Moral Hazard and the Division of Labor in Agricultural Land Leases[*]

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Many producers use leasing of agricultural land as a management strategy to conserve limited capital, expand their operation, or to reduce risk. The contractual form of land leases can vary depending on the type of crop, prevailing technology, market structure, and other characteristics of the social and economic environment (Eswaran and Kotwal, 1985). The USDA reported that 41% of U.S. farmland was operated under lease agreements in 1997 compared to 35% in 1950 (Hoppe and Wiebe, 2002).

Analysis of agricultural land lease arrangements has been a focus of economists since the early writings of Adam Smith and John Stewart Mill (Dasgupta et al., 1999). However, substantive empirical analysis on agricultural lease contracts represents a much younger and smaller literature (Allen and Lueck, 1992; Dasgupta et al., 1999).

The objective of this article is to model the incentive effects of the division of labor between landlord and tenant for production under limited-duration land lease contracts. The model provides an intuitive result: landlords will be responsible for provision of durable and landholding specific inputs, whereas tenants will tend to be responsible for inputs whose productivity is fleeting. Implications of the model as applied to specific production settings are then empirically tested using data from Oklahoma statewide farmland leasing surveys conducted in 1998 and 2000. There are many studies done on the reasons for the existence of various contractual forms (Alston and Higgs, 1982; Janssen et al., 2002; Otsuka and Hayami, 1988; Stiglitz, 1974). However, whatever the contract type, lease agreements and negotiations involve assignments of responsibilities to supply relevant inputs and tasks to the contracting parties of landlord and tenant. To our knowledge, little or no empirical work has focused on the division of labor and responsibility for input provision in agricultural land contracts.

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Some empirical studies have found that landlords expect tenant moral hazard. Kauffman (1993) finds that southern landlords were willing to pay extra to buy mules because they were a type of physical capital which could stand potential neglect and abuse from the tenants. Moral hazard can also take form as a mistiming in transplanting or a wrong fertilizer mix application, which can have negative consequences in future land productivity (Eswaran and Kotwal, 1985). It is also possible for the tenant to under-invest in inputs that have productive benefits beyond the lease term. The theoretical literature has shown that farmland owners usually have strong incentives to conserve soil as a means of protecting the land value over the long run, whereas tenants are concerned with investments in maintaining productivity only over the expected life of the contract (Lichtenberg, 2001). The landlord may also refrain from applying the long-term optimal level of an input, when the productivity of that input is solely for the lease term. This kind of behavior on the part of both parties is a phenomenon not yet fully explored in the literature (Eswaran and Kotwal, 1985).

Effects of moral hazard on 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 landlords, each can play a role in monitoring problem. For example, in a grazing lease contract between a landlord (pasture owner) and a cattle owner, if the landlord is responsible for checking cattle, the cattle owner cannot costlessly or perfectly detect landlord effort. Although the cattle owner can make some inferences about the landlord's effort from the status of the property at any given moment, this imperfect signal is not enough to induce fully efficient landlord effort.

A model of the distribution of benefits and the incentives of landowners and lessees is developed in this section. The incentives and welfare effects of shirking by both tenant and landlord are examined. The model encompasses both crop-share and cash-rent contracts, which affects the implications of the model. The landlord and tenant are assumed to be identical except for their position in the contract: they have identical productive capacity for any given input, each is assumed to have the same (fixed) marginal opportunity cost for any given input, both landlord and tenant are assumed to be risk neutral.[1] These assumptions are maintained to emphasize the impact of contract duration and input durability on the incentives of tenant and landlord.

Assume that the value of production during the contract period and the post-contract period is stochastic, and that the objective is to maximize the net expected

[1] Reliance on relative risk aversion is dubious at best in this type of setting. As pointed out by Allen and Lueck 1992, it is common for landowners to lease land elsewhere, making individuals both landlords and tenants simultaneously. This requires differences among individuals. Our approach requires differences only in the position of an individual as a party in a specific contract.

returns to the land, V, with respect to a specific input x that is applied during the contract period. Efficient input provision is found by maximizing

$$
\begin{aligned}
V(x) &= s_o V_1\big((1\text{-}d)x\big) + (1\text{-}s_o)V_1\big((1\text{-}d)x\big) + V_2(dx) - wx \\
&= V_1\big((1\text{-}d)x\big) + V_2(dx) - wx,
\end{aligned} \tag{1}
$$

where

- x is a composite input applied during the lease period that includes both quantity and quality.
- V_1 is the net returns to land during the lease period; V_2 is the net present value of returns to land after the end of the lease period, both of which are affected by the level of the variable input x.
- s_o is the tenant's share of first-period output V_1, $(1\text{-}s_o)$ is the landlord's share of V_1,
- d is the proportion of the applied input that remains after the end of the lease period
- w is the exogenously determined per unit opportunity cost of the input.

