THE NATURE OF THE FARM*

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Abstract

Using a model based on a trade-off between moral hazard incentives and gains from specialization, this paper explains why farming has generally not converted from small, family-based firms into large, factory-style corporate firms. Nature is both seasonal and random, and the interplay of these qualities generates moral hazard, limits the gains from specialization, and causes timing problems between stages of production. By identifying conditions in which these forces vary, we derive testable predictions about the choice of organization and the extent of farm integration. To test these predictions we study the historical development of several agricultural industries and analyze data from a sample of over 1,000 farms in British Columbia and Louisiana. In general, seasonality and randomness so limit the benefits of specialization that family farms are optimal, but when farmers are successful in mitigating the effects of seasonality and random shocks to output, farm organizations gravitate toward factory processes and corporate ownership.

I. Introduction

One of the salient characteristics of the history of industry is the transition from family firms to large factory-style corporations. Large corporations dominate modern economies. In 1989 corporations made up 18.5 percent of all nonfarm businesses but generated 90 percent of all nonfarm business receipts.[1] Agriculture, however, has largely resisted the transition to large corporate ownership. The 1992 U.S. Census of Agriculture shows

* We have received support from the National Science Foundation and the Social Science and Humanities Research Council of Canada. Dean Lueck was also supported as a John M. Olin Faculty Fellow at the Yale Law School. For helpful comments we thank Yoram Barzel, Gary Brester, Lee Craig, Harold Demsetz, Henry Hansmann, Julie Hewitt, D. Bruce Johnsen, Jim Johnson, Chuck Knoeber, Eric Rasmusen, Wing Suen, Gene Silberberg, Dan Sumner, Wally Thurman, and two anonymous reviewers, as well as seminar participants at the University of British Columbia; University of California, Davis; University of California, Los Angeles; University of Copenhagen; University of Kentucky; North Carolina State University; Montana State University; University of Montreal; University of South Carolina; and the University of Toulouse. The staff at the Institute for Regional Studies at North Dakota State University provided assistance in understanding bonanza farms.

[1] U.S. Bureau of the Census, Statistical Abstract of the United States 1993, table 848, at 531 (1993).

Journal of Law and Economics, vol. XLI (October 1998)
 0022-2186/98/4102-0002$01.50

that more than 85 percent of farms are organized as ''family farms.''[2] Excluding small family-held corporations, farm corporations made up only .4 percent of all farms in 1992, 1.3 percent of all farm acreage, and generated only 6 percent of all sales receipts.[3] Furthermore, farming continues to be dominated by small, family-based firms despite the tremendous changes that have taken place in agriculture over the past 2 centuries.[4] Specifically, farm numbers have declined, farm size has increased, and technological changes have converted farms into capital-intensive enterprises. As recently as 1920 there were over 6.5 million farms, averaging just 149 acres per farm. At the same time, nearly one-third (30.1 percent) of the U.S. total population lived on farms. In 1920 most farmers still used draft horses to power their equipment; there were over 25 million horses and mules on farms.[5] By 1992 farm numbers had fallen to less than 2 million farms, and the average farm size had more than tripled to roughly 500 acres. Similarly, by 1992 less than 2 percent of the U.S. population resided on farms.[6] By 1992 large tractors had long dominated farming, with 4.3 million tractors in total and nearly a quarter of all farms having at least four tractors.[7]

In this paper we explain why farming has remained in small, family-based firms and explain why and when the family farm has been occasionally supplanted by large factory-style corporations. Using a model that examines the trade-off between moral hazard incentives and gains from specialization, we focus on two dimensions of farm organization, the choice of farm ownership and the extent of farm control over successive stages of production. We focus on these two dimensions of firm organization because farms have been and continue to be organized around a well-defined set of

[2] U.S. Bureau of the Census, 1992 Census of Agriculture, table 18, at 58 (1992). The census definition of a farm is ''any place from which $1,000 or more of agricultural products were produced and sold or normally would have been sold during the census year.'' The Census uses the following categories: (*a*) individual or family, (*b*) partnership, (*c*) corporation (family held or nonfamily held), and (*d*) other (trusts, municipalities, and so on).

[3] *Id.*, table 50, at 119. Similar figures hold for Canada. See Statistics Canada, Census Overview of Canadian Agriculture: 1971–1991 (catalogs 93-348 and 21-001, 1992).

[4] There has been a slight increase in partnerships and family-held corporations in the last 2 decades.

[5] U.S. Department of Agriculture, Yearbook 1920, table 229, at 701 (1920).

[6] U.S. Bureau of the Census, Historical Statistics of the United States: Colonial Times to 1970, Pt. 1, 457–62 (1976); and U.S. Department of Agriculture, Agricultural Statistics 1994, table 536, at 330 (1994).

[7] Bureau of the Census, 1992 Census of Agriculture, *supra* note 2, table 13, at 20. Use of chemical fertilizer and pesticides has also increased. For instance, in 1930 American farmers used 16.5 pounds of commercial fertilizer per farmland acre. By 1985 that number had increased to 93.6 pounds per acre. Farm productivity has increased accordingly. In 1920 corn and wheat yields were 30.9 and 13.8 bushels per acre, respectively; by 1992 corn yields were 125.4 bushels per acre and wheat yields were 37.3 bushels per acre. *Supra* notes 5 and 6.

production stages. There are, of course, a number of issues related to the organization of agriculture that we do not examine, such as the determinants of hired farm labor and the determinants of owning versus leasing farm assets.[8]

As our title suggests, our framework is derived from Coase's[9] seminal work on the theory of the firm and falls squarely in the modern literature on the theory of the firm. In particular, our approach is closely tied to Alchian and Demsetz's[10] emphasis on the monitoring role of firm ownership and the emphasis on tasks and sets of incentives by Holmstrom and Milgrom.[11] Although our approach does not depend on asset specificity, we do incorporate an agricultural version of ''temporal specificity.''[12] Finally, in a manner similar to Becker and Murphy,[13] our model ultimately relies on the tradeoff between moral hazard and specialization.

Understanding farm organization requires marrying the modern theory of the firm to the seasonal constraints placed on production by nature. Seasonality is the main feature that distinguishes farm organization from ''industrial'' organization. Agricultural economists have long recognized this point.[14] Indeed, Holmes stresses seasonality in discussing the reason for the resilience of the family farm:

[8] Except for Hans Binswanger & Mark R. Rosenzweig, Behavioral and Material Determinants of Production Relations in Agriculture, 22 J. Dev. Stud. 503 (1986); Nancy L. Johnson & Vernon W. Ruttan, Why Are Farms So Small? 22 World Dev. 691 (1994); and Marc L. Nerlove, Reflections on the Economic Organization of Agriculture: Traditional, Modern, and Transitional, in Agricultural Markets: Mechanisms, Failures, and Regulations 9 (David Martimort ed. 1994), the organizational issue most often examined in agriculture has been sharecropping in less developed countries. Important recent studies of agriculture in The Economic Theory of Agrarian Institutions (Pranab K. Bardhan ed. 1989); Yuruiro Hayami & Keijiro Otsuka, The Economics of Contract Choice: An Agrarian Perspective (1993); and The Economics of Rural Organizations: Theory, Practice, and Policy (Karla Hoff & Avishnay Braverman & Joseph Stiglitz eds. 1993) focus on land and labor contracts and ignore broad organizational questions.

[9] Ronald H. Coase, The Nature of the Firm, 4 Economica 386 (1937).

[10] Armen A. Alchian & Harold Demsetz, Production, Information Costs, and Economic Organization, 62 Am. Econ. Rev. 777 (1972).

[11] Bengt Holmstrom & Paul Milgrom, The Firm as an Incentive System, 84 Am. Econ. Rev. 972 (1994).

[12] Scott Masten, James Meehan, & Edward Snyder, The Costs of Organization, 7 J. L. Econ. & Org. 1 (1991).

[13] Gary S. Becker & Kevin M. Murphy, The Division of Labor, Coordination Costs, and Knowledge, 107 Q. J. Econ. 1137 (1992).

[14] For example, John M. Brewster, The Machine Process in Agriculture and Industry, 32 J. Farm Econ. 69 (1950); Emery N. Castle & Manning H. Becker, Farm Business Management (1962); John C. Ellickson & John M. Brewster, Technological Advance and the Structure of American Agriculture, 29 J. Farm Econ. 827 (1947); Earl O. Heady, Economics of Agricultural Production and Resource Use (1952); and C. L. Holmes, Economics of Farm Organization and Management (1928).

> The most fundamental one [reason] is the peculiar seasonal nature of agricultural production and the consequent lack of continuous operations. Almost every line of endeavor on the farm must depend either upon the swing of the seasons or upon the periodic nature of some biological process. There are seed times and harvest times with their specific tasks which, in the main, are of short duration. There is also the case of livestock at the different stages of their development. In no case can a man be put to a single specific task and be kept at it uninterruptedly for a month or a year as is true in the factory.[15]

Until now, however, agricultural economists have not connected their insights regarding seasonal production stages, crop cycles, task specialization, and random events to modern theories of the firm. The contribution of our study is to merge these two traditions by incorporating seasonal forces into a model of farm organization.

Nature is incorporated into our model in two different ways: through random shocks to farm output and through seasonal forces, such as the length of production stages and the frequency of crop cycles. First, random production shocks from nature generate opportunities for moral hazard and provide a basis for family farms. Second, as suggested by many agriculture economists, seasonal parameters (cycles, stages, and so on) limit gains from specialization and cause timing problems between stages of production. Including seasonal parameters in our model allows us to examine Coase's fundamental concern: the trade-off between the ''costs of using the price system'' inherent in markets and the ''costs of organization'' in firms.[16] Expanding the size or extent of the farm—by contracting with partners or with firms in adjacent stages—entails increases in moral hazard costs. Expanding the firm also has the potential to generate gains from specialization, but in agriculture these are often severely limited by seasonal factors.

The simplest family farm avoids moral hazard because the farmer is the complete residual claimant. But the simplest family farm sacrifices gains from specialized labor available in more complex agricultural factories. Small farm partnerships fall between family farms and large, factory-style corporate farms. The small farm partnership captures some gains from specialization while mitigating moral hazard. By identifying conditions in which these forces vary, we derive testable predictions about the choice of organization and the extent of farm integration. We test these predictions using historical industry case studies as well as detailed microlevel data from over 1,000 farms in British Columbia and Louisiana. The results of both tests support our approach. Production stages in farming tend to be short, infrequent, and require few distinct tasks, thus limiting the benefits

[15] Holmes, *supra* note 14, at 40–41.

[16] Coase, *supra* note 9.

of specialization and making wage labor especially costly to monitor. When farmers are successful in mitigating the effects of seasonality and random shocks to output, farm organizations gravitate toward factory processes, developing the large-scale corporate forms found elsewhere in the economy.

II. A Model of Farm Organization

Farm organization can vary from a single owner or simple partnership, where labor is paid by residual claims, to a public corporation with many anonymous owners and specialized wage labor. A ''pure'' family farm is the simplest case, where a single farmer owns the output and controls all farm assets, including all labor assets.[17] Factory-style corporate agriculture is the most complicated case, where many people own the farm and labor is provided by large groups of specialized fixed wage labor. Partnerships are intermediate forms, in which two or three owners share output and capital and each owner provides labor.[18]

In addition to its organization, agriculture is characterized by several distinct stages of production—planting, cultivation, harvesting, and processing for plant crops; or breeding, husbandry, and slaughter for livestock—largely determined by nature.[19] In principle, there is no reason why a separate farmer could not own each stage. It would be possible, for example, for one farmer to prepare the soil, a second farmer to plant, a third farmer to apply pesticides, a fourth to harvest the crop, and so on. Each of these separate ''farms'' could be connected to the other farms at adjacent stages by market transactions for the output from their particular stage. In reality, however, most farmers control several stages of production, such as soil preparation, planting, cultivation, and harvest. At the same time, there are often differences in the number of firm-controlled stages across different farm products. In many cases, a family farmer harvests and stores his own crop. In other cases, a family farmer may be a member of a cooperative that owns the storage facility. In such a case, the farm is extended from

[17] We ignore intrafamily incentives and consider a husband-wife team (and their juvenile children) as a single agent. While this assumption ignores intrafamily shirking, this is unlikely to be serious as long as families are bound by intergenerational contracts. We also ignore the distinction between control of farmland through ownership and contracting.

[18] We include ''family-held corporations'' within ''partnerships'' because such corporations are often established under subchapter S of the Internal Revenue Service code and are more like small partnerships than large-scale corporations. For the issues we study this distinction is not important.

[19] For example, in the ''Feeke's Scale of Wheat Development,'' there are 11 stages of growth from planting to ripening. See the Wheat Grower, September 1994, at WF-8.

harvest into processing, but the ownership of the ''farm'' at the two stages is not the same.[20]

A. Mother Nature: Seasonal and Uncertain Production

To the farmer, a ''season'' is a distinct period of the year during which a stage of agriculture (such as planting and harvesting) is optimally undertaken. For example, for spring wheat grown on the northern Great Plains, the monthlong planting season usually begins in April, and the harvest season is primarily restricted to August. This broad definition of a season, however, hides some important features of nature that directly influence the incentives inherent in agricultural production. To uncover these features, we model seasonality as a collection of parameters: (1) C, the number of times per year the entire production cycle can be completed; (2) S, the number of stages in the process; (3) T, the total number of tasks in a given stage; and (4) L, the length of a stage.[21]

Since farm production is cumulative, our model uses a stage production function that depends on natural parameters and specialization.[22] Let Q be the final consumer product (such as bacon or bread) derived from a cumulative production process with S discrete stages of production. The output in each stage is an input into the next stage's production function, so that $Q = q_s = h(q_{S-1}(q_{S-2}(. . .)))$. At each stage the output depends on farmer effort (e), a capital input (k), and random stage-specific natural shock (θ) determined by such natural forces as pests and weather. Hence, the farmer in our model takes the output from a previous stage as an input into the next stage and makes an optimal effort choice that depends, in part, on what na-

[20] Recognizing that ownership is not constant across stages of production points out the ambiguity of questions like ''How big is the farm?'' A farm may be 1,000 acres at planting, but harvesting may be done by another ''farm'' over 80,000 acres.

