Appendix

Appendix A: Extensions to the Model

θ AS A FIXED PARAMETER

Suppose the elder is unable to choose θ, which is instead set by custom or by technological constraints. In that case, the condition that $V_E^C > V_E^P$ reduces to:

$$\left(\left(\frac{c}{c+\gamma}\right)^2(1-\theta)-\left(\frac{c}{c+d}\right)^2\right)p > \bar{k}$$

It will only be possible to satisfy this condition if θ is sufficiently small that the coefficient on p on the left-hand side is positive. If this is the case, then communal property is preferred if the price of palm oil is sufficiently high. This is similar to the condition given in equation 9, except that the elder will never prefer communal property if the share he must surrender is too great.

OTHER RESPONSES

Overview

Communal harvesting need not be the only option elders had available to cope with the rising costs of monitoring under private property. Why did they not respond by cooperating in their defense of private property, manipulating the village council in order to more cheaply protect their rights, or simply pay the youth to harvest for them?

Cooperative monitoring by the elders would be one possible alternative to communal harvesting. I extend the model to include this possibility. There are two points to consider. First, cooperative monitoring would have entailed a greater collective action problem than under communal harvesting. When monitoring is a public good, it will be underprovided. Whereas youths would have a direct interest in protecting their communal share from theft, other property owners had no direct interest in each other's property. The extension shows that this effort would only be provided if it were individually rational for each elder. An additional difficulty is that private monitoring might create negative externalities, as youth divert their efforts at theft towards less-secure plots. This would force all elders to monitor more intensively than if these spillovers did not exist.

Second, there is no reason to treat cooperative monitoring as an alternative to communal harvesting; cooperative monitoring could equally be used to defend private and communal tenure. The extension allows for this. With cooperative monitoring possible under both private and communal property, the switch to communal property is again occasioned by an increase in the price.

Judicial manipulation would have been self defeating. The village council was used to settle many disputes aside from palm harvesting. Traditionally, the village council gave orders for cleaning paths, regulated prices, and dealt with both economic and "minor judicial" matters, including issues arising within a single family or age grade.[1] Damaging its credibility in this case would have made it less useful in other instances, especially as the village council did not have a monopoly over dispute resolution. Further, if the standard of proof were lowered artificially, punishments meted out by the village council would have become more arbitrary, and would not have been effective deterrents.

Wage labor was problematic for several reasons. I model one of these—any worker employed to harvest oil for the elder would need to be monitored, in order to prevent him from keeping any oil for himself. Where the technology of theft and monitoring by a hired youth is the same as in the case with private property, I show that the elder can indeed do no better paying a wage than he can by defending his own property. Similar difficulties would face an elder who attempted to hire a youth to monitor for him. In addition, the wage paid to the youth would have to be made sufficiently high in order to elicit monitoring effort. I show that the youth's monitoring costs would need to be low relative to the elder's costs for this to be profitable for the elder.

There are additional difficulties with wage labor not captured by this extension. Elders may have feared that giving up symbolic control of the harvest would have led to them losing control of their palms altogether. I give examples where control of palms was politically valuable. Further, the timing of this payment presented a problem. Either elders would have to pay youth out of cash reserves prior to the harvest, or payment in cash afterwards would create the possibility of a hold up problem.

Further, wage labor was rare in Igbo society before the Second World War. What wage labor did exist by the end of the colonial period was largely migrant and seasonal (Uchendu 1965, p. 32). Susan M. Martin (1988, pp. 87–88) notes that, during the early twentieth century, "[m]arriage rather than contractual wage relationships continued to be the mainstay of labor recruitment." Hired labor was a minor component of the labor supply in precolonial Igboland. Slaves, age mates, and clientelist relationships remained important means of labor recruitment through the first half of the century (Brown 2003, p. 38).

Cooperative Monitoring

Suppose now that, rather than one elder and one youth, there are N elders and N youth. I abstract away from negative spillovers that can arise from private monitoring by allowing each youth to steal from only one particular grove. That is, youth i can only steal from elder i, youth j can only steal from elder j, and so on. To further simplify the analysis, I will only consider symmetric equilibria.

