Direct and Indirect Effects of Lease Size on Big Game Quality

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Abstract

Property rights have become a central issue in natural resource economics. This paper is the first to investigate the affects of property rights on intrinsic resource quality. We analyze the case of deer hunting on leased properties by hunting clubs. Our model illustrates that lease size has direct and indirect effects on antler quality. Using a time-series cross-section for 1991 to 1994 from the Mississippi Department of Wildlife and Fisheries, we estimate the direct and indirect effects and the lease size elasticity of both harvest and antler quality. Our results suggest lease size has a small but significant effect. For all clubs with smaller than average hunting leases, a simulated increase to the average size results in approximately a 4.5 percent increase in the average antler quality of deer harvested. Although we analyze properties leased by hunting clubs, the results should be applicable to various other management scenarios for the private landowner or state and federal wildlife agencies.

Keywords: property rights, intrinsic resource quality, game management, externalities, deer

JEL: Q20, Q24, Q57
1. **Introduction**

The theory of property rights in the exploitation of natural resources has been the focus of economists for decades. Without well defined property rights, externalities are not internalized, resources tend to be overused, and economic rents dissipate (Gordon, 1954; Scott, 1955; Coase, 1960; Hardin, 1968). Only recently has the literature begun to consider the role of property rights in determining resource quality. Broadly defining quality through a degradation or extraction framework, the majority of this literature focuses on the theoretical aspects of the property rights and quality relationship. However, certain resources may have intrinsic quality characteristics not captured in a degradation-extraction framework.

This article considers resources with intrinsic quality characteristics affected by management decisions. Incorporating property rights and intrinsic resource quality into a bioeconomic model, we develop theoretical relationships between varying levels of ownership and extraction and quality outcomes. The level of ownership directly affects the management of the resource, and subsequently the quality. Using data with ownership, extraction, and quality information we are able to estimate the developed relationships. Instrumental variable techniques are used to ensure robust results in the case of endogenous property rights.

There is no literature analyzing the role of property rights in determining intrinsic resource quality. Additionally, there is little empirical work estimating how resource use responds to changes in property rights. In terms of both theory and empirics, this article addresses these gaps. Our theoretical results suggest ownership affects intrinsic resource quality directly and indirectly. These results stem from ownership’s effect on internalizing intrinsic quality characteristics and optimal management decisions. We provide estimates of the ownership elasticity of both resource use and intrinsic quality supporting the theoretical results.
The little empirical evidence available suggests property rights indeed affect resource use and degradation. Supporting the theory of the “tragedy of the commons”, traditional communities with indigenous forms of property rights only partially internalize the shadow price of their resources and fail to maximize rents (Lopez, 1992). In a different context, insecure property rights, in the form of political instability, may increase deforestation (Deacon, 1994). The affect of property rights seems to depend on the capital intensity of resource use. Ownership risk decreases capital-intensive resource use while increasing the use of labor-intensive resources (Bohn and Deacon, 2000).

The first attention given to intrinsic quality characteristics is found in the shellfish literature. A number of studies suggest altering season timings may lead to harvesting larger individuals and increased prices (Conrad, 1982; Anderson, 1989; Kellogg et al., 1988). Extending the analysis to consider intraseasonal adjustments in the Pacific Whiting fisheries, internalizing intrinsic quality characteristics and timing harvest to coincide with seasonal changes in flesh compositions improved net industry revenues (Larkin and Sylvia, 1999; Larkin and Sylvia, 2004). The affects of ownership on intrinsic quality are not addressed.

We analyze the case of deer exploitation on leased properties by hunting clubs. The example of deer was chosen for three reasons. First, there is a thriving market for deer hunting in the US. In 2001, there were over 10 million deer hunters contributing $27.8 billion to the US economy (IAFWA, 2002). Second, deer are highly differentiated in what hunters perceive as quality. Antler characteristics are paramount in determining a hunter’s perceived quality of the deer. Hunters prefer big antlered deer (Loomis et al., 1989). For example, in Texas, where some of the largest antlered deer in the world are found, harvesting a trophy deer cost an average of $6,372 (Anderson et al., 2007). Finally, we have a unique data set with quality information that has not been used in the economics literature.
Antlers are only developed by male deer. Unless stated otherwise, we are referring to male deer. There are a number of determinants of antler size. Antler development is primarily a function of age, nutrition, and genetics. Assuming adequate nutrition, antler size increases significantly with age (Jacobson, 1995). Throughout the rest of this article antler size is a measure of deer quality.\(^1\) Given an uneven aged stock, the deer are heterogeneous in antler quality. Assuming a club values the average antler quality of deer harvested, there is a trade-off between quantity harvested and average quality. A simple way to improve the average quality of deer harvested is to pass up hunting opportunities of the lower quality deer. Additionally, this allows the stock of deer to age and increase in quality. In order to accomplish this, very specific management strategies must be implemented. However, because deer are a highly mobile resource, a number of issues arise.

The range of a stock of deer may not be contained within a single piece of land leased for hunting. If the range is located over multiple leases where the clubs are not collaborating, it is essentially a transboundary stock.\(^2\) In this case, one club’s harvest creates an externality for the other clubs in the form of lost hunting opportunities and the in situ value. These externalities affect management decisions. When externalities are not internalized, resources are overused (Hardin, 1968). When deer stocks are over harvested, antler quality suffers.

Lease size directly affects the extent to which clubs are exposed to and internalize these externalities. As lease sizes increase, deer are less likely to range across properties and be harvested by neighboring hunters. This may affect club management decisions. Given fewer lost hunting opportunities, clubs may be more willing to forego harvesting younger, lower quality deer for the

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\(^1\) It should be noted that body mass may also be a characteristic valued by hunters. However, because deer are not priced by body mass and are frequently priced based on antler quality, we focus on antler quality as the determinant of quality.

\(^2\) Transboundary resource management issues have been studied in the fisheries literature (see Munro, 1979; Vislie, 1987; Missios and Plourde, 1996; Naito and Polasky, 1997; and Bjørndal et al., 2004). The issues addressed are largely international management and cooperation problems.
opportunity to harvest higher quality deer. This type of selective harvesting will be evident in the club harvest per acre. Do clubs with larger leases harvest higher quality deer? Is harvest per acre decreasing with lease size? These are the questions we aim to answer in this analysis.

