The Formation of Cooperative Relationships

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This article investigates how individuals forge and maintain cooperative relationships when there is always the possibility of starting again with a new partner. The analysis shows that an ever-present opportunity to form new relationships need not destroy cooperation. Simple strategies achieve the (constrained) optimal level of cooperation. These strategies involve a "bond" in the form of reduced utility at the beginning of a relationship. Two newly matched agents may have an incentive to forgo paying this bond, given that everyone else in the population requires payment of a bond to start a new relationship. This incentive disappears, however, if there is enough initial uncertainty about a new partner's valuation of future utility. Accounts from the sociological and anthropological literature indicate that individuals may indeed pay bonds to form cooperative relationships.

1. Introduction

Cooperation among self-interested individuals is a puzzle that social scientists have studied for decades. It is now well known that a given set of individuals who repeatedly interact (with an infinite time horizon) can successfully cooperate if they observe each others' actions and place a sufficiently high value on future transactions. Yet in many economic settings, the grouping or pairing of individuals is not exogenous. Rather, individuals must forge cooperative relationships from a large population of potential partners. For example, in input markets, buyers must develop relationships with specific suppliers to mitigate the risk of ex post opportunism when contracts are incomplete.[1] In informal markets in developing countries, business people must cultivate long-term relationships to obtain credit, build a reliable workforce, and obtain supplies.[2]

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1. Lazerson (1993) describes relationships between small manufacturing shops and wholesalers in the knitting district in Modena, Italy. Lorenz (1988) discusses cultivating relationships between contractors and subcontractors in France. Woodruff (1993) finds that repeated interaction between specific manufacturers and retailers in the Mexican shoe industry sustains cooperation.

2. For a general discussion, see Jagannathan (1987). See de Soto (1989) for examples from Peru.

In bureaucracies, workers must develop long-term relationships with specific colleagues to exchange help and information.[3]

This article investigates how individuals form and maintain ongoing cooperative relationships. Cultivating a relationship with one party to the exclusion of others can commit a party to a relationship.[4] Yet, in a dynamic setting, the possibility of exiting a relationship and starting anew can make a current relationship difficult to sustain.

Previous research on cooperation among strategic individuals does not consider this problem. Information and matching assumptions preclude the development of new relationships. In research on repeated games, it is assumed that all agents observe the actions of all other agents. Agents base their actions on other agents' past actions—in other words, on their "reputations." No agent can escape his past and begin anew with a different set of players. If players are sufficiently patient, any feasible, individually rational payoffs can be supported by an equilibrium.[5] In random-matching games, agents within a given population are assumed to interact only infrequently. Agents randomly match with another agent in each period. Cooperation in this setting is also possible if agents have sufficient information about past trades (Kandori, 1992; Milgrom, North, and Weingast, 1990).

In this investigation, agents always have the opportunity to form and dissolve long-term relationships. Agents choose whether or not to repeatedly interact with another agent, and there is always a population of potential exchange partners who have no information about an agent's past actions. I find that an ever-present opportunity to form new relationships does not destroy cooperation. Simple strategies achieve the (constrained) optimal level of cooperation.[6] Agents can sustain cooperation by monotonically increasing the level of exchange within a relationship. With such strategies, the utility from remaining in the relationship always exceeds the utility from starting a relationship. Any agent who cheats her partner must begin a new relationship at the initial, low level of exchange. Essentially, both partners pay a Becker and Stigler (1974) "performance bond" in the form of reduced utility. If any agent cheats her partner, she forfeits the returns to the bond and must pay another bond to begin anew.[7]

These strategies, however, are not "renegotiation-proof." A matched pair begin their relationship at a low level of utility, even though higher levels are

3. See, for example, Blau (1964) and Fung (1991).

4. See discussion in Blau (1964: 94).

5. See Fudenberg and Tirole (1991: chap. 5) on the Folk Theorem in infinitely repeated games with observable actions.

6. The logic behind this result is the same as in Abreu, Pearce, and Stacchetti's (1993) derivation of the optimal renegotiation-proof equilibria in a symmetric repeated game among a fixed set of players. I thank an anonymous referee for pointing this out. The connection between the results is explained below.

7. These strategies are also analogous to rising wage profiles, which can deter workers from shirking. A worker who is caught and fired must begin again at a low wage level. See Lazear (1981) and Carmichael (1989).

enforceable. Two newly matched agents could jump directly to the higher level of cooperation and earn higher utility, given that if either cheats, they must both begin again at the lower level with a new partner. The incentive to jump directly to the high transfer levels disappears, however, if there is enough initial uncertainty about a partner's valuation of future transactions.

