Efficient Land Tenure Contract Under Asymmetric Information

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The economics of U.S. agricultural land tenure is often characterized by asymmetric information between the landlord and tenant. It is not uncommon to have absentee landlords who can observe only levels of cost-shared inputs and output to get an indication of the tenant's actions. In a recent survey, we discovered that among cotton producers in the southern high plains of Texas in 1995, there were 298 absentee landlords out of 351 observations and out of 308 observations the average distance of the landlord's residence from the farm was 134.71 miles (Dasgupta, Knight, Love and Smith).

Since land tenure contracts allocate resources and share wealth between contracting parties, the landlord's lack of full information can contribute towards inefficiency. For example, in contracts negotiated for a short time period each party usually optimize their individual payoff after assuming rationality of the other party. In the land tenure there are numerous such examples. In his investigations, Cheung assumed single-period contracts and so did later researchers such as Stiglitz, Newberry and Stiglitz, Braverman and Srinivasan, Braverman and Stiglitz, etc. who approached land tenure economics from the perspective of sharing risk and providing work incentives for the tenant under asymmetric information conditions between the two parties. Only recently did researchers begin to consider the benefits of cooperation in these contracts where both parties have a joint objective. Itoh considers inter-tenant cooperation in multi-tenant contracts while cooperative contracts through trigger strategies are discussed by Kreps along with other researchers. Since the decentralized decision making process inherent to these contracts implies an underlying game, some game-theory literature of cooperation under asymmetric information is also relevant. In this context, research on long-term Principal-Agent relations by Radner and Radner, Myerson and Maskin are important.

This article develops an efficient, long-term, sharecropping contract where it is possible for each party to receive an equilibrium cooperative payoff almost equivalent to receiving their full-information, cooperative payoff in each period. Due to such payoff potential, this contract is called efficient while contracts where payoffs are reduced due to imperfect or asymmetric information are called inefficient. We modify and extend the basic model of a repeated, Principal-Agent game developed by Radner. Our analysis differs from Radner's in that we model a flexible sharecropping contract and does not include assumptions unrealistic to agricultural land tenure, granted that Radner's model was not driven by considerations of land tenure economics.

As seen above, for convenience we refer the landlord with the pronoun 'she' and the tenant with 'he'. Also for convenience, we have kept our notation similar the Radner's, particularly denoting the landlord with 'P' and tenant with 'A,' signifying our assumption that in the U.S. and underlying Principal-Agent relation exist, as per Radner's definition, between the landlord and tenant.

The One-Period Game

Assuming x and l (labor) are the two inputs in the production process with per unit costs of r and w respectively, output is represented by $y = y(x,l,u)$, where u represents the uncertain state of nature ($y_x > 0, y_l > 0, y_{xx} < 0, y_{ll} < 0,$ y is quasi-concave in x and l). Let both parties share the cost of x with β being the tenant's share and let α be the tenant's output share. Thus the tenant's income is $i_A = \alpha y - \beta rx - wl$, while the landlord's income is $i_P = (1-\alpha)y - (1-\beta)rx$. We assume that both landlord and tenant are risk-averse with positive marginal utilities, decreasing with increase in their incomes.

In the non-cooperative game the tenant maximizes his expected utility by choosing input levels, conditional on the landlord's choice of α and β. The landlord maximizes her expected utility subject to the tenant's reaction functions $x(\alpha,\beta), l(\alpha,\beta)$. This is represented by $\text{Max}_{x,l}\, EU_A(i_A|\alpha,\beta)$ and $\text{Max}_{\alpha,\beta}\, EU_P(i_P|x(\alpha,\beta), l(\alpha,\beta))$ respectively. Assuming first and second order conditions are satisfied for the above problem, the non-cooperative solution functions are denoted $x^*, l^*, \alpha^*, \beta^*$ and the non-cooperative payoffs are denoted A^*, P^*.