Assuming well defined property rights, Naevdal et al. (2012) attempt to incorporate quality into a bioeconomic model of trophy elk hunting. Measuring quality as the number of male elk in the stock, their analysis completely ignores the one intrinsic quality characteristic responsible for trophy hunting—antler quality.³

We develop a bioeconomic model incorporating both lease size and antler quality. Our model illustrates how lease size and the quantity-quality trade-off affect club management decisions. We show lease size has direct and indirect effects on antler quality. The direct effect results from less exposure to externalities as lease size increases. The indirect effects stem from the effects of lease size on stock and harvest rates. In order for quality to increase with lease size, the sum of the direct and indirect effects must be positive.

Using time-series cross-sectional data from Mississippi hunting clubs, we empirically estimate the effect of lease size on quality. Our results suggest lease size has a small but significant effect on both harvest and the average antler quality of deer harvested. For all clubs with smaller than average hunting leases, a simulated increase to the average size results in approximately a 4.5 percent increase in the average antler quality of deer harvested. Given the increased interest in quality game management, these results may be of considerable interest to a variety of private landowners, businesses, hunting organizations, or state and federal wildlife agencies.⁴

³ The economics literature has recognized that hunters value antler characteristics. Cooper (1993) considers antler quality when estimating the consumptive and non-consumptive value of deer.
⁴ In Texas alone, breeding trophy bucks is a $650 million industry (Anderson et al. 2007).
The remainder of this article is organized as follows. Section 2 presents a bioeconomic model developing the relationship between lease size and harvest and quality outcomes. Section 3 introduces the data used in our empirical analysis. Section 4 describes our identification and estimation strategies. Results and discussion are found in section 5. Concluding remarks are given in section 6.

2. **Bioeconomic Model**

Hunting club behavior can be generalized into three stages; organization, leasing, and hunting. In the organization stage, the number of hunting clubs and their respective memberships are determined. In the leasing stage, the clubs choose their optimal hunting lease size, given their budget constraint. In the hunting stage, clubs make their management decisions and harvest the stock of deer. Our analysis focuses on the final stage. Modeling the first stage with endogenous club formation and membership is a complex topic beyond the scope of this paper. There is a rich literature addressing the economics of club formation.\(^5\)

We assume the number of clubs and their memberships are exogenously determined. For simplicity, we assume competitive markets where club dues, \(d\), and per acre lease prices, \(p\), are identical. Clubs face an identical cost structure, \(c\). These costs include organization and transaction costs. For a stock of deer with a range covering \(R\) acres, there are \(n\) clubs with \(m\) members such that,

\[
\sum_{i=1}^{n} [m_i d - c(m_i)] \leq pR
\]

where \(c_{m} > 0\) and \(c_{mm} \leq 0\). The above inequality does not require the entire range to be leased. Given identical cost structures, \(m_1 = m_2 = \ldots = m_n\). In the second stage, clubs maximize lease size, \(l\), subject to their budget constraint,

\(^5\) The first theory arose from Buchanan (1965). See Ahn et al. (2008) for a model of endogenous group formation.
\[ m \cdot d - c ( m_i ) \geq p l_i. \]

The optimal lease size for the \( i \)th club is then,

\[ l_i^* = \frac{m_i \cdot d + c ( m_i )}{p} \]

Given identical club sizes, membership dues, and lease prices, optimal lease size is identical across clubs. Henceforth, the optimal lease size will be denoted \( l^* \).

Shifting our attention to the final stage, consider a single transboundary stock, \( x \). Environmental conditions affecting the growth of the deer population are described by a set of ecological variables, \( E \). The stock follows some growth function \( g ( x, E ) \). The degree to which the stock is transboundary is determined by \( n \). The population dynamics are,

\[ \dot{x} = g ( x, E ) - \sum_{i=1}^{n} h_i \]

where \( h_i \) is the harvest of the \( i \)th hunting club. We assume harvest can be represented by a production function,

\[ h_i ( f_i, l^* x ). \]

where \( h_f \geq 0, h_g \leq 0, h_l \geq 0, h_m \leq 0, h_x \geq 0, h_m \leq 0 \), and \( f \) is a measure of club hunting effort. Club effort may be measured by the number of days in the field or a similar measure. We assume harvest is concave in effort and stock to reflect the standard yield-effort and maximum sustainable yield curves. In the steady state, where \( \dot{x} = 0 \), we can substitute (2) into (1) to rewrite (1) as

\[ g ( x, E ) = \sum_{i=1}^{n} h_i ( f_i, l^* x ). \]
From (3), we can solve for the equilibrium stock,

\[ \bar{x}(f_1, \ldots, f_n, l', E). \]  

(4)

By definition, when harvest increases, the stock must decrease, so \( \bar{x}_h \leq 0 \). From the concavity of harvest in effort, we know \( \bar{x}_f = \bar{x}_h h_f \leq 0 \). The relationship between the steady state stock and lease size requires some discussion. Consider an example where the entire range of the stock of deer is leased. Allowing for different sized leases, an increase in one club’s lease size requires a decrease in lease size of another club. The same total area is leased. However, the leased area becomes more concentrated among fewer clubs. The resulting steady state stock depends on whether harvesting behavior changes. Given an increase in lease size, if clubs become more selective and willing to pass up younger, lower quality deer, the steady state stock will increase. This behavior would be evident by a reduced harvest per acre. Alternatively, if there is no change in harvest behavior, the steady state stock will remain unchanged. The effect of lease size on stock is given by,

\[
\frac{dx}{dl^*} = \frac{\partial x}{\partial l^*} + \frac{\partial x}{\partial h} \frac{\partial h}{\partial f} \frac{\partial f}{\partial l^*}.
\]

Substituting (4) into (2), we get our equilibrium harvest in terms of effort, lease size, and ecological variables,

\[ \overline{h}(f_1, \ldots, f_n, l', E). \]  

(5)

In our case, the equilibrium harvest is identical across clubs. Similar to stock, harvest is also affected by lease size through effort. The effect of lease size on harvest can be decomposed into three effects,

\[
\frac{dh}{dl^*} = \frac{\partial h}{\partial l^*} + \frac{\partial h}{\partial f} \frac{\partial f}{\partial l^*} + \frac{\partial h}{\partial x} \left( \frac{\partial x}{\partial h} \frac{\partial h}{\partial f} \frac{\partial f}{\partial l^*} \right).
\]
The first term is the direct effect of lease size on harvest. As lease size increases, more deer are available to harvest. The second term is lease size directly effecting harvest through effort. The third term is lease size indirectly affecting harvest through effort’s affect on stock.