[21] Crop seasons (stages) are ultimately linked to biological processes (such as birth, planting, flowering, and mating) that depend on such variables as day length, temperature, and rainfall, which vary across nature's seasons. Annual crops like wheat and corn have $C = 1$; irrigated vegetables in southern California that generate several harvests may have $C = 5$; and timber with a 100-year rotation has $C = 0.01$. A continuously harvested (completely nonseasonal) crop would have $C = 365$. Among other things, C indicates how often a stage and its tasks are repeated during the year. Note that tree crops may be annual even though the plant is perennial. Trees for timber represent a case where crop frequency equals the life of the plant.

[22] Ellickson & Brewster, *supra* note 14, at 841, also recognize the common cumulative feature of agriculture: ''For the number of simultaneous operations in agriculture varies little with either the size of farm or the 'state of the industrial arts.' It makes little difference, for example, whether a corn-hog farm covers the whole state of Iowa or on 160 acres, or whether farming is done with oxen, flails, and sickles or with high-powered tractors and combines; the number of production steps that can be done at the same time on such farms remains substantially unchanged.''

ture did in the prior stage. In particular, for the s^{th} stage, the stage-specific random input of nature θ_s is distributed with mean 0 and variance σ^2. Consequently, the production function for a single stage is $q_s = h_s(e_s, k_s; q_{s-1}) + \theta_s$, where inputs e and k have positive and diminishing marginal productivity, and these marginal products are increasing in q_{s-1}.

Because there are many tasks within a given stage, we define t_{stn} as the effort (in hours) in the s^{th} stage, on the t^{th} task, performed by the n^{th} worker. Tasks are indexed by $t = 1, \ldots, T;$ stages are indexed by $s = 1, \ldots, S;$ and workers are indexed by $n = 1, \ldots, N$. Let T be the number of tasks for a given stage and assume that T is exogenous, determined by nature and technology. Tasks are well-defined jobs that take place during a stage, such as operating a combine or a grain truck during wheat harvest.[23] A given task may be common to any or all stages of production, like inspecting crops and livestock, or it may be unique to a stage, like operating a combine.

Effort (e), however, does not adequately describe the labor input into farm production. Because workers learn by doing, we define effective labor in stage s for task j as $e_{st} = a_s t_{st}$, where $a_s = (N_s L_s / T_s)^{\alpha_s}$ and $t_{st} = \sum_{n=1}^{N} t_{stn}$. The term t_{st} indicates that total task effort is the sum of all of the individual worker's efforts for a given task t in stage s. The effective effort parameter $a_s \in [0,1)$ measures the amount of task specialization and is assumed to be the ratio of the total number of workers multiplied by the length of the stage, and divided by the total number of tasks, raised to $\alpha_s \in [0,1)$. This means that a worker's marginal productivity increases when he spends more time working at a particular task, which in turn depends on how long a stage is and how many other tasks the worker is performing during the stage. To simplify, we assume that there is only one person working on a task, so $N \leq T$. Like Becker and Murphy, we assume that workers are identical, which means that gains from specialization do not arise from endowment effects. Instead, gains from specialization arise because, in the words of Becker and Murphy, ''[t]he increasing returns from concentrating on a narrower set of tasks raises the productivity of a specialist above that of a jack-of-all-trades.''[24]

The parameter α_s indicates the degree to which task specialization can potentially increase output. For some tasks (such as shoveling grain) there may be little to be gained from specialization ($\alpha_s \approx 0$), while for others (such as management decisions or pesticide application) these gains may be

[23] Tasks may be mostly mental (such as planning and marketing decisions) or mostly physical (such as lifting, shoveling, and operating heavy equipment). Task seasons do not always match stage seasons because a task may not be stage specific. Truck driving may be a task in several stages and have a long season compared with any one stage.

[24] Becker & Murphy, *supra* note 13, at 1139.

great ($\alpha_s \approx 1$). The length of a stage (L) can vary across stages for a single crop and vary across crops for the same stage.[25] Since L is determined by nature and has the same effect on a as changes in N, we initially normalize it to one to minimize notation.

Specialization effects are at their maximum when $a_s = 1$. This condition could arise for several reasons. First, there may be only one task and one worker ($N = T = 1$). Second, there may be many tasks, but the number of workers exactly matches the number of tasks ($T = N > 1$), allowing each worker to completely specialize. Finally, there may simply be no gains from specialization for some stages ($\alpha_s = 0$). Under these assumptions, the full stage production function becomes

$$q_s = h_s(a_s t_{s1}, \ldots, a_s t_{sT}, k_s; q_{s-1}(d)) + \theta_s, \qquad s = 1, \ldots, S. \quad (1)$$

In (1) k_s is a stage-specific (physical) capital input, h_s is the stage s production function, and d is a parameter (examined in Section IIC) measuring the timing of task effort during the production of the previous stage output.

B. The Structure of Farm Ownership

We now use the stage production framework to examine three different farm ownership structures: the family farm, partnerships, and corporate farms. In the first two models the number of workers and the number of owners are the same, so we use N to denote both variables. The marginal cost of capital for all ownership systems is $r = r(N)$, with r decreasing and convex in N and bounded by $r^{\min}$. There are two reasons these costs fall as the number of owners and workers increase. First, self-financing is easier with the pooled resources of many owners. Second, capital (such as land and equipment) will be used more intensively and thus more efficiently on a larger farm.[26] This implies that individual family farmers have the highest capital costs, so that $r(N = 1) \equiv r^{\max}$. To start, we analyze only one stage, so we drop the stage subscripts and denote the output from the previous stage as q_{-1}. We also normalize stage output prices (p_s) to one and let w be the opportunity cost of task effort in the labor market. Since all farmers are assumed to be risk neutral and to maximize expected profits, farmers

[25] For example, the harvest season for spring wheat might be 3 weeks but can be several months for sugarcane. In the simple case of homogeneous stages, $L = 365/(C \times S)$ so that if just one stage requires a year to complete the process, then $L = 365$ days.

[26] In making this assumption we assert that the reduction in capital costs outweighs the moral hazard problems that might arise with multiple owners or users of capital. Compared with labor effort, capital levels are easily observed and often assigned to a specific partner or hired worker.

choose the ownership structure that maximizes the expected value of the farm.[27]

Family Farms.—The family farmer must make several choices. He must decide how to allocate his farming time across tasks, decide on the level of capital, and decide how much time to spend on and off the farm. The farmer may earn an hourly wage (w) by supplying hours of effort (m) in the labor market. His effort allocation is constrained so that his total time (on-farm and off-farm activities) equals the total time available for the stage (stage length is normalized to 1). The family farm problem is to maximize expected profits Π^F, written as

$$\max_{t_1,\ldots,t_T,m,k} \Pi^F = h\left(\left[\frac{1}{T}\right]^{\alpha} t_1, \ldots, \left[\frac{1}{T}\right]^{\alpha} t_T, k; q_{-1}(d)\right) - r^{\max}k + wm, \quad (2)$$

subject to $\sum_{t=1}^{T} t_t + m = L = 1$, where $a_t = (1/T)^{\alpha}$ since $N = 1$. The optimal choices (t_t^F, m^F, k^F) solve the following first-order necessary conditions:

$$\left[\frac{1}{T}\right]^{\alpha} \frac{\partial h}{\partial t_j}(t_t^F, m^F, k^F) \equiv w, \qquad t = 1, \ldots, T, \quad (3a)$$

$$\frac{\partial h}{\partial k}(t_t^F, m^F, k^F) \equiv r^{\max}. \quad (3b)$$

These solutions have clear implications. Since the family farmer is the complete residual claimant in both activities, there is no moral hazard for task effort. The family farm is, however, hindered by a lack of specialization, which reduces the marginal product of labor in every given task, as long as there is more than one task ($T > 1$). In addition, although family farms equate marginal costs and benefits for capital, they face larger costs for capital compared with partnerships or corporations and therefore use less capital, implying a smaller farm with less equipment compared with partnership and factory-corporate farms.

Partnership Farms.—Like the family farmer, the partner allocates his time on and off the farm and among the various farming tasks. However, because each partner shares farm output but keeps all of his off-farm income, he shifts more effort into off-farm activities than he would if he had no partner. Because partners and tasks are homogeneous, partners share

[27] Thus, the random input (θ) and its variance (σ^2) play no direct role in the objective function or the optimality conditions. None of the organizations we discuss are first-best: this requires $a = 1$, $r = r^{\min}$, and no moral hazard.

tasks equally. This means that each partner allocates his farm labor over T/N tasks. Furthermore, because the combined resources of the partners exceed that of a single (family) farmer and because of a higher rate of use of those resources, partnerships benefit from a lower cost of capital than do family farms.

We model the partnership problem in two stages. In the first stage, partners jointly maximize the expected wealth of the farm in choosing capital and partners, subject to the task allocations chosen by each partner. In the second stage, each partner maximizes his expected profits (π^P) by choosing how to allocate his effort over T/N farm tasks and his own nonfarm labor, holding constant the joint choice of capital and the number of partners. Using backward induction, we solve the second stage first, so that for each partner, the problem is

$$\max_{t_{1n},\dots,t_{(T/N)\,n},\,m} \pi_n^P = \left[\frac{1}{N}\right] h\left(\left(\frac{N}{T}\right)^{\alpha} t_{tn}; \bar{k}, q_{-1}(d)\right) + w_n m_n, \qquad n = 1, \dots, N, \quad (4)$$

subject to $\sum_{t=1}^{T/N} t_{tn} + m_n = L = 1$; $n = 1, \dots, N$, where $\bar{k}$ is a fixed amount of capital owned jointly by the partners, w_n is the (shadow) wage for the n^{th} partner, m_n is the n^{th} partner's labor market effort, and $a_t = (N/T)^{\alpha}$ is the specialization scalar. Each partner takes $\bar{t}_m$, the task effort of all other partners for the remaining $T(N - 1/N)$ tasks, as given. The optimal task effort vector $t_{tn}^P(\Phi) = t_{tn}^P(N, T, \alpha, w, L, \bar{t}_{tn}, k, q_{-1}(d))$, solves the following first-order necessary conditions:

$$\left(\frac{N^{\alpha-1}}{T^{\alpha}}\right)\frac{\partial h}{\partial t_{tn}}(t_{tn}^P(\Phi)) \equiv w_n, \qquad t = 1, \dots, T/N, \qquad n = 1, \dots, N. \quad (5)$$

Equation (5) shows that the number of partners does not affect the marginal rate of substitution between tasks on the farm but does affect the amount of a partner's effort on the farm. Hence, as the number of partners increases, each partner spends less time on the farm, and this translates into less time spent on each farm task. Note that when potential specialization gains are greatest ($\alpha = 1$), equation (5) reduces to equation (3a) and the partner's choice of time spent on each task is identical to the family farmer's because $a = 1/T$ for each task. On the other hand, if specialization has no value ($\alpha = 0$), then equation (5) reduces to a classic Marshallian sharecropping first-order condition because $a = 1/N$ for each task. The lesson is that as the potential gains from specialization increase (higher α), partnership farms become more valuable.