These results provide insights into how individuals form cooperative relationships; they also allow a better accounting of the costs and benefits of institutions that facilitate cooperative behavior.[8] The analysis points out that individuals must incur a cost, pay a bond, to sustain cooperative relations. Accounts from the sociological and anthropological literature indicate that individuals may form cooperative relationships by paying bonds. These bonds appear in various forms. Researchers have found that cooperative relations build over time, beginning with small exchanges and moving to higher levels of exchange as partners fulfill their obligations. Similarly, bonds can be the expenditures and gifts that accompany the beginning of new relationships. Carmichael and MacLeod (1992), who study cooperation between matched individuals in an evolutionary framework, suggest that a custom of giving gifts at the beginning of a relationship can help sustain cooperation when the gifts are costly to the giver but worthless to the receiver.[9] Such gifts, therefore, serve the same purpose as does the reduction in utility that sustains cooperation among strategic actors in the present analysis. Finally, bonds, in the form of entry barriers, may segment populations into smaller groups within which cooperative relations are possible. I present examples and elaborate on these ideas after presenting the formal analysis.

The problem of maintaining cooperation when new partners are always available has received attention recently. Datta (1993) and Ghosh and Ray (1994) independently examine settings similar to the one presented here.[10] Datta (1993) shows the existence of cooperative equilibria that are characterized by a buildup of cooperation over time when agents have complete information. Ghosh and Ray (1994) explore cooperation within a community when agents initially have no information about other agents' discount factors. They restrict attention to norms, or strategies, that are robust to both deviations by any individual agent *and* by any pair of agents. Norms consist of two levels of cooperation, and they determine under what conditions these norms constitute a social equilibrium. They find that a community that has a smaller proportion of patient players—that is, players with positive discount factors—is able to sustain higher levels of cooperation in the second stage of a relationship.[11]

8. Bendor and Mookherjee (1990) consider the role of third-party sanctions in facilitating cooperation in a repeated game between three or more players. They do not consider, however, the formation of long-term relationships between any two players in the group or the possibility that an agent could form a new relationship with another individual or group of individuals.

9. If receivers valued the gift, a receiver would want to leave one relationship, start another, and collect a gift. Thus, gifts must be wasteful expenditures.

10. I learned of this work in the final stages of writing this article.

11. In a dynamic game with incomplete information, Watson (1995) examines how two agents (in isolation) can sustain a cooperative relationship. Each agent's discount factor is private information,

In this analysis, I consider settings where information is complete *or* incomplete and consider outcomes that are robust to deviations by individual agents *or* by individuals and matched pairs of agents. I find the optimal subgame perfect equilibrium strategies when information is complete, without making any initial restriction on strategies. As stated above, the optimal strategy can involve two levels of cooperation, and in the first, there is a reduction in utility. This strategy, however, is not robust to deviations by a matched pair of players. In fact, with complete information, there exists no cooperative equilibrium that is robust to deviations by both individuals and by matched pairs. However, introducing enough incomplete information restores cooperation. If there are enough agents in the population who do not care about the future—that is, have discount factors of zero—then any two newly matched agents will not want to give high levels of transfers at the beginning of the relationship. The optimal strategies in this setting also involves two stages, where in the first there is a reduction in utility.

The rest of this article is organized as follows: Section 2 provides the base case; it models the per-period interaction between individuals and considers the level of cooperation that can be sustained when agents cannot form new relationships. Section 3 determines how individuals can sustain cooperation when there is always a possibility of forming a new relationship. Section 4 considers cooperation that is robust to deviations by matched pairs of agents. Section 5 presents and discusses anthropological and sociological accounts of the formation of relationships and groups. Section 6, the Conclusion, summarizes and outlines future research.

2. Cooperation When Agents Cannot Form New Relationships

This section determines what level of cooperation can be sustained when agents cannot form new relationships. I construct a model in which there are gains from exchanging goods or services with another agent. In each period, each agent chooses the amount of his good to give to his partner. Higher transfers increase utility and correspond to higher levels of "cooperation."

Consider two goods and two corresponding agents i and j. Each agent's per-period utility is $v(x_i, x_j) = x_i^\alpha + x_j^\alpha$, where x_i and x_j are consumption of goods i and j.[12] At the beginning of each period, agent i (j) receives a nonstorable endowment of one unit of good i (j). Each agent chooses a transfer of his good to give to the other agent. After consuming, each agent decides whether to terminate the relationship. At the end of each period, each agent dies with probability $(1-\lambda)$. Agents do not inherently prefer consumption in the current

and the value of the relationship changes over time. Watson finds that if the relationship starts at low valuation levels, then agents with high discount factors can cooperate and sustain the relationship over time, despite incomplete information. He also determines when "external" signaling devices, such as gift giving or burning money, can be useful.

12. The parameter $\alpha \in (0, 1)$ represents the substitutability of goods. As $\alpha \to 0$, the goods become less substitutable, and exchange becomes more valuable.

period to consumption in future periods. But because agents survive to the following period with only probability λ, they discount future utility.

