INFLUENCE OF LAND TENURE ARRANGEMENTS ON GRAZING MANAGEMENT INCENTIVES

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INTRODUCTION

Alternative forms of land tenure influence soil and vegetation protection incentives faced by agricultural producers. Overgrazing is a common cause of declining ecological condition on rangeland and pasture (Ellison). Stocking rate, defined as the number of animals on a given land area for a fixed period of time, is the primary decision variable management can use to control overgrazing. Profit maximizing stocking rates may vary depending on the livestock operator's property rights associated with the land. Land tenure alternatives impact stocking rate incentives by influencing the livestock operator's planning horizon, and/or the cost structure of the grazing enterprise.

Length of the Planning horizon

The length of the planning horizon is often cited as an important factor in the livestock producer's incentive to stock appropriately (Torell, Lyon, and Godfrey; Workman). A relatively short planning horizon may encourage tenants to overstock and exploit the forage resource for short-term profitability at the expense of long-term pasture productivity. A short term planning horizon, however, does not guarantee that a tenant will have an incentive to overgraze a pasture. Grazing studies suggest excessive stocking can reduce profitability, even in a single year planning period. For example, Launchbaugh conducted grazing trials near Hays, Kansas and found that light stocking rates were more profitable than heavy stocking rates. Shoop and McIlvain suggest producers who overgraze are usually not behaving in their economic self-interest. Workman suggests overgrazing is usually a result of ignorance and over-optimistic forage production estimates, and occurs in spite of the profit motive, not because of it.

Several studies estimating the economic optimal stocking rate, however, suggest livestock operators periodically have an incentive to deplete or “mine” the forage. Hart et al. (1988) estimated the profit maximizing stocking rate near Cheyenne, Wyoming, assuming 1986-87 price/cost conditions, to be 60 to 80% above the SCS (presently NRCS) recommended level to maintain range condition. Manley et al. reported that stocking rates higher than the NRCS recommended maintenance level were profitable during favorable cattle price periods. McCollum et al. found the most profitable stocking rate under continuous grazing in tallgrass prairie exceeded NRCS recommendations.

These studies used single period models and did not consider the impact of the current stocking rate decision on future forage production. Evaluating stocking rate incentives under alternative forms of land tenure requires a model that considers the decision maker’s relevant planning horizon. Dynamic optimization models consider the impact of future pasture productivity and profitability by maximizing the sum of the discounted income stream over the relevant time horizon. Pope and McBryde used a dynamic optimization model to compare the profitability of systematic overstocking coupled with periodic re-vegetation treatments to maintaining a sustainable stocking rate. Optimal stocking rates approached the biological sustainable level as the planning horizon increased to perpetuity. The grazing strategy that maximized the sum of the discounted cash flow streams was to slightly overgraze and deplete the forage over a 10-year planning horizon.

Torell, Lyon, and Godfrey compared optimal stocking and forage utilization rates for a single period to an extended planning horizon based on Colorado production data (Sims, Dahl, and Denham.). Profit maximizing stocking rates were slightly lower in the dynamic model relative to the myopic model, but were not high enough in either model to impair forage production. The authors concluded that intertemporal impacts on forage production were a relatively minor consideration in the current stocking rate decision.

Cost and Revenue Structure

Economically optimal stocking rates are influenced by the cost and revenue structure of the grazing enterprise. For example, when hides were the principle livestock product and cattle were sold by the head, livestock producers had and incentive to graze heavily (Hooper and Heady). In the current system, stocker cattle are typically purchased by the head and sold by weight, a combination that favors lighter stocking rates.

The method grazing leases are denominated influences the cost structure of the grazing enterprise, and consequently, profit maximizing stocking rates. For example, when leases specify compensation on a per acre basis, tenants can reduce per unit costs by increasing stocking rates. Per acre leases, therefore, encourage tenants to stock heavily while per head agreements encourage the landowner to stock heavily (Langemeier). Klipple and Bement suggest per head lease agreements contributes to the historic abuse of grazing land.