The range of the depreciation variable d is $0 \le d \le 1$. A value $d = 0$ means the applied input is fully used in the contract period and no productivity is left from that input after the contract period ends. For example, all the benefits from using a mineral supplement for livestock in a pasture-grazing lease will be captured during the lease period. Hence, livestock mineral supplement has $d = 0$. A value of $d > 0$ means that the proportion d of the applied input carries over to the period after the lease ends. When fencing materials are used in the field during the lease period, some portion of those will be used during the lease period, but some of the productivity from a permanent fence may remain after the lease terminates. Therefore, for a one year lease, the d for permanent fencing materials may be greater than zero.

The value of s_o depends on the form of the contract agreement. The range is $0 < s_0 \le 1$. If $s_o = 0$, then it can not be considered a lease contract between a landlord and a tenant; it may be that a laborer is hired (fixed-wage) by the decision making farmer to help with farming chores, which is not relevant in this case. For a cash-rent tenancy contract, s_o will be equal to one. In a cash-rent contract, the tenant pays a lump-sum fee to the landlord for the contract and receives all the value during the contract period. For a crop share tenancy contract: $0 < s_o < 1$.

Assume that the contract is specified at the beginning of the period and is not renegotiable at any point, and that although input responsibilities are specified in general terms, the exact level of inputs required for any given setting is not specified in the contract. Recall that output is stochastic, so that input provision is not exactly inferable from output; also assume that input provision by one party is costly to monitor, so that monitoring is incomplete. These two characteristics, along with the incomplete nature of the contract, allow for shirking.

Given a cash-rent contract, the tenant receives 100 percent of the returns to land and inputs during the contract period (the landlord receives nothing but the up-front cash-rent). After the contract period is over the landlord receives any residual net present value of production, the ex-tenant receives nothing more. For a share contract, the tenant and landlord each receives a share of the value of production during the contract period, but the landlord retains any residual returns after the contract period. The consequence of this division of the value of output is that tenants and landlords will have different incentives for input investment. At this point, we will introduce the possibility of adding input cost shares such that the tenant pays s_i of the total cost of x, the landlord pays (1-s_i).[2] Given that the tenant has responsibility for providing the input, the objective function for the tenant is:

(2) $\max_x \; V_T(x) = s_o V_1\big((1-d)x\big) - s_i wx$

The landlord receives (1-s_0) of the contract period benefits V_1 and all of V_2 (after the lease period ends) and shares (1-s) portion of the input cost. The objective function for the landlord is:

(3) $\max \; V_L(x) = (1\text{-}s_0)V_1\big((1\text{-}d)x\big) + V_2(d\,x) - (1\text{-}s_i)wx$

(4)

Necessary and sufficient conditions for a maximum are assumed: $\partial V_1/\partial x > 0$, $\partial V_2/\partial x > 0$, $\partial^2 V_1/\partial x^2 < 0$, and $\partial^2 V_2/\partial x^2 < 0$. The first-order conditions for (1), (2) and (3) are as follows:

(4) $$\frac{\partial V_1}{\partial x} + \frac{\partial V_2}{\partial x} - w = 0$$

(5) $$s_o \frac{\partial V_1}{\partial x} - s_i w = 0$$

(6) $$(1\text{-}s_o)\frac{\partial V_1}{\partial x} + \frac{\partial V_2}{\partial x} - (1\text{-}s_i)w = 0$$

Solving (4) will give the first best efficient level of x^*. Whenever the applied input level is less or more than x^*, the value of the contract (net value of production) will be less than efficient. The scope of the present study is limited to two cases, when $s_i = 1$ and $s_i = 0$.

