Transaction Costs and the Design of Cropshare Contracts

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The RAND Journal of Economics, Vol. 24, No. 1. (Spring, 1993), pp. 78-100.

RAND Journal of Economics
Vol. 24, No. 1, Spring 1993

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Modern cropshare contracts are explained using a model in which agents are risk neutral and contract rules are chosen to maximize expected joint wealth. It is shown that the farmer either bears the entire cost of inputs or shares the costs with the landowner in the same proportion as the output. The incentives of altering the cropshare percentage are examined and are used to derive implications about the portion of the crop that will be owned by the farmer. The model is tested and supported using data from a 1986 survey of farmers and landowners in Nebraska and South Dakota.

1. Introduction

■ In modern agriculture, share contracts between farmers and landowners are common. These "cropshare" contracts—as they are called by American farmers—have also been common worldwide for centuries.[1] Despite numerous theoretical inquiries into agricultural share contracts, relatively little is actually known about them, especially the details concerning the sharing of input costs. This is an important omission, given that share contracts are so prevalent. We develop a theoretical model that determines the optimal sharing rule for both the crop output and the variable input costs. More important, we test the model's implications against data from the American Midwest. Our model explains the variation in the terms of cropshare contracts, including the chosen share of both output and inputs. Our dataset is unique in the study of share contracts; it contains over 1,600 observations that include details of both the contracts and the contracting parties and allows us to examine new questions as well as those that have largely been dormant.

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Bruce Johnsen, Steve Ferris, Frank Mathewson, Mike Ransom, and two anonymous referees provided helpful comments on earlier versions of this article. Steve Munk, USDA Extension Agent for Minnehaha County, South Dakota, helped us understand the details of cropshare contracts.

[1] In fact, share contracts are everywhere. They are found, for example, between authors and publishers, fishermen and boat owners, husbands and wives, and car salesmen and automobile dealers. Since the original efficiency rationale for sharecropping (Cheung, 1969), there have been many studies (Allen, 1985; Allen and Lueck, 1992b; Alston, Datta, and Nugent, 1984; Eswaran and Kotwal, 1985; Hallagan, 1978; Lucas, 1979; Newberry and Stiglitz, 1979; Shaban, 1987; Stiglitz, 1974), including studies of input cost sharing (Braverman and Stiglitz, 1986; Bardhan and Singh, 1987).

Although there are several approaches to the economic analysis of contracts, we rely extensively on the emerging theory of transaction costs (Barzel, 1989; Klein, Crawford, and Alchian, 1978; Williamson, 1979) rather than on the principal-agent or incentive contracts paradigm (Grossman and Hart, 1983; Harris and Raviv, 1979; Holmström, 1979 and 1982; Ross, 1973). In the principal-agent paradigm, the typical model takes the following form: a principal maximizes some objective function subject to an agent's utility constraint (Hart and Holmström, 1987; Sappington, 1991). For sharecropping, most of the principal-agent models (Harris and Raviv, 1979; Shavell, 1979; Stiglitz, 1974) postulate a risk-neutral landowner (principal) leasing land to a risk-averse farmer (agent).[2] One study (Braverman and Stiglitz, 1986) examined input cost sharing using such a model. These models generate a tradeoff between risk-avoidance and improper incentives. A principal without an agent has no incentive problem but "bears all the risk." By hiring an agent, the principal suffers from agent shirking but no longer bears the full risk of the project. A difficulty with these models is that they have been short on testable hypotheses because they rely on measurement of risk preferences or proxies for them.

We use the transaction cost approach in order to derive clear testable propositions and thus avoid the empirical difficulties of the risk-sharing models. In the process we reject certain aspects of the principal-agent paradigm, while retaining others. We abandon both the principal-agent distinction and the assumption of risk aversion, and, instead, assume both parties are risk neutral and that the chosen contract results from joint wealth maximization.[3]

By treating both parties as risk neutral we avoid the ad hoc definition of which party is the principal and which is the agent, and also which party is more or less risk averse. In Midwestern farming it is especially difficult to establish such a dichotomy because farmers and landowners have nearly identical demographic characteristics (Allen and Lueck, 1992b) and because farmers make virtually all the decisions, contrary to their oft-designated "agent" status. Rather than use the principal-agent distinction, we instead assume that farmers and landowners choose to participate in cropshare contracts because they maximize the (expected) value of the exchange, given the characteristics of both the farmer and the landowner, the desired crop to be produced, and the attributes of the land. This method assumes that "natural selection" has resulted in the most valuable contract being chosen (Alchian, 1950).[4] This assumption is supported by the fact that the basic structure of cropshare contracts in Midwestern agriculture has remained remarkably stable for at least 50 years (Heady, 1947; Johnson et al., 1988).

While we abandon some aspects of typical contracting models, uncertainty remains a crucial component of our model (Eswaran and Kotwal, 1985; Holmström, 1979). In the cropshare contract, uncertainty from weather and other natural forces means that the farmer has the opportunity to "exploit" the landowner in several ways: (a) the farmer may undersupply his effort; (b) the farmer may overuse soil attributes that are not completely specified in the contract; (c) the farmer may underreport the crop; and (d) the farmer may overreport use of shared inputs. We incorporate these four features into a model of a cropshare land lease for the use of a single tract of land of fixed acreage, contracted for use by a single farmer for a single growing season. Our model thus includes the classic moral-hazard[5] and

[2] Interestingly, the sharecropping arrangement has been used by theoretical economists as the prototypical principal-agent problem.

[3] Recent studies (Allen and Lueck, 1992b; Eswaran and Kotwal, 1985; Lazear, 1986; Leffler and Rucker, 1991) have examined contracts without resorting to risk-averse preferences.

[4] Several recent studies (Allen and Lueck, 1992b; Crocker and Masten, 1988; Joskow 1987; Leffler and Rucker, 1991) have taken this approach to the private contracting process.

[5] Consistent with the actual practices of Midwestern agriculture, we assume that the landowner cannot shirk, so the model is not one of "double moral hazard."

incomplete-contract problems, but it also adds the costs of measuring and dividing both output and inputs between farmer and the landowner. These last two points regarding measurement costs (Barzel, 1982) are new additions to the study of share contracts and are crucial to our model's ability to generate testable implications.[6] Uncertainty, then, is the source of transaction costs—reflected both as incentives and enforcement costs—which determine optimal contract design.

The model is developed in three stages. First, we examine the incentives of the farmer to choose inputs given exogenous input and output shares. Second, we derive the optimal cropshare and input shares that maximize the expected net value of the contract, taking the farmer's input choices as constraints in a joint-wealth-maximization problem. Third, comparative statics of various share contract forms are derived by examining the effects of parameter changes on the joint wealth of a contract. Testable implications are derived at each of the three stages.

Because farmers and landowners often renew their cropshare contracts, it may seem odd to use a one-period model to examine optimal contract design. The justification for the one-period model lies in an understanding of two fundamental issues that must be confronted in farmland contracting. The first issue—the subject of this article—is that contracts must insure that the daily actions of the farmer are in the landowner's interest. The choice of input-sharing rules as well as the choice between cropshare and cash rent handle this problem by giving the farmer the correct incentives. A second issue (Allen and Lueck, 1992a) is that contracts must be enforced so that gross violations, such as soil poisoning or outright theft, do not occur. Features such as contract length and contract detail handle these potential problems. In a setting like the Midwest, the problem of gross violations is neatly handled by market forces through the repeated-dealing mechanism (Klein and Leffler, 1981; Kreps, 1990; Shapiro, 1983). If a farmer was caught exploiting the soil, underreporting the harvest, or overreporting input costs, local landowners and farmers would refuse to deal with him in the future. Farm communities like those in Nebraska and South Dakota are extremely homogeneous and stable. Information about cheaters travels quickly, and cheaters are punished swiftly in the farmland market (Allen and Lueck, 1992a). For the contract elements examined in this study, the one-period construct serves the task of clarifying and illuminating tangible empirical phenomena.

2. Optimal cropshare contracts

■ Why is cropsharing often preferred to such alternatives as cash rent leasing of farmland? Although some theorists have argued that risk aversion is needed to explain cropsharing, risk-neutral farmers and landowners will choose cropsharing in order to reduce the costs of enforcing farmland contracts (Eswaran and Kotwal, 1985). By making both farmers and landowners partial residual claimants, the share contract can induce participants to "self-monitor" and alleviate input shirking by spreading "distortions" across many margins.