2.1 Quality

Antler quality increases as deer age. Due to natural deaths and hunting activity, only a small portion of deer will reach a high antler quality. Harvesting a high average quality of deer requires a club to forgo hunting opportunities of lower quality deer. The club willingness to pass up hunting opportunities is determined by their lease size. As lease sizes increase, clubs are exposed to fewer externalities in the form of lost hunting opportunities. Lost hunting opportunities occur when deer that have been forgone are harvested by neighboring clubs. As lease sizes increase and the likelihood of these externalities decrease, clubs become more willing to pass up younger, lower quality deer. The average quality of deer harvested is also determined by the harvest rate. The lower the harvest rate, the higher the average quality of deer. Similarly, the higher the harvest rate, the lower the average quality of deer. Average quality is given by a function that maps lease size and harvest rate to quality,

\[ q_i(x, l^*, h_i) \tag{6} \]

where \( q_s \geq 0, q_t \geq 0, \) and \( q_h \leq 0 \). Finally, substituting (4) and (5) into (6), we get our quality in terms of lease size and effort,

\[ \bar{q}_i(x, l^*, h_i) \text{ or } \bar{q}_i(f_i, ..., f_n, l^*, E) \tag{7} \]

From (7), we see lease size affects quality directly and indirectly through stock and harvest.
2.2 Club Utility

Hunting clubs derive utility from the average quality of deer and quantity of deer harvested. Each club has a planner that maximizes the following utility function,

$$U_i(q_i, h_i), \tag{8}$$

where $U_q > 0$, $U_{qq} \leq 0$, $U_h > 0$, $U_{hh} \leq 0$. Substituting (5) and (7) into (8), a club's utility maximization problem can be written as,

$$\max_{f_i} U_i\left(\bar{q}_i, \left( f_1, \ldots, f_n, l^*, E \right), l^*, \bar{h}_i \left( f_1, \ldots, f_n, l^*, E \right) \right).$$

The first order condition is,

$$\frac{\partial U}{\partial f} = \frac{\partial U}{\partial q} \frac{\partial \bar{x}}{\partial f} + \frac{\partial U}{\partial q} \left( \frac{\partial h}{\partial f} + \frac{\partial h}{\partial \bar{x}} \frac{\partial \bar{x}}{\partial f} \right) + \frac{\partial U}{\partial h} \left( \frac{\partial h}{\partial f} + \frac{\partial h}{\partial \bar{x}} \frac{\partial \bar{x}}{\partial f} \right) = 0. \tag{9}$$

The first term in (9) is the disutility from a decreased average quality as a result of a smaller stock. As effort increases, stock decreases, and quality suffers. The second term is the marginal utility associated with a change in average quality from an increased harvest. The sign of this term depends on where we are on the yield-effort curve. If $h_j + h_x \bar{x}_j > 0$, this term is negative. As effort increases, harvest increases, decreasing average quality. This will hold if harvest and effort are below the maximum sustainable yield levels. Once the maximum sustainable yield is reached, any increase in effort reduces equilibrium harvest. The last term is the marginal utility of harvest. Again, if $h_j + h_x \bar{x}_j > 0$, this term is positive. Rearranging (9) illustrates a club will choose effort such that the marginal utility from additional effort is equal to the marginal disutility of a lower average quality,

$$\frac{\partial U}{\partial h} \left( \frac{\partial h}{\partial f} + \frac{\partial h}{\partial \bar{x}} \frac{\partial \bar{x}}{\partial f} \right) = - \frac{\partial U}{\partial q} \frac{\partial \bar{x}}{\partial f} - \frac{\partial U}{\partial q} \frac{\partial \bar{x}}{\partial h} \left( \frac{\partial h}{\partial f} + \frac{\partial h}{\partial \bar{x}} \frac{\partial \bar{x}}{\partial f} \right). \tag{10}$$
From (9), the optimal level of effort can be solved for,

\[ f^*(l^*, E). \]  

(11)

Substituting (11) into (4) and (2), we get the optimal steady state stock and harvest rate,

\[ x^*(l^*, E), \]  

(12)

\[ h^*(l^*, E). \]  

(13)

Finally, substituting (12) and (13) into (6), we get the optimal quality,

\[ q^*(l^*, E) \text{ or } q(x^*(l^*, E), l^*, h^*(l^*, E)). \]  

(14)

2.3 Effect of lease size on quality

A change in lease size has three effects on quality. The first is the direct effect from a club’s willingness to pass up hunting opportunities. The second and third are through the effects of lease size on the stock and harvest rate. The stock and harvest effects are the indirect effects. The comparative static can be written as,

\[
\frac{dq^*}{dl^*} = \frac{\partial q^*}{\partial x^*} \left( \frac{\partial x^*}{\partial h^*} \frac{\partial h^*}{\partial f^*} \frac{\partial f^*}{\partial l^*} \right) + \frac{\partial q^*}{\partial h^*} \left( \frac{\partial h^*}{\partial f^*} \frac{\partial f^*}{\partial l^*} \right) + \frac{\partial q^*}{\partial x^*} \left( \frac{\partial x^*}{\partial h^*} \frac{\partial h^*}{\partial f^*} \frac{\partial f^*}{\partial l^*} \right). \]  

(15)

Our quality functional form assumes the direct effect to be positive. As lease size increases, clubs are more willing to pass up younger, lower quality deer. The sign of the indirect stock and harvest effects are ambiguous. They both depend on \( \frac{\partial f^*}{\partial l^*} \). The sign of the indirect stock effect is characterized by,
indirect stock effect \( \begin{cases} 
\geq 0 \text{ if } \frac{\partial f^*}{\partial l^*} \leq 0 \\
< 0 \text{ if } \frac{\partial f^*}{\partial l^*} > 0
\end{cases} \).

Similarly, the sign of the indirect harvest effect is given by,

\[ \text{indirect harvest effect} \begin{cases} 
\geq 0 \text{ if } \frac{\partial f^*}{\partial l^*} \leq 0 \\
\geq 0 \text{ if } \frac{\partial f^*}{\partial l^*} > 0 \text{ and } \frac{\partial h^*}{\partial x^*} \frac{\partial f^*}{\partial l^*} + \frac{\partial h^*}{\partial x^*} \frac{\partial f^*}{\partial l^*} \leq 0 \\
< 0 \text{ if } \frac{\partial f^*}{\partial l^*} > 0 \text{ and } \frac{\partial h^*}{\partial x^*} \frac{\partial f^*}{\partial l^*} + \frac{\partial h^*}{\partial x^*} \frac{\partial f^*}{\partial l^*} > 0
\end{cases} \]

In other words, if \( \frac{dx^*}{dl^*} \geq 0 \), the indirect stock effect is positive. If \( \frac{dh^*}{dl^*} > 0 \), the indirect harvest effect is negative. Assuming the indirect effects are not both positive, signing (15) depends on the magnitudes of the direct and indirect effects.

