Rate

Using earlier developments direct computation reveals

$$\frac{\partial_q^\infty}{\partial r} = \frac{1}{\Delta} q \left[\frac{\partial^2 H^o}{\partial q \partial l_1}\right] < 0,$$

$$\frac{\partial l_1^\infty}{\partial r} = -\frac{1}{\Delta}\left\{q \frac{\partial^2 H^o}{\partial q^2}\right\} < 0,$$

where

$$\Delta = -\left[\frac{\partial^2 H^o}{\partial q^2}\frac{\partial^2 H^o}{\partial l_1^2} + \frac{\partial^2 H^o}{\partial q \partial l_1} \cdot \left(r - \frac{\partial^2 H^o}{\partial l_1 \partial q}\right)\right],$$

q^∞ is the steady-state value of the co-state variable, and l_1^∞ is the steady-state value of owned land. These results say that an increase in the discount rate leads to a lower ownership of farmland in the very long run. The dynamics of the adjustment are best visualized with the aid of figure 5. The original, long-run equilibrium is at (l_1^0, q^0). A change in the discount rate has no effect on the long-run budget constraint and only affects the rate of adjustment in q. A rise in r shifts the $\dot{q} = 0$ locus back toward the origin as illustrated. In the very first instant, the level of land ownership is predetermined so that the instantaneous adjustment of the system is to jump to point B on the new convergent path. Since l_1 is constant, this is accomplished by an instantaneous decrease in savings to reflect the fact that the value of current consumption *vis-à-vis* the future benefit stream from owned land has increased. Put another way, the relative value of savings has declined and the farmer responds by cutting back on savings. After the instantaneous adjustments had been made the farmer is operating in a region where optimal behavior requires a reduction in land holdings, and he adjusts along the stable path to the new steady state (l_1^∞, q^∞). Hence, the farmer sells some of his land but simultaneously increases the amount of land that he rents in. Basically, he rents in land because he currently does not have an optimal long-run stock of owned land (recall previous discussion). This forces short-run adjustments in rental behavior to insure production efficiency. At the same time, however, as he moves along the stable path toward (l_1^∞, q^∞), l_1 falls but q rises so the farmer tends to cut back consumption.

Technical Change

In general, it is not possible to determine unambiguously what happens for general changes in the technology as characterized by shifts in Θ. If, however, the technology is of the general form of (17), then

$$\frac{\partial q^\infty}{\partial \Theta} = \frac{1}{\Delta}\left[\frac{\partial \pi^*}{\partial \Theta}\frac{1}{\alpha}\frac{\partial^2 H^o}{\partial l_1^2}\right], \text{ and}$$

$$\frac{\partial l_1^\infty}{\partial \Theta} = \frac{1}{\Delta}\left\{\left(r - \frac{\partial^2 H^o}{\partial l_1 \partial q}\right)\frac{\partial \pi^*}{\partial \Theta}\right\}.$$

Accordingly, if technical change is progressive $(\partial \pi_i^*/\partial \Theta > 0)$, the long-run shadow price of land falls while land ownership rises in the long run. The dynamics of the adjustment process are illustrated in figure 6. The original steady state is again (l_1^0, q^0). The instantaneous impact of a technical improvement is to enhance the farmer's income stream, which translates into an instantaneous consumption increase. This is illustrated by the movement from the original steady state to a point like B on the new convergent path. Along the convergent path, the farmer continuously accumulates land because long-run desired land holdings have risen from l_1^0 *to* l_1^∞. At the same time, however, he rents in less land. Furthermore, for certain farmers there is the possibility that such an adjustment process will include a switch from a tenant to a landlord position as the result of technical change. At the same time, the size of the farm operation as measured by L grows but at a less rapid rate than land ownership if owned and rented land are imperfect substitutes. As the farmer converges to his long-run equilibrium, he also expands consumption be-

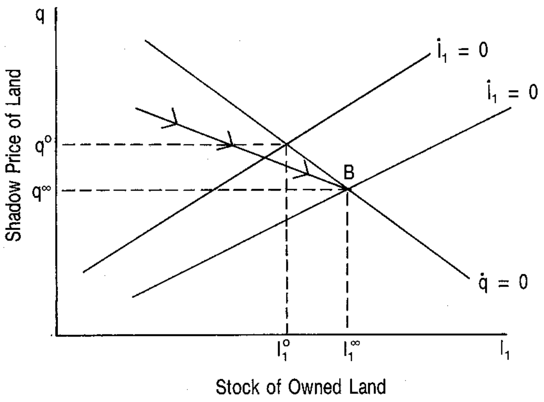

Figure 6. Dynamic effects of technical change

Table 2. Regression Results for Five Midwestern States 1949-84

State	Intercept	Time Trend	R^2	F
Ohio	.17	−.008	.51	32.8
	(6.06)[a]	(−5.72)		
Indiana	.18	−.008	.42	23.4
	(5.47)	(−4.84)		
Illinois	.15	−.007	.38	19.3
	(4.72)	(−4.40)		
Iowa	.18	−.007	.36	18.4
	(5.02)	(−4.29)		
Missouri	.22	−.01	.66	61.2
	(9.15)	(−7.84)		

[a] Numbers in parentheses are t-statistics for the null hypothesis that the parameter is zero.

cause the advent of technical change enhances the farmer's intertemporal income stream. In passing, one might note that figure 6 can also be interpreted as a representation of the differences between the intertemporal accumulation patterns of farmers with differing entrepreneurial ability. With this type of difference in entrepreneurial ability, the farmer with the greater ability will always end up accumulating more land in the long run regardless of the original land endowment.