The cooperative game is characterized by both parties optimizing the following joint objective: $\text{Max}_{x,l,\alpha,\beta}\, [E(U_A) - A^*][E(U_P) - P^*]$. This objective, known as the Nash product, gives $\hat{x}, \hat{l}, \hat{\alpha}, \hat{\beta}$ as solution functions and $\hat{A} = EU_A|_{\{\hat{x},\hat{l},\hat{\alpha},\hat{\beta}\}}$ and $\hat{P} = EU_P|_{\{\hat{x},\hat{l},\hat{\alpha},\hat{\beta}\}}$ as the cooperative payoffs, assuming that the prospect space is not trivial (Nash, Harsanyi). Therefore, from our assumptions we conclude that the cooperative payoff pair is Pareto superior to the non-cooperative payoff pair. Following Radner, we assume that cooperation is pre-declared by the landlord, giving the tenant opportunity to cheat, according to the following objective: $\text{Max}_l\, EU_A(i_A|_{\{\hat{x},\hat{\alpha},\hat{\beta}\}})$ which gives l^{**} as the solution function and $A^{**} ge \hat{A}$ as the cheating payoff, assuming the first and second order conditions are satisfied for the above maximization problem. Thus it is clear that the landlord's corresponding payoff is $P^{**} le \hat{P}$. Assuming the inequalities associated with the cheating payoffs are strict, the one-period game is comparable to the Prisoner's Dilemma game in that although non-cooperation gives a Nash equilibrium, cooperation fo one period does not result in an equilibrium.

The Supergame

In the supergame or infinitely repeated game, either non-cooperation, cooperation or cheating can occur. Our goal here is to derive conditions for a cooperative Nash equilibrium that will provide payoffs as per full-information efficiency (i.e., $\{\hat{A}, \hat{P}\}$). We assume that both parties play review strategies developed by Radner, with respect to their respective information sets which are assumed to be $I_{P,t} = \{\alpha_1,\ldots,\alpha_t,\beta_1,\ldots,\beta_t,x_1,\ldots,x_{t-1},y_1,\ldots,y_{t-1}\}$ and $I_{A,t} = \{I_{P,t},l_1,\ldots,l_{t-1},u_1,\ldots,u_{t-1}\}$ in period t.

The landlord's review strategy consists of consecutive periods of cooperation followed possibly by consecutive periods of punishment. After cooperating for *R* periods, comprising a review phase, the landlord compares the average output to her expected cooperative output (i.e., $\bar{y}_R = (\sum_{1=1}^{R} y_t)/R geor < \hat{y} - B$, where $\hat{y} = E(y(\hat{x},\hat{l},u))$ and *B* is an error margin). If $\bar{y}_R$ is at least $\hat{y} - B$, the tenant passes the review and the next review phase begins; otherwise he fails the review and a *M*-period, non-cooperative, punishment phase begins followed by another review phase. The tenant's review strategy involves playing the best response to the landlord's cooperation and if the landlord reneges from cooperation during a review phase, the tenant triggers non-cooperation for the remainder of the review phase and M' additional periods. Here *R*, *M* and M' characterize the supergame and review strategies and will be later qualified.

Let us now consider the tenant's patterns of cheating during a review phase. If he cheats

T out of *R* periods, *T* can remain fixed for all *R*, increase or decrease with *R* at varying rates or change in any combination of the three previous modes. To simplify matters, define $T_0(R)$ as the 'upper envelope' of $T(R)$ by $T_0(R) = T(R)$ if $T(R) \geq T(R-1)$ and $T(R-1)$, otherwise. A tenant cheats inconsistently if $\exists R_0 > 0, \ni \forall R \geq R_0, T_0(R) = t_0$ where t_0 is a constant ($T_0(R)$=0, if the tenant never cheats). If the tenant does not cheat inconsistently, he is said to cheat consistently.