Elders may now devote their efforts to either private monitoring, m, or cooperative monitoring g. The marginal cost of cooperative monitoring is δ. Define $G \equiv \sum_{i=1}^{N} g_i$ as the total amount of cooperative monitoring, and $G_{-i} \equiv G - g_i$ as total monitoring by all elders apart from elder i. I dispense with i subscripts below. If youth i devotes s

[1] SP 021 CSE 1/85/3708.

units of effort to stealing from elder i, elder i devotes m units of effort to private monitoring, and total cooperative monitoring is G, then the youth is able to successfully steal a fraction $\frac{s}{m+s+G}$ of the oil, while the elder retains a fraction $\frac{m+G}{m+s+G}$.

Each elder's problem can be written as

$$V_E^{PCM} = \max_{m,g}\left\{\frac{m+g+G_{-i}}{g+m+s+G_{-i}}\,p - dm - \delta g\right\} \tag{12}$$

while each youth's problem can be written as

$$V_Y^{PCM} = \max_{s}\left\{\frac{s}{g+m+s+G_{-i}}\,p - cs\right\} \tag{13}$$

Both equations 12 and 13 are concave, and so they can be maximized from their first-order conditions. Each elder's best responses, then, are

$$m_{BR}^{PCM} = \max\left\{\sqrt{\frac{sp}{d}} - s - g - G_{-i}, 0\right\} \tag{14}$$

and

$$g_{BR}^{PCM} = \max\left\{\sqrt{\frac{sp}{\delta}} - s - m - G_{-i}, 0\right\} \tag{15}$$

The youth's best response is

$$s_{BR}^{PCM} = \max\left\{\sqrt{\frac{(m+G)p}{c}} - m - G, 0\right\} \tag{16}$$

Comparing equations 14 and 15, it is apparent that the elder will either monitor privately or cooperatively, but not both. He will monitor cooperatively if $d > \delta$, and privately otherwise. If $d \le \delta$, then, this collapses to the baseline private property case. This is the first result of considering cooperative monitoring. Although it provides social benefits (from the perspective of the elders) that private monitoring does not, a self-interested elder does not consider these in his decision. Cooperative monitoring entails a collective action problem, and may be underprovided.

Consider the outcome where $d \le \delta$, and cooperative monitoring occurs. In a symmetric equilibrium, $G_{-i} = (N-1)g$. Substituting this into equations 15 and 16 and setting $m = 0$ gives equilibrium stealing and monitoring

$$g_*^{PCM} = \left(\frac{c}{c+\delta}\right)^2 \frac{p}{Nc} \tag{17}$$

and

$$s_*^{PCM} = \left(\frac{\delta}{c+\delta}\right)^2 \frac{p}{\delta} \tag{18}$$

Substituting equations 17 and 18 into equations 12 and 13 gives the equilibrium payoffs under private property with cooperative monitoring

$$V_E^{PCM} = \left(\frac{\delta}{c+\delta}\right)^2 \left(1 - \left(\frac{N-1}{N}\right)\frac{\delta}{c}\right) p \tag{19}$$

and

$$V_Y^{PCM} = \left(\frac{c}{c+\delta}\right)^2 p \tag{20}$$

Now consider the case of communal property. Assume again that there is a fixed cost $\bar{k}$. I restrict analysis to the case where each elder offers the same θ. As with private monitoring, I assume that cooperative monitoring under communal property has a marginal cost $\sigma > 0$ that is lower than the cost of monitoring under private property (δ). Conditional on θ, each elder's problem can be written as

$$V_E^{CCM} = \max_{m,g} \left\{ \frac{m+g+G_{-i}}{g+m+s+G_{-i}}(1-\theta)p - \gamma m - \sigma g - \bar{k} \right\} \tag{21}$$

while each youth's problem can be written as

$$V_Y^{CCM} = \max_{s} \left\{ \theta p + \frac{s}{g+m+s+G_{-i}}(1-\theta)p - cs \right\} \tag{22}$$

As in the private case, these can be solved from their first-order conditions, giving best response functions

$$m_{BR}^{CCM} = \max\left\{ \sqrt{\frac{s(1-\theta)p}{\gamma}} - s - g - G_{-i}, 0 \right\} \tag{23}$$

$$g_{BR}^{CCM} = \max\left\{ \sqrt{\frac{s(1-\theta)p}{\sigma}} - s - m - G_{-i}, 0 \right\} \tag{24}$$

and

$$s_{BR}^{CCM} = \max\left\{\sqrt{\frac{(m+G)(1-\theta)p}{c}} - m - G, 0\right\} \tag{25}$$