OBJECTIVES

The objective of this study is to explore the relationship between alternative tenure arrangements commonly applied to grazing land (Langemeier) and economic optimal stocking rates. Specific objectives are to: (1) estimate optimal stocking rates for each grazing season between 1975 and 1998 under alternative land tenure arrangements given price/cost conditions observed in the relevant year; and (2) quantify and compare expected returns and relative risks accruing to landowners and tenants under alternative land tenure arrangements (ie. Time horizon and unit of payment).

METHODS

Nonlinear programming models were used to estimate optimal the stocking rate each year over a 24 year period under "per acre" and "per head" one, four, eight, and 12-year lease agreements. The models were designed to represent a tenant under alternative lease terms and were compared to the results assuming an owner operator over a 24 year planning horizon. The objective function of each model was specified as follows:

$$(1)\ \text{Max}\ \Pi_c = \sum_{t=1}^{24} [HD_t * (OSP_t * OSW_t - MSP_t * MSW_t - VCH_t) / (1 + R)^t]$$

$$(2)\ \text{Max}\ \Pi_k = \sum_{t=1}^{k} [HD_t*(OSP_t*OSW_t - MSP_t*MSW_t - VCH_t - LRH_t)/(1+R)^t]$$

$$(3)\ \text{Max}\ \Pi_k = \sum_{t=1}^{k} [\{HD_t*(OSP_t*OSW_t - MSP_t*MSW_t - VCH_t) - LRA_t*640Ac\}/(1+R)^t]$$

Stocking rates are constrained by the following equations:

(4) $OSW_t = MSW_t + DOP_t * ADG_t$;

(5) $ADG_t = 2.450 - 0.0064 * GP_t$;

(6) $GP_t = HD_t * DOP_t/AF_t$

(7) $AF_t = FPC * HPI_t$

(8) $HPI_t = 0.4343 + 0.5824\ HPI_{t-1} - 0.00136\ GP_{t-1}$;

Variable names are defined as follows:

Π_c = Cumulative pasture profitability over the 24-year time horizon.

Π_k = Cumulative pasture profitability over the length of the lease.

HD_t = Number of head per section in year t

MSP_t = May steer price in year t

MSW_t = May steer weight in year t

OSP_t = October steer price in year t

OSW_t = October steer weight in year t

VCH_t = Variable cost per head in year t

LRH_t = Lease rate per head in year t

LRA_t = Lease rate per acre in year t

R = Discount rate

DOP_t = Days on pasture in year t

ADG_t = Average daily gain in year t

GP_t = Grazing pressure in year t

AF_t= Available Forage in year t

FPC = Forage production capacity

HPI_t = Herbage production index in year t

Equations 1 to 3 represent the objective functions for the owner operator, per head lease, and per acre lease models. The decision variable in all models is the number of head stocked on the pasture each year. Equations 4 through 8 express the relationships that limit the optimal stocking rate. MSW_t and DOP_t refer to the May steer weight in year t and the days on pasture in year t. These terms were constants in the model and the values were exogenously set at 600 lbs and 150 days.

Equation 5 represents average daily gain in year t. The linear functional form and equation specification was taken from Torell, Lyon, and Godfrey. Coefficient values were recalibrated to match weight gains observed at various stocking rates in the Flint Hills tallgrass region (Smith and Owensby, Launchbaugh and Owensby). A linear relationship between stocking rate and average daily gain is supported by experimental research (Hart 1972; Jones and Sandland; Hart 1993; Manley et al.).

Grazing pressure in year t (GP_t), expressed in equation 6, is defined as stocker days per unit of available standing herbage (Hart et al. 1988). Available standing herbage represented in equation 7 is a function of pasture forage production capacity (FPC) and the herbage production index in year t (HPI_t). Pasture FPC was exogenously assigned the equivalent of 3,200 lbs per acre (Launchbaugh and Owensby), which converts to approximately one animal unit month per acre (Ohlenbusch and Watson).