Taking this optimizing behavior into account, the partners' joint problem is to maximize expected profit by choosing the level of capital and the number of partners, subject to each partner's incentive compatibility (IC) and individual rationality (IR) constraints and the total time constraints of the partners. Because we assume that partners have identical endowments, the effective effort term for each task is $(N/T)^{\alpha}t$. Similarly, each partner earns off-farm income equal to $wm = w[1 - \sum_{t=0}^{T} t_t]$. Substituting this constraint directly into the objective function gives

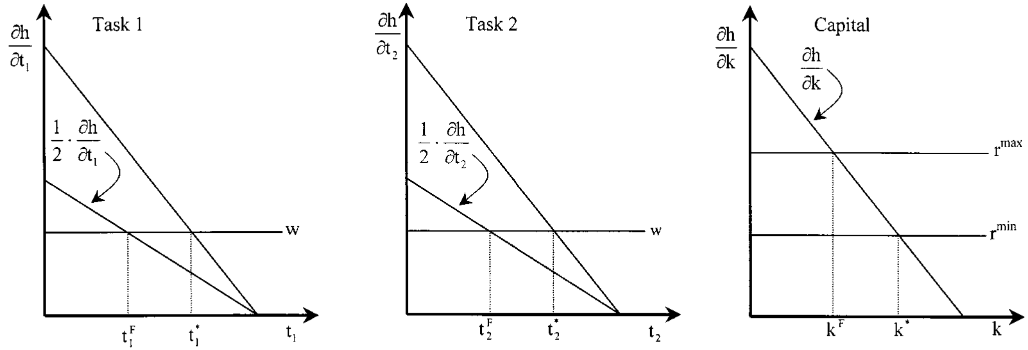
$$\max_{k,N} \Pi^P = h\left(\left(\frac{N}{T}\right)^{\alpha} t_t,\, k;\, q_{-1}(d)\right) - r(N)k + Nw\left[1 - \sum_{t=1}^{T} t_t\right], \quad (6)$$

$$\text{subject to } (IC_t) \quad t_t = t_t^P(\Phi) = \text{argmax}\, \pi_t^P, \qquad t = 1, \ldots, T,$$
$$(IR) \quad \pi_t^P \geq \overline{V},$$

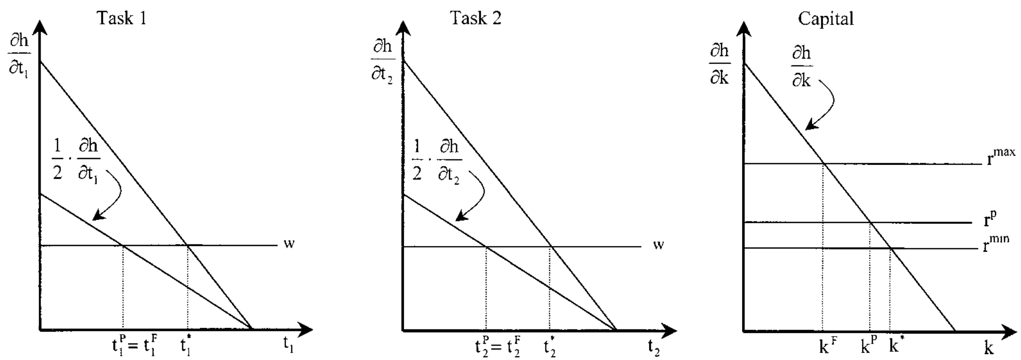
where $\overline{V}$ is the reservation income level for each partner.

The solution to equation (6) is derived in the appendix, but the main implications are illustrated graphically in Figure 1. Simply put, adding a partner yields a return from increased task specialization and lower capital cost. At the same time, adding a partner generates additional costs in terms of decreased farm effort from greater moral hazard. The partnership farm will also have greater capital levels than the family farm (see appendix). Depending on the relative size of these various effects, a partnership farm may or may not be more valuable than a family farm.

Figure 1 shows the trade-off involved in the choice between a family farm and a partnership farm. The figure shows the optimal allocations of effort and capital in each farm organization in the simplest case when (a) there are only two tasks and two partners (so $N = T$ in a partnership); (b) there is only one stage-specific type of capital; (c) capital and effort are independent inputs; and (d) $\alpha = 1$. For added simplicity, we have drawn the graphs with linear marginal products. For comparison, we show the first-best input levels, denoted by asterisks. Panel a shows the case of the family farm. Since there is just one farmer and two tasks, the marginal product rotates downward by one-half, and the optimal task choices are t_1^F and t_2^F. Given the higher cost of capital, the family farm uses k^F units of capital. Panel b shows the case of a two-farmer partnership where there are still only two tasks. Under the assumptions used in Figure 1, the specialization and moral hazard effects exactly offset each other. As a result, allocation of task effort is identical in the two regimes, but because of lower capital costs, the partnership is more valuable. It is easy to see, however, that if the potential gains from specialization decline enough (from smaller values of α or T, or larger values of L), the family farm will become more valuable than the partnership.



Panel (a) The Family Farm: $N = 1$, $T = 2$, $\alpha_t = 1$, $a_t = ½$; $t = 1, 2$



Panel (b) Two-Farmer Partnership: $N = 2$, $T = 2$, $\alpha_t = 1$, $a_t = ½$; $t = 1, 2$

FIGURE 1.—The choice between family farms and partnership farms

Factory-Style Corporate Farms.—Finally, consider the large, factory-style corporate farm. In this organization the firm's owners share revenues as well as capital and labor costs, but they do not work themselves. Labor in a factory-style corporate organization is provided exclusively by specialized wage employees who are not owners of the firm. With production uncertainty (at each stage), hired workers have incentives to shirk because, unlike family farmers or partners, they are not residual claimants. We capture this in our model by assuming that the corporate farm faces a higher effective wage for its hired workers than does the family or partnership farm; that is, $\overline{w} > w$.[28] We also assume that the corporation faces the lowest possible capital costs. The number of hired workers is determined by the hours of hired task effort through the daily time constraint, where Δ is a constant number of hours each worker can provide in a day. With homogeneous hired labor, the expected value of the corporate farm is given by the solution to

$$\max_{t_t,k} \Pi^{FC} = h\left(\left[\frac{N}{T}\right]^{\alpha} t_t, k; q_{-1}(d)\right) - kr^{\min} - \overline{w}_t t_t, \qquad t_t = 1, \ldots, T, \quad (7)$$

subject to $\sum_{t=1}^{T} (t_t/\Delta) = N$, and N now simply refers to the number of workers hired by the firm.

The solution to equation (7) is derived in the appendix, but the main implications are straightforward. The factory-corporate farm will tend to use more capital because it faces lower capital costs, but its overall ability to use more farm labor will depend on the potential gains from task specialization and the costs of monitored labor. If, for example, there were no moral hazard in task effort ($\overline{w} > w$), the corporate farm would set $N = T$ and have complete specialization as well as the lowest capital costs. Under these circumstances, the corporate-factory farm would obviously generate greater net value than all other organizational forms because of its greater task specialization and lower capital costs. In general, the value of the factory-corporate farm will be highest when capital is a relatively important input, when seasonal parameters allow gains from specialization to be high, and when labor monitoring is relatively inexpensive.

C. Connecting Stages through Firms and Markets

If we consider an adjacent production stage as simply a collection of additional tasks, then the model of organizational choice for multistage pro-

[28] We recognize that a firm with a corps of hired labor is likely to have hired managers as well. Our model simply lumps together the adverse selection and moral hazard problems of managers with the moral hazard of workers.

ducers is analytically identical to the one-stage model. However, the decision to keep the next stage of production in the same farm or to use the market depends on weighing the gains from specialized stage production against the cost of using the market to connect two firms. In agriculture, a new interstage moral hazard problem emerges because of timing problems between stages of production. This dimension of farm organization corresponds to Coase's original focus. Our emphasis on timing is similar to the issue of temporal specificity discussed by Masten et al.[29]

Agricultural timing problems depend on seasonal parameters and can be examined by letting $q_S = q(d)$, where q_S is the output for stage s and d is the date at which the stage's tasks are completed (such as the date at which planting is completed). Numerous studies of crop production have shown that this timing function is approximately quadratic in d, with a unique optimum, d^*.[30] Crop production studies have shown that small deviations from d^* (as little as 2 or 3 days) for certain crucial stages (planting, irrigating, spraying, and harvesting) can reduce crop output by relatively large amounts, possibly to zero (such as when hail falls before harvest). To generate predictions we assume the timing function takes the following form for the s^{th} stage ($s = 1, \ldots, S$):

$$q(d) = \delta d\left[1 - \frac{d}{L}\right] = \delta d - \left(\frac{\delta}{L}\right)d^2, \tag{8}$$

where L is the length of stage and δ is a crop-specific response parameter. All of these variables are stage specific even though we suppress the subscripts in equation (8). The stage length, L, indicates the possible dates for which the task can be undertaken and still generate positive output. The term δ reflects the crop's sensitivity to timing. Increases in δ make deviations from the optimal date more costly.[31] In this specification, the optimal time is exactly in the middle of the stage; that is, $d^* = L/2$.

Timing causes incentive problems, not because deviations from d^* re-

[29] Masten, Meehan, & Snyder, *supra* note 12.

[30] For a specific study, see H. G. Nass, H. Johnson, & J. Sterling, Effects of Seeding Date, Seed Treatment and Foliar Sprays on Yield and Other Agronomic Characteristics of Wheat, Oats, and Barley, 55 Can. J. Plant Sci. 43 (1973). This well-known relationship is described in elementary farm management textbooks such as Ronald D. Kay & William Edwards, Farm Management (3d ed. 1994).

[31] In practice, the importance of timing can vary greatly across crops and stages. Harvest timing, for example, is crucial (δ is large) in spring wheat, where delays can result in large losses from hail, rain, or wind. Once wheat is threshed, however, there is almost no timing problem associated with milling the wheat into floor ($\delta \approx 0$). In contrast, sugarcane must be processed into raw sugar within 24 hours after cutting, or the cane's sugar content will decline dramatically.

duce output but because there is temporal variance in d^* that makes it costly to contract across stages. Variance in d^* means that the optimal date for applying task effort cannot be known with certainty prior to the stage; variance in d^* can arise from variance in the length of the stage (L) or simply from variance in the time at which the stage begins. Accordingly, increases in the variance of d^* decrease the probability of firm-to-firm contracting between stages because the farmer in the later stage cannot accurately schedule a specific date. Obviously, increases in δ also decrease the probability of firm-to-firm contracting, for any level of variation in d^*, because the firm producing at the earlier stage can impose severe losses on the later stage firm by undertaking tasks at a nonoptimal time.

To focus on timing and integration incentives, we assume the organization is constant across two adjacent stages (s and $s - 1$). If the farm is integrated and if stage output has a per-unit value of p_s, then the value of the integrated firm is

$$V^I = p_s[h_s\ (a_s^t t_s,\ k_s,\ q_{s-1}(d^*)) + \theta_s]. \tag{9}$$

In (9) the superscript I denotes variables specific to the integrated case. Alternatively, two separate, specialized firms could produce the two stages and be connected by a market contract. When separate firms, connected by a market transaction, undertake different stages, the value of the market governance structure is

$$V^M = p_s[h_s\ (a_s^M t_s,\ k_s,\ q_{s-1}(d^M)) + \theta_s]. \tag{10}$$

In equation (10) the superscript M denotes variables specific to the market-connected case.

The trade-off between the values generated in equations (9) and (10) depends on the relative importance of timing and specialization. The benefit of the integrated regime is the guarantee of optimal timing of task effort at each stage. With integration there is no interstage moral hazard in timing because a single firm controls both stages and applies task effort at the optimal time ($d = d^*$). With market-connected stages, however, the date of task efforts are not optimal ($d^M \neq d^*$) because the incentives of the two farms are not identical. The magnitude of the loss from suboptimal timing will depend both on the impact of timing on output (δ) and on the marginal product of last period's output ($\partial h_s/\partial q_{s-1}$).

The cost of the integrated regime is the forgone gain from task specialization. As long as the tasks in the two stages are not identical, there must be a loss of specialization across stages because there are more tasks but the number of farmers is the same. In the simplest case, the number of tasks increases to $T^I = T_s + T_{s-1}$, but this increase is spread over two stages. In general, the effective effort parameter in the market-connected firms will be larger than for integrated firms; that is, $a^M \geq a^I$. Since $a = (NL/T)^{\alpha}$, this can arise if $T^I > T^M$, if $L^M > L^I$, or both. For example, a specialized firm can perform its tasks over a longer period by contracting with many farms (each producing stage $s - 1$) for stage s production as long as the stages for these farms do not perfectly overlap. In this case, the length of stage s for the contracting firm can get large, allowing greater gains from specialization. Finally, it is clear that stages with high values of α are more likely to be contracted for than stages with low values of α.

D. *The Comparative Statics of Farm Organization*

To generate predictions about the choice of farm organization we examine how various parameters affect the relative value of the three farm organizations we study. The general model for choosing which farm organization will maximize the expected value of production for any stage is: maximize $V = \max(V^F, V^P, V^{FC})$, where V^F, V^P, and V^{FC} are, respectively, the optimal value functions for the family farm, the partnership farm, and the factory-corporate farm. We can examine the choice of market connection versus cross-stage integration in a similar fashion. We derive optimal value functions by evaluating the firm's objective function at the optimal input levels (see appendix). Deriving comparative statics predictions requires examining how changes in various parameters (α, C, δ, L, σ^2, T) affect the relative values of these indirect objective functions.

Consider the effects of changes in the specialization parameter (α) on the value of the family farm. By the Envelope Theorem, $V^F_{\alpha} < 0$ and $V^F_{\alpha\alpha} > 0$ (see appendix). This means that the value of a family farm declines as specialization becomes more important. A partnership is just the general case of the family farm where $N \geq 2$ and is allowed to vary. Similarly, $V^P_{\alpha} < 0$ and $V^P_{\alpha\alpha} > 0$, but the absolute slope of V^P is less than the slope of V^F for low values of α. In addition, the absolute slope of V^P increases as α and N increase. Furthermore, from equations (3a) and (5), when $\alpha = 1$ the task input choices are the same for partnerships and family farms, so when $\alpha = 1$, $V^P > V^F$ by an amount equal to the net savings in capital costs. In the extreme case when $\alpha = 0$ the family farm makes a first-best task allocation since there are no gains to specialized task effort. The partnership, on the other hand, is penalized because of partner moral hazard. As long as the savings in capital costs are smaller than the moral hazard losses in a partnership, then $V^F > V^P$ when $\alpha = 0$.[32] These value functions are shown in

[32] This is most likely to hold for small partnerships (for example, if $N = 2$) and when capital is relatively unimportant because the marginal deadweight losses from moral hazard fall with an increase in partners while the marginal benefits of capital cost savings increase with the number of partners.

panel *a* of Figure 2, and show that the optimal number of owners varies with changes in the importance of specialization—low values of α lead to family farms; high values of α lead to partnerships.