We now investigate the effect of consistent and inconsistent cheating on the tenant's likelihood of passing a review. We define $\phi = Pr[\bar{y}_R \geq \hat{y} - B]$, where 'Pr' means 'probability'. Holmstrom found that in repeated games of imperfect information, the degree of imperfection of the information conveyed by a signal diminishes with the number of repetitions of the game. In this context, we present the following two lemmas.

Lemma 1. If the tenant cheats inconsistently, ϕ increases with R.

Proof. Let the tenant cheat in the first *T* periods of the *R*-period review phase. Thus, the actual number of times the tenant cheats is at most $T_0(R)$. Assuming, for $t = 1 \ldots T$, $y(\hat{x}, l^{**}, u_t) \sim iid(y^{**}, \sigma^2)$, Chebyshev's inequality,

$$\phi \geq Pr[(\sum_{t=1}^{T_0(R)} y(\hat{x}, l^{**}, u_t) + \sum_{t=T_0(R)+1}^{R} y(\hat{x}, \hat{l}, u_t)) / R \geq \hat{y} - B] \geq$$

$$Pr[(\sum_{t=1}^{T_0(R)} y(\hat{x}, l^{**}, u_t)) / T_0(R) \geq \hat{y} - B] \cdot Pr[(\sum_{t=T_0(R)+1}^{R} y(\hat{x}, \hat{l}, u_t)/(R - T_0(R)) \geq \hat{y} - B] \geq$$

$$[1 - \{\sigma^2/(\hat{y} - B - y^{**})^2\}]^{T_0(R)} [1 - \{\sigma^2/(R - T_0(R))B^2\}]$$. Since by definition of inconsistent cheating, $T_0(R) \to t_0$ (constant) for *R* large enough, ϕ increases with *R*. This is true provided RB^2 increases with *R*. We assume that the error margin *B* decreases with increasing length of the

review phase. In fact we assume that $B(R) = \tau R^{\rho}, \ \tau > 0, \ -1/2 < \rho < 0$ which is implies that RB^2 increases with R.

Consistent with Holmstrom's conclusions, we show in Lemma (2) that the tenant's likelihood of passing the review decreases with increasing R, and asymptotically he is assured of failing the review.

Lemma 2. If the tenant cheats consistently, ϕ decreases with R and asymptotically approach 0.

Proof. Let us denote $X_1 = \sum_{t=1}^{T_0(R)} y_t(\hat{x}, l^{**}, u_t) / T_0(R)$ and $X_2 = \sum_{t=T_0(R)+1}^{R} y_t(\hat{x}, \hat{l}, u_t) / (R - T_0(R))$,

where X_1 and X_2 are independent random variables. Thus,

$$\bar{y}_R = [\sum_{t=1}^{T_0(R)} y_t(\hat{x}, l^{**}, u_t) + \sum_{t=T_0(R)+1}^{R} y_t(\hat{x}, \hat{l}, u_t)] / R = \{T_0(R)/R\} X_1 + \{(R - T_0(R))/R\} X_2 .$$

Therefore, $\phi = Pr[(T_0(R)/R) X_1 + (R - T_0(R))/R X_2 \, ge \hat{y} - B] le Pr[(X_1 ge \hat{y} - B) UNION (X_2 ge \hat{y} - B)]$

$= Pr(X_1 ge \hat{y} - B) + Pr(X_2 ge \hat{y} - B) - Pr(X_1 ge \hat{y} - B) Pr(X_2 ge \hat{y} - B)$. Thus it is sufficient to show that, under consistent cheating, the right hand side of the above equation decreases with R.