HPI_t, expressed in equation 8, provides a link between past grazing pressure and current forage production. The functional form and coefficient values were derived from Torell, Lyon, and Godfrey. HPI_{t-1} and GP_{t-1} represent the herbage production index and grazing pressure in the previous year. Specifying HPI_t as a function of the previous year GP and HPI suggests HPI_t is an implicit function of all past GP levels.

Owner Operator Model

Twenty-four years was assumed to approximate the planning horizon faced by an owner operator. The objective of the owner-operator model was to maximize the cumulative discounted profitability over the entire planning period.

Owner operators do not face an explicit per head pasture charge in their stocking decisions. Land costs are typically incurred on a per acre basis but were not included in the owner operator model, as fixed costs were not relevant in the stocking rate decision.

Lease Models

Equations 2 and 3 represent the objective function of maximizing cumulative discounted pasture income over the length of the lease, measured in k years. Lease alternatives defined in the study were one-, four-, eight-, and 12-year per head and per acre agreements. The model solved for annual stocking rate k years at a time without considering impacts on future forage production beyond the length of the lease. The lease rate assigned to each term was the average rate observed over the relevant lease period reported by Kansas Agricultural Statistics.

The tenant in the one year per head lease model was able to stock zero head and avoid paying rent in the years stocking cattle at any level was not profitable due to market conditions. To maintain consistency between the per head and per acre models, the one year per acre lease model allowed the tenant to refuse the pasture lease in the years stocking cattle at any level was not profitable enough to cover per acre rental costs.

In the per head lease scenario, the tenant agreed to pay for a minimum number of head for the entire term of the lease. The tenant, however, had the option of deviating from the head guarantee. The number of animals stocked in excess of the head guarantee was paid for on a per head basis. The head guarantee each year was the reciprocal of the acreage guarantee reported by Kansas Agricultural Statistics.

Data Sources

All price and cost data were expressed in nominal dollars. Pasture lease rates were regional historic averages taken from the Bluestem Pasture Report (Kansas Agricultural Statistics).

May and October Dodge City, Kansas feeder cattle prices from 1975 through 1998 were used to represent incoming and outgoing stocker cattle prices. Calf prices typically decrease as the weight of the animal increases. This trend, referred to as the weight price slide, was approximated with a linear interpolation between the 700 and 800 weight prices observed each year.

The operating costs included in the model are normally incurred on a per head basis. Operating cost estimates were taken from Kansas summer stocker budgets compiled by Jones and Dhuyvetter and include a charge for interest on purchased livestock, veterinary care, labor, mineral, and miscellaneous costs. A continuous time series operating cost data stream was not available for the relevant time period. Nominal costs, therefore, were assigned to each year by inflating Jones and Dhuyvetter operating cost estimates using the producer price index. Interest on purchased livestock was calculated from operating loan rates observed each year reported by Beshear and Lamb.

RESULTS

Optimal Stocking Rates

Table 1 shows the optimal number of head stocked each year under the owner operator scenario, per head, and per acre lease agreements. The average number of steers stocked on the 640 acre pasture in the one-year per head lease scenario was 88 head, while the solution for the four, eight, 12-year lease agreements were 113, 109, and 108, respectively. The average number of head stocked by the owner operator was 110. The per acre lease scenario follows a similar trend at a higher stocking rate. The average number of steers stocked was 105, 118, 112, and 112 head in the one, four, eight, and 12-year leases, respectively.

As expected, a per acre lease agreement generated a higher average optimal stocking rate than the per head lease agreement when the term of the lease was held constant. Average number of animals stocked in the per acre lease agreement were 17, 5, 3, and 3 head greater than the per head agreement for the one, four, eight, and 12-year leases, respectively. In several individual years, however, the per head lease agreement generated a higher stocking rate than the per acre agreement. Lighter optimal stocking rates observed in individual years in the per acre lease scenario were the result of a reduced HPI and consequently, lower quantity of available forage. When forage was not a limiting constraint, per acre leases generated a higher optimal stocking rate.