For corporate-factory farms, the slope of V^{FC} is identical to that of the partnership for all values of α for a given N. Since corporate-factory farms have the lowest costs of capital but the highest labor costs, whether partnership farms or corporation-factory farms emerge depends in part on the net effect of these two costs. Other things equal, corporate-factory farms will tend to emerge where large numbers of workers are required and there are many tasks and large gains to specialization. This is because the costs of monitoring hired labor are likely to rise more slowly with T than the moral hazard effect caused by sharing output.[33] This would lead V^{FC} to be higher than V^P and would mean that for large values of α, corporate-factory farms (with specialized wage labor) would tend to dominate.

Another comparative static result arises from changes in the number of tasks (T). Panel *b* of Figure 2, which assumes that specialization gains are as high as possible ($\alpha = 1$), shows how V^P varies with changes in T for three different values of N. Family farms are the special case, where $N = 1$. Taking into account any differences in the level of task effort for the different size farms, the more partners there are, the lower total task effort is on the farm, which lowers V^P. The value functions are flat as long as $N > T$ because specialization is maximized when $N \geq T$. In the case of a single task ($T = 1$), it must be the case that $V^F > V^P$, unless there is a large capital saving to overwhelm the partnership moral hazard. In addition, the optimal number of owners (N) for a given number of tasks (T) is given by the upper envelope of these curves, which shows that the number of owners is positively related to the number of tasks.

There are similar comparative statics results that explain how timing will determine the extension of the farm into various stages of production. Panel *c* of Figure 2 shows how the values of the integrated and market farms vary with changes in crop sensitivity (δ). In particular, the relative value of the integrated firm increases in δ. Similarly, changes in uncertainty over the stage length (L) also influence the relative values of V^I and V^M. For a given δ, increases in this uncertainty increase the relative value of the integrated farm. When crops are more sensitive to timing errors, the farm is likely to be integrated over multiple stages. When timing is unimportant, the farmer is less likely to control delivery.

Combining these predictions with others derived earlier, we can summarize the predictions of our model:

[33] This is because increases in the number of partners lead to quadratic increases in moral hazard losses.

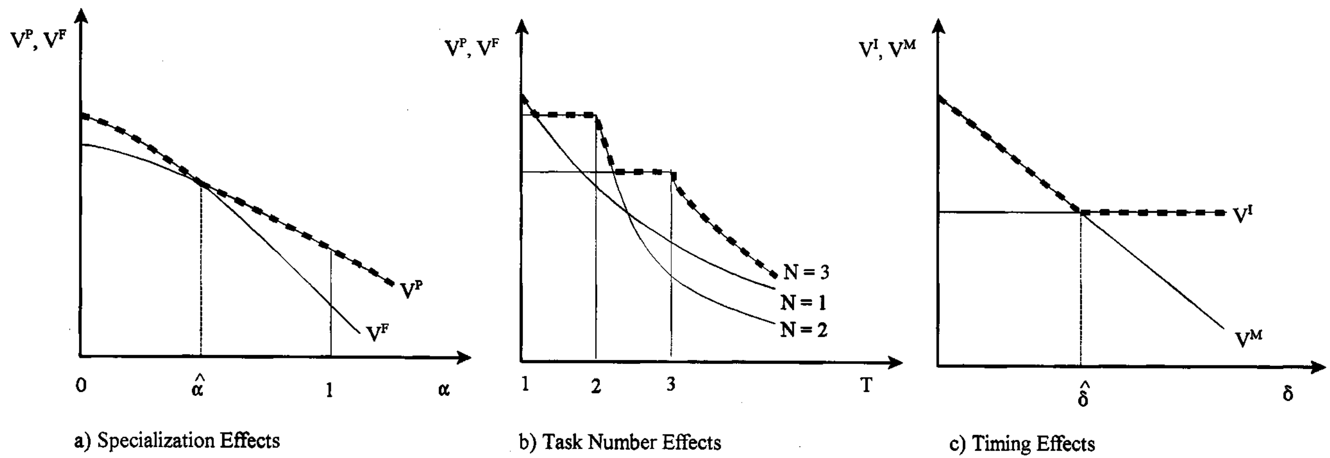


FIGURE 2.—Comparative statics of farm organizations

Choice of Farm Organization

1. As the importance of specialization (α) increases, the family farm becomes less likely and partnerships and corporate-factory farms become more likely.
2. As the number of tasks (T) increases, the family farm becomes less likely.
3. As the length of a stage (L) increases, the family farm becomes less likely.
4. As the number of cycles (C) per year increases (holding constant the number and length of stages), the total amount of time that a single task is undertaken ($L \cdot C$) increases over a given year, making the family farm less likely.
5. As variance in the stage-specific shock (σ^2) increases, the family farm becomes more likely.
6. As the costs of monitoring labor increase ($\overline{w}$), the family farm and partnership become more likely.

Extent of the Farm

7. As crop sensitivity to task timing (δ) increases, the farm is more likely to control adjacent stages.
8. As the variance in the optimal date (d^*) to complete a stage increases, the farm is less likely to control adjacent stages.
9. As the importance of task specialization (α) increases, the farm is more likely to control adjacent stages.

Farm Capital and Farm Size

10. As farm organization shifts from family farms to partnerships and corporate-factory farms, capital stocks (k) per farm increase (see appendix).
11. As farm organization shifts from family farms to partnerships and corporate-factory farms, farm size and farm output increase.

III. Empirical Analysis of Farm Organization

To test the predictions of our model, we both examine industry case studies (historical and contemporary) and analyze econometric evidence for a sample of modern farms.[34] The case study data show that family farms tend

[34] It may be argued that federal farm programs and state anticorporate farming statutes have artificially sustained family farms by preventing the efficient takeover of the industry by the factory-corporate farm. Daniel A. Sumner, Targeting Farm Programs, 9 Contemp. Pol'y Issues 93 (1991), however, finds no evidence that federal farm programs generally have subsidized the family farm. Philip M. Raup, Corporate Farming in the United States, 33 J.

to dominate in cases where the seasonal parameters limit specialization and that large, factory-corporate farms tend to dominate when seasonal factors can be mitigated. The case study data also show how changes in seasonal variables (sometimes as the result of technological changes) cause predictable changes in farm organization. The econometric evidence, using data from nearly 1,000 individual farms, more precisely tests some predictions.

A. Historical and Current Case Studies

The family unit has been the dominant organization in farming since the earliest days of agriculture. Family farms were present in ancient Egypt, Israel, and Mesopotamia[35] and among pre-Columbian American Indians.[36] Hayami and Otsuka[37] report owner-cultivated farm dominance in Asia, Europe, and Latin America as well as in North America. Even in Africa, where land often is owned in common by tribes, farmland is allotted customarily to individual families. Collective farms are a fairly recent political experiment, with typically catastrophic outcomes.[38]

Case studies allow us to examine many of our key predictions in a variety of times and places. After first examining the conditions for which family farming tends to dominate, we study several industry histories. The first of these histories looks at how the extent of the farm has diminished during the past 2 centuries. The other histories include an examination of the large bonanza farms that existed in the Red River Valley at the turn of the century, a discussion of the impact of the combine on the organization of wheat

Econ. Hist. 274 (1973), in contrast, argues that farm policies have subsidized corporate agriculture. Moreover, for two reasons, our study remains outside this debate. First, our historical data predate the implementation of federal and state farm policies. Second, where we examine detailed farm-level data (British Columbia and Louisiana), there are no anticorporate farming statutes. See Charles R. Knoeber, Explaining State Bans on Corporate Farming, 35 Econ. Inquiry 151 (1997). At the same time, it is surely true that taxes and government policies have influenced some farm organization decisions, such as the choice between partnerships and family corporations.

[35] Robert C. Ellickson & Charles DiA. Thorland, Ancient Land Law: Mesopotamia, Egypt, Israel, 71 Chi.-Kent L. Rev. 321 (1995).

[36] William Cronan, Changes in the Land (1984).

[37] Hayami & Otsuka, *supra* note 8.

[38] The crop failures and famines in China and the USSR are the most obvious cases, but other important examples abound. See Nerlove, *supra* note 8; and Frederic L. Pryor, The Red and the Green (1992). Closer to home, farming on Indian reservations in the western United States has been tremendously unproductive because typical land tenure institutions do not allow individual farmers to control land and other assets. See Terry L. Anderson & Dean Lueck, Land Tenure and Agricultural Productivity on Indian Reservations, 35 J. Law & Econ. 427 (1992). Raup, *supra* note 34, shows that history is littered with examples of factory farming outdone by small family farms.

farms, and the emergence of large-scale factory production in the modern livestock industry.

Seasonality and the Dominance of Family Farming.—Our model implies that differences in nature's parameters explain differences in agricultural organization. Recall that nature's parameters include the number of cycles (C), the number of stages per year (S), the number of tasks (T) in a stage, the length of the stages (L), and the variance in random production shocks (σ^2). Annual crops with many short stages, few tasks, and many unpredictable natural phenomena dominate farming in North America. These are precisely the conditions for which our model predicts that family farm organization is likely to be chosen. Seasonality in this environment severely limits the gains from specialization and accordingly places a premium on a type of organization that serves to squelch moral hazard.

When the number of cycles is low, as with annual grain crops like wheat, the gains from specialization are severely limited (prediction 4), the cost of extending a farmer's duties to adjacent stages is lower because the opportunity to do repetitive tasks is diminished, and timing between stages is more important. For many North American crops, a low number of cycles is associated with a large number of stages that have few tasks,[39] a condition that limits the gains from specialization (prediction 4) and makes labor-monitoring costs high (prediction 6). Production characterized by few cycles is sensitive to random shocks because hiring workers for a given single task is more expensive because there are more opportunities for shirking. Taken together, these forces imply that a family farm organization is more likely to be optimal when the number of cycles is low. Family units, for example, dominate wheat farms, where there is just one crop per year and sometimes less frequently when arid conditions require fallowing. As of 1992, over 80 percent of all wheat farms were family firms, and they were responsible for over 65 percent of all wheat sales, while only .27 percent of all wheat farms

[39] Farming typically has a number of complementary tasks across stages that also reduce the effective number of tasks. For example, many tasks, such as driving a tractor, are performed jointly with stage-specific tasks. Thus the skills for one task transfer easily to another task. Successful farming depends on making many small decisions, often on the spot, and often regarding the timing of actions. Timing and on-the-spot decisions are highly complementary and common across many tasks within a stage. Being a good judge of weather for planting is complementary with judging the weather for harvest. Also, if a family farm controls planting, it is likely to control other stages that require the same inputs. For example, cultivation and harvest require the use of tractors and general farming knowledge, and so it is predicted they would also be controlled by family farms. In contrast, because processing crops usually calls for large, discrete differences in capital, the farm that grows the crop is unlikely to process it. Farming is characterized by a host of complementary tasks both at a given stage and across stages.

were nonfamily corporations, responsible for just .6 percent of all wheat sales.[40]

When crop production is characterized by many cycles, long stages with many tasks, and few random shocks, farm organization tends toward the large, factory-corporate farm. Within the United States, the sole (family) proprietor has been much less common in southern agriculture than in northern agriculture.[41] This is consistent with the key predictions of our model.[42] As Gray[43] argues, plantation agriculture thrived because plantations used a ''one-crop system permitting the routinizing of operations''; because the crops required ''year round employment of labor''; and because the crops required ''a large amount of labor on a small amount of land, thus simplifying the problem of supervision.'' Compared with grain crops like corn and wheat, plantation crops had a small number of stages that lasted over long periods, allowing great gains from specialization and low cost monitoring. For example, cotton was continually cultivated by hand with hoes, and because the bolls ripened so unevenly cotton picking lasted for months (prediction 3).

Temporal Changes in Agriculture: Narrowing the Extent of the Family Farm.—From the colonial period until the mid-nineteenth century, nonplantation farms in the United States were organized as family businesses that controlled nearly the entire production process.[44] Since that time, the growth in the factory method of production has limited the extent of the family farm at both the beginning and the end of the production sequence. As a result, the modern family farm controls a more limited set of production stages.

Until the mid-nineteenth century, the family farm extended into virtually all stages of farm production, from ''farm making'' (clearing land and rais-

[40] Bureau of the Census, *supra* note 2, table 47 (1993).

[41] Beyond North America, the great exception to family-based agricultural organization is the equatorial plantation. See Frederic L. Pryor, The Plantation Economy as an Economic System–A Review Article, 6 J. Comp. Econ. 288 (1982). Plantation crops, including banana, coffee, and sugarcane, are characterized by relatively long growing stages and a relatively small variance in nature-driven shocks. Indeed, some plantation crops (such as bananas and coffee) may have a continuous year-round harvest. For these crops large hierarchical organizations with wage labor (or slaves) have dominated. See Raup, *supra* note 34; and Pryor, *supra.*

[42] For example, before the Civil War the South developed large slave plantations for cotton, rice, and sugarcane.

[43] Lewis Cecil Gray, 1 History of Agriculture in the Southern United States to 1860, at 463 (1941).