Our model suggests lease size affects quality through its role in preventing externalities. As lease size increases, the stock of deer becomes less transboundary. When clubs are less likely to lose hunting opportunities to neighboring hunters, they are exposed to fewer externalities and may harvest differently. If a club has a larger lease and harvests the same quantity of deer, they may be passing up hunting opportunities to increase the quality of deer harvested. Harvest per acre provides a testable hypothesis for this effect. If harvest per acre is decreasing with lease size, clubs may be forgoing lower quality, younger deer for higher quality, older deer. In the following sections we estimate the harvest per acre, the direct and indirect effects, and calculate the total effect in (15).
3. Data

The data used was provided by the Mississippi Department of Wildlife and Fisheries (MDWF) and Strickland and Demarais (2008). The data is a time-series cross-section from 1991 to 1994. It includes information for the quality and quantity of male deer harvested by a number of hunting clubs that were participating in MDWF Deer Management Assistance Program (DMAP). The data also includes the size of the hunting club’s lease and various lease specific ecological variables. The data includes 197 clubs. Each hunting season represents one observation per club. The panel is unbalanced in that it does not contain four hunting seasons for all clubs. There is a minimum of two observations per club. There are 768 observations in total.

To determine quality, each observation has antler measurements including the spread, length, circumference, and number of points. These measurements are used to create an index to assess overall antler size. The index is calculated as the sum of the spread, length, circumference, and number of points. Strickland and Demarais (2000) illustrate the index correlates very well with gross Boone and Crockett scores. The Boone and Crockett (BC) score is widely accepted as a measure of antler quality in the hunting community. Additionally, this index has been used to estimate gross Boone and Crockett scores in the ecology literature (Strickland and Demarais, 2008). However, the estimation was specifically for certain age groups. As our data includes age groups not included in their analysis, we use the antler index as our quality measure.

The quality of deer depends heavily on quality of their habitat. Ecological variables help us characterize the habitat quality for each club’s leased property. The ecologic information consists of land composition measures for vegetation, land-use and cover, and landscape structure. This information was gathered from the Gap Analysis Program (Vilella et al., 2003). We use 10 land

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6 The index has a Pearson correlation coefficient, r=0.97 and P < 0.001 (Strickland and Demarais, 2000).
composition measures and a Shannon’s diversity index. The ecological variables used are shown in table 1. Shannon’s index measures the diversity of land composition within each lease. It also captures the abundance and continuity of land compositions.

We aggregate the 10 land composition variables into three subcategories — pine forest, hardwood forest, and food sources. The pine forest variable is the sum of low-density, medium density, and high-density pine forest land compositions. The hardwood forest variable is the sum of bottomland hardwood, high-density hardwood, and medium-density hardwood land compositions. Both the pine and hardwood forest variables should capture some measure of the cover or shelter available to the deer. The food variable is the sum of land composition in agriculture, pasture, shrub land, or water.

Finally, our data includes the number of female deer harvested by each club. During the 1991-1994 seasons, only clubs participating in the DMAP program were able to harvest female deer. The number of female deer each club was allowed to harvest was determined by a biologist. The biologists based their decisions on herd density, habitat quality, and levels of depredation. We include female deer harvested in our empirical analysis to capture this information. The summary statistics are shown in table 2.

4. Empirical Strategy

The goal of this paper is to estimate the effect of lease size on big game quality. In section two we outlined a theoretical framework developing that relationship. Our model suggests there are direct and indirect effects. The indirect effects stem from lease size affecting harvest rates and stock size. Equation (14) shows quality is determined by lease size, harvest, and stock, where both harvest and stock are determined by lease size and ecological variables. Estimating the separate indirect harvest and stock effects requires harvest and stock data. We have harvest data, but stock data is not available. We
can estimate the indirect harvest effect and a combined direct and indirect stock effect. The combined effect is the sum of the direct effect and the indirect stock effect.

Recall the composition of the indirect effects in (15). The indirect harvest effect is the product of the effect of harvest on quality and the effect of lease size on harvest,

\[
\frac{dq^*}{dh^*} \cdot \frac{dh}{dl}.
\]  

(16)

We can estimate both the effect of lease size on harvest and the effect of harvest on quality. To find the effect of lease size on harvest, we estimate (13). We estimate (14) for the combined direct and indirect effect of lease size on quality and the effect of harvest on quality. Both regressions include various ecological variables. The ecological variables included are the pine forest, hardwood forest, and food source land composition variables, and the Shannon’s diversity index.

There still exists the risk of lease size endogeneity. If the quality of deer in an area affects leasing behavior, lease size is endogenous in the quality regression. Similarly, if the number of deer harvested affects leasing behavior, lease size is endogenous in the harvest regression. We use an instrumental variable approach to control for this endogeneity.

We instrument lease size using 1997 Census of Agriculture data on the average farm size for each county in which the hunting clubs are located. It is not difficult to imagine that the majority of hunting leases are found on some type of farmland. For legal and ecological reasons, hunting takes place in rural areas. Rural areas usually include lands used for various farming activities. The census defines a farm as any place producing $1000 or more of agricultural products during the census year. This also includes lands set aside for the Conservation Reserve Program and other lands not directly under use, provided they were part of the farm’s total operation. The census also includes hunting in
their definition of agricultural activity. Lands that are used solely for hunting activity are considered farmland.\footnote{http://www.agcensus.usda.gov/Publications/1997/Vol_1_Chapter_1_U_S_National_Level_Data/us-51/us1gexp.pdf} We assume as the average farm size for a county increases, the average size of the hunting lease within that county also increases. We cannot be certain landowners do not cooperate, leading to hunting leases crossing multiple properties. However, transaction costs suggest the occurrence of hunting leases spanning multiple properties is limited.

Additionally, harvest is endogenous in the quality regression. As a club increases the average quality of deer harvested, they are also decreasing their harvest rate. We instrument harvest in the quality regression using a lagged value. Using this approach, we lose an observation within each group. However, considering the majority of our variation is between groups, this should not be an issue. The alternative would be instrumenting harvest using predicted values from the harvest regression. The covariates used in the harvest regression are also used in the quality regression. To identify our second regression, an additional variable that only affects harvest and not quality would need to be included in the harvest regression. As no such variables are readily available, we use a lagged harvest value.