As under private property, cooperative monitoring will only occur if it is individually rational, that is, if $\gamma \geq \sigma$. Otherwise, this collapses to the case without cooperative monitoring. Following similar logic to the above, the equilibrium levels of cooperative monitoring and theft in a symmetric equilibrium with $\gamma \geq \sigma$ are

$$g_*^{CCM} = \left(\frac{c}{c+\sigma}\right)^2 \frac{(1-\theta)p}{Nc} \tag{26}$$

and

$$g_*^{CCM} = \left(\frac{c}{c+\sigma}\right)^2 \frac{(1-\theta)p}{Nc} \tag{26}$$

$$s_*^{CCM} = \left(\frac{\sigma}{c+\sigma}\right)^2 \frac{(1-\theta)p}{\sigma} \tag{27}$$

Payoffs conditional on θ are

$$V_Y^{CCM} = \left(\frac{\sigma}{c+\sigma}\right)^2 \left(1 - \left(\frac{N-1}{N}\right)\frac{d}{c}\right)(1-\theta)p - \bar{k} \tag{28}$$

and

$$V_Y^{CCM} = \theta p + \left(\frac{c}{c+\sigma}\right)^2 (1-\theta)p \tag{29}$$

If each elder chooses θ subject to the constraint that $V_Y^{CCM} \geq V_Y^{PCM}$, this gives an optimal θ of

$$\theta_*^{CCM} = \frac{\left(\frac{\delta}{c+\delta}\right)^2 - \left(\frac{\sigma}{c+\sigma}\right)^2}{1 - \left(\frac{\sigma}{c+\sigma}\right)^2} \tag{30}$$

Substituting this into equations 28 and 29 gives equilibrium payoffs

$$V_E^{CCM} = \left(\frac{c}{c+\delta}\right)^2 \left(\frac{c+2\delta}{c+2\sigma}\right)\left(1-\left(\frac{N-1}{N}\right)\frac{d}{c}\right)p-\bar{k} \tag{31}$$

and

$$V_Y^{CCM} = \left(\frac{\delta}{c+\delta}\right)^2 p \tag{32}$$

As in the case without cooperative monitoring, these payoffs ensure that the elder will prefer common property so long as the price of oil is above a given threshold.

Wage Labor

Suppose the elder hires the youth to gather palm oil. He offers a piece-rate wage of w for each unit of oil delivered. The youth, however, can steal some of this oil for himself. As before, if the youth exerts effort s in stealing and the elder exerts effort m in monitoring, assuming the same marginal costs as under the standard private property case, the youth will successfully steal a fraction $\frac{s}{m+s}$ of the oil, while the elder will receive a share $\frac{m}{m+s}$. Thus, the elder's problem, conditional on w, can be written as

$$V_E^W = \max_m \left\{\frac{m}{m+s}(p-w)-dm\right\} \tag{33}$$

while the youth's problem can be written as

$$V_Y^W = \max_s \left\{\left(1-\frac{s}{m+s}\right)w+\frac{s}{m+s}\,p-cs\right\} \tag{34}$$

Each player's best response function can be found from the first order conditions, as above. These can then be used to solve for equilibrium levels of stealing and monitoring. Conditional on w, the elder and youth receive payoffs

$$V_E^W = \left(\frac{c}{c+d}\right)^2 (p-w) \tag{35}$$

and

$$V_Y^W = w + \left(\frac{d}{c+d}\right)^2 (p-w) \tag{36}$$

Comparing the expression for V_E^W in equation 35 to the expression for V_E^P in equation 3, it is apparent that the elder can do no better paying a wage than he can under private property. If $w = 0$, he does just as well paying a wage, while if $w > 0$ he does worse.

Paid Monitoring

Suppose the elder hires a youth to monitor on his behalf. There will be no possible efficiency gains unless the youth's marginal cost of monitoring is less than that of the elder. Call this $e < d$. The elder offers a piece-rate wage of w for each unit of oil delivered. I abstract away from the problem that the hired monitor might steal, and instead focus on the elder's problem of providing the paid monitor with incentives to increase his effort.