Empirical Evidence

A primary implication of these results is that, contrary to an efficient markets hypothesis, systematic difference should emerge between rates of return on farmland and rates earned on other long-term investments. Moreover, our findings suggest that these systematic differences should be related to the state of technology, entrepreneurial ability, and individual farmer preference for owning land. Although it would be very difficult to test the effect of the later two elements on rate of return to farmland because of difficulties in measuring either entrepreneurial ability or farmer preference, a direct test of the effects of the state of technology is relatively easy to construct under plausible assumptions.

To test the hypothesis that the state of technology has systematic influence on the rental and accumulation decision and hence upon rates of return to farmland, we assume that changes in technology shift $\Pi(l_1, l_2, v, \Theta)$ over time. Simply put, Θ is taken as a time index. Then, to test our hypothesis, we need to determine whether there is a systematic relationship between the state of technology, rate of return on farmland, and rates of return on alternative investments. A first step is to ascertain if there is a statistically detectable relationship between the difference between the rates of return on farmland and alternative investments. Empirically, this was accomplished by regressing the difference between the total rate of return on farmland (defined as the ratio of cash rents to land price plus percentage capital gains) and the twelve-month Federal Intermediate Credit Bank (FICB) loan rate against a time trend for five midwestern states for the period 1949–84.[3] All land price and rental data are from Jones and Barnard. The results are reported in table 2. Midwestern states were purposely chosen to insure that factors unrelated to farming or the farm way of life, such as rapid expansion on the rural urban fringe and industrial development, would not have an undue influence on land prices.

The results in table 2 indicate that the null hypothesis (that the difference between these rates of return is unrelated to the state of technology) can be rejected at the .01 level for all five states. The results also indicate that the difference between these rates of return has experienced a markedly similar secular decline in each state. In each state, the total rate of return on farmland exceeded the twelve-month

[3] Although the theoretical analysis takes α as constant, for any reasonable time series this presumption is implausible. Therefore, our empirical analysis is predicted on the presumption that farmers accurately forecast their actual capital gain.

FICB loan rate at the beginning of the sample and was lower than that same rate at the end of the sample. In terms of our model, this suggests that in the early 1950s there was room for farmland investment that was sound on a purely pecuniary basis, while at the end of the sample the driving force for land investment seemed to be nonpecuniary benefits. Of course, alternative hypotheses could likely explain these results as well as our own. For example, consideration of risk factors and erroneous expectations by farmers could partially explain these results in the sense that they could account for differences between a plausible discount rate and the total rate of return on farmland. But they would be hard pressed to account for the systematic relationship uncovered in table 2 without an explicit recognition of technical change. In any case, the fact that alternative explanations exist for these phenomena really means that each potentially has something to offer in explaining phenomena that have long puzzled agricultural economists. A direction for future research would be a thorough investigation of the relative explanations.

Another interesting aspect of our results is that they suggest that technical change in these five midwestern states has tended to diminish the rate of return to farmland relative to the twelve-month FICB loan rates. That is, technical change has made it systematically less profitable to invest in farmland than in alternative investments. This raises the question of whether investment in agricultural technology may have exceeded a socially optimal rate. Of course, this hypothesis cannot be vigorously defended on the basis of such casual empirical analysis, but the issue merits further discussion especially because so much research into agricultural technology is carried on at public expense.

Conclusion

A farmer's choices of tenure and size of operating unit result from a complex interplay of technology, entrepreneurial capacity, and personal preferences. By examining these choices in a dynamic optimization framework, it was possible to determine the qualitative effects of many of these explanatory factors. The rate of land accumulation was shown to be positively related to the nonpecuniary benefits of farmland ownership, certain types of progressive technical change, and negatively related to the discount rate. In a steady state (zero land accumulation), the farmer's rate of return on land was found to be less than the discount rate if farmland ownership conveys nonpecuniary benefits. The amount of land rented in was negatively related to the land endowment, the opportunity cost of the farm operator, and the market rental rate and positively related to entrepreneurial ability and progressive technical change.

The rental market for farmland was shown to function in a short-run equilibrating capacity, analogous to the role played by the markets for stocks of agricultural commodities. The existence of an active rental market differentiates farmland accumulation from the traditional capital accumulation problem. The short-run, equilibrium rental rate for farmland was shown to depend on the distributions of the current farmland stock, entrepreneurial ability, and market prices.

An empirical test provided support for one implication of the theoretical model that changes in technology should cause systematic differences to be observed between rates of return on farmland and rates earned on comparable long-term assets. For the five midwestern states studied, technological change was also found to reduce the rate of return to farmland relative to the twelve-month FICB loan rate over the period 1949–84.

Other implications are generally supported by observed trends in farm tenure. The dominance of the part-owner operator in the large commercial farm category (fig. 1) seems consistent with the positive relation between entrepreneurial ability and the amount of rented land if farm size is an indication of entrepreneurial ability. The observed monotonic increases over time in both owned and rented land by part-owner operators (table 1) is explainable as a series of short-run adjustments to a rising optimal size of operating unit. While Harrington et al. note that average farm size appears to have stabilized, this does not necessarily imply the farm sector is in a steady state. An alternative explanation of this phenomenon is that the farm sector in the aggregate is approximately at a point where owned and rented land are perfect substitutes.

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