To summarize, we estimate the harvest regression, or equation (13), using lease size, our set of ecological variables, and the number of female deer harvested. This yields the effect of lease size on harvest, or the second term in (16). Using the same covariates with the addition of a lagged value of harvest, we estimate the quality regression, or equation (14). This yields two important results. First, the coefficient for harvest represents our estimated effect of harvest on quality, or the first term in (16). Using this and our coefficient for lease size from the harvest regression, we can calculate our estimate for the indirect harvest effect of lease size on quality. Second, the coefficient for lease size in the quality regression represents the combined direct and indirect effect. This is the sum of the direct effect and the indirect stock effect. Recall we cannot separate the indirect stock effect because we lack stock data.
4.1 Estimation

A random effects model is used, as the bulk of our data’s variation is between hunting clubs. The harvest and quality random effects estimators are estimated using both generalized lease squares and feasible generalized two-stage least squares (Balestra and Varadharajan-Krishnakumar, 1987). The

To derive the G2SLS estimator, consider the following equation,

\[ y_{it} = Y_{it} \gamma + X_{1it} \beta + \mu_i + \nu_{it} = Z_{it} \delta + \mu_i + \nu_{it} \]  \hspace{1cm} (17)

where \( y_{it} \) is the dependent variable, \( Y_{it} \) is a \( 1 \times k_1 \) vector of observations on \( k_1 \) endogenous covariates that may be correlated with \( \nu_{it} \), \( X_{1it} \) is a \( 1 \times k_2 \) vector of observations on the \( k_2 \) exogenous variables, \( Z_{it} = [Y_{it} \ X_{1it}] \), \( X_{it} = [X_{1it} \ X_{2it}] \), \( X_{2it} \) is a \( 1 \times k_3 \) vector of observations on the \( k_3 \) instruments such that \( k_3 \geq k_1 \), and \( \gamma \), \( \beta \), \( \delta \) are vectors of coefficients. Given an unbalanced panel, let \( T_i \) be the number of observation on panel \( i \), \( n \) be the number of panels, and \( N \) be the total number of observations.

The within and between transformations of (17) are,

\[ \tilde{y}_{it} = \tilde{Z}_{it} \delta + \tilde{\nu}_{it} \]  \hspace{1cm} (18)

and

\[ \bar{y}_i = \bar{Z}_i \delta + \mu_i + \bar{\nu}_i \]  \hspace{1cm} (19)

where \( \tilde{w}_{it} = w_{it} - \frac{1}{n} \sum_{t=1}^{T_i} w_{it} + \frac{1}{N} \sum_{i=1}^{n} \sum_{t=1}^{T_i} w_{it} \ \forall \ w \in \{y, Z, v\} \) and \( \bar{w}_i = \frac{1}{T_i} \sum_{t=1}^{T_i} w_{it} \ \forall \ w \in \{y, Z, v\} \). The combined residuals for the within estimator are \( \tilde{u}_{it}^w = \tilde{y}_{it} - \tilde{Z}_{it} \tilde{\delta}^w \). Let \( \tilde{u}_{it} \) be the within transformed

\[ ^8 \text{A Breusch and Pagan Lagrangian Multiplier test for the null hypothesis of no cross club variation is rejected at the 1 percent level for both regressions. Including club specific fixed effects is difficult to justify as it would result in the loss of 196 degrees of freedom.} \]
residuals. Following Swamy and Arora (1972), a consistent estimate of the idiosyncratic error component is given by 
\[ \hat{\sigma}_v = \frac{\sum_{t=1}^{T_i} \sum_{i=1}^{n} \tilde{u}_{it}^2}{N-n-K+1}. \]

The combined residuals from the between estimator are 
\[ u_{it}^b = \bar{y}_{it} - \bar{Z}_i \hat{\delta}^w. \]

Let \( \tilde{u}_{it} \) be the between transformed residuals. The individual error component can be estimated consistently by 
\[ \hat{\sigma}_\mu^2 = \frac{\sum_{t=1}^{T_i} \sum_{i=1}^{n} \tilde{u}_{it}^2 - (n-K)\hat{\sigma}_v}{N-r}, \]

where \( r = \text{trace}\left( (\bar{Z}_i' \bar{Z}_i)^{-1} \bar{Z}_i' Z_\mu Z_\mu' \bar{Z}_i \right) \).

\( Z_\mu = \text{diag}(i_i i_i') \), and \( i_i \) is a \( T_i \times 1 \) vector of ones. Finally, the feasible GLS transformation is

\[ w^* = w_a - \hat{\theta}_a \tilde{w}_i \quad (20) \]

where \( \hat{\theta}_a = 1 - \left( \frac{\hat{\sigma}_\mu^2}{T_i \hat{\sigma}_\mu^2 + \hat{\sigma}_v^2} \right)^{\frac{1}{2}} \) and \( \tilde{w}_i = \frac{1}{T_i} \sum_{t=1}^{T_i} w_a \quad \forall \ w \in \{y, Z, X, v\}. \)

The generalized two-stage least squares estimates are given by the instrumental variable regression of \( y_a^* \) on \( Z_a^* \) with instruments \( X_a^* \),

\[ \hat{\delta}_{G2SLS} = \left( X_a'^* Z_a^* \right)^{-1} X_a'^* y_a^*. \]

To “normalize” the errors, we use the logs of certain variables. The errors for the linear and log functional forms were assessed by plotting the overall error components against the predicted values. The logs of male and female deer harvested, lease size, and farm size are used in each regressions. The coefficients for these variables are elasticities. They will be converted into marginal effects to calculate the comparative static in (15).

4.2 Testing

We test for underidentification and weak instruments. Testing the rank condition is usually done
using canonical correlations or a Cragg-Donald Wald statistic (Anderson, 1951; Cragg and Donald, 1993). These statistics are only valid if the errors are independently and identically distributed. Given the nature of our data, this assumption may not hold. One club’s harvest may affect another club’s. Kleibergen and Paap (2006) propose a number of alternative robust test statistics. We use Kleibergen and Paap test statistics to evaluate our instruments.

How do we compare the G2SLS and GLS estimates? Given a panel and the presence of heteroskedasticity, the Durbin-Wu-Hausman test of exogenous regressors is not valid. If additional excluded instruments were available, the exogeneity of lease size could be tested using a Hansen–Sargan–Basmann GMM difference test, or C test (Baum et al., 2003; Hansen, 1982; Sargan, 1958; Basmann, 1960). Unfortunately, additional excluded instruments are not available and we cannot formally test between the G2SLS and GLS estimates.

Yet, an argument can be made for considering the G2SLS estimates over the GLS. Hunters often engage in an activity referred to as scouting. Scouting consists of visiting a potential hunting location to gather information to make an informed decision as to whether or not to hunt the area. The number and quality of game animals in the area is valuable information and will certainly influence the hunting decision. Hunters or hunting clubs are not likely to lease an area with no a priori knowledge of the number and quality of game in an area. Thus, leasing behavior is not independent of harvest and quality and the G2SLS estimates should be considered over the GLS. The GLS results are considered for comparison.

