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CONTRACT DURATION AND THE DIVISION OF LABOR IN AGRICULTURAL LAND LEASES

by

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ABSTRACT

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Short-term contracts provide weak incentives for durable input investment if post-contract asset transfer is difficult. Our model shows that when both agents provide inputs, optimal contract length balances weak incentives of one agent against the other. This perspective broadens the existing contract duration literature, which emphasizes the tradeoff between risk sharing and contract costs. We develop hypotheses and test them based on private grazing contracts from the Southern Great Plains. We find broad support for the implications of our model. For example, landowners provide durable land-specific inputs more often under annual versus multiyear contracts.

Keywords: land lease contracts, moral hazard, contract duration, division of labor.

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Abstract

Short-term contracts provide weak incentives for durable input investment if post-contract asset transfer is difficult. Our model shows that when both agents provide inputs, optimal contract length balances weak incentives of one agent against the other. This perspective broadens the existing contract duration literature, which emphasizes the tradeoff between risk sharing and contract costs. We develop hypotheses and test them based on private grazing contracts from the Southern Great Plains. We find broad support for the implications of our model. For example, landowners provide durable land-specific inputs more often under annual versus multiyear contracts.

1 Introduction

In his seminal article on agricultural land leases, Cheung (1969) discusses the choice of contract duration as a component of contract design. He argues that long leases are chosen when the costs of transferring tenant assets attached to the land are high, or if the depreciation of assets beyond the contract period are difficult to assess and therefore difficult to price for transfer to the landowner. On the other hand, short-term contracts reduce the costs of enforcing contract stipulations and the costs of renegotiation or tenant dismissal in the face of market uncertainties, poor tenant performance, or disputes over poorly defined rights to assets. When the tenant's land-specific assets are exhausted within the contract period or if the landowner provides the land-specific permanent assets, then short term contracts become more viable.

Agricultural contracts have been an epicenter of empirical research on contract design and analysis of the relative importance of risk preferences versus transaction costs as determinants of contract design (Rao, 1971; Allen and Lueck, 1995, for example).[1] This empirical literature has focused primarily on the choice between cash rent and crop share contracts, and on the parallel issue of input cost sharing as an element of contract design. The emphasis in this literature is the extent to which contracts are designed to address tradeoffs between aligning incentives by specifying parallel cost share arrangements on one hand and contracting costs on the other during the contract period.

Researchers have recognized an important distinction regarding how inputs are provided. In some cases, input costs are not readily shared, and "nonmarket" inputs are provided by either the tenant or the landowner directly (Reid, 1979; Eswaran and Kotwal, 1985; Allen and Lueck, 1993, for example). When these nonmarket inputs are part of contractual responsibilities, contract duration can become important. In particular, if the productive life of inputs extends beyond the contract period and if post-contract transfer of asset rights is difficult, the extent to which tenant or landowner becomes residual claimant of input productivity depends on contract duration. This affects incentives for input provision by each party to the contract.

The empirical literature examining the relationship between contract duration and the division of input responsibilities is thin. Allen and Lueck (1992) is one empirical analysis of agricultural land contracts that examines contract duration explicitly. Their premise is that the choice of contract length depends primarily on three factors: 1) mutual information about the reputation of contractees, 2) the existence of contract specific (sunk) assets and 3) the costs of contract renewal and of complex contingent contacts to address changing market conditions. Their point estimates show that their proxy for sunk assets (investment in irrigation) has a negative but statistically insignificant effect on the length of a contract. Although Allen and Lueck (1992) examine the determinants of contract duration and briefly discuss its relationship between the division of input responsibilities and contract duration, they do not empirically examine this relationship.

[1]Empirical studies on cost share contracts in other markets include Leffler and Rucker (1991) focusing on timber contracts and Hallagan (1978) on share contracting for gold, among others.

The objective of the present article is to examine the division of labor between landowner and tenant under limited-duration land lease contracts that require land-specific durable input investment. The model extends the existing literature in the following ways. First, it considers the effect of both the contract period and the post-contract period on incentives for input investment. Second, the model allows contract duration to be endogenous. Third, the model provides a basis for choosing for contact duration that is different from the existing literature on contract duration.

In regards to the literature on contract duration, two primary perspectives are of interest here. One perspective hypothesizes that the choice of contract duration pivots on the tradeoff between real or nominal market uncertainty on the one hand and transaction costs associated with renegotiation on the other (Rich and Tracy, 2004; Shelanski and Klein, 1995; Wallace and Blanco, 1991; Danziger, 1988; Crocker and Masten, 1988; Gray, 1978). Another focuses on the effects of relationship-specific assets on contract duration. For example, Joskow (1987) finds that length of coal supply contracts increases when relationship-specific assets are a dominant part of contracts. Our perspective is based on the importance of relationship-specific assets on contract length. When contracts involve two or more agents providing site-specific inputs, residual-claimancy will differ between the agents during and after the contract, and contract length may be chosen to balance the opposing incentives of the agents.

Our model provides simple and intuitive implications. In a short-term contract where nonmarket inputs with uncertain depreciation rates are provided but difficult to monitor, landowners will tend to be responsible for provision of durable land-specific inputs, whereas tenants will tend to be responsible for inputs whose productive value is fleeting. Furthermore, when one or more inputs are provided individually by each party, the optimal contract length is that which balances the marginal effects of weak incentives for input provision at the margin.

Implications of the model are empirically tested using data from Oklahoma statewide farmland leasing surveys conducted in 1998, 2000, and 2002. Most of the existing empirical research on farmland contracts focuses on leasing for annual crop production. In contrast, our data relate to private land leases for grazing rights on either native perennial pasture or annual wheat pasture. Livestock grazing requires the provision of inputs that are different than those for crop production including, among other things, an increased importance of investment in and maintenance of fences, labor for checking on the health and location of the livestock, and the provision of supplemental feed when pasture forage production is insufficient. Based on a battery of means tests and a Tobit regression applied to these data, we find broad support for our model. Thus, in addition to the contributions of the theoretical model, this article provides empirical results relating to a different type of land lease contract than those that have been widely studied, and is unique in its focus on the division of input responsibilities in short-term contracts.