Agents base their transfers and termination decisions in every period on transfer decisions in previous periods.[13] Consider a symmetric relationship in which agents give each other a transfer (or gift) g_t in period t as long as both have given the specified transfers in the past and neither has terminated the relationship. Let a *transfer profile*, g, be the time-ordered vector of transfers—that is, $g \equiv (g_0, g_1, \ldots, g, \ldots)$—and let $u(g) \equiv (1-g)^\alpha + (g)^\alpha$ be an agent's per-period utility when the specified transfer is g. A transfer profile is called *cooperative* if agents give each other a strictly positive transfer in at least one period. The first-best transfer profile, the transfer profile that maximizes agents' utility, is $g = \frac{1}{2}$.

For a given transfer profile, let U_t be an agent's current and expected discounted future utility from a relationship that has lasted $t-1$ periods:

$$U_t = u(g_t) + \lambda\,[\lambda U_{t+1} + (1-\lambda)U_A] \tag{1}$$

An agent earns $u(g_t)$ in period t. With probability λ she survives to the next period. With probability λ her partner also survives, and they continue the relationship. With probability $1-\lambda$ her partner dies, and she earns expected discounted utility U_A, the discounted future utility from autarky.

A cooperative transfer profile constitutes a perfect equilibrium if and only if each individual agent is willing to give the specified transfer in every period. In every period, U_t must (weakly) exceed the current utility of not giving g_t plus an agent's expected utility when he is "punished" for not giving a transfer. Let U_P be the discounted value of future utility an agent earns from a perfect punishment. In all periods t, a perfect transfer profile must satisfy the following *enforceability* constraint:

$$U_t \geq 1 + g_t^\alpha + \lambda U_P. \tag{2}$$

A transfer profile that satisfies (2), for a given punishment utility U_P, is called an *individually enforceable* (IE) transfer profile.

I determine next the maximum utility that agents can earn in a perfect equilibrium. To do so, I consider transfer profiles that are sustained by the worst possible, individually rational, perfect punishment (Abreu, 1988). The worst possible perfect punishment here is to terminate the relationship. Thus, I consider $U_P = U_A$. Substituting and rearranging (2), the enforceability constraint

13. Strategy spaces are as follows: Players' transfer space is the interval [0, 1]. Let $g_t \equiv (g_t^i, g_t^j)$ be the transfers given in period t. Let $\tau \in$ {(C)ontinue, (T)erminate} be the termination action space. Demarcate the beginning of the agent's life with period 0, with the null history h^0. For $t \geq 1$, let $h_t \equiv (g_0, g_1, \ldots, g_{t-1})$ be the realized choices of actions in a relationship for all periods before t. Let H_t be the space of all possible period-t histories. A pure transfer strategy, for player i, g_i, maps all possible period-t histories $h_t \in H_t$ to transfers $g_i \in [0, 1]$. A pure termination strategy, for player i, g_i, maps all possible period-t histories $h_t \in H_t$ to termination decision $\tau_i \in$ {(C)ontinue, (T)erminate}. If either agent chooses to terminate the relationship, the relationship ends forever.

becomes

$$\delta[V_{t+1} - V_A] \geq 1 - (1 - g_t)^{\alpha}, \tag{3}$$

where $\delta \equiv \lambda^2$ is the discount factor and the utilities V_t and V_A are defined as follows:

$$V_t \equiv \sum_{s=0}^{\infty} \delta^s u(g_{t+s}), \qquad V_A \equiv \sum_{s=0}^{\infty} \delta^s \cdot 1,$$

where s indexes the periods 0 to ∞.

The optimal IE transfer profile maximizes V_0 subject to (3). The optimal IE profile must be stationary. If any one transfer were higher than the others, raising all transfers to its level would yield strictly greater utility and would also be IE.

Proposition 1. When agents cannot form new relationships, if a transfer profile g is optimal IE, then $g_t = g$ for all periods t.

Proof. See Appendix. (All proofs are presented in the Appendix.) ■

With this result, it is straightforward to solve for the optimal IE transfer. Setting $g_t = g$ and rearranging (3) yields

$$\frac{1 - (1 - g)^{\alpha}}{g^{\alpha}} \leq \delta. \tag{4}$$

Let $g^*(\delta)$ be the optimal IE transfer. If (4) holds for $g = 1/2$, then $g^*(\delta) = 1/2$. If not, then $g^*(\delta)$ satisfies (4) with equality (and $g^*(\delta) < 1/2$).

Notice that the first-best transfer profile is IE for a sufficiently high discount factor. Thus, when agents must rely on their own resources after a relationship ends, the optimal IE profile is constant over time, and $g = 1/2$ is IE for a high enough discount factor. When agents can form a new relationship, however, the punishment for breaching an agreement with a partner is less severe. In the next section I explore how the opportunity to start new cooperative relationships affects the optimal IE transfer profile and thus the utility that agents can achieve in a long-term relationship.