The Eswaran and Kotwal model has been extended (Allen and Lueck, 1992b) by considering the ability of the farmer to exploit the soil as well as the costs of dividing and measuring the crop. Compared to a cash rent contract, the benefit of a cropshare contract is that it reduces the farmer's incentive to deplete the capital value of the soil. As a result, the cropshare contract is expected to be chosen over cash rent when the potential for soil exploitation is high and the measurement costs of dividing the crop are small.[7]

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[6] Only a few writers have recognized the output division costs inherent in share contracts (Allen and Lueck, 1992b; Lazear, 1986; Umbeck, 1977).

[7] Data on contracts from the American Midwest supports the contract-enforcement-cost approach (Allen and Lueck, 1992b).

□ **Production and the determination of input use.** We assume that there are three types of inputs: farmland owned by landowners; farm capital (human and physical) owned by farmers; and other variable inputs such as fertilizer and seed, that may be owned by both farmers and landowners. Consistent with the practice in Midwestern agriculture, farmers make all the input choices, which ultimately determines the crop output, and landowners are passive participants. Actual crop output is subject to random fluctuations because of such factors as pests and weather.

To begin, let $Q = \epsilon h(f, l, k_i)$, where Q is the harvested crop (with unit price) per tract of land, f is a composite input of farmer attributes, including his labor and his equipment, l is a composite input of land attributes that are *not specified* in the contract, such as fertility and moisture, k_i is one of several (n) inputs such as fertilizer, pesticide, or seed, and $\epsilon \sim (1, \sigma^2)$ is a positive, randomly distributed input that includes such factors as weather or pests. This specification of the production function, which is routinely used (Eswaran and Kotwal, 1985; Braverman and Stiglitz, 1986), has the intuitively appealing implication that the marginal productivity of the inputs is random and the variance in output increases with the scale of production (Just and Pope, 1978). Assume that the partial derivatives of the production function have the signs $h_i > 0$, $h_{ii} < 0$, and $h_{ij} = 0$ for $i, j = f, l$, and k, implying that the inputs are independent. The assumption of independent inputs simplifies the model and increases the number of testable implications. Not only are there no *a priori* reasons to assume which inputs are substitutes or complements, but there is empirical justification for their independence. If inputs were related, contracts could adjust certain input prices (up or down), in order to influence farmer behavior (Braverman and Stiglitz, 1982).

The opportunity cost of the farmer's input is w per unit of farmer's effort; the opportunity cost of the unpriced land attributes is r per unit;[8] and the opportunity cost of the ith variable input is c_i per unit. In the notation that follows, we drop the subscripts on the k_i inputs and examine one such input at a time. Because the inputs are assumed to be independent, this causes no problem and greatly clarifies the notation.

Because of harvest uncertainty and because a cropshare contract does not specify all of the inputs, the farmer can alter his input choices from what he would choose if he were a full owner of the output and all inputs. Such alterations can mean that the farmer may not "time" his actions as carefully on leased land as on his own land. For example, in the event of an impending hailstorm a farmer is expected to harvest wheat on his own land before he harvests wheat on adjacent land that he cropshares with another landowner. Uncertainty not only means that farmers will shirk, but also that the landowner is unable to discover the input level by simply observing the final output. Furthermore, production uncertainty implies that fixed coefficient technology is unlikely, ruling out the chance for the landowner to monitor the farmer by observing just one input. For instance, in a year with few insect pests, the seed-to-pesticide ratio will be higher than in years with many insect pests.

Assuming risk neutrality and zero contract-enforcement costs, the farmer and landowner jointly maximize expected profit by employing the first-best, full-information input levels f^*, l^*, and k^*. These input choices do not depend on the contracted input and output shares and satisfy the standard conditions that marginal products equal marginal costs.

When contract enforcement is costly, however, the chosen input levels will be second best. Because farmers do not have indefinite tenure of the land, they face lower opportunity costs of the land attributes, $r' < r$. As a result, they will exploit the land's unpriced attributes, l. Sharing also introduces other incentives. At harvest, the *crop* is divided between the farmer and landowner: the farmer owns sQ and the landowner owns $(1 - s)Q$, where

[8] The value r can be thought of as the capital value of the land's attributes.

$0 < s < 1$ is the farmer's output share.[9] Because the farmer receives less than the full marginal product of his own inputs, he supplies less of his own labor and capital than he would if he owned the entire crop. For each shared input, the farmer pays $q[ck]$ and the landowner pays $(1 - q)[ck]$, where $0 \leq q \leq 1$ is the farmer's share of input costs. If $q < 1$, the farmer overuses the shared inputs because he bears less than their full marginal cost.

Because of sharing, there are costs of measuring and dividing both the shared output and each shared input. It is important to understand that two crucial inputs—the farmer's capital and the landowner's land—are *not* shared. For these inputs, division costs are prohibitively high. Thus, for a single tract of farmland under a cropshare contract, the farmer's objective is

$$\max_{f,l,k} \Pi^s = s[h(f, l, k)] - wf - r'l - qck. \tag{1}$$

The second-best optimal input levels f^s, l^s, and k^s satisfy $sh_f(f^s) \equiv w$, $sh_l(l^s) \equiv r'$, and $sh_k(k^s) \equiv qc$.[10] From the first-order conditions and the assumption of independent inputs, it is clear that the optimal input choices differ from the first-best, or zero-transaction-cost, case. It follows that the farmer supplies too few of his inputs because he must share the output with the landowner; that is, $f^s < f^*$. Similarly, the farmer overworks the land because he does not face the full cost of using the land's attributes; that is, $l^s > l^*$.[11] Finally, it is evident that, depending on the relationship between q and s, the farmer may use too much, too little, or the optimal amount of the other inputs. For these inputs, if $q = s$, then $k^s = k^*$; if $q > s$, then $k^s < k^*$; and if $q < s$, then $k^s > k^*$.

□ **Measurement costs and the input-sharing dichotomy.** The farmer's optimal input choices—f^s, l^s, and k^s—effectively constrain the potential value of the cropshare contract. To maximize joint wealth, the farmer and landowner contract for the optimal output share (s^*) and input share (q^*) in recognition of these constraints. Their joint problem is

$$\max_{s,q} V = h(f^s, l^s, k^s) - wf^s - rl^s - ck^s - m, \tag{2}$$

where m is the cost of measuring and dividing each input. Without considering these measurement costs, s^* and q^* satisfy[12]

$$f_s(h_f - w) + l_s(h_l - r) + k_s(h_k - c) = 0 \quad \text{and} \tag{3a}$$

$$f_q(h_f - w) + l_q(h_l - r) + k_q(h_k - c) = 0. \tag{3b}$$

If input measurement costs are ignored, the solutions to (3a) and (3b) determine the optimal sharing rules, s^* and q^*. However, the costs of measuring and dividing the input must also be considered in order for s^* and q^* to be derived. If these costs (m) are lump-sum expenditures and the inputs are unrelated, then the solution to (3a) and (3b) is dichotomous and the choice of the optimal cropshare is made after the decision about input

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[9] In fact, the name "cropshare" emphasizes that the crop—not crop revenue or profits—is shared. The set of possible values for s excludes 0 and 1. If $s = 1$, the contract is cash rent; if $s = 0$, the contract is for a hired farm laborer.

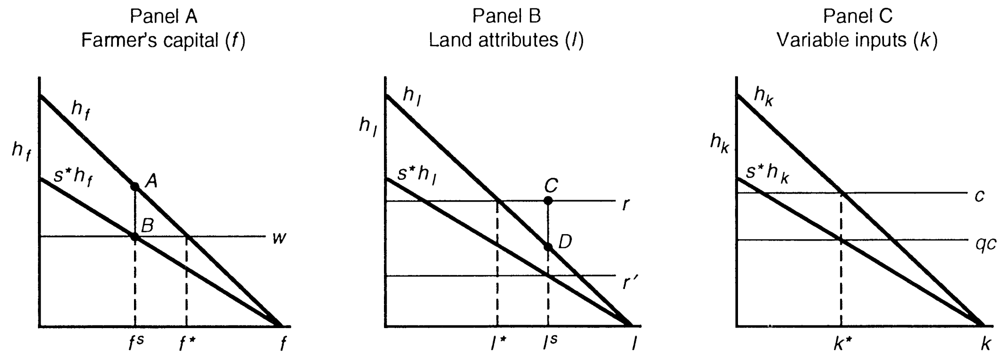
[10] Because risk-neutral parties maximize expected profits, the error term vanishes from the first-order conditions.