2 Specific assets and the division of labor

In an arrangement in which costs, benefits, and resource allocation decisions are shared among two or more parties, resources may not be efficiently allocated if the contract does not assign expected net present value of benefits in the same proportion as the expected net present value of costs. The incentive to shirk on contracted input responsibilities result when full observation and monitoring of actions are either impossible or prohibitively costly (Holmstrom, 1979). Asymmetric information between contracting agents, output uncertainty and existence of many absentee landowners, each can play a role in monitoring problems. For example, in a grazing lease contract between a pasture owner and a livestock owner, if the landowner is responsible for checking livestock, the livestock owner cannot costlessly or perfectly detect landowner effort. Although the livestock owner can make some inferences about the landowner's effort from the status of the property at any given moment, this imperfect signal is not enough to induce fully efficient pasture-owner effort.

A model of the distribution of benefits and the incentives of landowners and lessees is developed in this section. The landowner and tenant are assumed to be identical except for their position in the contract as residual claimants. They have identical productive capacity for any given input, each is assumed to have the same (fixed) marginal opportunity cost for any given input. Mounting empirical evidence suggests that transaction costs rather than relative risk aversion are the primary determinants of contract structure (Leffler and Rucker, 1991; Allen and Lueck, 1999; Prendergast, 2002). We therefore assume risk neutrality for both parties to the contract, and further assume that objective of the contractees is to maximize the net expected returns to the land with respect to a specific input that is applied during the contract period. Following Stiglitz (1974) and others since, assume also that the value of production during the contract period and the post-contract period is stochastic.

We begin by examining the incentives of the tenant and landowner individually in a model with one input, provided by either one agent or the other. This one-dimensional input investment problem suffices to generate a number of testable hypotheses about the optimal choice of input provider. We then include another input to further examine optimal contract duration. Inputs are often provided by either the landowner or the tenant, but not both (about 93.5 percent of the total number of inputs in our survey sample). It is well known, however, that skewed incentives in share contracts can be corrected by equating the input cost share with the output cost share (Heady, 1971). We therefore consider the case in which costs and/or responsibilities for specific inputs are shared, as a relatively small percentage of our sample suggests. Allen and Lueck (1993) hypothesize and find evidence that the costs of market inputs provided by third parties are more likely to be shared in the same proportion as the output, while nonmarket inputs are more likely to be the sole responsibility of the tenant. We extend that argument to recognize that it may be best for the landowner to have sole responsibility for input provision, particularly for durable investments.

Inputs provided by only one agent

Consider the present value of production from a parcel of land in which one of the agents provide a one-time investment in an input x that depreciates in productive capacity at an expected rate of δ over time. Although the expected value of depreciation is known, the exact *ex post* rate is unknown *ex ante*. Therefore transfer of rights to the depreciated asset at the end of the contract is difficult. We assume a simple stochastic production process with expected value $f(x,t) = e^{-\delta t}\ln(x)$ for $x > 1$ (zero otherwise), input cost of c. The expected net present value of livestock production is

$$\begin{aligned} V &= \int_0^\infty e^{-rt}\left(e^{-\delta t}\ln(x)\right)\mathrm{d}t - cx \\ &= \frac{\ln(x)}{r+\delta} - cx \end{aligned} \tag{1}$$

where r is the interest rate, δ is the depreciation rate, x is the level of input investment, and T is the contract length, taken to be exogenous for now. The first-order condition for a maximum of V is

$$\frac{1}{x(r+\delta)} = c, \tag{2}$$

which implies efficient input demand

$$x^e = \frac{1}{c(r+\delta)}. \tag{3}$$

Suppose now that the landowner and tenant agree to either a fixed per acre cash rental payment, paid in full at the beginning of the contract, or a share contract under which each agent receives some share of the value of production under the contract. With a cash rent contract, landowner remuneration is not dependent on realized output from the current contract, but, given that uncertainty and contracting costs preclude explicit transfer of rights from tenant to landowner at the end of the contract, the landowner does benefit from any remaining productivity of the input after the contract expires.[2] In a share contract the landowner retains a share of the output for the contract period as well.

If the tenant receives share s of the value of production during the contract and the landowner receives share $1 - s$ plus all of the post-contract residual benefit, the benefit stream in equation 1 can be rewritten as

$$\begin{aligned} V &= \left[s \int_0^T e^{-(r+\delta)t} f(x,t)\mathrm{d}t \right] + \left[(1-s) \int_0^T e^{-(r+\delta)t} f(x,t)\mathrm{d}t + \int_T^\infty e^{-rt} f(x,t)\mathrm{d}t \right] \\ &= \left[\frac{\ln(x)}{(r+\delta)} s \left(1 - e^{-(r+\delta)T}\right) \right] + \left[\frac{\ln(x)}{(r+\delta)} \left((1-s)\left(1 - e^{-(r+\delta)T}\right) + e^{-(r+\delta)T} \right) \right] \\ &= [V^n] + [V^l]. \end{aligned} \tag{4}$$

Equation 4 is broken down into two parts: the first set of brackets contains the stream of value acquired by the tenant (V^n) and the second is acquired by the landowner (V^l). If the landowner provides the input, he will choose x^l to maximize the second element in brackets and will not account for the first element in brackets. The tenant does not benefit from input productivity after the contract has expired, and so will choose x^n to maximize the first element in brackets. The input demands for the tenant and the landowner are

$$x^n = \frac{s\left(1 - e^{-(r+\delta)T}\right)}{c(r+\delta)} \qquad \text{(tenant)} \tag{5a}$$

$$x^l = \frac{1 - s\left(1 - e^{-(r+\delta)T}\right)}{c(r+\delta)} \qquad \text{(landowner).} \tag{5b}$$

For a given input cost c, contract duration $T \in (0, \infty)$ and $s \in (0, 1)$, both the tenant and landowner provide less than the efficient input levels as described by equations 3.[3] The

[2] Symmetrically, if the inputs provide benefits that are specific to the livestock beyond the contract duration, then the livestock owner retains the benefits beyond contract expiration.

[3] Given the incentive problems inherent in the model as designed above, the value of production would not be maximized with a contract among two parties. The incentive problems would disappear and the value of production would be maximized if the livestock owner were also the landowner and also provided all inputs. Because this paper focuses on contracts themselves, however, we assume that a contract among two parties is optimal, rather than sole ownership and input provision by a single party. See Barzel (1989), chapter 3 for a discussion of the costs of sole ownership.

crucial point here is that each input provider is a partial residual claimant in the relationship, because contracts have limited duration, monitoring is too costly to perform, and input levels cannot be inferred exactly from output (Barzel, 2002).