3. Cooperation When Agents Can Always Form New Relationships

This section analyzes cooperation in a dynamic environment in which agents who terminate a relationship can always begin a new relationship. Suppose that there are two equal-size populations of i-type agents and j-type agents. A proportion $(1 - \lambda)$ of each population is newly born each period, so there is always an unmatched population of agents. (Each death of an agent is offset by a birth, so the size of each population is constant over time.) At birth, each agent is matched with an agent of the other type. When agents leave a relationship because of termination or death of a partner, they are matched to a new partner at the beginning of the following period.[14] Interaction between two matched agents in any period t proceeds as in the previous section.

I make the following assumptions so that the setting here is comparable to the one above except for the possibility of forming a new relationship after a relationship ends.[15] First, any exchange between any two matched agents is private information.[16] Second, agents cannot observe any other agent's age or previous matches.[17] Third, agents' strategies do not depend on calendar time.[18] Finally, strategies depend only on the history of the interaction between any two matched agents.[19] With these assumptions, the decision to give a partner a transfer is completely "personal," and any gains from trade are due to the cooperation of two individuals within a specific relationship.

An agent's expected current and discounted future utility in period t from a given transfer profile g is now

$$U_t = u(g_t) + \lambda[\lambda U_{t+1} + (1-\lambda)U_0]. \tag{5}$$

With probability $(1-\lambda)$ her partner dies, and she is matched with a new partner and earns U_0.

To find the highest possible level of utility in a perfect equilibrium, set $U_P = U_0$. The worst possible perfect punishment is still the termination of the relationship. But now agents match with a new partner after a relationship ends. The IE condition that must be satisfied in all periods t is therefore

$$U_t \geq 1 + g_t^{\alpha} + \lambda U_0. \tag{6}$$

Rearranging (6) and using the definitions from the previous section, this con-

14. Agents are matched with another agent with probability one; there is no delay involved in finding a potential exchange partner. If agents were not matched with probability one, agents would incur a loss in utility when they "cheat" a partner simply because of the delay involved in meeting a new partner. With this loss, agents would be able to sustain cooperation in a given relationship. The analysis here shows that cooperation can be sustained even when agents can always find a new exchange partner.

15. Specifically, players have the same strategy space.

16. This assumption prevents a third party from "punishing" an agent who cheats her partner.

17. These first two assumptions guarantee that an agent always has the chance to form a new relationship unencumbered by his past. Agents initially have no information about an agent with whom they are matched. All agents who are matched are observationally equivalent: agents who have "cheated" their partners and agents whose partners have died are indistinguishable from the new agents who have entered the population.

18. This assumption eliminates "dismal" equilibria in which all players born after a date t never give transfers. Such a strategy would provide an incentive for those born in previous periods to give transfers to maintain their current relationships. However, after that date, an ever-diminishing proportion of the population would engage in cooperative exchange.

19. While agents cannot observe the exchanges between other pairs of agents, they do know what has transpired in their own past. This assumption requires that agents do not choose transfers to one partner based on what happened with any previous partner. It therefore rules out equilibria that are based on a notion of community trust or community norms like those found by Kandori (1992). Kandori shows that cooperation in a random-matching game can be sustained by players who, when they experience dishonest behavior, begin cheating everyone with whom they are matched.

dition becomes

$$\delta[V_{t+1} - V_0] \geq 1 - (1 - g_t)^\alpha. \tag{7}$$

To determine the optimal enforceable level of utility from a cooperative relationship, maximize V_0 subject to (7). Let a solution to this problem be $g^*(\delta)$, an optimal IE profile, and let V_0^* be the optimal IE level of utility.[20]

Examining this constrained maximization problem reveals a tension between the utility from exchange relationships and the sustainability of exchange relationships. Increasing any transfer g_t increases the utility from current relationships. However, increasing any transfer g_t also increases V_0, the utility from a new relationship. Thus, there is a trade-off between transfers in different time periods: increasing any g_t tightens the IE constraint on transfers in all other periods.

To analyze optimal IE utility, I show first that I can restrict attention to simple transfer profiles. No cooperative IE profile can be constant or decreasing over time because enforceability requires that utility from an existing relationship always exceed utility from starting a new relationship. In addition, all cooperative IE profiles must involve at least one transfer that is strictly greater than all other transfers. Reflecting these observations, let a *step profile* be a transfer profile whose transfers are monotonically increasing over time in the following way: transfers begin at 0, jump to an intermediate level, g_σ, for one period $\sigma \geq 0$, then jump to a higher level, $\bar{g}$, in period $\sigma + 1$ and remain at that level thereafter. Step profiles are distinguished by time period, σ, in which the "step" to positive transfers occurs. A "σ-step profile" is a transfer profile where $g_t = 0$ for periods $t \leq (\sigma - 1)$, $g_t = g_\sigma$ in period $t = \sigma$, and $g_t = \bar{g}$ in periods $t \geq (\sigma + 1)$, where $0 \leq g_\sigma \leq \bar{g}$ and $\sigma \geq 0$.

Proposition 2. When agents can form new relationships, if a cooperative profile is IE, then there exists an IE step profile that yields (weakly) higher discounted expected utility.