[44] For historical data we rely on Percy Wells Bidwell & John I. Falconer, History of Agriculture in the Northern United States (1925); Clarence H. Danhoff, Changes in Agriculture: The Northern United States, 1820–1870 (1969); and Gray, *supra* note 43.

ing buildings) to processing goods for retail consumption (such as making cheese or sausage). The family had almost no contact with the market for its inputs, except perhaps with a blacksmith. The only contact with the market came when the farmer sold (or bartered) his meat and dairy products directly to consumers.[45]

The main exception to selling products directly to consumers was selling grain to gristmills. Gristmills were the first of many firms that specialized in what would otherwise be a single stage of the farm production process and ultimately evolved into large firms that developed factory production techniques. Because grains are easily stored and a mill can be operated continuously, milling grain for flour is almost completely removed from seasonal forces. In this type of situation the gains from specialization are high: there are no cycles; stages are long; there are many tasks (predictions 2, 3, and 5); and there are no severe timing problems (predictions 7 and 8). All of these factors reduce the value of family production and favor large-scale, factory production.

After the early 1800s dramatic changes in technology led to the rise of separate firms that specialized in single stages of production and operated all year round. New technologies such as refrigeration, which limited natural forces, allowed seasonal tasks to be performed throughout the year (prediction 3). Overwhelmingly, the new firms engaged in production at either the beginning (equipment, fertilizer, and seed) or the end (marketing, processing, transportation, and storage) of the agricultural production sequence.[46] Accordingly, the family farm has abandoned these stages and now controls only the purely biological growth stages of farm production.

Bonanza Farms in the Red River Valley: An Experiment in Factory Farming.—In the last quarter of the nineteenth century, an experiment in farm organization took place on the virgin prairie of the Red River Valley dividing Minnesota and North Dakota. Between 1870 and 1890 a number of extremely large wheat farms were established, some exceeding

[45] See Danhoff, *supra* note 44. There were also sod-busting firms that contracted with family farmers in some areas. On the prairie, clearing land meant sod busting vast stretches of homogeneous grasslands divided into 1-mile-square sections. Sod busting is a routine task that has a long season (6 months even in the northern reaches of the plains) and almost no timing problems. Accordingly, it is not surprising that specialized firms sold this service to farmers, generally per acre of broken prairie.

[46] In the late nineteenth century these firms included flour mills, cheese factories, creameries, early equipment manufacturers (plows, reapers), grain brokers, meat packers, slaughterhouses, livestock breeders, canneries, and other food processors. This process has continued throughout the twentieth century as advances in biological and chemical technology and new product developments have led to fertilizers, seeds, feeds, pesticides, artificial insemination, and crop dusting that result in gains from specialization and reduced seasonality for certain stages of production.

50,000 acres (roughly 78 square miles). These farms were enormous, but their main distinguishing feature was not their size but rather their factory-corporate organization. The owners, typically businessmen with no farm experience, who raised capital in eastern markets, organized their farms along the lines of contemporary manufacturing firms (often as corporations with professional managers) and a specialized wage labor force. The ''bonanza farms,'' as they came to be known, were hailed as the future of agriculture.[47] Yet after only one generation, nearly all the bonanza farms were gone, systematically bought out by family farmers.

Most bonanza owners focused exclusively on wheat production and kept virtually the entire production sequence within the firm: from sod busting, seed development, machine repair, and hardware supply, to blacksmithing, grain cleaning, storage, and flour milling. The farms were also highly mechanized, and the latest large-scale equipment was used.[48] Labor was organized in a complex hierarchical system common to industrial manufacturing. Managers were paid a combination of a salary and a commission.[49] The labor force varied greatly in size over the seasons, with harvest crews typically twice the size of seeding crews.[50]

Although the bonanzas' combination of modern technology, specialized labor, and professional management practices seemed unstoppable,[51] bonan-

[47] Our most important source in this section is Hiram Drache, The Day of the Bonanza (1964). See also Harold E. Briggs, Early Bonanza Farming in the Red River Valley of the North, 6 Agric. Hist. 26 (1932); and Poultney Bigelow, The Bonanza Farms of the West, 45 Atlantic Monthly 33 (1880). Drache and others use ''bonanza'' for farms over 3,000 acres, although the most prominent of these tended to be between 20,000 and 50,000 acres. Drache finds 91 farms with at least 3,000 acres in the region in 1880. He also finds 15 farms that had at least 20,000 acres. This compares to an average farm size of little more than 200 acres during this time. In 1992, the Census of Agriculture reports that the average farm size in the relevant North Dakota counties was less than 1,000 acres.

[48] For example, in just the second crop season on the well-known Cass-Cheney farm, with only 4,000 acres of wheat planted, Oliver Dalrymple assembled 26 breaking plows, 40 plows for turning sod, 21 seeders, 60 harrows, 30 self-binding harvesters, 5 steam powered threshers, 80 horses, and 30 wagons.

[49] The farms were broken into 5,000-acre divisions headed by superintendents and 1,200-acre stations headed by foremen. Most of the labor force, including the field hands, hired in monthly increments and paid a daily wage, worked out of the stations. Accountants, blacksmiths, mechanics, and hands involved in grain cleaning and storage worked at the farm's headquarters.

[50] For instance, in 1877 (for 4,000 acres of wheat) Cass-Cheney had a seeding crew of 50 and a harvest crew of 100.

[51] Bigelow, *supra* note 47, at 43, for example, wrote: ''Against the unlimited use of this combination of capital, machinery, and cheap labor the individual farmer, either singly or in communities, cannot successfully contend, and must go under. It is a combination of the most powerful social and economic forces known to man, and all efforts for competition must and will fail so long as the three remain united.''

zas began to disappear as early as 1890, and by 1910 they were virtually extinct. There is substantial evidence that the crucial factors in the breakup were the monitoring costs and related inefficiencies associated with large labor forces spread out over great distances.[52]

The dissolution of the bonanza farms is consistent with the predictions of the model: with highly seasonal crops like wheat the family farm is the organizational structure that maximizes the value of the farm. Recognizing their labor problems early on, many owners of bonanzas began leasing their lands in small units to homesteaders who wanted to expand operations. The bonanzas ultimately sold their lands in small parcels, typically quarter (160 acres) and half (320 acres) sections, to family farmers. The bonanza era provides a market test of the viability of industrial farming of a highly seasonal crop.[53] Indeed, in 1900 the agricultural economist John Lee Coulter saw the future, writing: ''The great estates of the region are doomed to disintegration. The great wheat ranch cannot compete with the small diversified farm.''[54]

Wheat Organization and Changes in Harvest Technology.—The history of wheat harvesting provides another test for our model. Prior to the invention of a viable combine, harvesting (the cutting, binding, and shocking of the wheat plant) and threshing (separating seed from chaff) of grain were done separately, generally with specialized crews. Farmers would use their own reapers to cut the wheat and then another half-dozen men or so would bind (tie in bundles) and shock (stack) the grain. After the wheat had been shocked, it had to be threshed. This was often done in the field (although

[52] On the Cass-Cheney farm, for example, Oliver Dalrymple managed a harvest crew of 1,000 men and 30 threshing machines spread over 30,000 acres of wheat (roughly 7 miles square if contiguous). Dalrymple took great pains to mitigate his moral hazard problems. Managers, superintendents, and foremen were paid by commission. Grain from every field was weighed and recorded so that responsibility could be assigned. Labor was performed in crews one task at a time (such as plowing or seeding) to make supervision easier for the foremen, and rigid rules governed the daily routines of the field hands at work and in the bunkhouse.

[53] The bonanza farms should not, however, be considered a systematic business failure. The stockholders of the Northern Pacific and entrepreneurs like Oliver Dalrymple profited from introducing wheat and its technology to an uncultivated territory. The bonanza farmers capitalized on increasing land values that depended on their own efforts. For instance, land bought in 1875 for $1.00 per acre was sold in 1885 for as much as $25.00 per acre, yielding an annualized nominal return of 38 percent during a period in which price levels fell nearly 20 percent. As Drache, *supra* note 47, shows, bonanza farmers learned quickly that they could do better by abandoning the factory system and leasing or selling their land to local homesteaders. Because they could break soil all summer without having to establish homes for families, it is also likely that the bonanzas were able to exploit specialization gains in sod busting.

[54] Coulter is cited in Drache, *supra* note 47, at 213.

the binds could also be stored in barns), most often by a custom (hired) thresherman and his crew.[55] A key feature of this process was that the grain could remain in the shocked bundles for 3 or 4 months until threshing was completed without serious damage to the grain. This allowed the farmer to cut his wheat at the optimal time, independent of the time of the threshing.

The introduction of the ''combined harvester thresher,'' now known simply as the ''combine,'' radically changed wheat harvesting. The combine simultaneously harvests and threshes grain and eliminates the need for rakers, gleaners, shockers, and all of the support crew that go with them. The combine made an obvious and dramatic reduction in the number of tasks (T) during the harvest stage (prediction 2), eliminating the intermediate stages between cutting and threshing. After the introduction of tractors with power takeoff, one farmer could complete an entire harvest.[56] The combine took one stage of production that had potentially as many as 10 tasks and reduced them to one. Most likely, no other agricultural invention has had as great an impact on a single stage of production. Today approximately 75 percent of all wheat farmers harvest and separate their own grain with combines.

Perhaps even more important than reducing the number of tasks, the combine reduced the length of the harvest stage (L) by compressing two long stages (binding and threshing) into a single short stage (prediction 3). But in the process, the combine created a serious timing problem by increasing δ and the variance in $d*$ (predictions 7 and 8). With combines the cutting and threshing of grain is done simultaneously, and grain left standing in the field is exposed to natural elements such as hail, rain, or wind that can knock it down or dampen it. Furthermore, a combine requires grain to be ripe before cutting so that the threshing within the machine can be

[55] According to Thomas D. Isern, Bull Threshers and Bindle Stiffs: Harvesting and Threshing on the North American Plains 75 (1990): ''In pure custom threshing the thresherman provided not only the machinery, the engineer, and the separator man but also the full crew of men required to do the threshing. . . . [T]he farmer was responsible only for hauling away the grain as it fell from the spout of the separator. The pure custom thresherman provided board for his crew, usually by maintaining a mobile cook shack and hiring a cook.''

[56] One-man ''pull-type'' combines (pulled by tractors) were available by 1926, and by the 1940s self-propelled combines were on the market. Although the combine was invented in 1838, it was used sparingly (mainly in California) before the gasoline engine was perfected. Combines required an enormous amount of power that made them unwieldy in the fields when powered by horses or mules. See Isern, *supra* note 55. Data from the USDA show the adoption of the combine was swift and decisive. In 1920 there were only 4,000 combines, but by 1930 there were 61,000, by 1940 there were 190,000, and by 1950 there were 714,000 combines. See U.S. Department of Agriculture, Agricultural Statistics 1957, table 639, at 532 (1958).

done properly.[57] Our model predicts that all of these changes in tasks, skills, and timing encouraged family farm harvests.[58]

The combine also reduced the gains from specialized skills (α) (prediction 1). Threshing crews had been large—usually more than a dozen men. Some of the threshing jobs required different skills from general farming. The engineer, who maintained the steam engine and kept it running, and the separator man, who acted as his assistant and supervised the crew feeding the machine, were highly skilled relative to the other laborers and the farmer. Both had mechanical knowledge that was of little use in other farming stages where steam was not used. The combine and the gasoline tractor eliminated the need for these skills.

The organization of the turn-of-the-century custom threshing industry is also consonant with the predictions of our model. During the late nineteenth and early twentieth centuries, threshing crews were separate firms that collectively employed hundreds of thousands of men. In essence, they were highly specialized ''factory farms'' that focused on a single production stage. There were great gains from specialization of tasks in this stage and relatively low monitoring costs for hired labor. In this environment, factory-style threshing firms could thrive. Threshing was a long stage, but since the wheat yield was not sensitive to the time of threshing, binding and threshing could be cheaply connected through the market. Although the farmer had to pay close attention to the timing of reaping and binding so that severe weather would not damage the wheat, he could be flexible about threshing because the shocked bundles of wheat could remain unharvested for several months without damage. The combine extended the growing op-

[57] According to Isern, *supra* note 55, at 192: ''[h]arvesting with the combine began seven to ten days later than harvesting with the binder. During this time a hailstorm might level the crop, insect pests might attack it, lodging might occur, or the grain might bleach out. In addition, wheat that stood until dead ripe was more likely to shatter at the cutter bar.''

[58] Another test of our model arises from differences in spring and winter wheat. On the Great Plains, winter wheat is grown in the south, roughly from Texas to South Dakota, and harvested earlier than the spring wheat grown farther north in the Dakotas, Montana, and Canada. In terms of our model, spring wheat has more timing problems (larger δ and variance in d^*) than winter wheat. Spring wheat is more susceptible to weeds (which increase water content and cause mold), has shorter harvesting seasons, does not ripen evenly on the northern prairies, and has more morning dew, which can often delay combining until the afternoon. All of these features lowered the value of the combine for spring wheat compared with winter wheat. Combines were adopted in the winter wheat regions of the Great Plains, just after World War I, but they were not used in the spring wheat areas until the late 1920s, when the swather was invented. The swather cuts and lays the grain down on the stubble, suspended above the ground and exposed to the air, allowing it to dry and ripen quickly. After the grain dries in the ''windrow,'' it can be picked up by the combine and threshed. The swather reduced the timing problems endemic to the combine, and within a few years the combine was a fixture on the northern plains as well as on the southern plains.

eration into the harvest stage because it generated problems with the timing of harvest. When the number of tasks fell to one, eliminating the gains from specialization, the appropriate farm organization was the family farm.