An unexpected result from the model was that one-year leases generated a lower average optimal stocking rate than any of the multi-year leases or the owner operator scenario. The plausible explanation for this outcome is that a tenant with an annual lease could avoid pasture rent by not stocking any cattle in years with unfavorable price-cost margins. Table 1 shows the optimal solution in 9 of the 24 years was zero head if pasture rent could be avoided in the per acre lease agreement. By contrast, tenants operating under a long term lease are obligated to pay a minimum annual rent regardless of how many cattle are stocked, effectively converting the rent payment to a fixed cost for the duration of the lease. The optimal stocking rate response in this situation was to stock enough cattle to minimize unrecovered fixed costs. An example of this occurred in 1998, an adverse buy/sell margin drove the optimal solution to zero head for tenants under a one-year lease. The optimal solution for the remainder of the land tenure alternatives, however, was 42 head.

A model solution with zero optimal head may not be realistic. Optimal stocking rates were substantially higher under the one-year per acre lease agreement than all other land tenure alternatives when optimal stocking rates were non-zero. When the years with zero optimal head were excluded, the average optimal stocking rate in the one-year per acre lease was 169 head, substantially higher than any of the long-term leases.

These results suggest livestock price-cost margins and the stocking rate weight gain trade-off carry a larger influence on current optimal stocking rates than impacts on future forage production. If industry shifts occur that improve the profitability of livestock grazing, the importance of inter-temporal forage production impacts would increase.

Optimal stocking rates decreased slightly as the length of the grazing lease increased from 4 to 12 years. This trend was accounted for by considering a longer planning horizon in the stocking rate decision.

An owner-operator faces a cost structure similar to a tenant under a long-term lease on a per acre basis. Land ownership costs such as interest and property taxes are paid by the acre and cannot be avoided by destocking pastures during unprofitable years. Consequently, an owner operator's optimal stocking rates were similar to those incurred by a tenant under the eight and 12-year per acre leases.

Vegetative Conditions

Figures 1 and 2 shows the optimal HPI time path for the owner operator and the tenant under per acre and per head lease agreements. HPI values were used as an indicator of vegetation conditions under each land tenure alternative. The per head annual lease agreement maintained the highest average HPI of 0.80. The four-year per acre and per head leases maintained the lowest average HPI of 0.69 and 0.71, respectively.

Higher average HPI values observed in the one-year lease was a secondary impact of lower optimal stocking rate imposed by the cost structure. The model suggests pastures leased with a one-year contract may experience higher vacancy rates because these pastures were less likely to be leased during periods of unprofitable price/cost conditions. Higher vacancy rates allowed vegetation conditions to improve relative to pastures leased on a long-term contract and subjected to grazing every year. This result may not be realistic. Actual leasing and stocking rate decisions are based on tenant expectations of forage production and price/cost conditions, which may be over-optimistic.

The validity of the outcome suggesting one-year leases maintained higher range condition may depend on other constraints not considered in the model. For example, the model assumes tenants enjoyed complete autonomy in setting stocking rates. A landlord, however, would unlikely accept very low stocking rates that occurred during unfavorable price-cost conditions. The allocation of market power between landlords and tenants would determine the tenant's ability to set very low stocking rates and potentially and alter the relative stocking rate and HPI outcome of one year and multi-year leases.

An objective of this study was to identify differences in a tenant's incentive to maintain range condition in a per head relative to a per acre lease agreement. Average HPI values among per head leases were 2 percentage points higher than HPI values under per acre leases. This difference was statistically significant using a paired t-test (α = 0.05). Two percentage points on the HPI scale, however, amounts to approximately 70 lbs of forage per acre on Flint hills tallgrass pasture, a negligible value in terms of ecological condition. The model, therefore, suggests specifying lease payments on a per acre or per head basis is of minor consequence in terms of maintaining range condition.