If the tenant is responsible for the entire cost of the input ($s = 1$), he will maximize his objective function (2) and apply the level x_T^* (solving (5)). At $s = 0$, x_T^* is undefined. If $s_o = 1$ and $d = 0$, then the objective function of the tenant (2) is same as the overall

[2] Heady (1971) showed with a simple one period model that input application can be efficient when the input application levels are divided to the relevant parties according to their share in outputs. However, Heady did not consider the inputs that have productive benefits beyond the lease period in the model.

objective function (1). In this case, $x^* = x_T^*$. For other relevant cases, $0 < s_o < 1$ and $0 < d \leq 1$, the tenant receives only a portion of full benefit and $V_T < V$. Consequently, the tenant will apply less than the efficient input level ($x_T^* < x^*$) in equating his share of the value of the marginal product with the marginal factor cost. Figure 1 includes a chart to illustrate the divergence between a societal efficient level of x and the tenant's optimal level of x when $d \neq 0$.

If the landlord is responsible for the entire cost of the input ($s = 0$), he will solve (6) and apply x_L^*. At $s_i = 1$, x_L^* is undefined. When $d = 1$, V_1 will be zero and the landlord receives all the benefit from the applied input as V_2. Therefore, the landlord will apply the efficient level of input, $x_L^* = x^*$, in that case. For other cases, the landlord does not receive all the benefits ($V_L < V$) and will apply an input level that is less than the optimal level. The choice of whom should bear the responsibility depends on the degree of shirking relative to the efficient level, and this depends in part on the magnitude of d.

Some testable hypotheses that emerge from the model include:

H 1: As the output share to the landlord ($1-s_o$) increases, the landlord will more likely be responsible for input provision.

H 2: As the longevity of input productivity d increases, the landlord will more likely be responsible for input provision.

In the next section, we test these hypotheses using survey data from grazing leases from Oklahoma.

Data and specific hypotheses

Data were obtained from the Oklahoma statewide farmland leasing surveys conducted in December of 1998 and 2000 (Doye et al., 1999; Doye et al., 2001). Questionnaires were mailed to individuals involved in farming in Oklahoma. Approximately 624 surveys from 1998 and 528 surveys from 2000 were returned with useable data. 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 landlord for a grazing lease in which the tenant is the livestock owner and the landlord is the pasture owner. The data used on the analysis below include information on

- the type of payment (cash rent or share),
- the type of respondent (tenant or landlord),
- the duration of the contract (annual or multi-year),
- the form of the contract (oral or written).

With regard to the type of payment, respondents were asked to identify rental price method based on a set of alternatives. If the rental price 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 useage. If the method was $/lb of gain, the contract was considered a share contract. In this case the output (cattle gains) affects the revenue of both the tenant (livestock owner) and landlord (pasture owner).

A list of specific tasks is also provided on the questionnaire, and the respondent was asked to specify whether the landlord, 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 are either clearly durable and fixed (with benefits from investment may extend beyond the contract and accrue to the landlord), or are fleeting (accrue during the contract to the current tenant). The input data we use relate to

- fencing materials
- fencing labor
- checking livestock.
- supplemental feeding and/or pasture

We hypothesize that of all inputs, *fencing materials* are most durable (large *d*). *Fencing labor* often must be applied in a timely manner, and the benefits of timeliness will generally accrue to the current tenant, so *d* is smaller. *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 help the livestock in terms of weight gain. However, supplemental feed also may benefit the landlord 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.[3] Although a number of different pasture types were included in the survey, we focus on *native pasture* (perennial) and winter *wheat pasture* for this analysis.

Hypothesis 1 presented in the previous section applies to any input (landlord more likely to provide inputs if landlord share increases), and this hypothesis will be applied to fencing materials and labor and supplemental feed. Given the data described above, we are able to test a set of specific corollaries to hypotheses 1 and 2. In particular, we test the following hypotheses:

H 1.1: Landlords will more often be responsible for fencing materials under a share contract than a cash rent contract.

H 1.2: Landlords will more often be responsible for fencing labor under a share contract than a cash rent contract.

H 2.1: Landlords will more often be responsible for fencing materials than fencing labor.

[3] 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 before a specific point in the wheat maturation process known as first-jointing (Epplin, Hossain, and Krenzer 2000).

H 2.2: Landlords will more often be responsible for fencing materials than for checking livestock.

H 2.3: Landlords will more often provide supplemental feed and/or pasture for a native pasture contract than for a wheat pasture contract.