If the thieving youth exerts effort s in stealing and the hired youth exerts effort m in monitoring, the thief will successfully steal a fraction $\frac{s}{m+s}$ of the oil, while the paid monitor will deliver a share $\frac{m}{m+s}$ to the elder. In equilibrium, both s and m will depend on w. Thus, the elder's problem can be written as

$$V_E^{PM} = \max_{m,w} \left\{ \frac{m(w)}{m(w)+s(w)} (p-w) \right\} \tag{37}$$

The monitor's problem, conditional on w, can be written as

$$V_M^{PM} = \max_{m} \left\{ \frac{m}{m+s} w - em \right\} \tag{38}$$

while the thief's problem can be written as

$$V_Y^{PM} = \max_{s} \left\{ \frac{s}{m+s} p - cs \right\} \tag{39}$$

Following the same logic used to solve the standard private property case, equilibrium theft and monitoring will be given by

$$m_*^{PM} = \frac{p}{c} \left(\frac{wc}{pe+wc} \right)^2 \tag{40}$$

and

$$s_*^{PM} = \frac{w}{e}\left(\frac{pe}{pe+wc}\right)^2 \tag{41}$$

Substituting these into equation 42, the elder's problem can be rewritten as

$$V_E^{PM} = \max_m \left\{ \frac{wc}{wc+pe}(p-w) \right\} \tag{42}$$

Solving equation 42 from its first order conditions gives the elder's optimal wage

$$w_*^{PM} = \frac{\sqrt{e(e+c)}-e}{c}p \tag{43}$$

Thus, the elder's payoff is

$$V_E^{PM} = \left(\frac{c+2e-2\sqrt{e(e+c)}}{c}\right)p \tag{44}$$

Because equation 44 is decreasing in e, the elder will only be able to do better than under private or common property if the hired youth's cost of monitoring is sufficiently low.

OTHER CONSIDERATIONS

Overview

The model above abstracts away from altruism, observability, credibility of punishment, and Igbo seniority structures.

Adding *altruism* has the power to change the results. I extend the model to include this. If both the elder and youth take each other's material payoffs into account, it improves outcomes for both players, since monitoring and stealing are both reduced. If altruism is symmetric, this does not affect the material division of the oil, but does reduce the costs of both monitoring and theft. This improvement occurs under both private and communal property. Now that the youth cares about the fixed costs of common property $\bar{k}$, the elder's offer of θ is conditional on the price of oil. This, along with the addition of the youth's material payoffs to the elder's objective function, implies that the elder's preference for communal over private property is no longer necessarily equivalent to a price cutoff.

Adding reciprocity, would strengthen the case for common property. In public goods games, altruistic types will generally punish free riders, encouraging greater contributions (Fehr and Gachter 2000). Reciprocity would have two effects. First, while I have not modeled monitoring by the youth under common property, reciprocity would sustain greater aggregate monitoring than self-interest alone. This would reduce the returns to effort in theft, reinforcing the tendency for common property to become more attractive as the price rises. In addition, a youth motivated by reciprocity will view a relatively high offer of θ as "kind," and reciprocate by lowering his effort in theft. This will make common property more rewarding to the elder, as it would partially offset the cost of an increase in θ, a benefit that would also rise with the price.

Adding *observability* would add little to the model. The sharing rule $\frac{s}{s+m}$ could be interpreted as the probability that the youth steals successfully. The model excludes *punishment*. The evidence below, however, makes it clear that thieves were sometimes taken before the village council. If punishment is costly, repeated interaction is needed to make it credible. Credibility would be greater under common property, because the greater number of potential witnesses and lower burden of proof reduced the costs of proving a case (see below). In addition, in experimental public goods games that resemble the common property scenario, individuals will punish bad behavior, even if it is costly, provides them no material benefits, and is not observed (Masclet and Villeval 2003).