Another study objective was to identify the impact of the planning horizon on the tenant's incentive to maintain range condition. A paired t test was used to compare HPI values observed each year under alternative lease lengths. HPI values in one-year leases were higher on average than all other lease terms. HPI values observed in four year leases averaged 2 to 3 percentage points higher than HPI values observed in eight and 12-year leases. While these differences were statistically significant (α = 0.05), actual forage production differences were less than 50 lbs per acre. No difference was detected in HPI values between eight and 12-year leases. The model suggests, therefore, the impact of the planning horizon on a tenant's incentive to maintain range condition is relatively minor.

HPI values were highly correlated among lease alternatives. The most correlated land tenure alternatives were the owner operator and the eight-year per acre lease agreement, with a correlation coefficient of 0.99. The least correlated land tenure alternatives were the four-year per head and eight-year per acre lease agreements, with a correlation coefficient of 0.70. Cases where vegetative conditions improved under one lease agreement while deteriorating under another were rare. This suggests expected vegetation condition differences among the land tenure alternatives explored in this study were small.

Range scientists typically define "proper" stocking rates as a level that will maintain or improve ecological condition (Ohlenbusch and Watson, White and McGinty, Launchbaugh and Owensby. By this definition, all land tenure alternatives examined in this study periodically provided an incentive to overgraze. The land tenure alternative achieving the lowest observed HPI value was the one-year per acre lease. The minimum HPI value was 0.55 observed in 1990, suggesting economic optimal stocking rates reduced forage production to 55% of its capacity. The minimum HPI value achieved by all land tenure alternatives occurred in 1990-1991. This period represents peak cattle prices over the period of the study, supporting the conclusion that stocking rates and subsequent HPI values were primarily driven by livestock prices and production costs.

Expected Income

Table 2 shows the discounted cumulative income generated by each land tenure alternative. One year leases generated substantially higher tenant income than the multi-year leases, with the per head lease slightly higher than the per acre lease. Tenant income declined sharply as the lease jumped from one to four years, then decreased slightly as the length of the lease increased between four and 12 years. Per head agreements generated a slightly higher tenant income than per acre agreements in the one and four-year leases, while the opposite was true in the eight and 12-year leases.

The drastically higher tenant income observed in the one-year leases was explained by the greater flexibility in adjusting stocking rates to changing economic conditions. Tenants in a one-year lease could avoid paying rent when livestock grazing was not profitable. Multi-year lease agreements required the tenant to pay the lease and suffer a loss during unprofitable years in order to use the pasture during profitable price/cost conditions.

The lease alternative generating the highest cumulative discounted landlord income was the 12-year per acre agreement. One-year leases generated the lowest cumulative landlord income. The per head lease was slightly more profitable than the per acre lease in the one-year agreement, but the per acre leases generated substantially more landlord profits in the four-, eight-, and 12-year agreements.

The model considered the owner operator both the landlord and tenant. A consistent income comparison between the owner operator and the lease alternatives, therefore, would combine the landlord and tenant income. The owner operator expected income exceeded the cumulative combined landlord tenant income observed in any of the lease alternatives. The lease alternative with the lowest combined tenant landlord income was the 12-year per head agreement.

CONCLUSIONS

Results from this study suggest short-term pasture leases do not always promote substantially heavier stocking rates than long term leases. All land tenure arrangements examined in this study periodically reached optimal grazing intensities that led to an inter-temporal reduction in HPI levels. This conclusion is consistent with Torell, Lyon, and Godfrey suggesting inter-temporal impacts on forage production carry a minor impact on the current stocking rate decision.

Per head leases generated a higher optimal stocking rate than per acre leases. The stocking rate difference, however, did not appear large enough to cause a substantial difference in future forage production.

This study was intended to identify the economic incentives confronting landlords and tenants, not necessarily describe actual behavior. This model assumes stocking decisions were made with a full knowledge of costs and livestock prices throughout their entire planning horizon. Actual behavior depends largely on perceived risks and returns, which may not be realistic. For example, the length of the lease may impact stocking rates if a tenant believes heavy stocking in a short term lease is in his/her economic self interest.

The model did not account for the impact of precipitation and temperature variation on forage availability. Model results, therefore, should be interpreted as “holding weather conditions constant.” Actual forage production and vegetation conditions are impacted the weather. Additional research could focus on how incorporating weather risk would affect the results.