The comparative statics for a change in input investment with respect to a change in contract duration T, output share s, and depreciation rate δ for the tenant and landowner respectively are:

$$\frac{\mathrm{d}x^n}{\mathrm{d}T} = \frac{se^{-(r+\delta)T}}{c} = -\frac{\mathrm{d}x^l}{\mathrm{d}T} \geq 0,$$
$$\frac{\mathrm{d}x^n}{\mathrm{d}s} = \frac{1-e^{-(r+\delta)T}}{c(r+\delta)} = -\frac{\mathrm{d}x^l}{\mathrm{d}s} \geq 0.$$

For compactness let $d = r+\delta$. The function $e^{-dT}(dT+1)$ falls in the unit interval for positive d and T. It follows that

$$\frac{\mathrm{d}x^n}{\mathrm{d}\delta} = -\frac{s\left(1-e^{-dT}(dT+1)\right)}{cd^2} < 0, \tag{6}$$
$$\frac{\mathrm{d}x^l}{\mathrm{d}\delta} = -\frac{1-s\left(1-e^{-dT}(dT+1)\right)}{cd^2}$$
$$= -\left[\frac{1}{cd^2} + \frac{\mathrm{d}x^n}{\mathrm{d}\delta}\right] < 0. \tag{7}$$

Equations 6 and 7 indicate that the depreciation rate reduces input investment for both the tenant and landowner, but for any increase in the depreciation rate, the landowner reduces input investment more than the tenant.

The effect of an increase in δ, T and s on the present value of profits can be seen most clearly through its effects on x^n and x^l. Note that

$$\frac{x^n}{x^l} = 1 \quad \text{at} \begin{cases} \tilde{\delta} = \frac{\ln\left(\frac{2s}{2s-1}\right)}{T} - r \\ \tilde{T} = -\frac{\ln\left(\frac{2s-1}{2s}\right)}{d} \\ \tilde{s} = \frac{1}{2(1-e^{-(r+\delta)T})} \end{cases}$$

Ceteris Paribus, the tenant underinvests more than the landowner if $\delta < \tilde{\delta}$, $T < \tilde{T}$, or if $s < \tilde{s}$.[4] Given that the total contract value V is maximized at x^e (the optimal input level for a decision maker who owns both the pasture and the cattle) and declines as the x deviates from it, it also follows that

$$V(x^l) > V(x^n) \text{ if } \begin{cases} \delta < \tilde{\delta} \\ T < \tilde{T} \\ s < \tilde{s} \end{cases} \quad (8)$$

Figure 1 shows the change in contract value with respect to a change in the depreciation rate δ. At low depreciation rates it contract value is maximized by placing the responsibility for input provision on the landowner.

[Figure 1 about here.]

The following testable hypotheses follow from the relationships shown by the inequalities (8):

Hypothesis 1. *As the output share to the landowner* $(1 - s)$ *increases, the landowner will more likely be responsible for input provision.*

Hypothesis 2. *As the longevity of input productivity increases (as depreciation rate decreases), the landowner will more likely be responsible for input provision.*

Hypothesis 3. *As contract length decreases, the landowner will more likely be responsible for input provision.*

Input cost sharing

As Allen and Lueck (1993) point out, nonmarketed goods are likely to be provided by either the tenant or the landowner, while the costs of market goods (provided by a third party)

[4] Given the specific functional forms used, $\tilde{\delta}$ is not defined for $s \leq 0.5$.

are more likely to be shared. With market goods, input cost shares should be designed such that each party provides inputs at efficient levels (represented by equation 2). The input shares that satisfy this condition for both the tenant and the landowner are

$$s^n = s\left(1 - e^{-(r+\delta)T}\right) \tag{9}$$

$$s^l = s(1-s)\left(1 - e^{-(r+\delta)T}\right). \tag{10}$$

An output share for the tenant of $s = 1$ induces less-than-efficient tenant input provision given no input cost-sharing, but a share of $s < 1$ leads to still less input provision. Therefore, the optimal input cost share for the tenant would be lower if the tenant's output share is less than one. This leads to one additional hypothesis:

Hypothesis 4. *If input costs are divisible (in the sense that it is optimal to divide the costs for a specific input), then input cost sharing will be more likely under share contracts than under cash rent contracts.*

It is worth emphasizing also that when input investment provides productive capacity beyond the contract period, optimal input and output shares will not be equal, as is the case when all benefits are accrued during the contract period (Heady, 1971). More specifically, if an asset is land-specific, the tenant's (landowner's) optimal input share is smaller (larger) than his output share.

3 Optimal contract duration

As mentioned in the introduction, this paper relates to the existing literature on relationship-specific assets and their effect on the choice of contract length. This literature generally finds that longer term contracts tend to be adopted to reduce the risk of expropriation of relationship-specific assets (Shelanski and Klein, 1995). On the other hand, the costs of longer term contracts are generally thought to be efficiency losses due to contract rigidities in the face of market uncertainty. Below we show an additional cost associated with longer contracts for cases in which input providers are not the post-contract residual claimants of remaining input productivity. To use the terminology of Williamson (1983), *site-specificity* applies to many investments associated with grazing leases, wherein the landowner is likely to be the residual claimant of of input productivity beyond the contract period. If both the tenant and landowner provide one or more inputs (and our data suggest they often do), contract length can be seen as a way to balance the opposing investment incentives of the parties.

To justify our argument, we revert back to the assumption that a given input is provided by one or the other party to the contact, and consider two inputs, one provided by the landowner (x_l) and one provided by the tenant (x_n), each with their respective depreciation rate, δ_l and δ_n.[5] Total output is now a function of fixed land and livestock and two variable inputs, such that the expected present value of production at one point in time t can be characterized as

$$V_2(t) = \mathrm{e}^{-(\delta_l+r)t} \ln x_l + \mathrm{e}^{-(\delta_n+r)t} \ln x_n,$$

and the expected present value of the infinite stream of production into the future can be simplified to

$$V_2 = \frac{\ln x_l}{\delta_l + r} + \frac{\ln x_n}{\delta_n + r}.$$

Because of separability in production, the input demands are identical to the previous input demand equations 5a and 5b, except that they include agent-specific depreciation rates.