Industrialization of Livestock Production: Reducing the Role of Nature.—Nowhere in agriculture has there been more of a movement away from the family farm and toward factory-corporate farming than in livestock production. This has been especially true for broilers, feedlot cattle, and hogs, where in the past 50 years large factory-corporate firms have come to dominate what were once family farms with small numbers of livestock.[59] For instance, from 1969 to 1992, there was rising concentration in all livestock industries except cow-calf farms.[60]

The general trend has been to remove stock from an open environment and rear them in climate-controlled barns. In terms of our model, new technologies—in disease control, handling, nutrition, and transportation—have reduced seasonality by increasing the number of cycles per year (prediction 4) and reducing the importance and variability of random shocks from nature (prediction 5). Compared to field crops, livestock production allows for greater reduction of natural forces because stocks are mobile during growing stages and can often be reared indoors.

The most striking example of factory-corporate livestock production is in feedlot cattle. In the first half of this century ''farmer-feeders,'' located primarily in the Corn Belt, supplied the overwhelming majority of finished cattle to slaughterhouses.[61] These farmers typically had operations with less than 1,000 head of cattle, which were purchased in late summer or fall and fattened during the late fall and winter (an off-season for grain farming). During the last 40 years, the fed cattle industry has been almost completely transformed into one dominated by large corporate firms that employ highly specialized wage labor. The typical commercial feedlot produces fat cattle in a manner similar to how Ford or GM produces cars: 500–600 pound feeder calves are ''converted'' into finished cattle after 4 to 5 months of feeding and sold to slaughterhouses when they are roughly 1,150–1,250 pounds. Production is largely removed from seasonal forces: young cattle are brought in, and fat cattle are sold on a weekly and sometimes daily basis. Labor is highly specialized and includes accountants, feed buyers, cattle buyers, veterinarians, and engineers, as well as less skilled laborers who operate feed mills, load and unload cattle from trucks, and clean feeding

[59] Scott Kilman, Power Pork: Corporations Begin to Turn Hog Business into an Assembly Line, Wall St. J., March 28, 1994; and William D. McBride, Changes in U.S. Livestock Production, 1969–1992, Economic Research Service (Report No. 754, 1997).

[60] McBride, *supra* note 59, at 7.

[61] J. Rod Martin, Beef, in Another Revolution in U.S. Farming? (Lyle P. Schertz *et al.* 1979); and The Feedlot (G. B. Thompson & Clayton C. O'Mary eds., 3d ed. 1983).

pens. The *1992 Census of Agriculture* shows that huge firms dominated the fed cattle industry; 637 firms with average sales of 27,615 head of cattle per year accounted for over 65 percent of all fed cattle sold.[62] The *1992 Census of Agriculture* also reports that more than one-half of all cattle sold and receipts generated come from feedlots organized as corporations.[63]

The cow-calf industry, which supplies young feeder cattle to commercial feedlots, could not be more different. In the cow-calf system beef brood cows produce a single calf (twins are rare) each year. This calf is weaned after 7–8 months (weighing between 500–600 pounds) and sold to feedlots. Firms in this industry average only 44 head per farm and are dominated by small, family organizations.[64] The industry is strikingly unconcentrated; less than 1 percent of farms have more than 2,500 head. The *1992 Census of Agriculture* also shows the limited presence of corporations: only 2.3 percent of all farms are corporations, and just 9.6 percent of the cow inventory is held by corporations.[65] The performance of a cow-calf operation is highly subject to nature, especially seasonal forces.[66] Although there are regional differences that allow feedlots to operate year round, it is typical for operators in the northern regions to breed cows in the fall, calve in the early spring, pasture the animals during the summer, and wean and sell feeder calves in the following fall. Compared with the routine, factory processes in feedlots, running a cow-calf farm comprises relatively unpredictable short stages (such as calving) that occur only once a year and require on-the-spot decision making.

Like feedlots, the broiler industry has its roots in small farms. In fact, the industrialization of chicken production preceded that in cattle feedlots. Prior to the 1930s, most chickens were raised in relatively small flocks on family farms. During this period eggs, not meat, were the primary products, and most chickens were slaughtered in the spring. The reorganization of the poultry industry began in the 1930s, and today virtually all broilers (2 to 3 pound chickens) are produced by large, factory-corporate firms.[67] The introduction of antibiotics and other drugs have allowed poultry to be bred, hatched, and grown

[62] 1992 Census of Agriculture, *supra* note 2, table 25, at 29. The trend toward larger firms continues. The NASS ''Cattle on Feed'' report for February 14, 1997, shows the 45 largest firms with an average inventory of 54,689 head and an average annual sales of 124,578 head.

[63] *Id.* Many of the cattle on commercial feedlots are actually owned by producers who pay the feedlots for ''custom feeding.'' Also see Edward Uvaceck, Jr., Economics of Feedlots and Financing, in Thompson and O'Mary, *supra* note 61, ch. 2.

[64] Bureau of the Census, *supra* note 2, table 18, at 25. McBride, *supra* note 59, shows that this average of 40 head per farm has remained stable as far back as 1969.

[65] Bureau of the Census, *supra* note 2, table 47, at 64–65.

[66] Martin, *supra* note 61.

[67] Charles R. Knoeber, A Real Game of Chicken: Contracts, Tournaments, and the Production of Broilers, 5 J. L. Econ. & Org. 271 (1989).

in highly controlled indoor environments in which disease, climate, food, water, and vitamins and other inputs are regulated to the point where poultry barns are virtual assembly lines. At the various stages of production, broiler companies employ wage laborers who undertake specialized but routine tasks such as cleaning, feeding, and immunizing.

Modern broiler production begins in a company-owned breeding farm where eggs are laid. The eggs are typically delivered to a firm hatchery, which more closely resembles a hospital than a farm. After eggs are incubated and the chicks are hatched, the broiler organization takes on an old form. Because the critical ''grow-out'' period of a chicken's life, even using modern technology, is subject to highly random forces of disease and weather, large companies routinely contract out growing services to small, family-based ''growers.'' Growers feed and care for the chickens for a 6-week period until they become large enough for processing. Once chicks have matured, they return to the company for processing in large assembly-line facilities that employ hundreds of workers.

In the last 2 decades, the hog industry has followed the lead of the broiler industry.[68] Hog production is increasingly dominated by large, factory-corporate firms that breed and farrow pigs in confinement in huge indoor facilities. Like the broiler industry, the hog companies routinely contract out to small firms for the grow-out period and later do the processing in assembly-line fashion in company-owned facilities with company labor.

The contrast between industrial livestock and grain farming, which could hardly be more dramatic, results from the elimination of seasonal parameters and the reduction of random forces (θ and σ^2) in their production. The driving force in modern livestock production is to reduce the role of nature by bringing production indoors to control climate and disease. As a result, except for cow-calf operations, the livestock industry is perhaps the most specialized of any farm commodity and the most dominated by companies organized in the corporate-factory form.

B. Evidence from Contemporary Farms in Louisiana and British Columbia

The evidence from the historical and aggregate data provides support for our model, but it does not allow us to conduct any formal econometric hypothesis tests. In this section we use farm-level data to test some specific predictions. The data come from the *1992 British Columbia Farmland Ownership and Leasing Survey* and the *1992 Louisiana Farmland Ownership and Leasing Survey,* which we conducted in January 1993.[69] The sur-

[68] Kilman, *supra* note 59.

[69] Douglas W. Allen & Dean Lueck, 1992 British Columbia Farmland Ownership and Leasing Survey (1993); and Douglas W. Allen & Dean Lueck, 1992 Louisiana Farmland Ownership and Leasing Survey (1993).

veys were sent to a random sample of British Columbia and Louisiana farm operators. The number of usable responses was 460 from British Columbia and 544 in Louisiana. The 1,004 different farms that make up the sample resulted in 968 usable observations. Table 1 provides variable definitions and summary statistics for the variables we use in this section.

The Choice of Farm Organization.—We used the 1992 survey data to estimate the determinants of farm organization choice and to test some predictions from our model. We use the following empirical specification, where for any farm i the complete model is

$$F_i^* = X_i\beta_i + \epsilon_i, \qquad i = 1, \ldots, n, \tag{11}$$

and

$$F_i = \begin{cases} 1 & \text{if } F_i^* > 0 \\ 0 & \text{if } F_i^* \leq 0, \end{cases} \tag{12}$$

where F_i^* is an unobserved farm organization response variable; F_i is the observed dichotomous choice of farm organization for farm i, which is equal to 1 for family farms and equal to 0 for nonfamily farms; X_i is a row vector of exogenous variables including the constant; β_i is a column vector of unknown coefficients; and ϵ_i is a farm-specific error term. We use a logit model to generate maximum likelihood estimates of the model given by equations (11) and (12) for a sample of 959 farms.[70] The first column in Table 2 shows the logit coefficient estimates for the model.

One important element of seasonality that can be defined empirically is the number of cycles per year for a given crop in a given location. As the number of cycles increases, we predict that family farming will be less common (prediction 4). We classify the crops in our sample into three categories using the variable *CYCLES:* crops that potentially have more than one cycle per year; crops that always have just one cycle per year; and crops that may have fewer than one cycle per year.[71] In the equations reported in Table 2 we include the variables $CYCLES > 1$ and $CYCLES <$

[70] The survey asked the respondents to classify their farms as a family farm, partnership, corporate farm, or family corporation. Using other information on the survey, if a family corporation used no hired labor and contained only one family as a residual claimant, this farm was also classified as a family farm.

[71] For example, hay crops usually have three cycles per year, perhaps more under irrigation. Many nurseries and greenhouses have almost continuous production during the year. Although fruit trees provide only one crop per year, we classify them differently from grains because it takes several years for a tree to bear fruit and, as the tree ages, radical pruning may prevent a crop in the following year. Hence, on average a fruit tree has less than one cycle per year. We do not know, however, the number of cycles being used by the respondents to our survey.

TABLE 1

SUMMARY OF FARM DATA FROM BRITISH COLUMBIA AND LOUISIANA AGRICULTURE: 1992

Variable Name	Definition of Variable	Mean	Standard Deviation	Minimum	Maximum
Dependent variables:					
FAMILY FARM	1 if family farm; 0 if not	.74	.44	.00	1.00
CAPITAL	Total capital assets (buildings, equipment, land) in $100,000s	3.76	4.64	.00	42.14
ACRES	Total acres on the farm	517	811	.00	11,320
Exogenous variables:					
Crop variables:					
CYCLES > 1	Fraction of farmland in crops that have more than one cycle	.11	.27	.00	1.00
CYCLES < 1	Fraction of farmland in crops that have fewer than one cycle	.21	.34	.00	1.00
BEEF	1 if farm livestock are beef cattle; 0 if not	.20	.40	.00	1.00
DAIRY	1 if farm livestock are dairy cattle; 0 if not	.02	.14	.00	1.00
Farm variables:					
BC	1 if farm is in British Columbia; 0 if farm is in Louisiana	.46	.50	.00	1.00
IRRIGATED	Percent of farmland irrigated	6.37	11.44	.00	100.00
RENTED LAND	1 if farmer rents some land; 0 if not	.57	.50	.00	1.00
Farmer variables:					
AGE	Age of farmer in years	50.72	12.76	21.00	82.00
EDUCATION	Number of years of farmer's education	13.04	2.97	.00	18.00

SOURCE.—Douglas W. Allen & Dean Lueck, 1992 British Columbia Farmland Ownership and Leasing Survey (1993); Douglas W. Allen & Dean Lueck, 1992 Louisiana Farmland Ownership and Leasing Survey (1993). All values are in U.S. dollars.

1, leaving *CYCLES* = 1 out of the equations.[72] Prediction 6 implies that the estimated coefficient on *CYCLES* > 1 should be negative and the estimated coefficient on *CYCLES* < 1 should be positive. For the specifications shown in Table 2, both estimated coefficients for the *CYCLES* variable have the predicted signs and are statistically significant at the 5 percent level in one-tailed tests.

The distinction between beef and dairy cattle can also be used to test some predictions of our model. Dairy animals are kept close to their barns so that they can be milked twice a day, while beef animals usually range in open pastures. Daily milk production is easier to measure than beef production, and dairy processors engage in exceptional forms of measurement to ensure that the farmer does not carelessly handle or tamper with the milk.[73] Finally, there are more routine day-to-day tasks with dairy production than there are with cow-calf beef operations. None of the beef operations in our sample are large feedlots with similarly routine daily tasks. All of these factors reduce monitoring costs on dairy farms. In terms of our model, dairy farms have more cycles and fewer stages than beef operations. Hence, the use of farm managers and partners is more viable on dairy farms than on beef farms. Since the gains from specialization are greater with more tasks, our model predicts that the probability of family farm organization will be higher for beef operations (positive coefficient on *BEEF*) than for dairy operations (negative coefficient on *DAIRY*).[74] Table 2 shows that the coefficient estimates have the predicted signs and the estimates are statistically significant at the 5 percent level in a one-tailed test.

Our model also predicts that as the natural stage uncertainty (σ^2) diminishes, the farm is less likely to be a family farm (prediction 5). Irrigation can control the effect of nature by reducing variance in output.[75] As a result, we expect the estimated coefficient for *IRRIGATED* (percent of farmland irrigated) to have a negative sign. Indeed, the estimated coefficients for

[72] Included in *CYCLES* > 1 are hay crops, pasture, nursery crops, vegetables, and sugarcane (planted only once every 3–5 years); included in *CYCLES* = 1 are annual grain crops such as barley, rice, soybeans, and wheat; and included in *CYCLES* < 1 are tree fruits, nuts, and timber.