It is worth reiterating that tests for hypotheses H 2.* are in principle a joint test of two hypotheses: (a) that contacts account for moral hazard due to limited-duration contracts, and that the two inputs in question have durability characteristics as hypothesized.

Hypothesis tests

We employ two types of tests for the hypotheses listed above. We begin with simple tests for differences in input responsibilities based on differences in output shares (hypotheses 1.i) and input durability rates (hypotheses 2.i). We then extend the test to logistic regressions to control for other factors that might affect the probability of one outcome or another. From a theoretical perspective, we implicitly employ a random utility model framework in that as researchers we do not fully capture the variation in contract value as a function of input decisions, but that difference in expected values of contract specification will lead to different distributions of input responsibilities. Based on this framework, if a significantly higher proportion of landlords (rather than tenants) provide an input under condition A as compared to condition B, it is because the value of contracts tends to favor these outcomes.

For the means test, if group *i* has a binomial distribution with sample size n_{i+}, then the sample proportion is $p_i = n_i / n_{i+}$. The standard error of p_1 is computed as $se(p_i) = \sqrt{p_i(1-p_i)/n_{i+}}$. Assuming the two groups represent independent binomial samples, their difference is $diff = p_1 - p_2$, for which the standard error is $\text{se}(diff) = \sqrt{\text{var}(p_1) + \text{var}(p_2)}$. Using the normal approximation to the binomial distribution, the test statistic is calculated as $z = diff / \text{se}(diff)$, where z has a standard normal distribution. If the p-value is less than the chosen critical value, the null hypothesis of $diff = 0$ is rejected (Agresti, 1990). See Greene (2003, pp. 670-672) for a discussion of logistic regression. The FREQ and LOGISTIC procedures in SAS were used (SAS Institute, 1999).

For the means tests, only observations for annual agreements were used. Empirical evidence in the United States indicates that landlords and tenants are more likely to cooperate in sharing information in contracts negotiated for several years, whereas less information is shared in single-year contracts (Dasgupta et al., 1999). Oral contracts suggest that there may be a substantial amount of trust prevailing between landlords and tenants, perhaps a result of long-term acquaintances, and a long-term relationship between tenant and landlord will likely improve incentives even for a short-term contract. To the extent that an oral contract is an indicator that the tenant and landlord have a long-term relationship, there may be less of a chance of substantial shirking in their actions when the contract is oral. Therefore, the means tests are based on annual contracts only. The logistic regression provides a means of seeing the differences between these types of contracts with respect to input responsibilities.

Results

The results of the means tests and logistic regressions for the effects of output share are discussed first, followed by the results for input durability type.

Effects of output share type on input responsibilities

Landlords (pasture owners) were responsible for fencing materials in 53% of share contracts and 44% of cash rent contracts. Similarly, they were responsible for fencing labor 50% and 36% of share and cash rent contracts respectively (Table 1). As hypothesized (H 1.1, H1.2), landlords (pasture owners) were responsible for both inputs more often in share contracts compared to cash rent contracts. The differences of proportions were significant at the 5% level of confidence in the case of fencing labor and at the 10% level of confidence in the case of fencing materials. The differences of proportions also had the correct sign in the other two groups. However, the differences were significant at the 5% level in the "wheat pasture only" group, but only the difference for fencing labor was significant at the 10% level in the "native grassland only" group.

Inputs with different durability rates

Consider fencing materials and fencing labor. Materials have a higher *d* compared to that of labor. It may be beneficial for the landlords to have good quality materials with better longevity. This will increase the land attributes with respect to future leasing activities. Alternatively, fencing labor will mainly include maintaining and fixing the fences, which would clearly benefit more during the contract period. Using all the observations, it was found that landlords (pasture owners) provided fencing materials 43% of the time and fencing labor 37% of the time (Table 2). The difference was significant at the 5% level of confidence and consistent with the implied hypothesis. The difference also had the same correct sign in two other groups- "native grassland only" and "wheat pasture only".

Fencing materials clearly have a higher *d* than the checking livestock activity. Fencing materials have productive benefits beyond the lease period, whereas the benefits of checking livestock accrue solely during the lease period. Under the cash rent contract, landlords do not have a direct vested interest in the livestock's overall well being. The results supported the hypothesis; landlords were responsible for fencing materials more often than for checking livestock (Table 2). The differences of proportions were significant at the 5% level of confidence in all three groups.