Once the contract has been signed for a given pair of inputs with fixed depreciation rates, the tenant will choose to invest to the point where the marginal value of the input *for the duration of the contract only* is equal to marginal cost, and the landowner will choose to invest to the point where the marginal value of the input *for the period after contract*

[5] More generally, the analysis requires only that the input costs are not shared for a subset of the inputs. The result — an optimal contract length of finite duration — will still hold if the costs of some, but not all, inputs are shared. Notational comment: the input demands in the previous section were denoted with superscripts, while these are denoted by subscripts.

expiration equals marginal cost. Thus, the longer the contract, the weaker the incentive for the landowner, and the shorter the contract, the weaker the incentive for the tenant. Given that each provide inputs (and assuming necessary and sufficient conditions for a unique maximum are satisfied), some contract length will exist that maximizes the value of the contract by balancing the moral hazard effects.[6] From this perspective, contract design can be thought of intuitively as a two-step process: estimate the contract value for a set of feasible contract lengths and choose the contract that provides the highest expected value to be divided among the contractees.

[Figure 2 about here.]

Figure 2 provides an illustration of the result for two different sets of depreciation rates under the assumption that one input is provided by each agent. For this figure, a cash rent contract is assumed ($s = 1$) with marginal costs of 0.1 and an interest rate of 0.05. The solid line depicts a scenario in which the depreciation rates for both inputs are equal to 0.1, meaning that each productive capacity diminishes slowly. The consequence is a long contract of about 4 and a half years. In contrast, if the tenant provides an input that depreciates much more rapidly (in this example, with a depreciation rate of 0.9), then the optimal contract length is substantially shorter, at about 1.2 years. This short contract results in a larger proportion of the productive value of the input being captured by the landowner after the contract period, thus strengthening his investment incentive.

It is clear from this analysis that when conditions make cost-sharing and post-contract asset transfer difficult, contract length may be determined in part by trading off efficiency losses from poor investment incentives of each agent. Although our data do not allow explicit testing of this perspective on contract duration, it is useful for comparison to the more common perspective on contract duration that emphasizes the tradeoff between transaction costs and the costs of contractual rigidities under market uncertainties. These two perspec-

[6] A working paper by Barzel (2002) provides a discussion somewhat similar to our argument in this section, but in a different context.

tives on contract duration are not mutually exclusive, and their relative importance in terms of contract design is an empirical issue.

4 Data and testing methods

Data to test hypotheses 2 – 4 were obtained from the Oklahoma statewide farmland leasing surveys conducted in December of 1998, 2000 and 2002 (Doye et al., 1999, 2001, 2002) Questionnaires were mailed to individuals involved in farming in Oklahoma. The 1998, 2000, and 2002 surveys included useable observations of 536, 568 and 552 respectively. Each questionnaire includes a section that focuses on wheat pasture grazing leases, and another section that focuses on other pasture leases. Each observation in the dataset created from the survey responses represents a single lease contract between a tenant and a landowner for a grazing lease in which the tenant is the livestock owner and the landowner is the pasture/forage owner. Summary statistics for all variables used are shown in Table 1.

[Table 1 about here.]

The data used on the analysis below include information on

- the type of payment from the tenant to the landowner,
- the duration of the contract (annual or multi-year),
- a list of common inputs and who is responsible for providing them,
- the type of pasture.

With regard to the type of payment, respondents were asked to identify rental price payment method based on a set of alternatives. If the payment method was $/acre/year or $/acre/month or $/head/month, the contract was classified as a cash rent contract because it is based on input usage, not output levels. If the method was $ per pound of gain, $ per pound of weight per month, or partnership, the contract was considered a share contract.

A list of specific input-related tasks is also provided in the questionnaire, and respondents were asked to specify whether the landowner, the tenant, or both were responsible for each of the tasks listed. This analysis focuses on input durability in relation to contract duration, so of the inputs listed, we focus on those inputs that seem either durable and fixed (with benefits from investment that may extend beyond the contract and accrue to the landowner), or are fleeting (accrue during the contract to the current tenant). The input information we use includes who (the tenant or the landowner) provides the following inputs: *fencing materials*, *fencing labor*, *checking livestock*, *supplemental feeding*, *supplemental pasture*, and *fertilizer cost*. There are two important pasture types: *wheat pasture*, and other pasture or range, which we will refer to as *native pasture*. Wheat is an annual grass, and winter wheat grazing is a common practice in the southern Great Plains. Cattle are placed on wheat pasture during early wheat development, and removed prior to a specific developmental stage called first jointing, after which point grazing will substantially negatively affect wheat grain production. Native pasture includes native grasses, bermuda grass, Old World bluestem, and fescue – each of which are perennial grasses.

We hypothesize that of all inputs, *fencing materials* are most durable (small δ). Fencing labor often must be applied in a timely manner, and the benefits of timeliness will generally accrue to the current tenant, so δ is larger. Checking livestock is hypothesized to be mostly of benefit to the current tenant, and again, timeliness is likely to be important. Supplemental feeding is a bit more complex. Benefits surely accrue to the tenant, because it will affect livestock weight gain. However, supplemental feed also may benefit the landowner to the extent that it reduces overgrazing in worse-than-expected forage conditions, because long-term forage productivity can be diminished on rangeland as a consequence of overgrazing Ellison (1960). The type of pasture matters, however. In particular, excessive pressure on perennial grasses may have substantial long-term impacts, but it may have little or no long-term effects on annual wheat.[7]

[7]The pasture owner could conceivably be affected by the impact of overgrazing on wheat yield. However, evidence suggests that grazing wheat has little impact on wheat yield as long as the cattle are removed

We perform two types of tests for the hypotheses listed above. We begin with simple tests for differences in the proportion of contracts for which the landowner provides an input for given different conditions (e.g. pasture type) or contract type (e.g cash rent or share contract). We then estimate Tobit regressions to control for other factors that might affect the probability of one outcome or another.[8]

From a theoretical perspective, we implicitly employ a random utility model framework. As researchers, we do not perfectly observe the variation in contract value as a function of input choice, but the theoretical model suggests, that variation will lead to different assignments of input responsibilities. Based on this framework, if a significantly higher proportion of landowners (rather than tenants) provide an input under condition A as compared to condition B, it is because the value of contract tends to be higher when the landowner provides the input under condition A.

For the means test, let n_i be the number of contracts for which the landowner provides an input under condition $i = 1, 2$. The sample proportion of contracts for which landowner provides the input is $p_1 = n_i/n_{i+}$,where n_{i+} is the total number of contracts under condition i. The sample proportion p_i has a binomial distribution with standard error $se(p_i) = \sqrt{p_i(1 - p_i)/n_{i+}}$. Assuming the two groups represent independent binomial samples, their difference is $d = p_1 - p_2$, for which the standard error is $se(d) = \sqrt{\text{var}(p_1) + \text{var}(p_2)}$. Using the normal approximation to the binomial distribution, the test statistic is calculated as $z = d/se(d)$, where z has a standard normal distribution. If z is sufficiently large such that the p-value is less than the chosen critical value, the null hypothesis of $d = 0$ is rejected (Agresti, 1990). Because our hypotheses imply one sided alternative hypotheses, we provide p-values for one-sided and two-sided tests. See (Greene, 2003, pp. 764-768) for a discussion of Tobit regression. The econometric software Stata (2004) was used for all means tests and regressions.

before a specific point in the wheat maturation process known as first hollow stem (Hossain et al., 2003).