Sketch of Proof. A cooperative IE profile must involve at least one transfer that is strictly greater than all other transfers. Label the highest transfer $\bar{g}$. Since the IE enforceability constraint on $\bar{g}$ is satisfied, raising to $\bar{g}$ all transfers in *subsequent* periods would also be IE and would yield strictly greater utility. The transfers in periods *prior* to $\bar{g}$ can be changed as follows: $g_t = 0$ for periods $t \leq (\sigma - 1)$, $g_t = g_\sigma$ in period $t = \sigma$, and $g_t = \bar{g}$ in periods $t \geq (\sigma + 1)$, where the proper choice of g_σ and σ maintains the enforceability of the profile. ■

The logic behind this result is analogous to that in Abreu, Pearce, and Stacchetti (1993). In a repeated game with a fixed set of players, they solve for the optimal payoffs possible in a symmetric perfect equilibrium with the following property: the equilibrium is renegotiation-proof in the sense that no continua-

20. An optimal IE profile $g^*(\delta)$ is not necessarily unique.

tion payoffs are so low that there exists an alternative perfect equilibrium that always gives strictly greater payoffs. The problem has a similar intertemporal incentive structure to the one here. On any punishment path, the payoffs must be at least some minimum level. But increasing the payoffs in the punishment phase reduces the payoffs that can be sustained on the equilibrium path. As here, of the best symmetric equilibria at least one has this simple structure.

This result allows us to restrict attention to the optimal IE step profile. Moreover, since agents discount future utility, the utility from any optimal IE step profile is equal to the utility from the optimal IE zero-step profile.

Proposition 3. When agents can form new relationships, V_0^* is equal to the utility from the optimal IE zero-step profile.

The optimal IE zero-step profile, therefore, shows how the opportunity to form new relationships affects agents' utility. The optimal IE zero-step profile simply maximizes the utility $[u(g_0) + u(\bar{g})\delta/(1-\delta)]$ subject to two individual enforceability constraints:

$$\delta[u(\bar{g}) - u(g_0)] \geq 1 - (1 - g_0)^{\alpha}, \tag{8}$$

$$\delta[u(\bar{g} - u(g_0)] \geq 1 - (1 - \bar{g})^{\alpha}. \tag{9}$$

Solving for g_0^* and $\bar{g}^*$—the optimal IE g_0 and $\bar{g}$, respectively—yields

$$\bar{g}^* = \frac{1}{1 + \left(\frac{1}{\delta}\right)^{\frac{1}{1-\alpha}}} \tag{10}$$

and g_0^* defined by the following equality:

$$u(g_0^*) = u(\bar{g}^*) - \frac{1 - (1 - \bar{g}^*)^{\alpha}}{\delta}. \tag{11}$$

This profile clearly exhibits the tension between transfers in different periods. The optimal first-period transfer, g_0^*, is less than the optimal transfer in later periods, $\bar{g}^*$. The deduction from $u(\bar{g}^*)$, seen in (11), provides the punishment for cheating on a partner. An agent who cheats on his partner must begin a new relationship at a utility level below $u(\bar{g}^*)$. As δ increases, this deduction falls and $\bar{g}^*$ increases, because agents care less about current gains and more about future utility. However, for all $\delta < 1$, $\bar{g}^*$ is below $1/2$, the first-best transfer. Maintaining $\bar{g}^*$ below $1/2$ is a second-order loss that allows an increase in g_0^*, a first-order gain.

Thus far, I have considered profiles from which no individual agent has an incentive to deviate, given his partner's and all other agents' strategies. However, two agents who are matched to each other might have an incentive to deviate *together* from this profile, given all other agents' strategies. The next section examines this problem.

4. Cooperation and Pair-wise Deviations

The strategies found above are, loosely speaking, not "renegotiation-proof" for a matched pair of agents. Two agents begin their relationship at a low level of utility, even though higher levels are enforceable. When they first meet, two agents could credibly agree to skip the initial, low level of exchange and move directly to the higher level of cooperation. To see this, suppose two players who have just been matched agree to begin their relationship with a transfer $\bar{g}^*$, rather than g_0^*, and to give each other $\bar{g}^*$ thereafter. If ever either partner does not give $\bar{g}^*$, the relationship ends. Given the strategies of the rest of the population, this is a profitable and enforceable deviation *for the pair*. Because $\bar{g}^* > g_0^*$, the two players earn higher utility. Because an agent must begin a new relationship at the lower transfer level if he does not give $\bar{g}^*$, each partner also has an incentive to give $\bar{g}^*$ in the initial and subsequent periods.

Given this observation, I consider here *pair-wise enforceable* (PE) transfer profiles: profiles that are robust both to deviations by individual players *and* to deviations by pairs who are matched to each other, given the strategies of all other players in the population. A transfer profile g with utility levels V_t is PE if g is IE and there exists no transfer profile g' with corresponding utility V_t', such that for any t, $u(g_t') > u(g_t)$ and

$$\delta[V_{t+1}' - V_0] \geq 1 - (1 - g_t')^\alpha \qquad (12)$$

for all t. In other words, a profile is PE if there exists no alternative profile that yields higher utility for both partners and that satisfies the enforceability constraint, given the strategies of the rest of the population.