[11] It may seem possible that $l^s < l^*$ obtains, but as we show in Figure 1, this cannot occur because it would imply such a small output share (s) to the farmer that the input distortions would not be minimized.

[12] The terms $f_s(h_f - w) > 0$, $l_s(h_l - r) < 0$, and $k_s(h_k - c) \geq 0$ are the marginal distortions resulting from using f^s, l^s, and k^s rather than f^*, l^*, and k^*. The positively signed partial derivatives f_s, l_s, and k_s indicate the effect of a change in the output share on the farmer's input use. Equation (3a) requires that the marginal cost of an increase in the farmer's share of the crop—shown by the positive terms $f_s(h_f - w)$ and $k_s(h_k - c)$—equal the marginal gain from the increased share, as shown by the negative term $l_s(h_l - r)$. Equation (3b) has an analogous interpretation for changes in the input shares.

FIGURE 1

OUTPUT SHARES AND INPUT USE WHEN INPUT SHARES EQUAL OUTPUT SHARES, $q^* = s^*$



Note: s^* is chosen so that $AB = CD$.

cost sharing is made.[13] As long as these measurement costs are worth incurring, the model implies that input-sharing and output-sharing rules will be identical; that is, $q^* = s^*$. If these costs are not worth incurring, however, then input costs will not be shared and the farmer will bear all costs; that is, $s^* < q^* = 1$. This is proved by examining (3b) and considering the case for which measurement costs are small and worth incurring. Because inputs are independent, $f_q = l_q = 0$. Also, because $k_q < 0$, a drop in the farmer's cost of input k leads him to choose an increased amount of the input. Thus, equation (3b) implies that $h_k = c$. The first-order condition, $sh_k(k^s) \equiv qc$, must also hold, implying that $q^* = s^*$. Therefore, when inputs are shared the optimal sharing rules must satisfy

$$f_s(h_f - w) + l_s(h_l - r) = 0 \qquad \text{and} \tag{4a}$$

$$q^* = s^*. \tag{4b}$$

The optimal use of inputs is illustrated by Figure 1, which considers the case where input shares equal output shares. In Figure 1 (and later Figure 2) the marginal product curves for each input are identical and linear. This assumption is not required, but it simplifies the graphs and the analysis of input distortion. At the same time, it does not alter the main predictions of the model. Each panel shows the marginal product curve for each input; it also shows the farmer's share of the marginal product that depends on the optimal share s^*. Because the farmer shares the crop, he applies less capital and labor, which results in a marginal distortion equal to AB. The landowner's inability to fully price the land's attributes results in overuse by the farmer and a marginal distortion equal to CD. For the other variable inputs, sharing rules yield no marginal distortion, because input and output shares are identical. For the value of the contract to be maximized, the optimal output share s^* must be chosen so that the marginal distortions on inputs f and l exactly offset ($AB = CD$).[14]

When measurement costs are "large" and not worth incurring, the farmer must bear all of the input costs; that is, $q = 1$. The assumption of independent inputs still implies that $f_q = l_q = 0$; but now $h_k \neq c$, because $s \neq q$ and $s < 1$ in any cropshare contract, which also implies $k_q = 0$. Where inputs are not shared, the optimal sharing rules must satisfy

$$f_s(h_f - w) + l_s(h_l - r) + k_s(h_k - c) = 0 \qquad \text{and} \tag{5a}$$

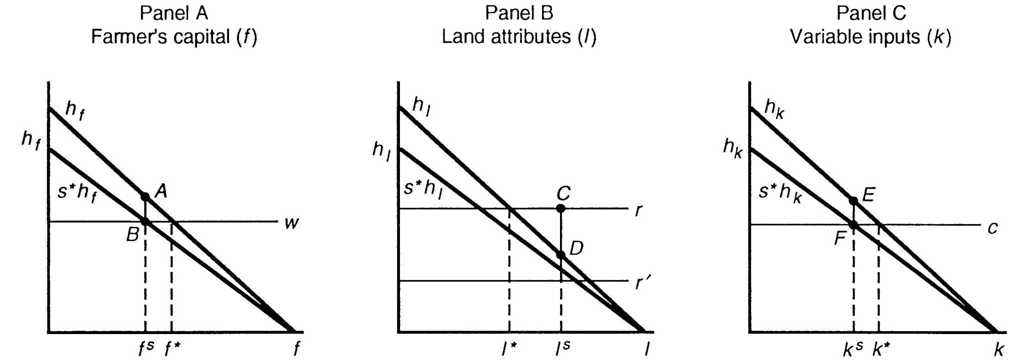
$$q^* = 1. \tag{5b}$$

[13] The assumption of lump-sum input measurement costs seems reasonable for a single farmland contract. In particular, there is no reason to think these costs would depend on s or q.

[14] Note that if $l^s < l^*$, this condition cannot be satisfied.

FIGURE 2

OUTPUT SHARES AND INPUT USE WHEN INPUTS ARE NOT SHARED, $q^* = 1$



Note: s^* is chosen so that $AB + EF = CD$.

The optimal use of inputs is illustrated by Figure 2, which considers the case where the farmer pays all of the input costs. For f and l, the incentives for input use are the same as when the inputs are shared, resulting in the marginal distortions AB and CD. For each of the other k inputs, however, the lack of input sharing results in lower use and a marginal distortion equal to EF per input. The optimal output share s^* is chosen so that the marginal negative distortions (AB and EF) are exactly offset by the marginal positive distortion (CD); that is, $AB + EF = CD$. If there are many (n) other k inputs, then $AB + \sum_{i=1}^{n} (EF) = CD$.

This analysis indicates a dichotomy in the choice of an optimal input share: either input and output shares are equal, or the farmer pays the entire input cost. For an optimal cropshare contract, there should be no middle ground: $q^* = s^*$ or $q^* = 1$. Two predictions immediately fall from this analysis. First, because the distortions are spread over more inputs when inputs are not shared ($q^* = 1$), the optimal output share (s^*) will be higher than when inputs are shared ($q^* = s^*$). (This can be seen by comparing Figures 1 and 2.) Second, when inputs are not shared the model implies that the optimal output share s^* will rise as the number of other k inputs increases, because the distortions will be spread across more margins. Furthermore, this analysis refutes the argument that proportional input sharing is required for efficient cropshare contracts.

□ **Pure cropshare contracts and input-output cropshare contracts.** The choice between a pure cropshare contract ($q^* = 1$, $s^* < 1$) and an input-output cropshare contract ($q^* = s^* < 1$) is a dichotomous one that can be examined by comparing the expected net return to the land in both contracts.[15] The tradeoff between the two contracts is straight-

[15] One study (Braverman and Stiglitz, 1986) compared cost-sharing contracts with those "fixed input contracts" that specify input level in the contracts. In the Midwestern data we examine, this type of contract is not observed.

[16] Let V^1 and V^2 be the indirect objective functions for input-output sharing and pure cropsharing, respectively. Then for any input k, the envelope theorem yields $\partial V^1/\partial m = 0$ and $\partial V^2/\partial m < 0$.

[17] For any input k, the envelope theorem yields $\partial V^1/\partial r = -l^1$ and $\partial V^2/\partial r = -l^2$, where $l^1 > l^2$, l^1 is derived when $q = 1$, and l^2 is derived when $0 < q < 1$. Because neither l^1 or l^2 depends on r, the second derivatives of V^1 and V^2 with respect to r are zero. Thus, V^1 and V^2 are declining linear functions of r. Similar derivations can be made for c and w.

forward. The pure cropshare contract has the advantage of avoiding the input division costs, m. The input-output share contract further reduces the input distortion that arises in any share contract. With the input-output cropshare contract, each input k is used at its optimal level, allowing for a further reduction in the output share in order to abate soil exploitation. The effect of parameter changes on the net value of each contract can illuminate this tradeoff and lead to hypotheses about contract choice.

Consider exogenous changes in m. The net value of the pure cropshare contract does not depend on input division costs. But the net value of the input-output cropshare contract declines as these costs increase.[16] For low costs, the input-output cropshare contract maximizes net value; for high costs, the pure cropshare contract maximizes net value. The implication is clear: As the costs of input division increase, it is more likely that the pure cropshare contract will be chosen $(q^*) = 1$.