5. Results

Recall our interest in the affect of lease size on harvest per acre. If lease size affects club harvesting behavior, harvest per acre will change with lease size. The estimated harvest equation takes
the form,

$$\text{harvest} = \beta_0 \text{lease}_\text{size}^{\beta_1} \times \text{covariates}_\text{logged}^{\beta_2} \times \exp[\beta_3 \text{covariates}_\text{levels}]$$  \hfill (21)

where $\beta_0$ is an intercept, $\beta_1$ is the coefficient for lease size, $\text{covariates}_\text{logged}$ is a vector of logged covariates, $\text{covariates}_\text{levels}$ is a vector of covariates in levels, and $\beta_2$ and $\beta_3$ are vectors of their corresponding coefficients. Given lease size is measured in acres, dividing (21) by lease size yields harvest per acre,

$$\frac{\text{harvest}}{\text{lease}_\text{size}} = \beta_0 \text{lease}_\text{size}^{\beta_1-1} \times \text{covariates}_\text{logged}^{\beta_2} \times \exp[\beta_3 \text{covariates}_\text{levels}]$$.  \hfill (22)

A coefficient for lease size such that $\beta_1 < 1$ suggests harvest per acre is decreasing with lease size. If the coefficient is less than zero, harvest per acre is decreasing with lease size at an increasing rate. A coefficient equal to one will result in a constant harvest per acre. Lastly, harvest per acre will increase with lease size given a coefficient greater than one.

Consider the harvest regressions in table 3. The lease size coefficient for the G2SLS estimator is 0.2013. However, with a p-value of 0.501, it is not significantly different from zero. The GLS coefficients are found in the second column. The coefficient for lease size is 0.3067. It is significantly different from zero at the 1 percent level. Both coefficients suggest harvest per acre decrease with lease size. Consider the G2SLS estimator. If $\beta_1 = 0.2013$, a one percent increase in lease size will result in a 0.7987 percent decrease in harvest per acre. Considering the GLS estimator, a one percent increase in lease size would result in 0.6933 percent decrease in harvest per acre.

The results for the G2SLS reduced form (first stage) regressions are presented in table 5. The coefficient for average farm size is positive and significantly different from zero at the 1 percent level. From these results, we can surmise average farm size to be a relevant instrument for lease size. The
partial R-Squared suggests 3.63 percent of the variation in lease size can be explained by farm size. The Kleibergen-Paap test statistics are reported in table 6. Considering the LM statistic, the $X'Z$ matrix has full rank and our equation is not underidentified. The F statistic suggests any size distortions of the instrumental variable estimates are less than 10 percent of their maximum values.\(^9\)

Moving to the quality regressions, consider table 4. The coefficients for lease size are 0.2605 and 0.0279 for the G2SLS and GLS. With a p-value of 0.057, the G2SLS coefficient is significantly different from zero. The GLS coefficient is much smaller and less significant with a p-value of 0.104. Both estimates suggest the average quality of deer harvested increase with lease size. Also, note the coefficient for harvest is negative and significantly different from zero for both estimators.

In the reduced form regression, the coefficient for our instrument, average farm size, is positive and significantly different from zero. The partial R-Squared of 0.0348 suggests only 3.48 percent of variation in lease size is explained by our excluded instrument. From the Kleibergen-Paap LM statistic, we can reject the null of underidentification. However, the Kleibergen-Paap F statistic suggests our coefficients may be slightly distorted. The F statistic is 15.24. The critical value for a distortion less than 10 percent of the estimate’s maximum value is 16.38.

Using the results from both regressions, we can calculate the total effect of lease size. However, our variables of interest are in logs, so the coefficients are elasticities. Before calculating the total effect, the elasticities must be converted into marginal effects. The marginal effect is simply the product of the elasticity and its ratio of variables in levels. For example, the marginal effect of lease size on harvest is,

$$
\beta_{\text{harvest}}^{\text{lease}\_\text{size}}
$$

\(^9\) See Stock and Yogo (2005) for critical values.
The relevant marginal effects are shown in table 7. The total effect is the sum of the combination effect, which corresponds to the marginal effect of lease size from the quality regression, and the indirect harvest effect, which we will now calculate. Recall the indirect harvest effect in (16). It is the product of the marginal effect of lease size on harvest and the marginal effect of harvest on quality. Considering the harvest G2SLS marginal effects, the indirect harvest effect is -0.000250. This suggests an increase in lease size of 1000 acres will result in a decrease in the antler index of 0.25 units. If we treat the harvest G2SLS lease size coefficient as zero, the indirect effect is obviously zero. Using the GLS estimates, we have an indirect harvest effect of -0.000388. This suggests a 1000 acre increase in lease size would result in the antler index decreasing 0.388 points.

Table 8 presents the combination, indirect harvest, and total effects of lease size. Using the marginal effects from the G2SLS estimators, and assuming the lease size coefficient from the harvest regression is really 0.2013 and not zero, we have a total effect of 0.005258. This suggests a 1000 acre increase in lease size will result in the antler index increasing 5.26 points. Treating the lease size coefficient from the harvest regression as zero, the total effect is simply the combined marginal lease effect from the quality regression. Using the GLS estimates, the total effect is 0.000202. A 1000 acre increase in lease size will result in the antler index increasing by 0.2 points.

To illustrate the impact of these results, we estimate the effects of a simulated increase in lease size. The average lease size is 3736.5 acres. There are 121 hunting clubs with smaller than average lease sizes. Using the G2SLS estimates, a simulated increase in lease size to the average decreases the average harvest per acre 38.25 percent, from 8.23 to 5.83, and increases the average antler index 4.50 percent, from 49.09 to 53.52. If we treat the harvest effect as zero, the increase in antler index becomes 4.75 percent.
In summary, our results suggest club harvest per acre is decreasing with lease size and the total effect of lease size on antler quality, given by equation (15), is indeed positive. Combined, it appears that as lease size increases, clubs harvest fewer and higher quality deer per acre. Although we analyze properties leased by hunting clubs, the results should be applicable to various other management scenarios. These results have implications for state wildlife agencies and the individual game manager. Certain states have deer management programs that give participants more management flexibility. One of the primary goals of these programs is to increase the quality of deer. A requirement for participation in these programs often includes a minimum acreage. An optimal minimum acreage requirement should consider the potential benefits to quality illustrated here. For the individual game manager, in conjunction with estimates of hunter willingness to pay, these results may also prove valuable in the decision to cooperation with neighbors or increase acreage.