Notice first that since all cooperative IE profiles involve at least one transfer that is strictly greater than all other transfers, all cooperative IE profiles are subject to deviations by a matched pair of players. Thus, the only PE transfer profile is $g = 0$.

Proposition 4. When agents can form new relationships, there exists no cooperative PE transfer profile.

The nonexistence of cooperative PE profiles disappears, however, when there is enough uncertainty about a new partner's valuation of future utility. Suppose that a proportion ρ of the agents in each population are "trustworthy" and will give transfers as long as it is in their interest to do so.[21] These agents, like those above, discount future utility to the extent that they do not survive to the next period. For them, $0 < \delta < 1$. The remainder are "untrustworthy"; they never give transfers in any period. They place no value on future exchange. For them, $\delta = 0$. Assume that an agent's trustworthiness is private information.[22] Because agents do not know in the initial period of a relationship whether they are matched to a trustworthy partner, agents who are matched to each other do not necessarily have an incentive to deviate to higher transfers in the initial period.

Cooperative PE profiles in this setting must be zero-step profiles, since un-

21. In other words, these agents are trustworthy but not stupid. See discussion in Dasgupta (1988: 51).

22. Ghosh and Ray (1994) analyze this case with a general payoff function.

certainty is resolved after the initial exchange.[23] In all periods after the initial exchange, transfers must be the same level. If any transfer were strictly greater than another, a pair would have an incentive to deviate to the higher transfer.

Proposition 5. When information is incomplete, if g is PE, then $g_t = g$ for all periods $t \geq 1$.

In this case, any cooperative PE profile consists of two transfers: Let g_0 be the transfer in period 0 and $\bar{g}$ be the transfer in periods $t \geq 1$ with corresponding lifetime utility $V_0 = \rho(g_0)^\alpha + (1 - g_0)^\alpha + u(\bar{g})\delta/(1 - \delta)$. Transfers g_0 and $\bar{g}$ must satisfy the individual enforceability constraints

$$\delta[u(\bar{g}) - \rho(g_0)^\alpha - (1 - g_0)^\alpha] \geq 1 - (1 - g_0)^\alpha \tag{13}$$

and

$$\delta[u(\bar{g}) - \rho(g_0)^\alpha - (1 - g_0)^\alpha] \geq 1 - (1 - \bar{g})^\alpha \tag{14}$$

and the following pair-wise enforceability constraints: there exists no g_0' that yields higher expected utility in the initial period and is enforceable given the strategies of the rest of the population. That is, there exists no g_0' such that

$$\rho(g_0')^\alpha + (1 - g_0')^\alpha > \rho(g_0)^\alpha + (1 - g_0)^\alpha \tag{15}$$

and

$$\delta\left[\frac{1}{1-\delta}u(\bar{g}') - V_0\right] \geq 1 - (1 - g_0')^\alpha. \tag{16}$$

And there exists no $\bar{g}'$ that yields higher utility in subsequent periods and is enforceable given the strategies of the rest of the population; that is, there exists no $\bar{g}'$ such that

$$u(\bar{g}') > u(\bar{g}) \tag{17}$$

and

$$\delta\left[\frac{1}{1-\delta}u(\bar{g}') - V_0\right] \geq 1 - (1 - \bar{g}')^\alpha. \tag{18}$$

Consider the following profile: $(g_0^{**}, \bar{g}^{**})$ where g_0^{**} maximizes $\rho(g_0)^\alpha + (1 - g_0)^\alpha$ and either $\bar{g}^{**}$ equals 1/2 or $\bar{g}^{**}$ is the highest transfer that satisfies (14) for $g_0 = g_0^{**}$. If there is "enough" uncertainty over agents' types, $\rho \leq \delta$, then this is the unique cooperative PE profile.

Proposition 6. If $\rho \leq \delta$, the unique cooperative PE profile is $(g_0^{**}, \bar{g}^{**})$.

Sketch of Proof. Since g_0^{**} maximizes $\rho(g_0)^\alpha + (1 - g_0)^\alpha$, agents have no incentive to deviate to any other transfer in the initial period. If $\bar{g}^{**}$ equals

23. For δ sufficiently high, trustworthy agents will have an incentive to give positive transfers in the initial period. As long as untrustworthy agents have a sufficiently low discount factor, untrustworthy agents will not have an incentive to give a transfer in the first period. All uncertainty will be resolved after the initial exchange.