Declining ecological condition on rangeland and pasture is a common consequence of overgrazing (Ellison, 1960). Native grassland in particular may suffer serious long-term negative effects in terms of the land's reproductive capacity due to overgrazing, whereas overgrazing is not a big problem on winter wheat pasture. Providing supplemental feed is one of the decision variables management can use to control overgrazing problems on native grassland. Good supplemental feeding and pasture activities in the case of native grassland help to limit the exploitation of forage resource for short-term profitability and preserve long-term soil and vegetation resource. From this point of view, it can be said that supplemental feed and supplemental pasture have a higher *d* in native grassland leases than in winter wheat pasture leases. The landlords with the intention of maintaining long-term pasture productivity on grazing land will more often be responsible for supplemental feed and supplemental pasture for native grassland than for wheat pasture leases. Results in Table 3 were consistent with this hypothesis. However, the difference of proportions was significant for supplemental feed and not significant for supplemental pasture at the 5% level of confidence.

Logistic Regressions

Logistic regressions were applied to model the probability that the landlord was responsible for *supplemental feed* (table 4) and for *fencing materials* (table 5), and *fencing labor* (table 6). Included in these regressions is a variable *other inputs*, that represents the proportion of other inputs that were provided by the landlord --- inputs other than the dependent variable. This variable is included as a proxy to capture general factors that affect the agreed-upon responsibility set. For example, how far the land is from the home of both the tenant and the landlord will affect the relative costs of input provision to the extent that it requires a trip to the pasture. This may affect the propensity of one or the other agent to provide all or none of the inputs. The variables *written*, *annual,* and *cash rent* are dummy variables taking the value one if the contract was written, if it was an annual contract, and if it was a cash rent rather than share contract, respectively.

One additional explanatory variable was included in the regression on *supplementary feed.* This is the dummy variable *wheat pasture*, which takes the value one if the contract relates to wheat pasture grazing. Based on hypothesis H 2.1, landlords are more likely to provide supplemental feed for perennial native pasture than for annual wheat pasture. Consistent with hypothesis H 2.1, *wheat pasture* is negative and strongly significant; landlords are indeed more inclined to provide supplemental feed where overgrazing is more likely to have long-lasting effects.

It is useful to consider together the *fencing material* and *fencing labor* regressions (tables 5 and 6). Landlords are statistically more likely to provide fencing materials and labor for share contracts than for cash-rent contracts. These results are consistent with hypotheses H 1.1 and H 1.2. However, landlords are more likely to provide fencing materials under annual contacts but not statistically more likely to provide fencing labor. These results are consistent with the notion embodied in hypothesis H2.1 and H2.2, that the benefits of quality materials beyond the contract period outweigh the benefits within the contract period, whereas timely labor has important consequences in the short term that outweigh long-term benefit.

Summary and Conclusions

Delegation of inputs and management responsibilities to the contracting parties is an important aspect of contract design that has received little attention in the large literature on agricultural land lease contracts. Since benefits from agricultural inputs may extend beyond the contractual period and since a privately optimal decision on the part of one party may not result in an efficient resource allocation leases may suffer from moral hazard.

When actions cannot be directly monitored because of high cost and output uncertainty, and input responsibilities are non-divisible, economic theory suggests that assignments of responsibilities need to take into account the possibility of moral hazard, and an important method to control moral hazard and increase efficiency is to assign input responsibilities in ways that will induce proper input use incentives.

The empirical results, based on simple means tests and logistic regression, are generally consistent with the hypotheses that follow from the theory. Landlords tend to take responsibility for inputs that have long-term consequences, and tenants tend to have responsibility for inputs that have short-term consequences. If there were no uncertainty, if contracts were perfectly specified, and monitoring were costless and perfect, then input assignment would not matter.

References

Agresti, A. 1990. Categorical Data Analysis. John Wiley & Sons, NY.

Allen, D., and D. Lueck. 1992. Contract Choice in Modern Agriculture: Cash Rent Versus Cropshare. J. of Law & Econ. 35:397-426.

Alston, L.J., and R. Higgs. 1982. Contractual Mix in Southern Agriculture since the Civil War: Facts, Hypotheses, and Tests. The J. of Economic History 42:327-353.