6. Conclusions

There is no literature empirically testing the effects of property rights on wildlife quality. This article develops a theoretical model analyzing the effects of varying levels of property rights on resource quality and estimates the developed relationships. Our model considers the case of deer hunting leases held by hunting clubs maximizing a club utility function. Utility is determined by the quantity and quality of deer harvested. Quality is determined by their harvest decisions. Equation (13) and (14) illustrate how harvest and quality are determined by lease size and ecological variables.

This article is the first to incorporate property rights and resource quality into a bioeconomic model. The effect of lease size on quality can be decomposed into three effects; a direct effect, an indirect stock effect, and an indirect harvest effects. Using a time-series cross-section from the

10 For example, see the Antlerless and Spike-Buck Deer Control Permits Program or the Landowner Assisted Management Permitting System in Texas: http://www.tpwd.state.tx.us/huntwild/wild/game_management/deer/
Mississippi Department of Wildlife and Fisheries with harvest rates and antler measurements for various hunting clubs, we are able to estimate the total effect of lease size on quality. Given data limitations, we are only able to estimate the indirect harvest effect and a combined effect in the form of the sum of the direct effect and indirect stock effect. If stock levels were available, the indirect stock effect could have been estimated separate from the direct effect.

The mechanism considered in our example is driven by externalities. As lease size increases, the level of ownership of the stock increases. As the stock becomes less transboundary, externalities are increasingly internalized and the resource is used more efficiently. In this case, more efficient use corresponds to fewer deer harvested per acre and higher average quality of deer harvested. Our results support this hypothesis. Club harvest per acre decreases with lease size. Additionally, lease size has a small but significant effect on the average quality of deer harvested. For all clubs with smaller than average hunting leases, a simulated increase to the average size results in approximately a 4.5 percent increase in the average antler index of deer harvested.

The affect of lease size on harvesting behavior may even be reflected in hunting club policies. Hunting clubs usually have a set of standards or rules their members must follow. One of the rules may include a minimum quality threshold for harvesting. This might be a club antler point minimum — members cannot harvest any deer with few than the minimum antler points. By encouraging members to forgo harvesting lower quality deer, clubs can increase the average quality of deer harvested. As lease size increases, the risk of losing forgone deer to neighboring hunters decreases and clubs may be more willing to impose higher minimum quality thresholds. Considering these endogenous minimum quality thresholds may be an interesting extension of our analysis.
References


Table 1. Land composition variables

<table>
<thead>
<tr>
<th>Percentage of land in agricultural</th>
<th>Percentage of land in bottom-land hardwood forest</th>
<th>Percentage of land in high-density hardwood forest</th>
<th>Percentage of land in medium-density hardwood forest</th>
<th>Percentage of land in high-density pine forest</th>
<th>Percentage of land in medium-density pine forest</th>
<th>Percentage of land in low-density pine forest</th>
<th>Percentage of land in pasture land</th>
<th>Percentage of land in shrub habitat</th>
<th>Percentage of land in water</th>
</tr>
</thead>
</table>

Table 2. Summary Statistics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lease size (acres)</td>
<td>3736.5</td>
<td>2799.19</td>
<td>432.00</td>
<td>15750.00</td>
</tr>
<tr>
<td>Number of male deer harvested</td>
<td>25.11</td>
<td>15.25</td>
<td>2</td>
<td>101</td>
</tr>
<tr>
<td>Number of female deer harvested</td>
<td>33.60</td>
<td>26.63</td>
<td>0</td>
<td>215</td>
</tr>
<tr>
<td>Antler index</td>
<td>48.95</td>
<td>10.55</td>
<td>23.47</td>
<td>80.03</td>
</tr>
<tr>
<td>Shannon’s diversity index</td>
<td>1.47</td>
<td>0.46</td>
<td>0.10</td>
<td>2.28</td>
</tr>
<tr>
<td>Pine Forest</td>
<td>15.05</td>
<td>16.86</td>
<td>0</td>
<td>87.12</td>
</tr>
<tr>
<td>% of land in high-density pine forest</td>
<td>4.62</td>
<td>8.08</td>
<td>0.00</td>
<td>66.11</td>
</tr>
<tr>
<td>% of land in medium-density pine forest</td>
<td>8.43</td>
<td>8.42</td>
<td>0.00</td>
<td>34.74</td>
</tr>
<tr>
<td>% of land in low-density pine forest</td>
<td>1.98</td>
<td>3.46</td>
<td>0.00</td>
<td>15.98</td>
</tr>
<tr>
<td>Hardwood Forest</td>
<td>52.72</td>
<td>23.12</td>
<td>3.20</td>
<td>98.22</td>
</tr>
<tr>
<td>% of land in bottom-land hardwood forest</td>
<td>24.23</td>
<td>28.79</td>
<td>0.00</td>
<td>98.22</td>
</tr>
<tr>
<td>% of land in high-density hardwood forest</td>
<td>1.61</td>
<td>2.44</td>
<td>0.00</td>
<td>14.26</td>
</tr>
<tr>
<td>% of land in medium-density hardwood forest</td>
<td>26.88</td>
<td>25.29</td>
<td>0.00</td>
<td>85.17</td>
</tr>
<tr>
<td>Food Sources</td>
<td>21.65</td>
<td>11.89</td>
<td>0.90</td>
<td>77.35</td>
</tr>
<tr>
<td>% of land in agricultural</td>
<td>4.75</td>
<td>8.46</td>
<td>0.00</td>
<td>70.25</td>
</tr>
<tr>
<td>% of land in pasture land</td>
<td>10.95</td>
<td>9.74</td>
<td>0.00</td>
<td>46.01</td>
</tr>
<tr>
<td>% of land in shrub habitat</td>
<td>0.77</td>
<td>1.80</td>
<td>0.00</td>
<td>13.32</td>
</tr>
<tr>
<td>% of land in water</td>
<td>5.17</td>
<td>7.96</td>
<td>0.012</td>
<td>38.43</td>
</tr>
</tbody>
</table>
### Table 3. Harvest regressions