[8]We have no information regarding input shares for the cases in which the respondent reported that both the tenant and landowner a specific input. We therefore omit these observations for our analyses to focus on those inputs for which a clear distinction about the input provider is reported.

5 Results and discussion

We examine the division of input responsibilities in a number of ways: 1) We examine the effects of output share on input provision, 2) we compare the relationship between input durability and input provision, 3) we examine the differences in input provision in short- versus long-term contracts, 4) we compare input provision associated with perennial versus annual forage, and 5) we examine the effects of various contract characteristics on the total number of inputs provided by the landowner.

Effects of output share on input responsibilities

Table 2 provides results of t-tests for differences in the proportion of contracts for which only landowners are responsible for inputs under share contracts (p_1) and cash rent contracts (p_2).

[Table 2 about here.]

Based on hypothesis 1, the signs of the differences $p_1 - p_2$ should be positive in each case, and the results are consistent with the hypothesis in this respect in every case: Inputs were provided more often by landowners for share contracts than for cash rent contracts. For example, landowners provided all fencing materials in about 57 percent of share contracts but only 34 percent of cash contracts — a statistically significant difference of about 23 percent.

For a relatively small percentage of inputs, about 6.5 percent, both the tenant and the landowner are responsible for input provision. Table 3 provides tests that the proportion of contracts in which inputs are provided by both parties is different for share contracts (p_1) than for cash rent contracts (p_2). If contracts attempt to align input shares with output shares according to hypothesis 4, we should see $p_1 - p_2 > 0$.

[Table 3 about here.]

The proportion of fencing materials and labor provided by both parties is not statistically different between cash rent and share contracts. However, the results for the rest of the inputs are consistent with theory. For example, supplemental feed is provided by both parties in share contracts about 9 percent of the time but only about 4 percent of the time in cash rent contracts. Thus, although input responsibilities are shared relatively rarely in this sample, they tend to be shared in share contracts more so than in cash rent contracts. The insignificance of the tests for fencing materials and labor is interesting. One potential explanation for this result relates to the longevity of investment in fences. As the longevity of fencing increases, the optimal input cost share for the tenant declines. Similarly, as the output share to the tenant declines, so does the optimal input share.

In the case of a long-lived input, the optimal tenant input share may be so small that the efficiency gains are not worth the effort it takes to divide the input responsibilities.[9] In this case, it may make sense more sense for the landowner to provide all of an input under a share contract, but for input responsibilities to be shared under cash rent contract. This corollary to hypothesis 4 is supported by an additional pair of tests based on the more durable inputs of fencing materials and fencing labor. The tests use a truncated sample that excludes those observations for which only the tenant provides the input. Based on this sample, we test whether the proportion of contracts with an input provided by only the landowner is different from the proportion of contracts with an input provided by both agents. fencing costs are shared for inputs significantly more under cash rent contracts than under share contracts. For fencing materials, $p_1 - p_2 = -0.113$, with a two-sided p-value of 0.0072. For fencing labor, $p_1 - p_2 = -0.151$, with a two-sided p-value of 0.0017. These two results are much larger (in absolute value) than the negative but statistically insignificant differences presented in Table 3.

[9]Specifically, in equation 9, if δ is very small and s is small, then s_n will be small.

Inputs of different durability

Consider fencing materials and fencing labor. The quality of fencing materials affects the durability of a fence, and the productive life of these materials are likely to extend beyond a one or even a five year contract. Fencing labor affects the longevity of a fence, but importantly, the timeliness of fencing repair (fencing labor) may clearly affect the containment of the current livestock herd. If fencing labor is not applied in a timely manner livestock are likely to escape, creating a hazard for the livestock, additional work collecting them, and even liability concerns. Thus, we hypothesize that fencing labor has, generally, a more immediate value (larger δ) and is more likely to be provided by the livestock owner than is fencing materials. This hypothesis is a specific case of the general hypothesis 2 on page 9.

Using the same logic, we hypothesize that the benefits of fertilizer application, provision of supplemental feed and pasture, and checking livestock have increasingly short-duration or more timely benefits, and therefore will also more likely be provided by the livestock owner than will fencing materials. Table 4 shows the results of tests that compare the proportion of contracts in which fencing materials were provided by the landowner (proportion p_1) with the proportion of contracts in which fencing labor, fertilizer, supplemental feed, supplemental pasture, and livestock monitoring were provided by the landowner (proportion p_2). In each case, the hypothesized difference in proportions $p_1 - p_2$, is positive.

[Table 4 about here.]

The results presented in Table 4 strongly support the hypotheses discussed above, with positive differences $p_1 - p_2$ in each case. For example, landowners provide fencing materials approximately 38 percent of the contracts, but are responsible for checking livestock in approximately 24 percent of the contracts, for a difference of approximately 14 percent.

Notice also that the inputs in Table 4 are arranged so that the differences increase with the row number. This arrangement provides an ordering of input types that seems quite consistent with increasingly less durable inputs.

Differences between annual and multiyear contracts

Incentives of tenants to provide durable site-specific inputs are weakest for short contracts and stronger for longer contracts. Similarly, landowners have weaker incentives to provide inputs during a longer contract — particularly a cash rent contract — because the benefits will accrue more to the tenant. Therefore, we expect landowners to provide inputs more often for annual contracts than for multi-year contracts for durable inputs, and zero for non-durable inputs (hypothesis 3).

Table 5 shows the results of tests that the proportion of a given input provided by the landowner is larger for annual contracts than for multi-year contracts. These comparisons of input provision between annual and multi-year contracts are likely to be particularly sensitive to whether or not the contracting parties have long term relationships beyond the duration of the contract. We expect that individuals with no long term relationships face pronounced moral hazard issues, because the effects of shirking are less likely to carry over into other aspects of their relationship, including future contracts. Therefore, we have included two sets of results. The first is based on the entire sample, and the second is based only on the 2002 sample, because the 2002 survey is the only one in which the respondents were asked if the parties to the contract were related. We do not have this information for the other years. Whether or not the parties to the contract have familial ties is an imperfect measure of long term relationships, but it is a strong indicator, nonetheless.