Finally, the *seniority* structure of Igbo society has complex effects. I extend the model to include seniority, using a repeated game. The possibility of becoming an elder and acquiring trees of his own can be used to secure the youth's respect for private property. If the youth is sufficiently patient, and the share θ offered to him under common property is small, then increases in θ can be used to encourage his adherence to common property, even if he cannot be made to respect private property. If θ is sufficiently large, however, this has the perverse effect of making the position of an elder less enviable, weakening the usefulness of the possibility of promotion as a tool to secure the youth's cooperation. Colonial rule disrupted the Igbo seniority structure, gave youth outside options beyond their communities and changed the rules of the political hierarchy, weakening youths' incentives to observe community rules. This helps explain examples in the court records where common property arrangements had collapsed, and where elders' authority is questioned.

Altruism

Suppose that, in addition to valuing their own payoffs, each player has an altruism parameter $\alpha \in [0,1]$, which he uses to weight the payoff received by the other player. Denoting payoffs as y, this is is equivalent to stating that $V_Y = y_Y + \alpha y_E$, and $V_E = y_E + \alpha y_Y$. Under these conditions, the elder's problem with private property can be rewritten as

$$V_E^{PA} = \max_m \left\{ \frac{m}{m+s} p - dm + \alpha \left(\frac{s}{m+s} p - cs \right) \right\} \tag{45}$$

while the youth's payoff is given as

$$V_Y^{PA} = \max_s \left\{ \frac{s}{m+s} p - cs + \alpha \left(\frac{m}{m+s} p - dm \right) \right\} \tag{46}$$

Following similar steps to those given above gives equilibrium stealing and monitoring

$$m_*^{PA} = \left(\frac{c}{c+d}\right)^2 \frac{(1-\alpha)p}{c} \tag{47}$$

and

$$s_*^{PA} = \left(\frac{d}{c+d}\right)^2 \frac{(1-\alpha)p}{d} \tag{48}$$

It is clear from equations 53 and 54 that both players restrict effort as a result of their altruism. Equilibrium payoffs under private property become

$$V_E^{PA} = \left(\frac{c}{c+d}\right)^2 \left(1+\frac{\alpha d}{c}\right)p + \alpha\left(\frac{d}{c+d}\right)^2 \left(1+\frac{\alpha c}{d}\right)p \tag{49}$$

and

$$V_Y^{PA} = \left(\frac{d}{c+d}\right)^2 \left(1+\frac{\alpha c}{d}\right)p + \alpha\left(\frac{c}{c+d}\right)^2 \left(1+\frac{\alpha d}{c}\right)p \tag{50}$$

Altruism, then, reduces each player's effort, increasing both players' material payoffs, even ignoring any utility benefits from altruism.

Under communal property, the players' payoffs can be rewritten to include altruism. For the elder, taking θ as given, this becomes

$$V_E^{CA} = \max_m \left\{ \frac{m}{m+s}(1-\theta)p - \gamma m - \bar{k} + \alpha\left(\theta p + \frac{s}{m+s}(1-\theta)p - cs\right)\right\} \tag{51}$$

while the youth's payoff is given as

$$V_Y^{CA} = \max_s \left\{ \theta p + \frac{s}{m+s}(1-\theta)p - cs + \alpha\left(\frac{m}{m+s}(1-\theta)p - \gamma m - \bar{k}\right)\right\} \tag{52}$$

Following the same logic as before gives equilibrium stealing and monitoring

$$m_*^{CA} = \left(\frac{c}{c+\gamma}\right)^2 \frac{(1-\alpha)(1-\theta)p}{c} \tag{53}$$

and

$$s_*^{CA} = \left(\frac{\gamma}{c+\gamma}\right)^2 \frac{(1-\alpha)(1-\theta)p}{\gamma} \tag{54}$$

Payoffs, conditional on θ, become

$$V_E^{CA} = \left(\frac{c}{c+\gamma}\right)^2\left(1+\frac{\alpha\gamma}{c}\right)(1-\theta)p-\bar{k}+\alpha\left(\theta p+\left(\frac{\gamma}{c+\gamma}\right)^2\left(1+\frac{\alpha c}{\gamma}\right)(1-\theta)p\right) \tag{55}$$

and

$$V_Y^{CA} = \theta p+\left(\frac{\gamma}{c+\gamma}\right)^2\left(1+\frac{\alpha c}{\gamma}\right)(1-\theta)p+\alpha\left(\left(\frac{c}{c+\gamma}\right)^2\left(1+\frac{\alpha\gamma}{c}\right)(1-\theta)p-\bar{k}\right) \tag{56}$$