Since, $X_1 \_ (y^{**}, \sigma^2 / T_0(R))$ and $X_2 \_ (\hat{y}, \sigma^2 / \{R - T_0(R)\})$, by Chebychev's theorem,

$Pr(X_1 ge \hat{y} - B) le \frac{\sigma}{\sqrt{T_0(R)}(\hat{y} - B - y^{**})}$ and $Pr(X_2 ge \hat{y} - B) = Pr(z ge \frac{-B}{\sigma / \sqrt{R - T_0(R)}})$, where

$z = \{X_2 - \hat{y}\} / \{\sigma / \sqrt{R - T_0(R)}\} \_$ (mean 0, variance 1). From the definition of consistent cheating, $T_0(R)$ is strictly increasing – $R ge R_0 > 0$. Therefore, for a B decreasing with R, $Pr(X_1 ge \hat{y} - B)$ decreases with R, while $Pr(X_2 ge \hat{y} - B)$ approaches a constant ($Pr(z ge 0)$). Hence, ϕ decreases with R and approaches 0 for R large enough.

Let us now derive the supergame payoffs for both parties. If P_t and A_t are respectively the landlord's and tenant's payoffs in period t, and γ and δ are their discount factors, their normalized, discounted, expected current and future utilities (NDCFU) are

$P(\gamma) = (1-\gamma)\sum_{t=1}^{infinity} \gamma^{t-1} P_t$ and $A(\delta) = (1-\delta)\sum_{t=1}^{infinity} \delta^{t-1} A_t$ respectively. Using the strong Markov property, from the definition of review strategies we obtain:

$$A(\delta) = (1-\delta)\sum_{t=1}^{R}\delta^{t-1} A_t + (1-\phi)[\delta^R (1-\delta)\sum_{t=1}^{M}\delta^{t-1} A^* + \delta^{R+M} A(\delta)] + \phi\delta^R A(\delta)$$ or

$$A(\delta) = \{(1-\delta)\sum_{t=1}^{R}\delta^{t-1} A_t + (1-\phi)\delta^R (1-\delta^M) A^*\} / \{(1-\delta^R) + (1-\phi)\delta^R (1-\delta^M)\}$$ and similarly we get,

$$P(\gamma) = \{(1-\gamma)\sum_{t=1}^{R}\gamma^{t-1} P_t + (1-\phi)\gamma^R (1-\gamma^M) P^*\} / \{(1-\gamma^R) + (1-\phi)\gamma^R (1-\gamma^M)\}.$$

Since a rational agent will cheat only if his subsequent payoff is higher that his payoff under cooperation, the lower bound of $A(\delta)$ is obtained when the tenant never cheats. Since the tenant's cheating is at the expense of the landlord, if he never cheats the corresponding payoff of the landlord is the maximum she can get and hence is the upper bound of $P(\gamma)$. These payoffs are

$$\hat{A}(\delta) = \{(1-\delta^R)\hat{A} + (1-\hat{\phi})\delta^R (1-\delta^M) A^*\} / \{(1-\delta^R) + (1-\hat{\phi})\delta^R (1-\delta^M)\}$$ and

$$\hat{P}(\gamma) = \{(1-\gamma^R)\hat{P} + (1-\hat{\phi})\gamma^R (1-\gamma^M) P^*\} / \{(1-\gamma^R) + (1-\hat{\phi})\gamma^R (1-\gamma^M)\}$$ respectively, where

$\hat{\phi} = Pr[(\sum_{t=1}^{R} y(\hat{x},\hat{l},u)) / R ge \hat{y} - B]$. Since the tenant increases his payoff above $\hat{A}(\delta)$ by cheating, we define the upper bound of $A(\delta)$ ($A_0(\delta)$) by assuming he cheats for the first T periods. Since the tenant cheats at the expense of the landlord, $A_0(\delta)$ defines a lower bound ($P_0(\gamma)$) for $P(\gamma)$.

Thus

$$A_0(\delta) = \{(1-\delta^{T_0(R)})A^{**} + \delta^{T_0(R)}(1-\delta^{R-T_0(R)})\hat{A} + (1-\phi)\delta^R(1-\delta^M)A^*\}/\{(1-\delta^R)+(1-\phi)\delta^R(1-\delta^M)\}$$

and

$$P_0(\gamma) = \{(1-\gamma^{T_0(R)})P^{**} + \gamma^{T_0(R)}(1-\gamma^{R-T_0(R)})\hat{P} + (1-\phi)\gamma^R(1-\gamma^M)P^*\}/\{(1-\gamma^R)+(1-\phi)\gamma^R(1-\gamma^M)\}$$

where $\phi = Pr[\{\sum_{t=1}^{T_0(R)} y_t(\hat{x}, l^{**}, u_t) + \sum_{t=T+1}^{R} y_t(\hat{x}, \hat{l}, u_t)\}/R ge \hat{y} - B]$.