[Table 5 about here.]

Consider the difference in the proportion of annual contracts versus the proportion of multiyear contracts in which the landowner provides fencing materials. Based on all contracts, landowners provide fencing materials 7.5 percent more often for annual contracts than for multiyear contracts because, as we hypothesize, they have stronger incentives at the margin to invest in durable fences. For unrelated parties, the difference is about 12 percent. The results presented in Table 5 are consistent with our theory in three ways. First, all differences in proportions that are statistically significant are positive as hypothesized. The only negative signs are not significantly different from zero at conventional significance levels. Second, the differences in proportions are largest for fencing materials, fencing labor, and fertilizer provision, which we maintain are those inputs with the highest durability. Third, even though the sample size is substantially smaller for tests based on unrelated parties only, all differences in proportions are positive as hypothesized, and the three inputs highest potential for long term effects are positive at conventional levels of significance.

Allen and Lueck (1992) test whether annual contracts are less likely on irrigated land than in non-irrigated land, based on the maintained hypothesis that investment in irrigation technology opens up contractees to rent appropriation. They find a negative but statistically insignificant relationship between irrigation and annual contracts. The negative relationship is consistent with our view of long-term investment in land-specific assets *if* landowners were the party responsible for investment in irrigation technology. Allen and Lueck (1992) do not, however, have information in the division of irrigation input responsibilities, and so were unable to make this distinction.

Conservation and investment for annual versus perennial forage

Declining ecological condition on rangeland and pasture is a common consequence of overgrazing (Ellison, 1960). Native grassland in particular may suffer substantial long-term negative effects in terms of the land's productive capacity due to overgrazing. In contrast, overgrazing is not likely to be a major problem on wheat pasture because it is an annual crop; overgrazing this year will most likely not affect next year's grazing or wheat production nearly as much as on perennial grasses.

From this point of view, it can be argued that supplemental feed and supplemental pasture have a lower δ for native grassland and other perennial grasses than for (annual) wheat pasture. Landowners of native pasture will be more concerned about long-term pasture productivity on native perennial grasses than on wheat pasture, and so will more often be responsible for supplemental feed and supplemental pasture for native grassland than for wheat pasture leases. This is essentially a restatement of hypothesis 2, where input durability plays a role as an investment in future forage productivity.

The same logic can be applied to fertilizer application, but one important difference exists between fertilizer application and supplemental feed. On wheat pasture, fertilizer affects forage production, but it has the important effect of increasing this years wheat grain production, for which the landowner — not the tenant — is the residual claimant.[10] Thus, if the marginal value of fertilizer for wheat production tends to overpower the marginal value of fertilizer for future (post-contract) perennial grass production, then the landowner will be more likely to provide fertilizer on wheat pasture. In a sense, even if the grazing contract is cash rent, the benefits from fertilizer application of wheat pasture are shared even in the short term, so the landowner is more likely to provide it than otherwise (hypothesis 1).

[Table 6 about here.]

Table 6 provides results of tests for differences in the proportion of perennial versus wheat pasture contracts in which the landowner provides supplemental feed, supplemental pasture, and fertilizer. The expected difference $p_1 - p_2$ is positive for supplemental feed and pasture. The sign of $p_1 - p_2$ for fertilizer is negative if the marginal value of fertilizer for annual wheat yield outweighs the marginal value of fertilizer for long term (post-contract) forage productivity.

The results for supplemental feed are strong and consistent with theory. For example, pasture producers provide supplemental feed for perennial pasture almost 6 percent more often than for wheat pasture when all observations (including both annual and multiyear contracts) are included. The results for supplemental pasture are not inconsistent with hypothesis 1, but are odd in that the expected effect is strong in multiyear contracts, but insignificantly different from zero for annual contracts. The results for fertilizer show that

[10]It is sometimes the case where grazing land involves three people: a landowner, a wheat-growing tenant, and a livestock owner. We do not have information to distinguish cases such as these, so we treat the landowner and pasture producer as the same, even though they may be different individuals.

pasture owners are much more likely to provide fertilizer on wheat than on perennial pasture, which strongly suggest that the short-run shared benefits of fertilizer far outweigh the longer-run incentives for benefits to perennial forage.

Tobit regressions

To summarize the relationship among different components of grazing contracts, we estimate a regression on the number of inputs (out of 8) provided by the landowner in a given contract, as a function of other contract characteristics. The results are presented in Table 7. The binary explanatory variables include whether or not the contract is annual or multi-year (*annual*), whether or not the contract was written or oral (*written*), whether or not the contract is a rent (*cash*) or a share contract (*share*), and whether or not the contractees are related by family (*related*). Regression 1 includes each of these independent variables, but because there are numerous missing observations on *cash* and *related* we have included two additional regressions. Regression 2 omits *related* and regression 3 omits *related* and *cash*.

The dependent variable in each regressions is the natural log of the number of inputs, out of a total of eight, that are provided by the landowner. In each case, the regression analysis is based on the Tobit model with censoring at zero and eight, because in a substantial proportion of the contracts the landowner provided either all or none of the inputs.[11] The variable *written* is a dummy variable that takes the value of one for written contracts and zero for oral contracts. This is included because, we hypothesize, the preference for written contracts may signal that the contractees are less familiar with each other, which may

[11]For contracts in which the landowner provided no inputs, the zero value was replaced with 0.0001 for a finite natural log. A log transformation is used because preliminary regressions showed an improved fit. Given this specification, the estimated percent changes of the dependent variable for these binary variables in the Tobit regressions are

$$\frac{\Delta \ln(y_i)}{\Delta d_j} = \Phi\left(\frac{\boldsymbol{\beta}'\mathbf{x}_i}{\sigma}\right) \cdot (\exp([\beta_j - 0.5v_j] - 1))$$

where d_j is the j^{th} dummy variable, v_j is the estimated variance of the coefficient β_j for the j^{th} dummy variable, and $\Phi(\cdot)$ is the standard normal cumulative density function. See Van Garderen and Shah (2002) for details about estimating dummy variable effects in log linear models and Greene (2003) for details of the Tobit regression model.

affect the degree of expected cooperation and shirking in input investments. The variable *related* is included for the same reason — to account for the influence of potential long-term relationships among contractees.

[Table 7 about here.]