The comparative statics for r are similar.[17] An increase in the costs of land attributes will lower the value of the input-output cropshare contracts, but it will lower the value of the pure cropshare contract even more because the land is used more intensively in the pure cropshare contract $(l^1 > l^2)$ as a result of a larger cropshare. As the costs of land attributes increase (and as land exploitation becomes more costly), the chosen contract will more likely be an input-output cropshare contract, which inherently reduces the farmer's incentive to overuse the variable inputs.

By recognizing how land attributes may be exploited in various situations, we derive specific implications. The problem of land exploitation tends to be less serious for irrigated land than for dry-farming land because tilling is not as important and soil moisture storage is not important. For row crops (such as corn, potatoes, soybeans, and sorghum), tilling during the growing season is much more important than it is for such small grain crops as barley and wheat. For these crops, the widespread practice of tilling can lead to soil exploitation, which can be curtailed by reducing the output share to the farmer. As a result, we expect the farmer's share of output to be lower for row crops and higher for irrigated land. These implications are consistent with findings that, *ceteris paribus,* irrigated land and hay land tend to be governed by cash rent contracts and that row crops tend to be governed by cropshare contracts (Allen and Lueck, 1992b).

3. Empirical analysis

■ Our model allows two sets of empirical tests. First, there are implications about the relationship between input shares and output shares, including implications about the choice between pure $(q = 1)$ and input-output $(q = s)$ cropshare contracts. Second, there are implications about the size of the optimal share (s). Both of these tests result from our model in which the ability of the farmer to exploit soil $(r - r')$ and the costs of measuring inputs (m) are determining parameters. Even though these parameters are not directly observable, there are distinct situations in which measurement costs are high and the farmer's ability to exploit the soil is great, allowing us to test the model's implications. In addition, we are able to directly observe input and output shares and identify situations—farmer, landowner, and land characteristics—in which we can expect soil exploitation or input measurement to be problematic. As a result, we are able to empirically examine the following predictions:

(1) Parties to cropshare contracts will either (i) only share output, the pure cropshare contract where $q^* = 1$ and $s^* < 1$ or (ii) share both inputs and output in the same proportion, the input-output cropshare contract where $q^* = s^* < 1$.

(2) The optimal output share (s^*) will be higher when inputs are not shared $(q^* = 1)$ than when inputs are shared $(q^* = s^*)$.

(3) When inputs are not shared ($q^* = 1$), the optimal output share s^* will rise as the *number* of other k inputs increases.

(4) As input division costs (m) increase, it is more likely that the pure cropshare contract will be chosen ($q^* = 1$).

(5) As the costs of land attributes increase or as land exploitation becomes more costly ($r - r'$ increases), the chosen contract will more likely be an input-output cropshare contract ($q^* = s^*$).

(6) The fraction of input costs that are shared will increase as the farmer's share of the output decreases.

For both sets of tests we perform, data on individual farmer-landowner contracts comes from the 1986 Nebraska and South Dakota Land Leasing Survey (Johnson et al., 1988). The survey collected data from both farmers and landowners and contains detailed information on the terms of cropshare contracts for the 1986 crop year. This data includes 1,628 cropshare contracts, where each contract is an exchange of rights over a tract of land. The variables used in the empirical tests are defined in Table 1; descriptive statistics are reported in Table 2.

TABLE 1 Definition of Variables

Variable	Definition
Independent variables	
ACRES	= number of acres of farmland governed by the contract
CORN	= 1 if the crop was corn
HIGHVALUE	= 1 if crops were irrigated or were row crops
IRRIGATION	= 1 if land is irrigated
INPUTS	= the number of inputs for which the farmer pays all costs
LEASEDACRES	= the fraction of the farmer's total farming acreage in the current lease
MARKET	= 1 if the input is seed, fertilizer, herbicide, or insecticide
OATS	= 1 if the crop is oats
ROW	= 1 if the crop is corn, sugar beets, soybeans, or sorghum
SOYBEANS	= 1 if the crop is soybeans
WHEAT	= 1 if the crop is wheat
YEARS	= number of years of contract renewals
Dependent variables	
CROPSHARE	= fraction of crop owned by the farmer
QSHARE	= 1 if farmer pays all input costs
	= 0 if farmer pays input costs proportional to his output share
CHEMICAL APPLICATION	= 1 if farmer pays 100% of chemical application cost
	= 0 if the farmer pays the same portion as his cropshare
DRYING	= 1 if farmer pays 100% of crop drying cost
	= 0 if the farmer pays the same portion as his cropshare
ENERGY	= 1 if farmer pays 100% of the irrigation energy cost
	= 0 if the farmer pays the same portion as his cropshare
FERTILIZER	= 1 if farmer pays 100% of the fertilizer cost
	= 0 if the farmer pays the same portion as his cropshare
HARVEST	= 1 if farmer pays 100% of the harvesting cost
	= 0 if the farmer pays the same portion as his cropshare
HERBICIDE	= 1 if farmer pays 100% of the herbicide cost
	= 0 if the farmer pays the same portion as his cropshare
INSECTICIDE	= 1 if farmer pays 100% of the insecticide cost
	= 0 if the farmer pays the same portion as his cropshare
SEED	= 1 if farmer pays 100% of the seed cost
	= 0 if the farmer pays the same portion as his cropshare

TABLE 2 Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Independent variables				
ACRES	249.544	288.612	.00	3892.00
CORN	.698	.459	.00	1.00
HIGHVALUE	.899	.031	.00	1.00
IRRIGATION	.478	.500	.00	1.00
INPUTS	4.699	2.172	.00	8.00
LEASEDACRES	62.105	34.566	.00	100.00
MARKET	.494	.500	.00	1.00
OATS	.164	.370	.00	1.00
ROW	.842	.365	.00	1.00
SOYBEANS	.489	.500	.00	1.00
WHEAT	.452	.498	.00	1.00
YEARS	12.633	10.859	.00	71.00
Dependent variables				
CROPSHARE	.59	.09	.20	.99
QSHARE (full sample)	.71	.67	.00	1.00
QSHARE (farmers)	.60	.49	.00	1.00
CHEMAPP (full)	.71	.45	.00	1.00
CHEMAPP (farmers)	.75	.43	.00	1.00
DRYING (full)	.62	.48	.00	1.00
DRYING (farmers)	.57	.50	.00	1.00
ENERGY (full)	.81	.39	.00	1.00
ENERGY (farmers)	.78	.41	.00	1.00
FERTILIZER (full)	.18	.38	.00	1.00
FERTILIZER (farmers)	.15	.36	.00	1.00
HARVEST (full)	.91	.28	.00	1.00
HARVEST (farmers)	.92	.28	.00	1.00
HERBICIDE (full)	.42	.49	.00	1.00
HERBICIDE (farmers)	.39	.49	.00	1.00
INSECTICIDE (full)	.45	.50	.00	1.00
INSECTICIDE (farmers)	.43	.49	.00	1.00
SEED (full)	.76	.43	.00	1.00
SEED (farmers)	.74	.44	.00	1.00

Note: Because of crop rotation, the sum of the means of the crop dummies is greater than one.

Although many features of cropshare agreements are relatively stable (Allen and Lueck, 1992a and 1992b; Johnson et al., 1988), the division of the output between the farmer and the landowner varies considerably. This variation refutes a common belief (Allen, 1985; Hurwicz and Shapiro, 1978; Newberry and Stiglitz, 1979) that sharing arrangements necessarily divide the crop equally between the farmer and the landowner. Fifty-fifty contracts are common, but they are not dominant (as shown in Table 3), and farmers routinely receive a minimum of 50% of the crop. In our sample less than 5% (71 out of 1,628) of the contracts granted less than a 50% output share to the farmer.

The division of input costs between farmers and landowners also varies across contracts (see Table 3). The input shares tend to take one of two forms: either the farmer bears all input costs other than the land costs, making his input share 100%, or the farmer and the landowner share the input costs in the same proportion as the output. In other words, if the farmer's output share is 50%, then his input cost share is 50%. An early writer (Heady, 1947) argued that output share must be equal to input share for a cropshare contract to be efficient. More recently, it has been shown (Braverman and Stiglitz, 1986; Bardhan and Singh, 1987) that this need not be the case if moral hazard and risk were considered. We also reject Heady's contention, but do not consider risk-based arguments.