Let us now investigate the tenant's incentives to cheat. If he cheats inconsistently for during each review phase, for $R > R_0 > 0$, R large enough, δ and γ <1,

$1-\phi le\{1-(\sigma^2/(\hat{y}-B(R)-y^{**})^2)\}^{t_0}$, $\delta^R, \gamma^R \to 0$. Therefore, $A_0(\delta) \to \delta^{t_0}\hat{A} + (1-\delta^{t_0})A^{**} > \hat{A}$ and $P_0(\gamma) \to \gamma^{t_0}\hat{P} + (1-\gamma^{t_0})P^{**} < \hat{P}$, provided δ^R, $\gamma^R \to 0$. If the tenant never cheats, $t_0 = 0$ and $A_0(\delta) \to \hat{A}$ and $P_0(\gamma) \to \hat{P}$. Hence given an ε>0 $\_ R_\varepsilon \ni R ge R_\varepsilon, \delta$ and γ close enough to 1 implies $|A_0(\delta) - \hat{A}| < \varepsilon$ and $|P_0(\gamma) - \hat{P}| < \varepsilon$.

Let us assume that the tenant cheats consistently for every review phase. If his normalized, expected payoff from a review phase is A^{**}, $A(\delta)$ =

$(1-\delta)[A^{**} + (1-\phi)\sum_{t=1}^{M} A^*] + (1-\phi)\delta^{M+1}A(\delta) + \phi\delta A(\delta)$ which implies $A(\delta)$ =

$[(1-\delta)/\{1-(1-\phi)\delta^{M+1} - \phi\delta\}]A^{**} +$, $[(1-\phi)\delta(1-\delta^M)/\{1-(1-\phi)\delta^{M+1} - \phi\delta\}]A^*$, a weighted average of A^{**} and A^{*}. For any φ, as δ (< 1) increases, the weight of A^{**} decreases and since $A^{**} > \hat{A} > A^{*}$, $\_\delta_{\min} \ni \_\delta ge\, \delta_{\min}, A(\delta) le \hat{A}$, that is, the tenant is better-off never cheating than cheating consistently every review phase. Let us now assume that the tenant cheats consistently for only the first review phase and inconsistently thereafter. If ϕ_1 is the probability of passing the first review and ϕ_2 is the probability thereafter, the $A(\delta) = (1 - \delta)\, A^{**} + \; (1 - \phi_1)\delta(1 - \delta^M)\, A^{*} + \{(1 - \phi_1)\delta^{M+1} + \phi_1 \delta\}\, A_2(\delta)$ where $A_2(\delta)$ is the tenant's NDCFU if he cheats inconsistently for *T* periods starting from the second review phase.

$$A_2(\delta) = (1 - \delta^{R-T})\hat{A} + \delta^{R-T}(1 - \delta^{T})\, A^{**} + (1 - \phi_2)\delta^{R}(1 - \delta^{M})\, A^{*} + \{(1 - \phi_2)\delta^{R+M} + \phi_2 \delta^{R}\}\, A_2(\delta)$$

which simplifies to $A(\delta) = (a)\hat{A} + (b)\, A^{*} + (c)\, A^{**}$ where

$(a) = \{(1 - \phi_1)\delta^{M+1} + \phi_1 \delta\}(1 - \delta^{R-T}) / (d)$,

$(b) = (1 - \phi_1)\delta(1 - \delta^{M}) + \{(1 - \phi_1)\delta^{M+1} + \phi_1 \delta\}(1 - \phi_2)\delta^{R}(1 - \delta^{M}) / (d)$ and