Recall that when input investment provides benefits beyond the duration of the contract, landowners will have a stronger incentive for investment than otherwise, so for a given set of inputs, landowners will have stronger incentives for input investment with shorter contracts (hypothesis 3). In all three cases, the coefficient on *annual* is positive (and significant for the larger sample sizes. The variable *written* has no apparent effect on the general incentive for landowner provision of inputs.

Holding contract duration constant, landowners are expected to provide inputs more often in share contracts than in cash rent contracts (hypothesis 1). The negative (and significant) coefficients on *cash* are consistent with this hypothesis.

Finally, the coefficient on *related* is negative and significant, suggesting that tenants provide inputs more often when the contractees are related. This might suggest that the potential to shirk on durable-input investment is a more substantial problem than investment in inputs of short-term value.

In summary, the results presented in the three Tobit regressions in Table 7 are qualitatively consistent with theory.

6 Conclusion

The relationship between contract duration, input longevity, and the division of input responsibilities is an important aspect of contract design that has received relatively little attention in the large literature on agricultural land lease contracts. Benefits from agricultural inputs may extend beyond the contract period, and when private actions cannot be monitored or inferred exactly from output and property rights to assets are not readily transferred at the end of the contract, each party is a partial — not complete — residual claimant of input investment, so private input incentives are weak, and do act to maximize total contract value.

Our theoretical model focuses on the relationship between contract duration and input investment. We show that in order to maximize contract value, landowners are more likely to be the input provider for shorter contracts, for durable site-specific inputs, and for share contracts rather than cash rent contracts. Further, we show how contract duration can chosen to balance optimally balance the weak investment incentives of each agent.

We test implications of the model using data on grazing leases of the Southern Great Plains of the United States. We test for differences in the proportion of contracts for which landowners provide inputs under various conditions, and we estimate a series of Tobit regressions that model the probability that the landowner provides a given input. The results are generally consistent with the hypotheses that follow from our theory. Landowners tend to take responsibility for inputs that have long-term consequences and when they accrue a share of the output during the contract period. Tenants tend to have responsibility for inputs that have short-term consequences and for cash rent contracts.

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Figure 1: Change in contract value with respect to a change in the depreciation rate δ. Tenant investment x^t is lowest for low depreciation rates and landowner investment is lowest for high depreciation rates. Evaluated at $s = 1$, $c = 0.1$, and $T = 4$.

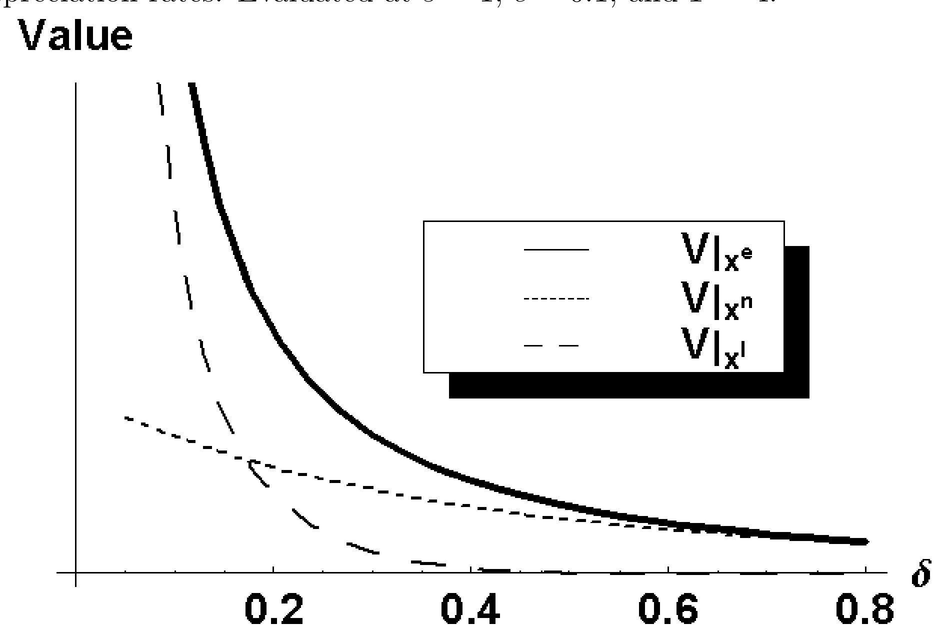

Figure 2: Different contract durations for different depreciation rates δ. Long contracts are associated with lower depreciation rates for landowner-provided inputs. Value functions have been normalized for graphical comparison. See text on page 12 for specification details.

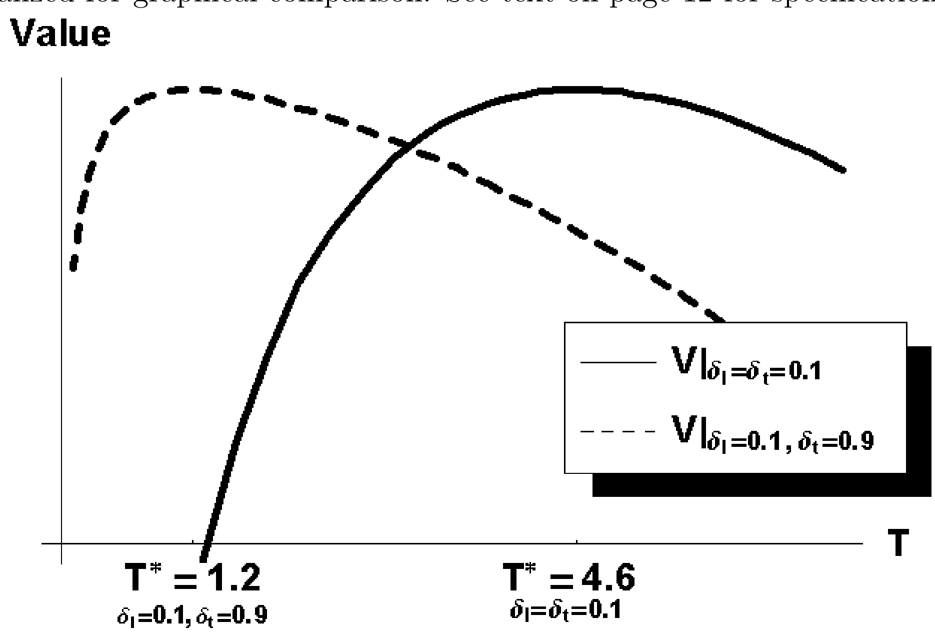

Table 1: Summary Statistics. Sample Proportions. One minus the value is the proportion for the alternative.