If the elder selects θ subject to the constraint that $V_Y^{CA} \geq V_Y^{PA}$, he will choose

$$\theta_*^{CA} = \frac{B_1-B_2+\alpha(A_1-A_2)}{1-B_2-\alpha A_2}+\frac{\alpha\bar{k}}{p(1-B_2-\alpha A_2)} \tag{57}$$

where

$$A_1 = \left(\frac{c}{c+d}\right)^2\left(1+\frac{\alpha d}{c}\right)$$

$$A_2 = \left(\frac{c}{c+\gamma}\right)^2\left(1+\frac{\alpha\gamma}{c}\right)$$

$$B_1 = \left(\frac{d}{c+d}\right)^2\left(1+\frac{\alpha c}{d}\right)$$

$$B_2 = \left(\frac{\gamma}{c+\gamma}\right)^2\left(1+\frac{\alpha c}{\gamma}\right)$$

The final payoffs can be obtained by substituting equation 57 into equations 55 and 56. Now that the fixed administrative costs of communal property enter into the youth's payoff, the elder's offer of θ_*^{CA} is contingent on p. In addition, the fact that each player takes the other's payoffs into account when evaluating his own utility means that the condition $V_E^{CA} \geq V_E^{PA}$ no longer necessarily simplifies to a cutoff value for p.

Seniority

Suppose now that the standard game with one elder and one youth is repeated infinitely. The youth and elder each discount future payoffs by the factor β. The elder remains an elder indefinitely. Each period, there is a probability π that the youth can be promoted to the rank of elder. If that happens, the original elder and the newly made elder continue playing the game as elders with two newly created youths. The purpose of this extension to the model is to assess the effect of a youth's future prospect of becoming an elder on outcomes under both private and communal property.

First, consider private property. I discuss one particular "cooperative" outcome, in which cooperation is sustained by the threat of a trigger strategy. In particular, the elder retains the the entirety of his harvest for himself, offering nothing to the youth. The youth's adherence to private property, then, is sustained by nothing more than the promise that he will someday have property of his own.

For simplicity, I assume the elder does not monitor in this scenario. This gives the youth the opportunity to steal the oil for himself with negligible effort. Even so, the elder may be able to sustain the youth's cooperation through the threat of reverting to a punishment strategy and revoking the possibility of promotion to the rank of elder if the youth steals. Because the equilibrium in the static game is also a subgame perfect Nash equilibrium, it is a natural candidate for a punishment strategy. If this occurs, the youth receives V_Y^P and the elder receives V_E^P forever, and the youth is never made an elder. Private property with no stealing will be implementable so long as the youth's payoff from continuation is greater than his payoff from the optimal one-shot deviation and its associated continuation payoff.

I denote V_Y^{PC} as the present value of lifetime utility for a youth who never deviates, V_Y^{PD} as the present value of lifetime utility for a youth who deviates in the current period, V_E^{PC} as the present value of lifetime utility for an elder if the youth never deviates, and V_E^{PD} as the present value of lifetime utility for an elder if the youth deviates in the current period. Following the setup above, these payoffs can be written as

$$V_Y^{PC} = 0 + \beta\left((1-\pi)V_Y^{PC} + \pi V_E^{PC}\right) \tag{58}$$

$$V_Y^{PD} = p + \frac{\beta}{1-\beta}\left(\frac{d}{c+d}\right)^2 p \equiv p + \frac{\beta}{1-\beta}\lambda_Y p \tag{59}$$

$$V_E^{PC} = \frac{p}{1-\beta} \tag{60}$$

and

$$V_E^{PD} = 0 + \frac{\beta}{1-\beta}\left(\frac{c}{c+d}\right)^2 p \equiv \frac{\beta}{1-\beta}\lambda_E p \tag{61}$$

It is possible to use equation 60 to rewrite equation 58 as

$$V_Y^{PC} = \frac{\beta\pi p}{(1-\beta)(1-\beta+\beta\pi)} \tag{62}$$

Thus, the youth will cooperate so long as $V_Y^{PC} \geq V_Y^{PD}$, which simplifies to

$$\pi \geq \bar{\pi}^P \equiv \left(\frac{1-\beta}{\beta}\right)\left(\frac{1-\beta(1-\lambda_Y)}{\beta(1-\lambda_Y)}\right). \tag{63}$$

Thus, if the youth's prospect of becoming an elder is sufficiently promising, it can sustain his adherence to private property.