$(c) = (1 - \delta) + \{(1 - \phi_1)\delta^{M+1} + \phi_1 \delta\}\delta^{R-T}(1 - \delta^{T}) / (d)$ where

$(d) = \{1 - \phi_2 \delta^{R} - (1 - \phi_2)\delta^{R}(1 - \delta^{M})\}$. It can be shown that for any (ϕ_1, ϕ_2), as δ increases (*a*) increases and (*c*) decreases. Therefore, from our above reasoning, $\_\delta_{\min}2 \ni \_\delta ge\, \delta_{\min}2, A(\delta) le \hat{A}$. Hence , for $\delta ge\, \mathrm{Max}\{\delta_{\min}, \delta_{\min}2\}, A(\delta) le \hat{A}$ and the tenant will be better-off if he does not cheat consistently in the first review phase.

Let us now investigate the landlord's incentives of reneging from cooperation.

Suppose she stops cooperating in the *T*th period, since her actions are transparent to the tenant, he triggers a $(R - T + M')$ punishment phase. The landlord's resulting NDCFU measured from the *T*th period is $P_1 = (1-\gamma)\sum_{t=1}^{R-T+M'} \gamma^{t-1} P^* + \gamma^{R-T+M'} P(\gamma)$. If she did not stop cooperating, her payoff from the *T*th period is

$P_2 = (1-\gamma)\sum_{t=1}^{R-T}\gamma^{t-1} P_t + \gamma^{R-T}(1-\gamma^{M^*}) P^* + \gamma^{R-T+M^*} P(\gamma)$, where M^* equals *M* if the tenant fails the review and is 0 otherwise. The landlord will not stop cooperation if $P_1 < P_2$.

Since $P_t \geq P^{**}, \forall$ t, $P_2 \geq \tilde{P}_2 = (1-\gamma)\sum_{t=1}^{R-T}\gamma^{t-1} P^{**} + \gamma^{R-T}(1-\gamma^{M}) P^* + \gamma^{R-T+M} P(\gamma)$ and it is sufficient to show $P_1 < \tilde{P}_2$. This simplifies to

$\gamma^{R-T}(\gamma^M - \gamma^{M'})(P(\gamma) - P^*) > (1-\gamma^{R-T})(P^* - P^{**})$, $\forall T = 0,\dots,R$. Since, $P(\gamma) \geq P^*$ for a rational landlord and this inequality is only strengthened by making *T*=0, we arrive to the condition $\gamma^R(\gamma^M - \gamma^{M'})(P(\gamma) - P^*) > (1-\gamma^R)(P^* - P^{**})$ or

$\gamma^{M'} < \gamma^M - [(1-\gamma^R)(P^* - P^{**}) / \{\gamma^R(P(\gamma) - P^*)\}]$. Thus, for *M* such that the right hand side of the last inequality is positive and $M' \geq M'_{\min}$ = Min{M': the last inequality holds}, the landlord will be better-off cooperating.