Proportion	Obs	Mean	Std. Dev.	Min	Max
Written contract	1656	0.37	0.483	0	1
Annual lease	1656	0.628	0.483	0	1
Wheat, annual grasses	1656	0.266	0.442	0	1
Cash rent	1656	0.294	0.456	0	1
Related parties (2002 only)	552	0.185	0.388	0	1
Pasture owner checks livestock	1656	0.242	0.428	0	1
Pasture owner provides fence materials	1656	0.352	0.478	0	1
Pasture owner provides fencing labor	1656	0.299	0.458	0	1
Pasture owner provides fertilizer	1656	0.307	0.461	0	1
Pasture owner provides supplemental feed	1656	0.231	0.422	0	1
Past. owner provides supplemental pasture	1656	0.235	0.424	0	1

Table 2: Tests of whether inputs are provided by only the pasture owner more often in share contracts (p_1) than cash rent contracts (p_2). Predicted difference in proportions is $(p_1 - p_2) > 0$. N=680 for all tests, unequal variances assumed.

	Share p_1	Cash p_2	Difference $p_1 - p_2$	$H_a : p_1 - p_2 \neq 0$ p-value	$H_a : p_1 - p_2 > 0$ p-value
Fencing materials	0.571	0.339	0.2318	0.0000	0.0000
Fencing labor	0.498	0.238	0.2597	0.0000	0.0000
Supplemental feed	0.239	0.170	0.0685	0.0479	0.0239
Supplemental pasture	0.307	0.175	0.1326	0.0004	0.0002
Check livestock	0.268	0.118	0.0872	0.0151	0.0075
Fertilizer	0.619	0.238	0.3816	0.0000	0.0000

Table 3: Tests of whether inputs are provided by both the tenant and landowner more often in share contracts (p_1) than cash rent contracts (p_2). Predicted difference in proportions is $(p_1 - p_2) > 0$. N=680 for all tests, unequal variances assumed.

	Share p_1	Cash p_2	Difference $p_1 - p_2$	$H_a: p_1 - p_2 \neq 0$ p-value	$H_a: p_1 - p_2 > 0$ p-value
Supplemental feed	0.093	0.042	0.0506	0.0241	0.0120
Supplemental pasture	0.068	0.040	0.0283	0.1545	0.0772
Check livestock	0.137	0.048	0.0882	0.0008	0.0004
Fertilizer	0.151	0.067	0.0839	0.0026	0.0013
Fencing materials	0.088	0.114	-0.0259	0.2934	0.8533
Fencing labor	0.073	0.095	-0.0216	0.3417	0.8291

Table 4: Tests for differences between proportions of hypothesized most durable input (fencing materials) provided by landowner (p_1) versus proportion of less durable inputs provided by the tenant (p_2). Expected difference $p1 - p2 > 0$. P-values are for two sided tests: $H_a : p1 - p2 \neq 0$.

Fence materials: $p_1 = 0.3798$, N=1040			
Other input	p_2	$p_1 - p_2$	p-value
Fencing labor	0.324	0.0558	0.0001
Fertilizer	0.3067	0.0731	0.0000
Checking livestock	0.2394	0.1404	0.0000
Supplemental pasture	0.2337	0.1461	0.0000
Supplemental feed	0.2269	0.1529	0.0000

Table 5: Tests for differences in proportions of annual (p_1) and multiyear (p_2) contracts in which inputs are provided by the landowner. Expected difference: $p1 - p2 > 0$.

	Annual p_1	Multiyear p_2	Difference $p_1 - p_2$	H_a: $p_1 - p_2 \neq 0$ p-value	H_a: $p_1 - p_2 > 0$ p-value
All observations (N=1656)					
Fencing materials	.380	.305	.0746	0.0018	0.0009
Fencing labor	.307	.286	.0210	0.3644	0.1822
Fertilizer	.324	.278	.0464	0.0452	0.0226
Supplemental feed	.227	.239	-.0117	0.5868	0.7066
Supplemental pasture	.234	.237	-.0033	0.8764	0.5618
Check livestock	.239	.245	-.0057	0.7937	0.6031
Unrelated parties only (N=450)					
Fencing materials	.418	.298	.1192	0.0084	0.0042
Fencing labor	.297	.229	.2667	0.1006	0.0503
Fertilizer	.333	.253	.0796	0.0644	0.0322
Supplemental feed	.169	.164	.0044	0.8989	0.4495
Supplemental pasture	.180	.174	.0066	0.8559	0.4279
Check livestock	.177	.169	.0075	0.8335	0.4168

Table 6: Tests for differences in proportions of supplemental feeding, supplemental pasture, and fertilizer provided by the landowner for native grass versus wheat pasture.

	Perennial p_1	Wheat p_2	Difference $p_1 - p_2$	H_a:$p_1 - p_2 \neq 0$ p-value	H_a:$p_1 - p_2 > 0$ p-value[a]
			All observations (N=1656)		
Supplemental feed	.247	.188	.0587	0.0088	0.0044
Supplemental pasture	.237	.229	.0080	0.7328	0.3664
Fertilizer	.256	.447	-.1908	0.0000	1.0000
			Annual contracts (N=1040)		
Supplemental feed	.241	.186	.0554	0.0524	0.0262
Supplemental pasture	.228	.250	-.0219	0.4753	0.7624
Fertilizer	.259	.515	-.2561	0.0000	1.0000
			Multiyear contracts (N=616)		
Supplemental feed	.257	.192	.0653	0.0729	0.0364
Supplemental pasture	.253	.198	.055	0.1321	0.0660
Fertilizer	.251	.345	-.0941	0.0237	0.9881

[a]P-value for $H_a : p_1 - p_2 < 0$ is one minus the reported p-value.

Table 7: Tobit regressions. Dependent variable: log of the number of inputs (out of 8) provided by the landowner only. Standard errors in parentheses.

	Tobit 1	Tobit 2	Tobit 3
Annual	2.021	1.694**	2.167***
	(1.352)	(0.847)	(0.673)
Written	1.275	0.641	0.037
	(1.397)	(0.809)	(0.666)
Cash	-4.017***	-4.694***	
	(1.241)	(0.827)	
Related	-5.805***		
	(1.653)		
Constant	-2.845**	-4.139***	-9.330***
	(1.230)	(0.999)	(0.623)
$\hat{\sigma}$	6.272***	9.240***	11.744***
	(0.523)	(0.416)	(0.389)
N	137	680	1656
Uncensored	89	335	655
Pseudo-R^2	0.0446	0.0125	0.0016

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$