$1/2$ or if $\bar{g}^{**}$ is the highest transfer that satisfies (14) for $g_0 = g_0^{**}$, both the individual and pair-wise enforceability constraints on $\bar{g}$ are satisfied. Since $\rho \leq \delta$, $g_0^{**} \leq \bar{g}^{**}$. Hence, the individual enforceability constraint (13) is also satisfied. ■

5. The Formation of Cooperative Relationships and Groups

The above analysis establishes that when agents can form new relationships, agents must incur a cost, pay a bond, to sustain ongoing cooperative relations. In this section I consider evidence from the sociological and anthropological literature that indicates that individuals may indeed form cooperative relationships by paying bonds. I also discuss how bonds may segment populations into smaller groups within which cooperative relations are possible.

Anthropologists and sociologists find that individuals "invest" in relationships in the initial stages and that this investment allows increased cooperation at a later stage.[24] Researchers who have studied long-term exchange relationships—that is, reciprocal exchange or gift exchange—find that individuals actively cultivate these relationships. People start reciprocal exchange with small transfers, then move to larger transfers as partners reciprocate over time. Souchou (1987: 89) recounts an interview with a business owner in Singapore about *guan xi* (long-term relationships): "*Guan xi* is cultivated through years of mutually beneficial exchanges by two partners. Generally kinship ties are considered to be the best basis for building such a relationship because of the affective bonds already in existence 'through blood.'"

While the best basis for reciprocal exchange may be a kinship connection, not all kin become exchange partners. Moreover, people spend time and money to recruit partners for reciprocal exchange. These partners then sometimes become "fictive kin." In de Soto's (1989: 166) study of business practices in the informal sector in Peru, he relates that "it takes a fair amount of time and resources to establish and cultivate a wide network of friends, 'uncles,' and 'cousins.'" Similarly, in a study of shantytowns surrounding Mexico City, Lomnitz (1977: 167) describes *compadrazgo* (godfather), an institution that "has become a mechanism for conferring official status to a situation of social closeness, for expressing and consolidating preexisting trust, and for preventing potential conflict." The *compadrazgo* institution "involves expenses to all parties," including the costs of recruitment and gifts on various occasions that maintain the relationships. The analysis here suggests that these expenditures to cultivate relationships serve as bonds. If an individual ever reneges on an implicit agreement with an exchange partner, to start a new relationship, she must incur the expenses again.[25]

Bonds or entry barriers may also segment populations into smaller groups within which cooperative relations are possible. As discussed in the Introduction, work on repeated games has shown that cooperation is possible among a

24. See, for example, Blau (1964: 94–98).

25. Kranton (1996) considers reciprocal exchange relationships between given pairs of agents when agents can exchange goods on a market if they renege on an exchange agreement.

fixed group of individuals who interact over time and can observe each others' actions. Social interaction within a group helps transmit information about group members and, thus, provides the necessary condition for the success of a reputation mechanism within the group.[26] If information transmission is costly, however, the size of any group is limited. An entire population cannot be contained in a single group.

The analysis here suggests that if individuals can costlessly quit one group and enter another, cooperation within any one group is not possible. Barriers to entry are needed to prevent people from exiting and entering groups and starting new relationships.

There is evidence that people create entry barriers to groups within which cooperation is possible. Anthropologists and sociologists have documented and analyzed the various institutions that divide a population into groups and establish group identity.[27] Between well-defined ethnic or religious groups there are natural barriers to entry such as language acquisition and religious conversion.[28] Limiting trade to a specific group occurs not only within the "natural" boundaries of clans and religious minorities. In the urban sectors of developing economies, for example, people create subgroups and communities from within large, ethnically and religiously *homogeneous* populations. From among the potential trading population, individuals carve out communities within which cooperative relationships are possible. People create these groups by expending resources or starting at low levels of exchange—in other words, by paying bonds. Roberts (1973: 10) describes the formation of groups in the fluid urban environment of Guatemala City:

> [. . .]the social identities of the others with whom they interact are imprecise. This means that [. . .] secure information about the identities of others is found mainly when a group is small and interacts intensively. Trust thus develops by first extending small favors and then greater ones within a small group and by creating a bond within this group that causes its members to recognize a common identity separating themselves from others in their immediate environment.

6. Conclusion

This article asks if individuals can form and maintain cooperative relationships when there is always the possibility of starting new relationships. The analysis shows that cooperation can be sustained if agents monotonically increase the level of cooperation within a relationship. With this strategy it always better

26. See Greif's (1989, 1993) research on the Maghribi traders in the 11th-century Mediterranean and Clay's (1993) work on traders in Mexican California.

27. For an interesting summary of these practices, see Carr and Landa (1983).

28. Clay (1993) provides evidence that outsiders (Anglos) had to go to great lengths to assimilate to Mexican society in order to become part of the Mexican trader coalition. Carr and Landa (1983) provide additional evidence of conversion and adoption of dietary restrictions necessary to be accepted into a new group.

to continue in a current relationship than to "cheat" and start again with a new partner. Moreover, if there is enough initial uncertainty about a new partner's value of future trade, two newly matched agents will want to follow such a profile rather than jump immediately to the higher transfer levels. There is anthropological and sociological evidence that supports these results. Researchers have observed that individuals begin cooperative exchange relationships at low levels of exchange. As partners fulfill their exchange obligations, cooperation rises to higher levels.