Let us now investigate the conditions necessary for credibility of the tenant's threat of triggering a punishment. Assuming that the tenant's payoff in the period when the landlord stops cooperating (*T*) is $A^0 (\leq \hat{A})$, if he triggers a punishment phase, his NDCFU from the *T*th period will be $A_1 = (1-\delta)[A^0 + \sum_{t=1}^{R-T+M'} (\delta^t A^*)] + \delta^{R-T+M'+1} A(\delta)$. If he did not punish the landlord, his corresponding NDCFU will be $A_2 = (1-\delta)[\sum_{t=0}^{R-T-1} (\delta^t A^0) + \sum_{t=R-T}^{R-T+M^*-1} (\delta^t A^*)] + \delta^{R-T+M^*} A(\delta)$, where M^* is as defined earlier. For the tenant's threat of punishment to be credible, we need to show that $A_1 > A_2$. Since, for a rational tenant $A(\delta) ge A^*$, A_2 does not get any smaller if we replace M^* by 0. Thus the credibility condition is simplified to $\delta^{R-T+M'+1}(A(\delta) - A^*) > (\delta - \delta^{R-T}) A^0 - \delta A^* + \delta^{R-T} A(\delta)$, that is M' has to be such that $\delta^{M'} > \frac{\delta(A^0 - A^*) + \delta^{R-T}(A(\delta) - A^0)}{\delta^{R-T+1}(A(\delta) - A^*)}$. Thus if the landlord's cheating causes the tenant to obtain a payoff inferior enough to his non-cooperative payoff ($A^0 < A^*$) and the landlord decides to cheat early enough in a sufficiently long review phase, that is (*R-T*) is large enough such that $\delta(A^* - A^0) > \delta^{R-T}(A(\delta) - A^0)$, the tenant's punishment will be credible for any M' > 0. If A^0 is close enough to A^* such that , $\frac{\delta(A^0 - A^*) + \delta^{R-T}(A(\delta) - A^0)}{\delta^{R-T+1}(A(\delta) - A^*)} > 0$, M' has to be small enough for credibility of the tenant's threat of punishment. If $M'_{\max} = \text{Max}\{M' : \delta^{M'} > \frac{\delta(A^0 - A^*) + \delta^{R-T}(A(\delta) - A^0)}{\delta^{R-T+1}(A(\delta) - A^*)}\}$ then the tenant's threat of punishment is credible for all M' such that $M'_{\min} le M' le M'_{\max}$, provided $M'_{\min} le M'_{\max}$, otherwise the cooperative equilibrium will not exist.

We now investigate the credibility of the landlord's threat of punishment. If the landlord did not trigger any punishment, a rational agent will always cheat. Hence the landlord will receive P^{**} every period, which will equal to her NDCFU. If she punishes according to her review strategy, from our earlier analysis, for $\delta ge \text{Max}\{\delta_{\min}, \delta_{\min} 2\}$, the tenant will never cheat consistently. If the tenant only cheats inconsistently, from our earlier analysis, for ε>0 $- R_\varepsilon \ni R ge R_\varepsilon$ and γ close enough to 1, $|P_0(\gamma) - \hat{P}| < \varepsilon$ i.e., the upper bound of $P(\gamma)$ will be within ε of $\hat{P}$. Hence the landlord's NDCFU, calculated from the beginning of the punishment phase, $(1-\gamma)\sum_{t=1}^{M-1}\gamma^{t-1} P^* + \gamma^M \hat{P} = (1-\gamma^M) P^* + \gamma^M \hat{P}$, for ε small enough, is superior to P^{**}, for γ close enough to 1. Hence, the landlord's threat is credible for γ close enough to one.

A further condition we impose on the tenant is restricting his ability of defaulting the contract. Since the landlord detects consistent cheating with almost certainty, for *R* large enough (lemma(2)), the tenant can cheat throughout a review phase and default the contract, avoiding the punishment. We assume that the tenant faces a transaction cost of defaulting (TC_A) such that the following sufficiency condition for default-prevention holds: $(1-\delta)\sum_{t=1}^{R}\delta^{t-1} A^{**} - TC_A < A^*$. Thus, a rational agent will never default the contract. The landlord never defaults a contract because she does not have the opportunity to cheat and receive a higher payoff and escape punishment, since her actions are contemporaneously transparent to the tenant, who will then exercise a prohibitively costly punishment on her. Thus, we assume that the landlord is better-off receiving $P(\gamma)$ through playing her review strategies than receiving her maximum one-period cheating payoff and nothing thereafter (i.e., defaulting).

From our analysis, we can arrive at the following proposition:

Proposition. If the conditions of credibility of the threats of punishment of each party are satisfied and threats of one party is credible to the other, for any $\varepsilon > 0, \_ R_{\varepsilon} \ni R ge R_{\varepsilon}, \delta, \gamma$ close enough to 1, $|P(\gamma) - \hat{P}| < \varepsilon$ and $|A(\delta) - \hat{A}| < \varepsilon$.