TABLE 3 **Distribution of Cropshare and Input Share Terms in Nebraska and South Dakota**

Cropshare to Farmer	Number of Contracts (%)
20	1 (0.1)
25	10 (0.6)
30	1 (0.1)
33	30 (1.8)
40	27 (1.6)
43	2 (0.1)
50	389 (23.7)
55	3 (0.2)
60	590 (36.0)
65	5 (0.3)
67	530 (32.3)
69	2 (0.1)
70	3 (0.2)
75	29 (1.8)
80	1 (0.1)
90	3 (0.2)
99	11 (0.7)

	Number of Contracts (%)		
Farmer's Input Share	Fertilizer	Harvest	Seed
0	6 (0.4)	15 (0.9)	30 (1.8)
25	5 (0.3)	0 (0.0)	2 (0.1)
33	13 (0.8)	0 (0.0)	0 (0.0)
40	16 (1.0)	2 (0.1)	2 (0.1)
43	2 (0.1)	2 (0.1)	0 (0.0)
50	363 (22.4)	91 (5.6)	298 (18.3)
55	2 (0.1)	1 (0.1)	2 (0.1)
60	531 (32.7)	25 (1.5)	51 (3.1)
65	0 (0.0)	1 (0.1)	1 (0.1)
67	397 (22.6)	25 (1.5)	38 (2.3)
70	3 (0.2)	0 (0.0)	2 (0.1)
75	17 (1.0)	3 (0.2)	1 (0.1)
80	1 (0.1)	0 (0.0)	0 (0.0)
85	0 (0.0)	2 (0.1)	0 (0.0)
100	268 (16.5)	1,461 (89.6)	1,199 (73.7)

Our model also has implications about the level of inputs chosen by the farmer under different sharing rules. Unfortunately, the data available in the 1986 survey does not have information on the level of any farm inputs. One study of sharecropping in Indian villages (Shaban, 1987), however, supported the model's implications about input choices. Shaban found that input use was sizably (19% to 55%) and significantly lower on shared land compared to owned land.

□ **Dichotomous rules for input shares.** The evidence from the Johnson et al. (1988) survey is remarkably consistent with our prediction of a dichotomous choice of optimal input shares. For the three most common cropshare rules (50-50, 60-40, and 67-33), q = 100% or $q = s$ in nearly all contracts (see Table 4).[18] It is rare to find cases where $q \neq s$ if

[18] We do not report the astronomical chi-squared statistics from the crosstabs of input and output shares from which Table 4 was derived.

TABLE 4 Input and Output Sharing

Percentage of Cropshare Contracts for which Input Share (q) Equals Output Share ($q = s$) or Equals 100% ($q = 1$)

	s = 50%			s = 60%			s = 67%		
Input	q = 50%	q = 100%	Both	q = 60%	q = 100%	Both	q = 67%	q = 100%	Both
FERTILIZER	92%	1%	93%	94%	1%	95%	83%	13%	96%
HERBICIDE	92	3	95	81	16	97	57	38	95
INSECTICIDE	92	3	95	83	13	96	57	39	96
SEED	80	16	96	11	85	96	8	90	98
HARVESTING	30	66	96	6	93	99	7	93	100
CHEMICAL APPLICATION	48	47	95	41	57	98	39	58	97
DRYING	86	10	96	77	18	95	58	39	97
ENERGY	92	5	97	60	32	92	34	51	85

Percentage of Cropshare Contracts for which Output Share (s) Equals Input Shares (q) When Inputs are Shared

	q = 50%	q = 60%	q = 67%
CHEMICAL APPLICATION	91%	94%	90%
DRYING	94	95	96
FERTILIZER	90	95	90
HARVESTING	90	92	96
HERBICIDE	93	96	93
ENERGY	87	96	89
INSECTICIDE	93	96	93
SEED	95	96	84

or $q = s$ in nearly all contracts (see Table 4).[18] It is rare to find cases where $q \neq s$ if $q < 100\%$. For instance, in 83% of 67-33 cropshare contracts, farmers and landowners share equally in the cost of fertilizer; 13% of the contracts have the farmer pay all such costs. Thus, these two input-sharing rules account for 96% of all cases. For all inputs considered, Table 4 shows that these two rules ($q = s$ or $q = 100\%$) always combine for at least 85% of all input-share policies.

In addition, for contracts with input shares of 50%, 60%, and 67%, the top section of Table 4 shows the percentage of contracts for which the output share is the same as the input share. For example, for cropshare contracts that require the farmer to bear 50% of the costs of chemical application (row one), 91% also have an output share of 50%. The evidence presented offers strong support for our prediction that input costs will either be shared by the farmer and landowner in the same proportion as output or the farmer will bear all costs. This dichotomy is also contrary to the implications of a model that relies on interlinkage of inputs by manipulating input prices (Braverman and Stiglitz, 1982). Furthermore, this evidence refutes the prediction that output shares always equal input shares. Finally, our explicit consideration of contract enforcement costs—here, input measurement costs—allows an explanation of the contract dichotomy.

□ **Determinants of input shares.** Our model implies that output shares will be higher for pure cropshare contracts ($q = 1$) than for input-output cropshare contracts ($q = s$). The input-output cropshare contract results in the use of variable inputs at the "optimal" level ($s = q$ implies that $k = k^*$). We test this key implication by comparing the farmer's mean output share for pure cropshare contracts with the mean share for input-output cropshare contracts. Table 5 shows the mean output share to the farmer for each input according to whether input costs were shared ($q = s$) or fully borne by the farmer ($q = 1$). For each

TABLE 5 **The Relationship between Cropshare Rules and Input Share Rules**

Input	Rule	Cropshare Mean	T-Value (d.f.)	2-Tailed Probability
CHEMICAL APPLICATION	$q = s$	.5800	4.45	.0001
	$q = 1$	.6013	(1577)	
DRYING	$q = s$	.5764	6.52	.0001
	$q = 1$	.6061	(1582)	
FERTILIZER	$q = s$	.5908	7.33	.0001
	$q = 1$	.6311	(1501)	
HARVEST	$q = s$	.5364	8.46	.0001
	$q = 1$	.6006	(1611)	
HERBICIDE	$q = s$	.5771	10.36	.0001
	$q = 1$	.6215	(1554)	
INSECTICIDE	$q = s$	.5766	9.52	.0001
	$q = 1$	.6181	(1561)	
ENERGY	$q = s$	.5505	10.03	.0001
	$q = 1$	.6062	(1595)	
SEED	$q = s$	.5240	20.15	.0001
	$q = 1$	.6179	(1600)	

input, the farmer's mean output share is significantly higher (averaging 61% versus 56%) when the farmer bears all the input costs ($q = 1$) than when he shares them with the landowner ($q = s$). This evidence further supports the theory that input measurement costs are an important determinant of the details of agricultural contracts. If there were no such costs ($m = 0$), input sharing would always occur and in the same proportion as output sharing ($q = s$).

When input measurement costs are low, the input-output cropshare contract is more likely to be chosen because it comes closer to the first-best level of input use. We can examine cases in which we expect input division costs to be low, and we can distinguish between various inputs. Inputs such as fertilizer and seed are purchased in the market. Other inputs, such as harvesting, are not routinely purchased, but are usually provided by the farmer. Measurement costs are likely to be much lower for inputs purchased directly in the market than for those provided by the farmer. Inputs purchased in the market will necessarily be measured and sold by a noninterested third party, making it difficult for the farmer to cheat the landowner by overbilling the landowner or simply carelessly wasting the inputs.

Thus, we expect that market inputs (fertilizer, herbicide, insecticide, and seed) are more likely to be shared by the farmer and landowner in the same proportion as the output, while nonmarket inputs (chemical application, drying, irrigation energy, and harvesting) are more likely to be the complete responsibility of the farmer.[19] In other words, we expect $q = s$ for market inputs and $q = 1$ for nonmarket inputs. The evidence bears out this prediction. For all three major cropshare rules represented in Table 4 (50-50, 60-40, and 67-33), the percentage of contracts for which the farmer pays all costs tends to be greatest for market inputs.[20] For example, in 67-33 cropshare contracts the farmer pays for all harvest costs 93% of the time; he pays for all fertilizer costs only 13% of the time.