This study examines the relationship between historically observed economic conditions, and the incentive to select stocking rates that maintain or improve ecological condition. Understanding the economic consequences of various management incentives is an important component of addressing management-induced pasture deterioration. These results should be of interest to landlords and tenants, as well as public officials interested in improving grazing land productivity while reducing the negative impacts resulting from overgrazing.

Table 1. Optimal number of head stocked in a full section pasture each year under alternative land tenure arrangements.

		Per Acre Leases				Per Head Leases			
	Owner-Operator	1 Year	4 Year	8 Year	12 Year	1 Year	4 Year	8 Year	12 Year
Year	---------------------------------------Head per Section-----------------------------------								
1975	222	242	226	222	222	174	163	156	156
1976	39	0	50	39	39	9	61	50	49
1977	112	174	133	113	112	91	148	128	127
1978	166	195	196	168	167	150	145	145	145
1979	80	109	72	83	81	73	93	93	90
1980	153	158	150	157	153	134	139	139	139
1981	105	111	111	114	106	89	119	119	111
1982	96	0	112	114	97	75	117	117	101
1983	53	0	52	48	57	35	56	51	61
1984	132	186	134	128	139	114	140	131	145
1985	37	0	67	36	69	28	85	47	88
1986	174	240	205	173	207	178	147	145	148
1987	146	187	124	147	122	146	137	145	135
1988	101	122	96	105	92	103	101	109	97
1989	133	137	136	141	128	121	138	143	132
1990	110	112	124	127	108	91	126	128	111
1991	37	0	36	31	36	15	43	43	43
1992	172	190	172	167	172	146	152	152	152
1993	77	0	90	76	77	43	93	80	80
1994	42	0	84	41	42	0	85	45	45
1995	124	177	123	123	123	105	109	127	127
1996	169	188	169	169	169	138	156	156	156
1997	120	0	120	120	120	66	116	122	122
1998	42	0	42	42	42	0	41	42	42
Average	110	105	118	112	112	88	113	109	108

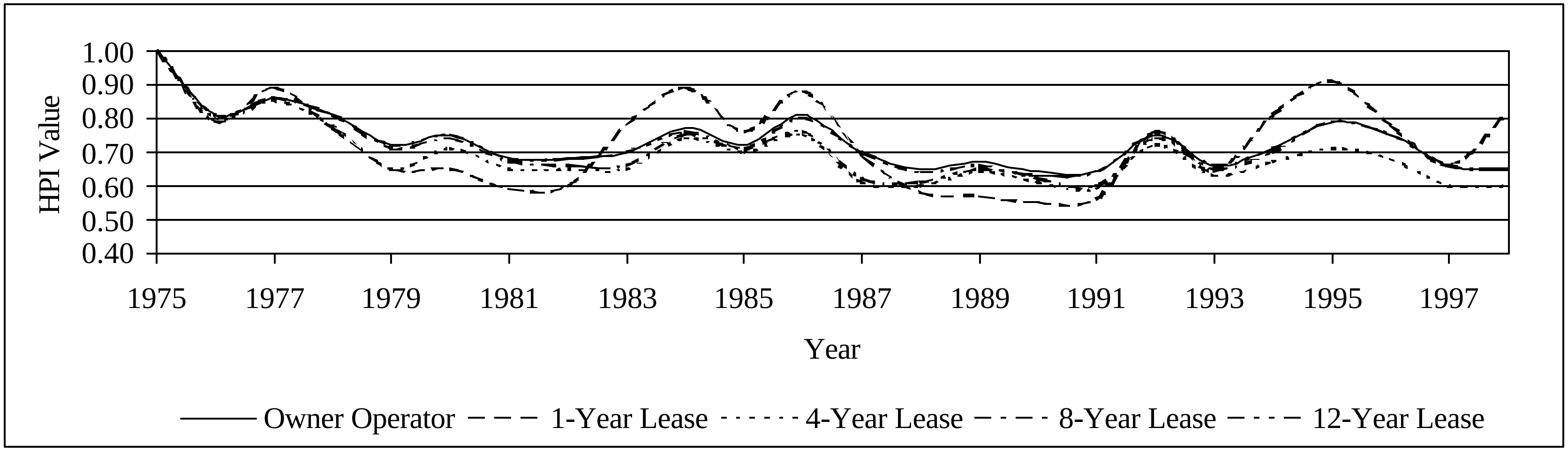

Figure 1. Optimal HPI time path comparison of owner operator and per acre lease agreements.