Dasgupta, S., T.O. Knight, and H.A. Love. 1999. Evolution of Agricultural Land Leasing Models: A Survey of the Literature. Review of Agricultural Economics 21:148-176.

Doye, D., D. Kletke, and B.L. Fischer. 1999. Oklahoma Pasture Rental Rates: 1998-99. CR-216. Oklahoma State Univ. Coop. Ext. Serv., Stillwater.

Doye, D., D. Kletke, B.L. Fischer, and D.D. Davies. 2001. Oklahoma Pasture Rental Rates: 2000-2001. CR-216. Oklahoma State Univ. Coop. Ext. Serv., Stillwater.

Ellison, L. 1960. Influence of grazing on plant succession of rangelands. The Botanical Review 26:1-78.

Epplin, F. M., I. Hossain, and E.G. Krenzer Jr. 2000. "Winter wheat fall-winter forage yield and grain yield response to planting date in a dual purpose system." *Agricultural Systems* 63:161-173.

Eswaran, M., and A. Kotwal. 1985. A Theory of Contractual Structure in Agriculture. The American Economic Review 75:352-367.

Greene, W. 2003. *Econometric Analysis*. Fifth edition. Upper Saddle River: Prentice Hall.

Heady, E.O. 1971. Optimal Sizes of Farms Under Varying Tenure Forms, Including Renting, Ownership, State, and Collective Structures. American J. of Ag. Econ. 53:17-25.

Holmstrom, B. 1979. Moral Hazard and Observability. The Bell J. of Econ. 10:74-91.

Hoppe, R., and K. Wiebe. 2002. Agricultural Resources and Environmental Indicators: Land Ownership and Farm Structure. Agricultural Resources and Environmental

Indicators No. (AH722). [Online]. Available: http://www.ers.usda.gov/publications/arei/arei2001/arei1_3/AREI1_3farmtenure.pdf

Janssen, L., J. Cole, X. Xu, and B. Johnson. 2002. Economic Evaluation of Cropshare and Cash Lease Contracts in South Dakota and Nebraska. Presented at the Annual Meeting of the Western Agricultural Economics Association. Long Beach, CA.

Kauffman, K.D. 1993. Why Was the Mule Used in Southern Agriculture? Empirical Evidence of Principal-Agent Solutions. Explorations in Economic History 30:336-351.

Lichtenberg, E. 2001. Tenancy and Soil Conservation in Market Equilibrium. Presented at the Annual Meeting of the American Agricultural Economics Association. Chicago, IL.

Otsuka, K., and Y. Hayami. 1988. Theories of Share Tenancy: A Critical Survey. Economic Development and Cultural Change 37:31-68.

Redmon, L.A., G.W. Horn, E.G. Krenzer, Jr., and D.J. Bernardo. 1995. A Review of Livestock Grazing and Wheat Grain Yield: Boom or Bust? Agron. J. 87:137-147.

SAS Institute. 1999. SAS OnlineDoc Version 8, SAS/STAT User's Guide: The FREQ Procedure. SAS Inst. Inc., Cary, NC. [Online]. Available: http://www.okstate.edu/sas/v8/saspdf/stat/pdfidx.htm

Stiglitz, J.E. 1974. Incentives and Risk Sharing in Sharecropping. Review of Economic Studies 41:219-255.

Table 1. Fencing provided by the landlord (pasture owner) in annual share versus annual rent contract (proportions). Predicted difference (*p_1-p_2*)>*0* for each case.

	Share *p_1*	**Cash Rent** *p_2*	***Difference*** *p_1-p_2*	***P-value***	**Sample Size**
Fencing					
Native Grassland only					
Fencing Materials	0.52	0.41	0.11	0.155	243
Fencing Labor	0.48	0.33	0.15*	0.085	252
Wheat Pasture only					
Fencing Materials	0.56	0.39	0.17**	0.048	94
Fencing Labor	0.55	0.32	0.23**	0.01	94
All					
Fencing Materials	0.53	0.44	0.09*	0.064	525
Fencing Labor	0.50	0.36	0.14**	0.009	535