The model further implies that the fraction of contracts for which input costs are shared in proportion to output will increase as the farmer's share of the output decreases. For any input k, the input distortion increases as the output share to the farmer falls. This occurs because the farmer's incentives are increasingly at odds with those of a complete owner of the crop. This distortion can be viewed as an increase in the potential benefit of having the

[19] Although it is true that these "nonmarket" inputs can occasionally be purchased in the market, they are generally provided by the farmer. In all cases the "market" inputs are purchased in the market.

[20] The obvious exception is seed. Later we address another aspect of inputs that explains this anomaly.

farmer pay the same portion of the input costs as his share of the output. Sharing input costs creates incentives that move the contract toward the first-best input use, but requires that inputs be measured. Because the costs of dividing inputs are assumed to be a lump-sum expenditure, the model implies that these costs are more likely to be worth overcoming as the share of the farmer's harvest decreases.

Therefore, we expect that the fraction of contracts where $q = s$ will be greater for 60-40 contracts than for 67-33 contracts, and that it will be even greater for 50-50 contracts. This prediction is confirmed by Table 4. For instance, drying costs are proportionally shared ($q = s$) in 58% of the 67-33 contracts, in 77% of the 60-40 contracts, and in 86% of the 50-50 contracts. With a few minor exceptions, this relationship holds for all inputs. Furthermore, it is expected that input shares (q) and output share (s) will be positively correlated for all crop inputs. We calculated correlation coefficients for all inputs and found them to be positive in all cases; the null hypothesis of zero correlation was rejected at less than the 1% level.

□ **Input sharing within contracts.** To this point our efforts have focused on the variation in input-sharing rules across contracts. Our model, however, has implications for the structure of input sharing within each cropshare contract. Within each contract, market inputs should be treated the same, and likewise for any nonmarket inputs. For instance, if seed is shared at 60-40, then so should fertilizer, pesticide, and herbicide be shared at 60-40, and the cropshare should also be 60-40. Nonmarket inputs (chemical application, drying, irrigation energy, and harvesting) are predicted to be the responsibility of the farmer. Tables 6 and 7 show the distribution of inputs shared within contracts and strongly support the implications of our model. The data expose the dominance of the sharing rule dichotomy ($q = s$ or $q = 100$) and make clear the distinction between sharing rules for market and nonmarket inputs.

Table 6 shows the input-sharing rules breakdown for the entire sample of 1,628 contracts. The upper section of the table shows all eight inputs, while the lower part distinguishes between market and nonmarket inputs. The entry in each cell shows the number of contracts (out of the 1,628 total) that satisfy the respective numbers of inputs that are shared in the same proportion as the crop (horizontal axis) and those that are fully the responsibility of the farmer (vertical axis). For instance, the entry "220" at the intersection of row 5 and column 3 indicates that 220 of the 1,628 contracts have four input shares equal to the cropshare, with the remaining four inputs fully the farmer's burden. The entry in row 0, column 8 shows that 209 contracts stipulated that all eight inputs were paid fully by the farmer; by contrast, the entry in row 8, column 0 shows that 24 contracts required all inputs to be shared exactly the same as the crop.

Our dichotomy theory implies that the contract entries should lie on the diagonal. As is evident from the table, this is the overwhelming outcome. In fact, 1,405 (86%) of the contracts meet this test. The diagonal just to the left of the main diagonal (the 7-7 diagonal) is also supportive. The 7-7 diagonal shows the number of contracts for which seven of the eight inputs fit the dichotomy. If these contracts are included, the dichotomy covers 1,525 (94%) of the contracts. Again, the dichotomy is self-evident from the lower section of the table, which separates market from nonmarket inputs. For market inputs, 1,456 (89%) contracts are on the main diagonal; for nonmarket inputs, 1,432 (88%) of the contracts are on the main diagonal. If contracts on the 3-3 diagonal are added, then the numbers are 1,540 (95%) for market inputs and 1,552 (95%) for nonmarket inputs. Table 7 breaks down the contracts even further into contract groups that have identical cropshares (50-50, 60-40, and 67-33 respectively). In all cases the main diagonal accounts for between 91% and 96% of the contracts. Including the 3-3 diagonal accounts for between 96% and 99% of all contracts.

TABLE 6 Distribution of Input-Sharing Rules Within Contracts

All Inputs

Number of inputs that satisfy $q = s$ \ Number of inputs that satisfy $q = 100\%$	0	1	2	3	4	5	6	7	8
0	1	7	5	21	11	24	9	49	209
1	1			1	3	3	11	186	
2		1		1	1	5	144		
3					12	162			
4		1		21	231				
5		3	18	220					
6		10	158						
7	4	71							
8	24								

Market Versus Nonmarket Inputs

Market Inputs

Inputs for which $q = s$ \ Inputs for which $q = 100\%$	0	1	2	3	4
0	16	47	17	59	233
1	2	5	6	262	
2	1	8	153		
3	11	498			
4	310				

Nonmarket Inputs

Inputs for which $q = s$ \ Inputs for which $q = 100\%$	0	1	2	3	4
0	9	19	30	77	723
1	2	6	26	372	
2	10	12	233		
3	5	82			
4	22				

Total contracts = 1628.

Tables 6 and 7 also confirm our predictions about market versus nonmarket input-sharing rules. Market inputs are easier to measure, so we expect their sharing to more often be equal to the output share ($q = s$). Nonmarket inputs are more likely to be the full responsibility of the farmer ($q = 100\%$). All four tables show this to be the case. This prediction can be tested by examining the main diagonal of the tables. For market inputs we expect to see a greater portion of the contracts on the lower left portion of the diagonal (where $q = s$ dominates); for nonmarket inputs we expect a greater portion on the upper right section (where $q = 100$ dominates). Casual inspection shows this to be true. For example, when all contracts are considered, Table 6 shows that 233 contracts (14%) have all four market input shares equal to 100%, whereas 723 contracts (44%) have all four nonmarket shares equal to 100%. Similarly, 310 contracts (19%) have all four market input shares equal to the cropshare, whereas only 22 contracts (1%) have all four nonmarket shares equal to the cropshare. As Table 7 shows, the pattern is consistent even when cropshare is held constant.

Additional support for the model comes from comparing market and nonmarket sharing rules while letting cropshare vary. As noted in the previous section, the model suggests that the fraction of contracts for which input costs are shared in proportion to output will increase as the farmer's share of the output decreases. Again, inspection of the tables shows that the fraction of contracts where the number of inputs shared like output shares (or borne fully by the farmer) falls as cropshare rises. To illustrate, track the row 4, column 0 entry for

TABLE 7 Distribution of Input-Sharing Rules for Market and Nonmarket Inputs

50-50 Cropshare (total contracts = 389)

Market Inputs

Inputs for which $q = 50\%$ \ Inputs for which $q = 100\%$	0	1	2	3	4
0	2	12	3	8	33
1	1	1		5	
2		2	17		
3	5	49			
4	251				

Nonmarket Inputs

Inputs for which $q = 50\%$ \ Inputs for which $q = 100\%$	0	1	2	3	4
0			3	12	93
1		1	10	90	
2	2	5	106		
3	2	50			
4	15				

60-40 Cropshare (total contracts = 580)

Inputs for which $q = 60\%$ \ Inputs for which $q = 100\%$	0	1	2	3	4
0	6	11	2	8	40
1		2		95	
2		2	63		
3	3	311			
4	37				

Inputs for which $q = 60\%$ \ Inputs for which $q = 100\%$	0	1	2	3	4
0	1	2	4	23	242
1		1	14	157	
2		3	100		
3		27			
4	6				

67-33 Cropshare (total contracts = 530)

Inputs for which $q = 67\%$ \ Inputs for which $q = 100\%$	0	1	2	3	4
0	3	6	2	23	125
1		2	2	154	
2		2	66		
3	1	131			
4	13				

Inputs for which $q = 67\%$ \ Inputs for which $q = 100\%$	0	1	2	3	4
0		1	2	15	353
1			2	124	
2		1	27		
3		5			
4					

market inputs in Table 7. For 50-50 contracts the percentage of all four input shares equalling the cropshare is 65, for 60-40 it is 6, and for 67-33 it is 2. This trend is robust for market and nonmarket inputs and for all cropshare rules.