[73] Milk tanks must be cleaned by the farmer, which implies he must have access to the inside. Farmers can exploit this access by adding water, stones (or other bulky items), or milk from other farms to increase the reading on the outside of the tank in order to cheat the milk processor. The processors test the milk constantly for foreign parts to police this, and in the process simultaneously police workers on the dairy farm.

[74] The omitted category is farms with either no stock or noncattle stock.

[75] Douglas W. Allen & Dean Lueck, Risk Sharing and Agricultural Contracts (unpublished manuscript, Montana State Univ. 1998), verify this in Nebraska and South Dakota, where irrigation always reduces the coefficient of variation in yield and nearly always reduces the variance in yield. In terms of the model, irrigation reduces σ^2.

TABLE 2

ESTIMATES OF FARM ORGANIZATION AND FARM CAPITAL

Exogenous Variables	Logit Estimation of Farm Organization (Dependent variable = FAMILY FARM)	OLS Estimation of Farm Capital (Dependent variable = CAPITAL)	OLS Estimation of Farm Acreage (Dependent variable = ACRES)
CONSTANT	−1.92	−1.92	−15.75
	(1.31)	(2.78)*	(.03)
Crop variables:			
CYCLES > 1	−1.17	.65	19.61
	(5.18)*	(1.42)	(.25)
CYCLES < 1	1.03	−.60	−163.36
	(2.43)*	(.99)	(1.53)
BEEF	.83	−.86	25.41
	(3.56)*	(2.17)*	(.38)
DAIRY	−1.39	4.18	−347.46
	(2.59)*	(3.93)*	(1.86)*
Farm variables:			
BC	−.20	1.36	−270.15
	(.34)	(3.79)*	(4.62)*
IRRIGATED	−.01	.06	−6.10
	(1.15)	(4.49)*	(2.58)*

RENTED LAND	−.35	−.20	N.A.
	(1.90)*	(.55)	
FAMILY FARM	N.A.	−2.54	−431.96
		(7.22)*	(7.45)*
Farmer variables:			
AGE	.07	.10	13.53
	(1.48)	(1.23)	(.97)
AGE^2	−.006	−.008	−.14
	(1.53)	(1.09)	(1.01)
EDUCATION	.34	.52	84.95
	(2.21)*	(1.79)*	(1.68)*
EDUCATION^2	−.01	−.02	−2.19
	(2.44)*	(1.81)*	(1.13)
Observations	959	859	959
Goodness-of-fit measures:			
Correct predictions (%)	74.77		
−2 log likelihood	1100.50	N.A.	N.A.
Model χ^2	78.08 (df = 12)	N.A.	N.A.
$\overline{R}^2$	N.A.	.171	.129
Overall F statistic	N.A.	16.68 (df = 12,846)	13.95 (df = 12,946)

NOTE.—Absolute value of the (asymptotic for logit equation) t-statistics are in parentheses; N.A. = not applicable.
* Significant at the 5% level for a one-tailed t-test.

IRRIGATED are negative, although the estimates fall just short of being statistically significant at the 5 percent level in a one-tailed test. The estimated equation also included numerous control variables including percent of rented farmland (*RENTED LAND*), farmer's age (*AGE*, AGE^2), farmer's education (*EDUCATION*, $EDUCATION^2$) and a dummy for British Columbia (*BC*). Many of the coefficient estimates are statistically significant.

Level of Capital across Farm Organizations.—Our model predicts that the level of capital will be lowest for family farmers who face the highest costs of capital and largest for corporate farms that face the lowest cost of capital (prediction 10). Simple farm-level averages from the British Columbia and Louisiana data confirm this prediction. In these data the average value of capital, across all crops, for family farms is $75,474; for partnerships the average is $122,583, for family corporations the average is $191,692, and for nonfamily corporate farms the average is $281,205.[76]

The model also predicts that farm capital choice depends on the choice of farm organization. We test this prediction by estimating the level of capital per farm (k_i) using the following empirical model:

$$k_i = F_i\gamma + X_i\xi_i + \mu_i, \qquad i = 1, \ldots, n, \tag{13}$$

where F_i is a farm organization choice dummy variable; γ_i is the corresponding coefficient; X_i is a row vector of exogenous variables including the constant; ξ_i is a column vector of unknown coefficients; and μ_i is a farm-specific error term.

We estimate equation (13) using OLS for a sample of 859 farms. This sample is slightly smaller than that used to estimate the farm organization model because of missing data for the *CAPITAL* variable. The second column in Table 2 shows the OLS coefficient estimates for the model. Prediction 10 implies the hypothesis that the coefficient on F_i (measured with the variable *FAMILY FARM*) is negative; that is, $\gamma_i < 0$ because a family farm will have the highest capital costs among the farm organizations we examine. As predicted, the estimated coefficient is negative and statistically significant at the 5 percent level in a one-tailed test. In the OLS estimate of *CAPITAL* we use the same set of exogenous variables (X) used in the farm organization estimates. In general, the estimated coefficients for these variables are statistically significant. These estimates are also, in many cases, consistent with human capital theory. For example, older and more educated farmers tend to have greater capital stocks, but the effects of education and experience tend to have diminishing returns. The estimates also show that dairy farms use more capital than do nondairy farms and that farms with irrigated land are more capital intense.[77]

[76] The differences in these means are all statistically significant at the 5 percent level.

[77] It may seem that equations (11)–(13) represent a simultaneous system, but it is appropriate to estimate (13) using OLS. This is because (11)–(13) are actually a recursive system

In addition to using the dollar level of capital as a measure of a farm's capital intensity, we also estimate equation (13) by substituting farm acreage for capital (prediction 11). Because farm acreage includes rented land, the variable *RENTED LAND* is omitted from the *ACRES* equation. The results shown in the third column of Table 2 support prediction 11 and further confirm the capital stock regression. Family farms not only have less capital, they also utilize less land. Our estimates show that family farms use roughly 400 acres less land than do nonfamily farms.

IV. Summary and Conclusion

Although the organization of industry has generally followed a transition from family firms to large, factory-style corporations, farming remains a last bastion of family production. Production stages in farming tend to be short, infrequent, and require few distinct tasks, thus limiting the benefits of specialization and making wage labor especially costly to monitor. Only when farmers can control the effects of nature by mitigating the effects of seasonality and random shocks to output does farm organization gravitate toward factory processes, developing into the large-scale corporate forms found elsewhere in the economy.

Our model explains both important historical trends in agriculture and more subtle differences in farm organization. As our model predicts, family-controlled farm production has narrowed to those stages that include the most biologically based aspects of farming. Factory farming has failed in highly seasonal crops. Changes in wheat harvesting technology, which shortened stages and increased the severity of timing problems, have altered the structure of farm organization by extending the family farm into the harvest stage. Changes in livestock technology, which largely eliminated nature, have allowed factory-corporate production to dominate in feedlot cattle, hogs, and poultry. Our model also correctly predicts impacts on farm organization in British Columbia and Louisiana due to crop cycles and monitoring costs. Finally, our model correctly predicts the differences in capital levels and farm acreage observed in different farm organizations.

Although there is compelling support for our approach, we have made a number of simplifications. First, we limited the discussion of hired labor to the corporate farm. Although this is where hired labor is most important, it remains true that nearly all farms hire some part-time labor and often use family labor. Second, we did not examine leasing and ownership of assets, interstage complementarity, and changing farm ownership over different stages. These important features of organization are left for future research.

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since capital levels depend only on farm choice in our model. As a check, we also estimated (13) using a two-stage method in which F_i was replaced by the predicted value of the farm organization (from the logit model); this did not appreciably change the coefficient estimates.

Third, we have ignored the role of economies of scale. It is possible, for example, that farms become large factory-corporate firms when the extent of the market increases enough for firms to capture scale economies. The economies-of-scale argument would imply that for commodities like corn and wheat, actively traded in world markets, farms should be large corporate firms. Certainly, an extensive market is a necessary condition for large-scale production, but it is not sufficient. Only when seasonal forces are limited can economies of scale be realized, as, for example, in milling grain into flour. It simply would not pay to invest in highly specialized, large-scale capital unless seasonal forces were so lacking that highly specialized wage labor could effectively be employed. In this regard, our findings are more consistent with Becker and Murphy who note: ‘‘The efficient division of labor is then limited by coordination costs, not by market size.’’[78]

Coase's essential insight is that transaction costs and the costs of the firm explain organization. By merging Coase's analysis with an understanding of the role of nature in farming, we generated a framework that yields a broad understanding of the agricultural firm. In particular, we have examined how natural parameters influence both the costs of using the ‘‘pricing system’’ and the costs of organizing production within a firm. This insight helps us understand why farms remain small and why family farms will likely be with us for a long time to come.

APPENDIX

I. The Solution to the Partnership Problem

Assuming the first-order approach is satisfied, noting that $h = h(e, k, q_{-1i})$ and $e = at$, the following two first-order necessary conditions define the solution to equation (6):

$$\left[\frac{\partial h}{\partial k} - r(N)\right] + N\left[\frac{\partial h}{\partial e_t}\left(\frac{N}{T}\right)^{\alpha} - w\right]\left[\sum_{t=1}^{T}\frac{\partial t_t^P}{\partial k}\right] = 0, \tag{A1}$$

$$\left[\frac{\partial h}{\partial e_t}(\alpha)\left(\frac{N^{\alpha-1}}{T^{\alpha}}\right) - w\right]\left[\sum_{t=1}^{T} t_t\right] + N\left[\frac{\partial h}{\partial e_t}\left(\frac{N}{T}\right)^{\alpha} - w\right]\left[\sum_{t=1}^{T}\frac{\partial t_t^P}{\partial N}\right] + \left[w - \left(\frac{\partial r}{\partial N}\right)k\right] = 0. \tag{A2}$$

Equations (A1) and (A2) illustrate the trade-offs in a partnership farm. Equation (A1) defines the conditions for the optimal level of capital and can be discussed as

[78] Becker & Murphy, *supra* note 13, at 1142.

two parts. In part 1, the first bracketed term is simply the net marginal product of capital. Part 2 is the total indirect effect of capital choices on task effort and comprises three terms. The last bracketed term is the effect of a change in capital stock on task effort, summed over all tasks, while the first bracketed term is the size of the ‘‘distortion’’ in effort. The sign of $(\partial t_t/\partial k)$ depends on whether capital and task effort are complements or substitutes (see appendix, Sec. II). Term 3 multiplies all of this by the number of partners (N) to get a total effect.

Equation (A2) defines the conditions for the optimal number of partners. The marginal benefit of adding another partner comprises an increase in task specialization (part 1) and a fall in marginal capital costs (part 3). The marginal cost is the total indirect effect of reduced farm task effort that results from an increase in the number of residual claimants (part 2). Part 1 comprises two terms. The first term in brackets is the specialization effect of changing the number of partners (holding the number of tasks constant), which is then summed over all the tasks in the stage (term 2). Part 3 comprises two independent terms, the direct effect on capital costs and the addition of off-farm income. Part 2 parallels the second part in (A1) and, accordingly, comprises three terms. The only difference is that the distortion on effort is multiplied by the effect of partnership size on task effort. This effect can be shown to be nonpositive (see appendix, Sec. III); the effect is negative except in the case in which specialization effects are at their maximum ($\alpha = 1$), thus eliminating the effect altogether.

II. Effect of Partnership Capital (k) on a Farm Partner's Task Effort (t)

We want to evaluate the partial derivative $\partial t_t^P/\partial k$, so, first, create an identity from equation (5), assuming homogeneous partners, to get

$$\left(\frac{N^{\alpha-1}}{T^{\alpha}}\right)\frac{\partial h}{\partial t_t}(t_t^P(\Phi)) \equiv w. \tag{A3}$$

Differentiate (A3) with respect to k and solve to get

$$\left[\frac{\partial t_t^P}{\partial k}\right] = \frac{-(\partial^2 h/\partial t_t \partial k)}{(\partial^2 h/\partial t_t^2)}. \tag{A4}$$

The denominator in equation (A4) is negative by assumption, but the sign of the numerator depends on whether capital and effort are substitutes or complements (or independent).

Thus, sign $(\partial t_t^P/\partial k)$ is positive (negative) if k and t are complements (substitutes).

III. Effect of Partnership Size (N) on a Farm Partner's Task Effort (t)

To evaluate the partial derivative $\partial t_t^P/\partial k$, first create the identity (A3) and differentiate (A3) with respect to N and solve to get

$$\left[\frac{\partial t_t^P}{\partial N}\right] = \left(\frac{-(\alpha - 1)}{N}\right)\left(\frac{\partial^2 h/\partial t_t \partial N}{\partial^2 h/\partial t_t^2}\right) \leq 0. \tag{A5}$$

The sign of the second term on the right-hand side is negative, but the sign of the first term depends on the value of $\alpha \in [0,1)$. If $\alpha = 1$ (maximum specialization potential), then changes in the number of partners (N) have no effect on task effort

(t). However, if $0 \leq \alpha < 1$, then an increase in the number of partners will decrease task effort.