** Significant at the 0.05 probability level.
* Significant at the 0.10 probability level.

Table 2. **Inputs responsibilities provided by the landlord (pasture owner) in annual cash rent. Proportions of durable inputs and nondurable inputs provided by pasture owner are p_1 and p_2, respectively. Predicted difference is p_1-p_2>0.**

	p_1	p_2	*Difference* p_1-p_2	*p-value*	Sampl e Size
	Fencing Materials	**Fencing Labor**			
Native Grassland only	0.41	0.34	0.07*	0.068	434
Wheat Pasture only	0.40	0.31	0.09	0.189	90
All	0.43	0.37	0.06**	0.025	860
	Fencing Materials	**Checking Livestock**			
Native Grassland only	0.40	0.31	0.09**	0.018	440
Wheat Pasture only	0.40	0.16	0.24**	0.008	86
All	0.44	0.33	0.11**	0.0009	874

** Significant at the 0.05 probability level.
 * Significant at the 0.10 probability level.

Table 3. **Proportions of supplemental feeding and supplemental pasture done by the landlord (pasture owner) in native grassland versus in wheat pasture (cash rent and annual contract). Predicted value for difference p_1-p_2>0**

	Native Grassland p_1	*Wheat Pasture* p_2	*Difference* p_1-p_2	*p-value*	*Sample Size*
Supplemental Feed	0.30	0.15	0.15**	0.013	291
Supplemental Pasture	0.30	0.26	0.04	0.32	259

** Significant at the 0.05 probability level.
Significant at the 0.10 probability level.

Table 4. Logistic regression. Response Variable=1 if supplemental feed provided by pasture owner; zero otherwise (N=536).

Parameter	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	-6.97	1.43	23.83	<.0001
Other inputs	1.91	0.25	57.83	<.0001
Written	-0.15	0.67	0.05	0.8240
Wheat pasture	-2.98	0.86	11.98	0.0005
Annual	-0.89	0.67	1.75	0.1853
Cash rent	1.03	0.85	1.47	0.2247

Likelihood Ratio (5 df) = 631.02, P<0.0001
Percent Concordant=99.4

Table 5. Response Variable=1 if fencing materials provided by pasture owner; zero otherwise (N=536).

N=536	param.	std. Err.	Chi-sq.	P-value
Intercept	-1.29	0.32	15.80	<.0001
other inputs	0.37	0.03	127.50	<.0001
Written	-0.15	0.25	0.35	0.5551
Annual	0.50	0.24	4.43	0.0352
Cash rent	-0.91	0.27	11.11	0.0009

Likelihood Ratio (4 df)=170.96; P<.0001
Percent Concordant=80.5

Table 6. Dependent variable = 1 if fencing labor provided by pasture owner, 0 otherwise.

N=536	param.	std. Err.	Chi-sq.	P-value
Intercept	-3.04	0.58	27.16	<.0001
other inputs	1.03	0.08	154.37	<.0001
Written	-0.16	0.44	0.12	0.7247
Annual	0.31	0.44	0.51	0.4764
Cash rent	-1.34	0.44	9.19	0.0024

Likelihood Ratio (4 df)= 509.49; P<.0001
Percent Concordant=97.5

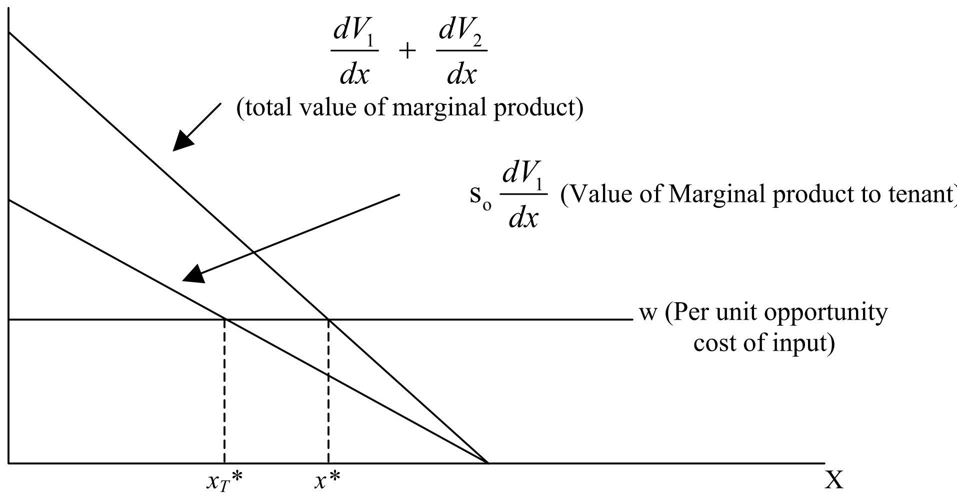

Figure 1. Application of input by tenant compared to the efficient level ($0 < s_o < 1$ and $0 < d \leq 1$, and $s_i = 1$).