Now, consider a similar scenario under communal harvesting. Here, the elder offers the youth a share θ of the oil each period, keeping a share $(1-\theta)$ for himself. As before, the elder does not monitor, giving the youth the opportunity to deviate with negligible effort and appropriate the remaining share $(1-\theta)$ for himself. Again, the punishment strategy used is reversion to the static equilibrium under private property, and permanent removal of the possibility that the youth becomes an elder.

I denote V_Y^{CC} as the present value of lifetime utility for a youth who never deviates, V_Y^{CD} as the present value of lifetime utility for a youth who deviates in the current period, V_E^{CC} as the present value of lifetime utility for an elder if the youth never deviates, and V_E^{CD} as the present value of lifetime utility for an elder if the youth deviates in the current period. Following the setup above, these payoffs can be written as

$$V_Y^{CC} = \theta p + \beta\left((1-\pi)V_Y^{CC} + \pi V_E^{CC}\right) \tag{64}$$

$$V_Y^{CD} = p + \frac{\beta}{1-\beta}\lambda_Y p \tag{65}$$

$$V_E^{CC} = \frac{(1-\theta)p}{1-\beta} \tag{66}$$

and

$$V_E^{PD} = 0 + \frac{\beta}{1-\beta}\lambda_E p \tag{67}$$

It is possible to use equation 66 to rewrite equation 64 as

$$V_Y^{CC} = \frac{(1-\beta-\beta\pi)\theta+\beta\pi}{(1-\beta)(1-\beta+\beta\pi)}p \tag{68}$$

Thus, the youth will cooperate so long as $V_Y^{CC} \geq V_Y^{CD}$. If $1-\beta-\beta\pi > 0$, this simplifies to

$$\theta \geq \frac{(1-\beta+\beta\lambda_Y)(1-\beta+\beta\pi)-\beta\pi}{1-\beta-\beta\pi} \tag{69}$$

If, however, $1-\beta-\beta\pi < 0$, then the youth always deviates. The condition in equation 69 becomes a restriction that θ is less than a negative number, which cannot occur. This will be the case if either β or π are sufficiently large that the adverse effect of an increase in θ on the youth's expected payoff when he becomes an elder outweighs the benefit while he is a youth.

Comparing V_E^{CC} with V_Y^{PC}, it is clear that the elder will prefer private property so long as he can induce the youth to cooperate, since his per-period payoff is greater (p versus $(1-\theta)p$). The possible advantage of common property here becomes the range of π over which the youth's cooperation can be secured. Define the following cutoff value for π

$$\overline{\pi}^C \equiv \left(\frac{1-\beta}{\beta}\right)\left(\frac{1-\beta(1-\lambda_Y)-\theta}{\beta(1-\lambda_Y)-\theta}\right) \tag{70}$$

If the youth is sufficiently patient, i.e., if $\beta > \frac{1}{2(1-\lambda_Y)}$, then $1-\beta(1-\lambda_Y) < \beta(1-\lambda_Y)$. If this case holds, then $\overline{\pi}^C < \overline{\pi}^P$ for any $\theta > 0$. Otherwise, $\overline{\pi}^C > \overline{\pi}^P$ for any $\theta > 0$. Under communal property, it may be possible for the elder to secure the youth's cooperation, even if $\pi < \overline{\pi}^P$. If the youth is sufficiently patient, the elder will be better off gaining this cooperation than under infinite repetition of the static game. Consider the extreme case, where $\pi = 0$. Then, equation 69 simplifies to $\theta > 1-\beta+\beta\lambda_Y$. If the elder makes this minimal offer of θ to the youth, he will be better off than with the infinite repetition of the static game so long as $(1-(1-\beta+\beta\lambda_Y))p > \lambda_E p$. This simplifies to the condition that $\beta > \frac{\lambda_Y}{1-\lambda_E}$, i.e., that the youth is sufficiently patient.

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