IV. The Solution to the Factory-Corporate Farm Problem

The solution to equation (7) is given by the optimal input choices t_t^{FC} and k^{FC} that solves the following first-order necessary conditions:

$$\left[t_t \left(\frac{(\alpha/\Delta)(N^h)^{\alpha-1}}{T} \right) + \left(\frac{N}{T^\alpha} \right)^\alpha \right] \frac{\partial h}{\partial t_t} (t_t^{FC}, k^{FC}) \equiv \overline{w}, \qquad t = 1, \ldots, T, \quad \text{(A6)}$$

$$\frac{\partial h}{\partial k} (t_t^{FC}, k^{FC}) \equiv r^{\min}. \quad \text{(A7)}$$

V. The Relationship between Farm Capital and Farm Organization

Prediction 9 states that family farms will employ less capital than will partnerships and that partnerships will employ less capital than will corporate farms. Although it appears to be a straightforward implication of our assumption that the capital costs function, $r = r(N)$, is decreasing and convex in N, the prediction also depends on the relationship between task effort (t) and capital (k) and on the specialization coefficient a. Consider a move from a family farm to a partnership, which means that N increases. The main prediction is that, ceteris paribus, k must increase, but an increase in N (inherent in a shift from a family farm to a partnership) must decrease the level of task effort (t).

When N changes, the marginal product of effort shifts outward because of specialization gains. The marginal product also shifts inward because of shirking. Under our maintained assumptions—$\alpha \in [0,1)$ and $N \leq$ T—the outward shift (specialization gains) can never be larger than the inward shift (moral hazard losses). In general, the inward shift will be larger so that an increase in N will reduce t. Only when $\alpha = 1$ do the two effects exactly offset each other. To see this, note that a worker's full marginal product depends on (a) his ownership share of the output, or $1/N$, and (b) the specialization coefficient, $a = (N/T)^\alpha$. Now define Ψ to be the marginal product "shifter" where

$$\Psi = \left(\frac{1}{N} \right) \left(\frac{N}{T} \right)^\alpha = \left(\frac{N^{\alpha-1}}{T^\alpha} \right). \quad \text{(A8)}$$

It is easy to see from (A8) that $\Psi \in [0,1)$, which means that an increase in the number of owners (N) can never increase task effort (t). Given that t must decline from an increase in N, there are three possible cases to consider in order to determine the final choice of capital.

1. Capital (k) and effort (t) are independent ($h_{tk} = 0$): in this case an increase in N unambiguously leads to an increase in k because the decrease in t from the change in N has no effect on the marginal product of k.
2. Capital (k) and effort (t) are substitutes ($h_{tk} < 0$): in this case an increase in N unambiguously leads to an increase in k because the decrease in t from the

change in N shifts out the marginal product of capital, thus adding to the effect of lower capital costs.

3. Capital (k) and effort (t) are complements ($h_{tk} > 0$): in this case an increase in N can possibly lead to a decrease in k because the decrease in t from the change in N shifts in the marginal product of capital, thus countering the effect of lower capital costs. Only if the complement effect is strong enough to exceed the effect of reduced capital costs, $r'(N)$, can a partnership optimally employ less capital than a family farm. However, when this is the case, the value of the family farm will always exceed the value of the partnership because the deadweight loss (compared with first-best) for the partnership will be greatest since the partnership cannot attain greater efficiency in task effort and is less efficient in capital employment.

Thus, even though it is possible for the model to generate a partnership with less capital than a family farm, such a partnership will never be the wealth-maximizing choice of farm organization. The same analysis holds for the comparison between corporate and family or partnership farms, although a sufficiently low effective wage ($\overline{w}$) could, in principle, lead to greater task effort under corporate organization.

VI. Comparative Statics of Farm Organizations

The value function for the family farm is

$$V^F = h\left(\left[\frac{1}{T}\right]^{\alpha} t_t^F, \ldots, \left[\frac{1}{T}\right]^{\alpha} t_T^F, k^F; q_{-1}(d)\right) - r^{\max}k^F + wm^F. \tag{A9}$$

The value function for the partnership farm is

$$V^P = h\left(\left[\frac{N^P}{T}\right]^{\alpha} t_1^P, \ldots, \left[\frac{N^P}{T}\right]^{\alpha} t_T^P, k^P; q_{-1}(d)\right) - r(N^P)k^P + wm^P. \tag{A10}$$

Changes in α:

$$\begin{aligned} V_\alpha^F &= (1/T)^\alpha \ln(1/T) \sum_{t=1}^{T} \partial h/\partial t_t(\cdot)t_t < 0, \\ V_{\alpha\alpha}^F &= (1/T)^\alpha [\ln(1/T)]^2 \sum_{t=1}^{T} \partial h/\partial t_t(\cdot)t_t > 0, \\ V_\alpha^P &= (N/T)^\alpha \ln(N/T) \sum_{j=1}^{T} \partial h/\partial t_j(\cdot)t_j, \end{aligned} \tag{A11}$$

so when α is close to zero, the first term approaches one, and the derivative is smaller in absolute terms than V_α^F. However, as α increases in size, the first term also decreases, but more slowly than for V_α^F. Hence, the whole derivative can be larger than V_α^F in absolute terms.

Changes in T (assuming that $\alpha = 1$):

$$
\begin{aligned}
V^F_T &= (-1/T)\sum_{t=1}^{T} \partial h/\partial t_t(\cdot)t_t < 0,\\
V^F_{TT} &= (1/T^2)\sum_{t=1}^{T} \partial h/\partial t_t(\cdot)t_t > 0.
\end{aligned}
\tag{A12}
$$

Bibliography

Alchian, Armen A., and Demsetz, Harold. ''Production, Information Costs, and Economic Organization.'' *American Economic Review* 62 (1972): 777–95.

Allen, Douglas W., and Lueck, Dean. *The 1992 British Columbia Farmland Ownership and Leasing Survey*. Burnaby, B.C.: Simon Fraser University, 1993.

Allen, Douglas W., and Lueck, Dean. *The 1992 Louisiana Farmland Ownership and Leasing Survey*. Baton Rouge: Louisiana State University, 1993.

Allen, Douglas W., and Lueck, Dean. ''Risk Sharing and Agricultural Contracts.'' Unpublished manuscript. Bozeman: Montana State University, 1998.

Anderson, Terry L., and Lueck, Dean. ''Land Tenure and Agricultural Productivity on Indian Reservations.'' *Journal of Law and Economics* 35 (1992): 427–54.

Bardhan, Pranab K., ed. *The Economic Theory of Agrarian Institutions*. Oxford: Clarendon Press, 1989.

Becker, Gary S., and Murphy, Kevin M. ''The Division of Labor, Coordination Costs, and Knowledge.'' *Quarterly Journal of Economics* 107 (1992): 1137–60.

Bidwell, Percy Wells, and Falconer, John I. *History of Agriculture in the Northern United States, 1620–1860*. Washington, D.C.: Carnegie Institution, 1925.

Bigelow, Poultney. ''The Bonanza Farms of the West.'' *Atlantic Monthly* 45 (January 1880): 33–44.

Binswanger, Hans, and Rosenzweig, Mark R. ''Behavioral and Material Determinants of Production Relations in Agriculture.'' *Journal of Development Studies* 22 (1986): 503–39.

Brewster, John M. ''The Machine Process in Agriculture and Industry.'' *Journal of Farm Economics* 32 (1950): 69–81.

Briggs, Harold E. ''Early Bonanza Farming in the Red River Valley of the North.'' *Agricultural History* 6 (January 1932): 26–37.

Castle, Emery N., and Becker, Manning H. *Farm Business Management*. New York: MacMillan, 1962.

Coase, Ronald H. ''The Nature of the Firm.'' *Economica* 4 (November 1937): 386–405.

Cronan, William. *Changes in the Land*. New York: Hill & Wang, 1983.

Danhoff, Clarence H. *Changes in Agriculture: The Northern United States, 1820–1870*. Cambridge, Mass.: Harvard University Press, 1969.

Drache, Hiram. *The Day of the Bonanza*. Fargo: North Dakota Institute for Regional Studies, 1964.

Ellickson, John C., and Brewster, John M. ‘‘Technological Advance and the Structure of American Agriculture.’’ *Journal of Farm Economics* 29 (1947): 827–47.

Ellickson, Robert E., and Thorland, Charles DiA. ‘‘Ancient Land Law: Mesopotamia, Egypt, Israel.’’ *Chicago-Kent Law Review* 71 (1995): 321–411.

Gray, Lewis Cecil. *History of Agriculture in the Southern United States to 1860.* Vols. 1 and 2. New York: Peter Smith, 1941.

Hayami, Yuruiro, and Otsuka, Keijiro. *The Economics of Contract Choice: An Agrarian Perspective.* Oxford: Oxford University Press, 1993.

Heady, Earl. *Economics of Agricultural Production and Resource Use.* New York: Prentice Hall, 1952.

Hoff, Karla; Braverman, Avishnay; and Stiglitz, Joseph, eds. *The Economics of Rural Organization: Theory, Practice, and Policy*. Oxford: Oxford University Press, 1993.

Holmes, C. L. *Economics of Farm Organization and Management.* Boston: Heath & Co., 1928.

Holmstrom, Bengt, and Milgrom, Paul. ‘‘The Firm as an Incentive System.’’ *American Economic Review* 84 (1994): 972–91.

Isern, Thomas D. *Bull Threshers and Bindlestiffs: Harvesting and Threshing on the North American Plains.* Lawrence: University of Kansas Press, 1990.

Isern, Thomas D. *Custom Combining on the Great Plains.* Norman: University of Oklahoma Press, 1981.

Johnson, Nancy L., and Ruttan, Vernon W. ‘‘Why Are Farms So Small?’’ *World Development* 22 (1994): 691–706.

Kay, Ronald D., and Edwards, William. *Farm Management.* 3d ed. New York: McGraw-Hill, 1994.

Kilman, Scott. ‘‘Power Pork: Corporations Begin to Turn Hog Business into an Assembly Line.’’ *Wall Street Journal,* March 28, 1994, 1.

Knoeber, Charles R. ‘‘A Real Game of Chicken: Contracts, Tournaments, and the Production of Broilers.’’ *Journal of Law, Economics, and Organization* 5 (1989): 271–93.

Knoeber, Charles R. ‘‘Explaining State Bans on Corporate Farming.’’ *Economic Inquiry* 35 (1997): 151–66.

Louisiana Agricultural Statistics Service. *Louisiana Agricultural Statistics.* Baton Rouge: Louisiana Department of Agriculture, 1975–91.

Marion, Bruce W. *The Organizational Performance of the U.S. Food System.* Lexington, Mass.: Lexington Books, 1986.

Martin, J. Rod. ‘‘Beef.’’ In *Another Revolution in U.S. Farming?* Lyle P. Schertz, *et al.* Washington, D.C.: U.S. Department of Agriculture, 1979.

Masten, Scott; Meehan, James; and Snyder, Edward. ‘‘The Costs of Organization.’’ *Journal of Law, Economics, and Organization* 7 (1991): 1–26.

McBride, William D. ‘‘Changes in U.S. Livestock Production 1969–92.’’ Economic Research Service Report No. 754. Washington, D.C.: U.S. Government Printing Office, 1997.

Nass, H. G.; Johnston, H.; MacLeod, J.; and Sterling, J. ‘‘Effects of Seeding Date, Seed Treatment and Foliar Sprays on Yield and Other Agronomic Characteristics of Wheat, Oats and Barley.’’ *Canadian Journal of Plant Science* 55 (1973): 43–47.

Nerlove, Marc L. ''Reflections on the Economic Organization of Agriculture: Traditional, Modern, and Transitional.'' In *Agricultural Markets: Mechanisms, Failures, and Regulations,* edited by David Martimort, pp. 9–30. Amsterdam: North-Holland, 1996.

Pryor, Frederic L. ''The Plantation Economy as an Economic System—A Review Article.'' *Journal of Comparative Economics* 6 (1982): 288–317.

Pryor, Frederic L. *The Red and the Green.* Princeton, N.J.: Princeton University Press, 1992.

Raup, Philip M. ''Corporate Farming in the United States.'' *Journal of Economic History* 33 (1973): 274–90.

Schlebecker, John T. *Whereby We Thrive: A History of American Farming, 1607–1972.* Ames: Iowa State University Press, 1973.

Statistics Canada. *Census Overview of Canadian Agriculture, 1971–1991.* Ottawa: Queen's Printer, 1992.

Sumner, Daniel A. ''Targeting Farm Programs.'' *Contemporary Policy Issues* 9 (1991): 93–106.

Thompson, G. B., and O'Mary, Clayton C., eds. *The Feedlot.* 3d ed. Philadelphia: Lea and Febiger, 1983.

U.S. Department of Commerce, Bureau of the Census. *Historical Statistics of the United States: Colonial Times to 1970.* Washington, D.C.: U.S. Government Printing Office, 1976.

U.S. Department of Commerce, Bureau of the Census. Vol. 4. *Corporations in Agricultural Production.* 1974 Census of Agriculture, Special Reports, Pt. 5. Washington, D.C.: U.S. Government Printing Office, 1978.

U.S. Department of Commerce, Bureau of the Census. *Agricultural Economics and Land Ownership Survey (1988).* Washington, D.C.: U.S. Government Printing Office, 1988.

U.S. Department of Commerce, Bureau of the Census. *Statistical Abstract of the United States 1993.* Washington, D.C.: U.S. Government Printing Office, 1993.

Uvaceck, Edward, Jr. ''Economics of Feedlots and Financing.'' Chapter 2 in *The Feedlot,* edited by G. B. Thompson, and Clayton C. O'Mary. 3d ed. Philadelphia: Lea & Febiger, 1983.