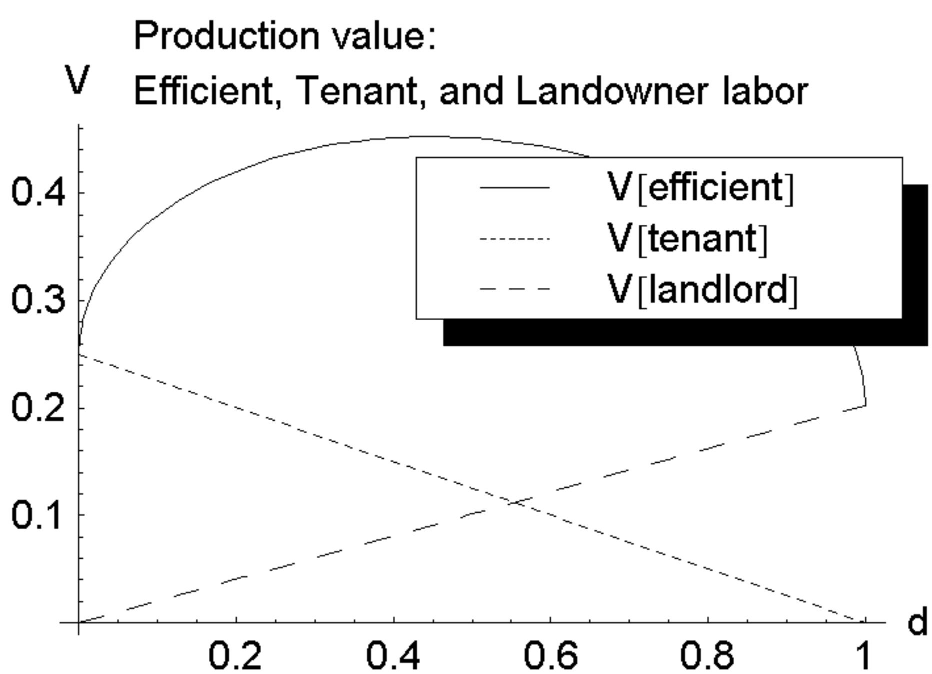

Figure 2. Value of production under three scenarios as a function of the input depreciation rate and limited-duration contract: Efficient input allocation, input use given tenant responsibility, and input use given tenant responsibility. Contract value is higher

under tenant responsibility for $d<0.55$, and optimal division of labor is for the tenant to provide input when d is greater than 0.55.

Appendix

Figure 2 is based on a specific model with a simple Cobb-Douglas production function, with input depreciation and discounting. The specific functional forms for equations (1), (2) and (3) are (respectively)

(7) $$V_E(x) = s_o[(1\text{-}d)x]^{\beta} + (1\text{-}s_o)[(1\text{-}d)x]^{\beta} + \rho(dx)^{\beta} - wx$$

(8) $$V_T(x) = s_o[(1\text{-}d)x]^{\beta} - s_i wx$$

(9) $$V_L(x) = (1\text{-}s_o)[(1\text{-}d)x]^{\beta} + \rho(dx)^{\beta} - (1 - s_i)\, wx$$

The parameters used to generate figure 2 are w=1, β=0.5, and the discount rate is ρ=0.9. A cash-rent contract is assumed, so $s_o=0$. Solving for optimal levels of x_E^*, x_T^*, and x_L^* from the respective first order conditions, yields derived input demands of

(10) $$x_E^* = \left[\frac{\beta\left((1\text{-}d)^{\beta} + \rho d^{\beta}\right)}{w}\right]^{\frac{1}{1-\beta}}$$

(11) $$x_T^* = \left[\frac{s_o\beta(1\text{-}d)^{\beta}}{w}\right]^{\frac{1}{1-\beta}}$$

(12) $$x_L^* = \left[\frac{\beta\left((1+s_o)(1\text{-}d)^{\beta} + \rho d^{\beta}\right)}{w}\right]^{\frac{1}{1-\beta}}$$