□ **Estimation of contract choice.** Even though the evidence above is supportive of our contracting model, these findings are tentative because each test fails to hold constant other forces. To estimate the choice between pure cropshare and input-output cropshare contracts, the contract data are reorganized so that input shares are dichotomous; that is, input costs are either fully borne by the farmer or shared proportionally. Thus, for any contract i the complete model is

$$\hat{q}_i = X\beta + \mu_i \quad \text{and} \tag{6}$$

$$q_i = \begin{cases} 1 & \text{if} \quad \hat{q}_i = 1 \\ 0 & \text{if} \quad \hat{q}_i = s, \end{cases} \tag{7}$$

where X is a row vector of explanatory variables including the constant, β is a column vector of unknown coefficients, and μ is an error term. In equation (6), $\hat{q}_i$ denotes the "true" underlying input share that is observed as either shared or not shared. The equality $q_i = 0$ means that the farmer's share of input costs equals his output share; the similarly observable equality $q_i = 1$ means that the farmer pays all the input costs. Tables 8 and 9 show the results of logit estimation of the model given by (6) and (7).

For Table 8, a new pooled dataset was created in which each input for each contract became an observation. This resulted in 12,485 observations on input-sharing rules. Two logit equations estimate the probability that the cost of any input will be fully borne by the farmer rather than shared with the landowner. The variable *HIGHVALUE* measures the value of the land attributes and is predicted to be negatively correlated with the dependent variable. The problem of land exploitation is more serious for highly valued land than for poor land. By sharing input costs, the farmer's share of the output can be reduced (l^s gets closer to l^*), thus reducing the farmer's incentive to exploit the soil. This expectation is fulfilled in both equations.

MARKET measures whether or not an input is purchased in the market.[21] Inputs purchased in the market are less expensive to measure and to divide, so this variable is expected to have a negative coefficient. The estimated equations bear this out.[22] *LEASEDACRES* measures the fraction of farm acres that the farmer leases in the observed contract. If the farmer leases all of his acres from one landowner, then his ability to shirk on shared input use is severely curtailed. However, if a farmer has other farm acres, it is possible for him to divert shared inputs from one plot of land to another and bill the landowner for the extra costs. *LEASEDACRES* is used only in a sample in which farmers responded to the survey. As expected, we found the coefficient on *LEASEDACRES* to be negative.

Table 9 shows separate logit estimation for each of the eight crop inputs. As in the pooled dataset, we estimated two equations for each input. As Table 9 illustrates, the estimated coefficients for individual inputs add further support to the model. In all cases the coefficients have the predicted sign, and in the majority of the cases they are significantly different from zero. Although the magnitude and significance of the coefficient estimates vary from input to input, this evidence shows that the economic relationships found in Table 8 are robust and generally hold across many different crop inputs. *MARKET* cannot be defined in the unpooled sample, so it is left out of the logit estimates in Tables 9.

□ **Estimation of cropshare rules.** As the two sets of first-order conditions (4a, 4b and 5a, 5b) imply, once the decision about input cost sharing has been made, the optimal cropshare rule can be chosen. The optimal input share ($q^* = 1$ or $q^* = s$) will influence the optimal cropshare, s^*, as well as variables that measure the potential for soil exploitation. In particular, when inputs are not shared, output share will rise as the number of other k inputs increases, because the distortions will be spread across more margins. For each contract i the model is

$$\ln (s_i / 1 - s_i) = Z\xi + Q_i\Theta + \epsilon_i, \tag{8}$$

[21] We also estimated these equations by modifying the *MARKET* dummy to include irrigation energy as a market input. This specification slightly decreased the size of the *MARKET* coefficients, but it did not appreciably alter the other estimates or any significance levels.

[22] In separate equations, we used a dummy that measured whether or not the inputs had long-term effects on the land by increasing the value of the land beyond the production of the current crop. If the input enhances the value of the land, then the landowner is more likely to share the costs in order to maximize the contract value of the land lease. As expected, this variable had a negative effect on the probability of the farmer's paying all input costs. Because nearly all of these long-term inputs are market inputs, the *MARKET* coefficient is also capturing this effect.

TABLE 8 Input Share Logit Estimates on Pooled Data

Independent Variable	Estimated Logit Coefficients: Full Sample	Farmer Sample	Predicted Sign
CONSTANT	60.99	52.91	
	(30.07)	(16.69)	
MARKET	−33.93	−29.78	−
	(−35.43)	(−20.46)	
HIGHVALUE	−34.21	−27.58	−
	(−17.49)	(−9.62)	
LEASEDACRES	NA	−9.95	−
		(−4.12)	
Observations	12,485	3,940	
Model chi-square	1693.41	562.21	
Degrees of freedom	(2)	(3)	

Notes: Dependent variable = 1 if farmer pays all input costs ($q = 1$); 0 if farmer pays input costs proportional to his output share ($q = s$). Asymptotic t-statistics in parentheses. NA = not applicable. Coefficients are $\partial\%/\partial X = \beta[P(1 - P)]*100$ from the logit $P = 1/(1 + e^{-X\beta})$, where P is calculated at the mean of the dependent variable.

where Z is a row vector of explanatory variables, ξ is a column vector of unknown coefficients, Q_i is the number of inputs paid fully by the farmer, Θ is the corresponding coefficient, and ϵ_i is an error term. The natural logarithm of the output share ratio, $\ln(s/1 - s)$, is used instead of the output share because s is a limited-dependent variable, where $0 < s < 1$. Table 10 shows the results of ordinary least squares (OLS) estimation of (8) using three different specifications.[23] *INPUTS* measures the number of inputs for which the farmer pays all costs (Q) and is expected to be positively correlated to the farmer's share of the crop. The variables *IRRIGATION* and *ROW*, which measure the potential for the farmer to exploit the soil, have the predicted signs. *ROW* and *IRRIGATION* might seem to be simultaneously chosen with output share, but in fact they depend on the characteristics of the land and are exogenous to the contract choice. For instance, soybeans are not grown in the arid western parts of Nebraska and South Dakota, and barley is not often grown in the more humid eastern reaches of these states. In the last equation, dummy variables for specific crops—*CORN*, *OATS*, *SOYBEANS*, and *WHEAT*—are included instead of *ROW*. Because *CORN* and *SOYBEANS* are row crops, we expect their coefficients to be negative; *OATS* and *WHEAT* are not row crops, and we expect their coefficients to be positive. All of these crop coefficients have the predicted sign.

We include a variable (*YEARS*) that measures the number of years of continuous contracting as a control variable in our estimates, but this variable might also have an economic interpretation. If the number of years of past contracting can be taken as a proxy for a farmer's reputation for good husbandry, then as the number of years increases the farmer is expected to act more as if he were an integrated landowner-farmer.[24] As a result, soil exploitation is reduced compared to a situation in which the landowner contracts with a farmer for the first time (r' is closer to r for long-term contractors), and there is less need for the farmer's share of the crop to be low to mitigate that problem. In turn, a higher share

[23] Because we include those few cases where the input share does not equal 100% of the cropshare, our sample size for these equations is slightly larger than for the logit estimates of contract choice in Table 7.

[24] Reputation is likely to affect the structure of farmland lease contracts (Allen and Lueck, 1992a).

TABLE 9 Input Share Logit Coefficient Estimates for Eight Crop Inputs

Input (sample size)	Independent Variables: *HIGH VALUE*	*LEASED ACRES*	Model Chi-square	Degrees of Freedom
SEED	−26.610			
(full, n = 1572)	(−4.766)		32.92	1
(farmer, n = 500)	−30.601	−18.873		
	(−2.915)	(−2.892)	20.07	2
FERTILIZER	−22.429			
(full, n = 1497)	(−8.345)		64.22	1
(farmer, n = 467)	−15.354	−4.311		
	(−3.451)	(−0.749)	10.96	2
HERBICIDE	−44.654			
(full, n = 1544)	(−8.989)		100.50	1
(farmer, n = 487)	−36.701	−9.152		
	(−4.631)	(−1.178)	24.97	2
INSECTICIDE	−48.517			
(full, n = 1558)	(−9.126)		111.04	1
(farmer, n = 493)	−44.005	−13.066		
	(−5.039)	(−1.637)	33.13	2
CHEMICAL APPLICATION	−12.042			
(full, n = 1563)	(−2.770)		8.45	1
(farmer, n = 497)	−14.715	−2.964		
	(−1.860)	(−.400)	4.14	2
ENERGY	−46.556			
(full, n = 1576)	(−4.256)		54.85	1
(farmer, n = 495)	−42.582	−11.686		
	(−2.442)	(−1.902)	22.92	2
DRYING	−58.712			
(full, n = 1577)	(−7.182)		102.03	1
(farmer, n = 496)	−66.219	−4.375		
	(−4.485)	(−.568)	41.21	2
HARVESTING	−5.224			
(full, n = 1598)	(−1.712)		3.49	1
(farmer, n = 505)	−1.004	−12.052		
	(−.245)	(−3.515)	11.79	2

Notes: Dependent variable = 1 if farmer pays all input costs (q = 1); = 0 if farmer pays input costs proportional to his output share ($q = s$). Asymptotic t-statistics in parentheses. Coefficients are $\partial\%/\partial X = \beta[P(1 - P)] * 100$ from the logit $P = 1/(1 + e^{-X\beta})$, where P is calculated at the mean of the dependent variable.

of the crop to the farmer assures a more ideal use of the farmer's inputs. To test this prediction, we include *YEARS* in two equations, and find that in both equations the *YEARS* coefficient is positive and significant.