<table>
<thead>
<tr>
<th>Variable</th>
<th>G2SLS</th>
<th>GLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log of lease size</td>
<td>0.2013</td>
<td>0.3067***</td>
</tr>
<tr>
<td></td>
<td>(0.2990)</td>
<td>(0.0503)**</td>
</tr>
<tr>
<td>% of land in pine forest</td>
<td>0.0045</td>
<td>0.0057***</td>
</tr>
<tr>
<td></td>
<td>(0.0064)</td>
<td>(0.0056)</td>
</tr>
<tr>
<td>% of land in hardwood forest</td>
<td>0.0091</td>
<td>0.0115***</td>
</tr>
<tr>
<td></td>
<td>(0.0087)</td>
<td>(0.0056)**</td>
</tr>
<tr>
<td>% of land in food sources</td>
<td>0.0011</td>
<td>0.0021***</td>
</tr>
<tr>
<td></td>
<td>(0.0066)</td>
<td>(0.0058)</td>
</tr>
<tr>
<td>Shannon’s diversity index</td>
<td>0.3561</td>
<td>0.3731***</td>
</tr>
<tr>
<td></td>
<td>(0.1275)**</td>
<td>(0.1037)**</td>
</tr>
<tr>
<td>Log of female deer harvested</td>
<td>0.2001</td>
<td>0.1500***</td>
</tr>
<tr>
<td></td>
<td>(0.1501)</td>
<td>(0.0560)**</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.3157</td>
<td>-1.1836***</td>
</tr>
<tr>
<td></td>
<td>(2.5322)</td>
<td>(0.7187)**</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* significant at 15%; ** significant at 10%; *** significant at 5%

### Table 4. Quality Regressions

<table>
<thead>
<tr>
<th>Variable</th>
<th>G2SLS</th>
<th>GLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log of lease size</td>
<td>0.2605</td>
<td>0.0279*</td>
</tr>
<tr>
<td></td>
<td>(0.1366)**</td>
<td>(0.0172)</td>
</tr>
<tr>
<td>% of land in pine forest</td>
<td>-0.0002</td>
<td>-0.0029*</td>
</tr>
<tr>
<td></td>
<td>(0.0029)</td>
<td>(0.0021)</td>
</tr>
<tr>
<td>% of land in hardwood forest</td>
<td>0.0057</td>
<td>0.0006***</td>
</tr>
<tr>
<td></td>
<td>(0.0040)*</td>
<td>(0.0020)</td>
</tr>
<tr>
<td>% of land in food sources</td>
<td>0.0058</td>
<td>0.0038***</td>
</tr>
<tr>
<td></td>
<td>(0.0029)**</td>
<td>(0.0023)*</td>
</tr>
<tr>
<td>Shannon’s diversity index</td>
<td>-0.0890</td>
<td>-0.1236***</td>
</tr>
<tr>
<td></td>
<td>(0.0581)*</td>
<td>(0.0378)**</td>
</tr>
<tr>
<td>Log of lagged male deer</td>
<td>-0.0457</td>
<td>-0.0465***</td>
</tr>
<tr>
<td>harvested</td>
<td>(0.0200)**</td>
<td>(0.0156)**</td>
</tr>
<tr>
<td>Log of female deer harvested</td>
<td>-0.0604</td>
<td>0.0502***</td>
</tr>
<tr>
<td></td>
<td>(0.0649)</td>
<td>(0.0216)**</td>
</tr>
<tr>
<td>Constant</td>
<td>1.8443</td>
<td>3.7485***</td>
</tr>
<tr>
<td></td>
<td>(1.1360)*</td>
<td>(0.2530)**</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* significant at 15%; ** significant at 10%; *** significant at 5%
### Table 5. First Stage G2SLS Regressions on the Log of Lease Size

<table>
<thead>
<tr>
<th>Variable</th>
<th>Harvest</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of land in pine forest</td>
<td>-0.0072</td>
<td>-0.0078</td>
</tr>
<tr>
<td></td>
<td>(0.0035) ***</td>
<td>(0.0040) ***</td>
</tr>
<tr>
<td>% of land in hardwood forest</td>
<td>-0.0220</td>
<td>-0.0226</td>
</tr>
<tr>
<td></td>
<td>(0.0034) ***</td>
<td>(0.0040) ***</td>
</tr>
<tr>
<td>% of land in food sources</td>
<td>-0.0094</td>
<td>-0.0096</td>
</tr>
<tr>
<td></td>
<td>(0.0037) ***</td>
<td>(0.0043) ***</td>
</tr>
<tr>
<td>Shannon’s diversity index</td>
<td>0.0129</td>
<td>-0.0192</td>
</tr>
<tr>
<td></td>
<td>(0.0807)</td>
<td>(0.0931)</td>
</tr>
<tr>
<td>Log of lagged male deer harvested</td>
<td>-</td>
<td>0.0973</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0241) ***</td>
</tr>
<tr>
<td>Log of female deer harvested</td>
<td>0.4774</td>
<td>0.4505</td>
</tr>
<tr>
<td></td>
<td>(0.0300) ***</td>
<td>(0.0352) ***</td>
</tr>
<tr>
<td>Log of average county farm size</td>
<td>0.2857</td>
<td>0.2759</td>
</tr>
<tr>
<td></td>
<td>(0.0534) ***</td>
<td>(0.0616) ***</td>
</tr>
<tr>
<td>Constant</td>
<td>6.1720</td>
<td>6.1098</td>
</tr>
<tr>
<td></td>
<td>(0.5331) ***</td>
<td>(0.6133) ***</td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* significant at 15%; ** significant at 10%; *** significant at 5%

### Table 6. Kleibergen-Paap Tests

<table>
<thead>
<tr>
<th></th>
<th>Harvest</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kleibergen-Paap LM statistic</td>
<td>21.281</td>
<td>13.955</td>
</tr>
<tr>
<td>P-value</td>
<td>0.0000</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Harvest</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kleibergen-Paap F statistic</td>
<td>23.149</td>
<td>15.240</td>
</tr>
</tbody>
</table>

Critical values for size distortion less than:

- 10% maximal IV size: 16.38
- 15% maximal IV size: 8.96
- 20% maximal IV size: 6.66

### Table 7. Marginal Effects

<table>
<thead>
<tr>
<th></th>
<th>Harvest</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>G2SLS</td>
<td>GLS</td>
<td>G2SLS</td>
</tr>
<tr>
<td>Lease size</td>
<td>0.00184309</td>
<td>0.00280767***</td>
</tr>
<tr>
<td></td>
<td>(0.0027372)</td>
<td>(0.0004606)</td>
</tr>
<tr>
<td>Harvest</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Standard errors in parentheses
* significant at 15%; ** significant at 10%; *** significant at 5%
Table 8. Direct, Indirect, and Total Effects of Lease Size on Quality

<table>
<thead>
<tr>
<th></th>
<th>G2SLS</th>
<th>GLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect Harvest Effect</td>
<td>-0.000250</td>
<td>-0.000388</td>
</tr>
<tr>
<td>Combined direct effect and</td>
<td>0.005508</td>
<td>0.000590</td>
</tr>
<tr>
<td>indirect stock effect.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total effect</td>
<td>0.005258</td>
<td>0.000202</td>
</tr>
</tbody>
</table>