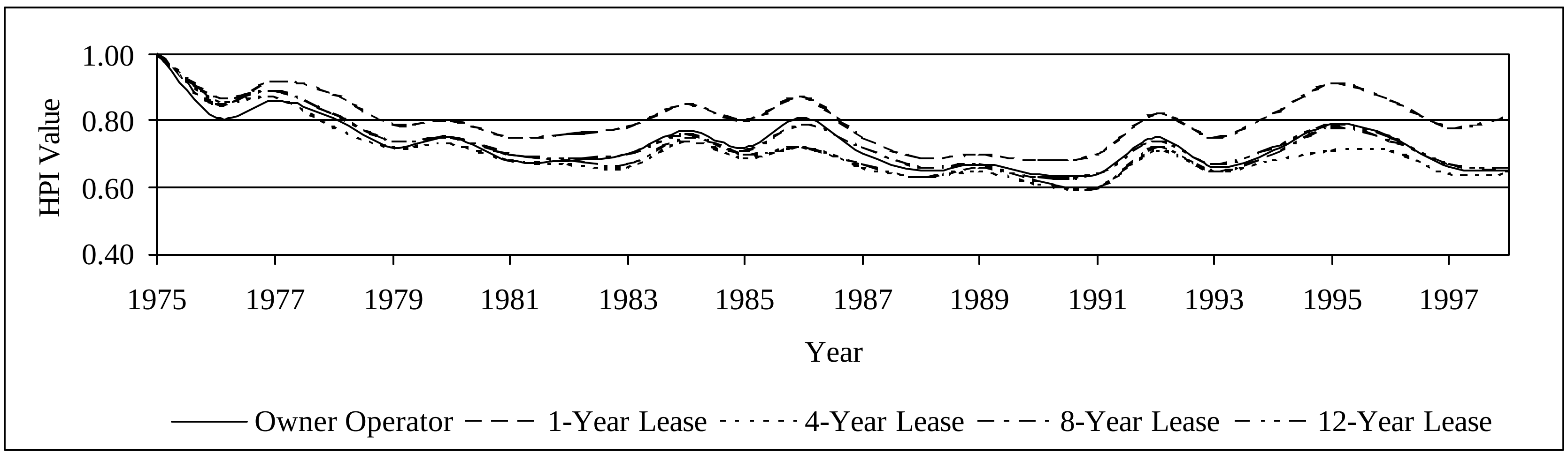

Figure 2. Optimal HPI time path comparison of owner operator and per head lease agreements.

Table 2. Cumulative discounted income accruing over a 24-year period to tenants and landlords under each land tenure alternative.

	Per Acre Agreement				Per Head Agreement				
	1 Year	4 Year	8 Year	12 Year	1 Year	4 Year	8 Year	12 Year	Owner-Operator
Cumulative Tenant Income ($)	33,309	14,311	14,654	13,641	36,182	14,984	14,654	13,641	
Standard Deviation	2,224	2,586	2,595	2,546	1,890	2,267	2,267	2,545	
Cumulative Landlord Income ($)	37,721	62,387	63,108	63,932	38,381	47,891	46,652	47,518	
Standard Deviation	1,860	1,673	1,772	1,811	1,548	1,519	1,618	1,668	
Combined Income ($)	71,030	76,698	77,762	77,573	74,563	62,875	61,108	60,796	77,981
Standard Deviation									3,502
Cumulative Beef Production (lbs/Acre)	704	897	886	888	775	916	900	904	888

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