ACRES is included as a control variable in two equations. In both equations, the coefficient on *ACRES* is not significantly different from zero, indicating that the size of the contracted land parcel does not influence the terms of the cropshare rule.

4. Summary and discussion

■ Our focus has been on contract incentives and measurement costs, but other factors might influence contract choice. Among these factors are the role of risk sharing, the effect of government programs on contract choice, and the apparent discrete limitations on the choice of output-sharing rules. Risk sharing has often been suggested as an important rationale for share contracting. By this theory (Cheung, 1969; Stiglitz, 1974) cropshare contracts are chosen when crop-yield variability is high, and cash rent contracts are chosen when crop

TABLE 10 Cropshare Regression Estimates

Independent Variable	Estimated OLS Coefficients			Predicted Sign
	Full Sample	Full Sample	Full Sample	
CONSTANT	.15556	.11018	.043502	
	(3.076)	(1.998)	(.881)	
INPUTS	.06517	.06526	.05807	+
	(10.953)	(10.972)	(9.920)	
ROW	−.12020	−.11691		−
	(−3.471)	(−3.313)		
IRRIGATION	.09846	.09929	.11690	+
	(4.025)	(4.058)	(4.545)	
YEARS		.00305	.00289	+
		(2.787)	(2.675)	
ACRES		1.284E−05	−3.372E−05	??
		(.305)	(−.805)	
CORN			−.04282	−
			(−1.364)	
OATS			.13384	+
			(4.149)	
SOYBEANS			−.08220	−
			(−3.180)	
WHEAT			.11228	+
			(4.554)	
Observations	1628	1628	1628	
F-value	58.836	37.031	31.217	
Adjusted R^2	.0964	.0999	.1294	

Notes: Dependent variable = ln ($s/1 - s$). t-statistics in parentheses.

yields are stable. Risk sharing has been relatively unsuccessful in explaining why cropshare contracts are often preferred to cash rent contracts. Evidence from Indian agriculture showed that high-variance crops like tobacco were cash rented and low-variance crops like rice were cropshared (Rao, 1971). In regions of Nebraska and South Dakota that had historically high crop-yield variability, cropshare contracts were no more (or less) prevalent than cash rent agreements (Allen and Lueck, 1992b). Instead, the decision to share was best explained by contract-enforcement costs.

Federal farm commodity programs are another factor that could potentially influence farmland contracts. For some crops (barley and wheat, for example) farmers get direct payments; for some crops (soybeans and sugarbeets) farmers do not receive direct payments, but receive indirect subsidies through tariffs; and for other crops (hay) there are no programs (U.S. Department of Agriculture, 1988). It is not clear what a model based on government programs would imply, since the payments do not depend on the allocation of input costs. Furthermore, in the context of our model, it is not at all clear how government programs would influence input-measurement costs or soil exploitability.[25] All these programs reduce income variability, so—assuming risk aversion—one might argue that nonprogram crops be treated differently from program crops. But, for the Nebraska and South Dakota data *all* crops are program crops, so there is no way to test for effects even if implications were available. Interestingly, the only nonprogram crop is hay, and it is virtually never cropshared, contrary to the risk-sharing hypothesis (Allen and Lueck, 1992b).

[25] Midwestern data showed that government programs did not affect the choice between cropshare and cash rent contracts (Allen and Lueck, 1992b).

A curious feature of the 1986 data is that cropshares take on relatively few discrete values. Table 1 shows that 50-50, 60-40, and 67-33 are by far the most common divisions. Less common are 25-75, 33-67, 40-60, and 75-25. Completely absent are such divisions as 58.5-41.5 or 62-38. What causes these divisions to take on so relatively few values? Should not the distribution of cropshares be smooth and continuous, rather than lumpy? We have no definitive answer, but suggest that measurement costs of another variety may be at work. Among farmers and landowners, 50-50 contracts are called "halves," 60-40 contracts are called "fifths," 67-33 contracts are called "thirds," and so on. It seems that these simple fractions hark back to the days when crop division was split as follows: In a two-thirds/one-third contract the farmer would keep for himself two truckloads of wheat for every one delivered to the landowner. In fact, this type of load-by-load division is still found, although not often, because most crops are now weighed at public granaries. The use of discrete sharing rules that mimic simple fractions can be viewed as rules that economize on measurement costs when measurement technology is imprecise.[26]

This study has focused on the differential incentives of various contractual provisions and derived implications about the fraction of the crop that is owned by the farmer as well as the fraction of the input costs borne by both the farmer and the landowner. In particular, we expect that with cropsharing the farmer either bears the entire cost of inputs or shares the costs with the landowner in the same proportion as he shares the output. With striking clarity, the data from Nebraska and South Dakota show the input-sharing dichotomy predicted by the model. In these two Midwestern states farmers either pay all input costs or share them in the same proportion as their share of the crop. The 1986 data also show that proportional input sharing is more likely as the farmer's share of the output decreases. This is expected because the distortions from output sharing are greater as the farmer's share of the harvest falls. Input sharing is a method of reducing these distortions. We also found that inputs readily purchased in the market were more likely to be shared than other inputs, and farmers who had land in addition to the observed cropshare plot were less likely to share inputs than farmers who leased all their land in a single cropshare contract.

Our focus on the incentives inherent in each contract and the costs of measuring and dividing shared resources has implications for the study of share contracts outside agriculture. In general, we expect parties to a share contract to become full residual owners of inputs when these inputs are difficult to divide. When inputs are shared we expect them to be shared in the same proportion as output or revenue.

Returning to the farm setting, we note that many inputs are never shared because of these measurement costs. Farmers and landowners may routinely share the costs of fertilizer and seed, but they rarely jointly own and share buildings, combines, and tractors. In light of our model, this finding is not surprising. The costs of measuring and dividing the ownership of such assets are likely to be prohibitive. Our model also has implications for agriculture in developing economies. Because markets are less prevalent, we expect pure cropshare contracts to dominate over input-output sharing. As economies develop and markets arise, along with more precise measurement technology, we expect farmland contracts to develop along the lines of those found in modern agriculture.

Appendix

■ Data for the landowner-farmer cropshare contracts come from the "1986 Nebraska and South Dakota Leasing Survey," conducted by Professors Bruce Johnson of the University of Nebraska and Larry Jannsen of South Dakota State University. A summary of the study and the survey procedures is available (Johnson et al., 1988).

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[26] The discreteness in input-sharing rules arises directly from the cropshare rules because of the conditions shown in (4a and 4b) and (5a and 5b).

Using the Agricultural Stabilization and Conservation Service List of Producers, Johnson and Jannsen obtained a list of landowners and farmers in each county in Nebraska and South Dakota that participate in, or are eligible to participate in, federal commodity programs. (According to Steve Munk, USDA Extension Agent for Minnehaha County, South Dakota, nearly 100 percent of all farmers are eligible for these programs, so we can ignore any sample selection bias.) From this list, they chose a random sample of names; they sent the survey to 6,347 individuals in Nebraska and 4,111 in South Dakota. The response rate was 32% in Nebraska and 35% in South Dakota. In the dataset, the number of usable responses was 1,615 for Nebraska and 1,155 for South Dakota. Each observation represents a single farmer or landowner for the 1986 crop season.

For empirical testing we broke down the data into observations on individual contracts. This resulted in 2,101 observations for Nebraska and 1,331 for South Dakota. Ignoring cash rent contracts, we were left with 1,592 cropshare contracts for Nebraska and 834 for South Dakota, or a total of 2,426. We also omitted contracts for hay land and examined 1,628 cropshare contracts for annual crops.

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