Proof. From our above analysis, the landlord will never renege from cooperation and the tenant will never cheat consistently. Suppose the tenant cheats inconsistently $T(R)$ periods out of R, which approaches t_0 for $R ge R_0$. The tenant's NDCFU is

$$(1-\delta)[\sum_{t=1}^{t_0}\delta^{t-1} A^{**} + \sum_{t=t_0+1}^{R}\delta^{t-1}\hat{A}] + (1-\phi)\delta^R [\sum_{t=1}^{R}\delta^{t-1} A^{*} + \delta^M A(\delta)] + \phi\delta^R A(\delta)$$

where $\phi ge \phi_0 = \{1-(\sigma^2/(\hat{y} - B(R) - y^{**})^2)\}^{t_0}$. This simplifies to

$$(1-\delta^{t_0}) A^{**} + \delta^{t_0}(1-\delta^{R-t_0})\hat{A} + (1-\phi)\delta^R(1-\delta^M) A^{*} + \{(1-\phi)\delta^{R+M} + \phi\delta^R\} A(\delta).$$

It can be shown that the coefficient of A^{**} decreases as δ increases, coefficient of $\hat{A}$ decreases as δ increases (provided δ > $(t_0/R)^{\frac{1}{R-T_0}}$), while the coefficient of A^{*} increases with δ if $R > M$ and so does the coefficient of $A(\delta)$. Since $A^{*} < \hat{A} < A^{**}$ by assmption, the tenant's payoff decreases with increasing δ. If the tenant did not cheat, $t_0 = 0, A(\delta) = \hat{A}$, which will be superior to his payoff under inconsistent cheating. Thus, for R large enough and δ close enough to 1, the rational tenant will not cheat, and since the landlord also cooperates during a review phase if γ is close enough to 1, for any $\varepsilon > 0, \_ R_\varepsilon \ni R ge R_\varepsilon, \delta, \gamma$ close enough to 1, $|P(\gamma) - \hat{P}| < \varepsilon$ and $|A(\delta) - \hat{A}| < \varepsilon$.

Corollary. Given the above proposition holds, the landlord's best response to the tenant's cooperation during a review phase is not deviating from cooperation and vice versa. Hence, the above proposition gives a cooperative Nash equilibrium in review strategies.

Conclusion

The main conclusion from this article is that a long-term, cooperative equilibrium is attainable in land tenure contracts by following Radner's review strategies. We see that this equilibrium is dependent upon several conditions most of which have to do with credibility of the threats of punishment of each party and the credibility of one party's threat to the other party. An important conclusion is that the landlord will never cheat or default if the tenant's threat is credible to her. Hence, attaining the cooperative equilibrium is entirely up to the tenant. This is explained by the information asymmetry underlying the game: the landlord's actions are instantly observable to the tenant while the tenant's actions are not observable to the landlord, except through the level of input x used and the level of output.

Another conclusion that can be drawn is that review strategies provide the landlord with nearly full-information about the tenant's actions in cooperative phases, provide the review phase is long enough. This conclusion is evident from Lemma (1) and (2) where the tenant is (nearly) assured of passing a review if he never cheats during the review phase ($\phi \rightarrow 1$) and consistent cheating of the tenant is detected with (near) certainty by the landlord ($\phi \rightarrow 0$), provided the cooperative game is repeated long enough (*R* is large enough). This conclusion is consistent withHolmstrom's findings as indicated earlier.

Avenues for future reserch exist in modifying the above game by allowing the landlord to include relevant exogenous information in the review process (for example, the average county level output using nearly identical technology) and/or allowing the tenant to have some notion of the state of nature prior to applying inputs. It would be interesting to investigate the stability of the cooperative equilibrium and the relative speed at which it is achieved.

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