The analysis also suggests that when information transmission is costly, establishing communities within which cooperation can be sustained must involve costly barriers to entry. Consequently, a population can become segmented into different groups. Future research on the formation of cooperative relations should explore the trade-off between the increased economic activity that occurs thanks to establishment of groups and the market segmentation that occurs as a result of their establishment.

Appendix: Proofs

A.1 Proof of Proposition 1

Suppose not. Suppose g is the optimal IE transfer profile, with corresponding expected discounted utility V_0, and there exists a period τ such that $g_\tau > g_t$ for all $t \neq \tau$. Let $\bar{g} \equiv g_\tau$, and let $\bar{u} \equiv u(\bar{g})$. Since g is IE, the IE condition in period t is satisfied:

$$\delta[V_{\tau+1} - V_A] \geq 1 - (1 - \bar{g})^\alpha. \tag{A.1}$$

Consider now a transfer profile $\bar{g}$ where $\bar{g}_t = \bar{g}$ for all t. Let the corresponding level of current and discounted future payoffs in any period t be $\bar{V}_t$. This transfer profile $\bar{g}$ is also IE. To see this, examine the IE constraint in period τ:

$$\delta[\bar{V}_{\tau+1} - V_A] \geq 1 - (1 - \bar{g})^\alpha. \tag{A.2}$$

Since $\bar{u} \geq u(g_t)$, for all $t \neq \tau$, $\bar{V}_{\tau+1} \geq V_{\tau+1}$. Therefore, since (A.1) is satisfied, (A.2) is also satisfied. And since $g_t = \bar{g}$ for all t, enforceability constraints in all periods are the same as (A.1). Finally, since $\bar{u} \geq u(g_t)$ for all $t \neq \tau$, $\bar{V}_0 \geq V_0$. Therefore, g cannot be the optimal IE transfer profile. ■

A.2 Proof of Proposition 2

The proof follows the sketch in the text. Consider any IE transfer profile g with corresponding expected discounted utility in period t, V_t. Assign the label $\bar{g}$ to the highest transfer in g and let $\bar{u} \equiv u(\bar{g})$. Define τ to be the first time period in which $\bar{g}$ appears (i.e., $g_\tau \equiv \bar{g}$). (Note that it must be that $\tau \geq 1$.) Since g is IE, the IE constraint in period τ is satisfied:

$$\delta[V_{\tau+1} - V_0] \geq 1 - (1 - \bar{g})^\alpha. \tag{A.3}$$

Define

$$x_\tau \equiv \sum_{s=0}^{\tau} \delta^s u(g_s), \tag{A.4}$$

the discounted sum of utility in periods up to τ.

There exists a step profile $\tilde{g}$ with corresponding current and discounted future payoffs in any period t, $\tilde{V}_t$, such that $\tilde{V}_0 \geq V_0$ and $\tilde{g}$ is IE. This step profile consists of the following transfers: $\tilde{g}_t = 0$ for periods $t \leq (\sigma - 1)$, $\tilde{g}_t = g_\sigma$ in period $t = \sigma$, and $\tilde{g}_t = \bar{g}$ in periods $t \geq (\sigma + 1)$, where g_σ and σ satisfy the equality

$$\delta^\sigma u(g_\sigma) + \sum_{s=\sigma+1}^{\tau} \delta^s \bar{u} = x_\tau. \tag{A.5}$$

Such a g_σ and $\sigma \leq \tau$ exists because in all periods prior to τ, $u(g_t) \leq \bar{u}$ and $u(g_0) < \bar{u}$.

This profile yields a weakly higher discounted expected lifetime utility than g, since $\bar{u} \geq u(g_t)$ for all $t \geq \tau + 1$. The profile $\tilde{g}$ is also IE. Consider first the IE constraint on $\tilde{g}$ in period τ. It holds because (A.3), the IE constraint on g, is satisfied. To see this, rewrite $[V_{\tau+1} - V_0]$ as follows:

$$V_{\tau+1} - V_0 = (1 - \delta^{\tau+1}) \sum_{s=0}^{\infty} \delta^s u(g_{\tau+1+s}) - x_\tau. \tag{A.6}$$

Clearly, $[V_{\tau+1} - V_0]$ is (weakly) increasing for an increase in a transfer in any period $s \geq \tau + 1$ (for $g_s \leq 1/2$), that is,

$$\frac{\partial [V_{\tau+1} - V_0]}{\partial g_s} = (1 - \delta^{\tau+1}) \delta^s u'(g_s). \tag{A.7}$$

Thus, the IE constraint for profile $\tilde{g}$ in period τ is also satisfied, since the transfers in $\tilde{g}$ are higher than the transfers in g for periods $s \geq \tau + 1$. We have

$$\delta[\bar{V} - \tilde{V}_0] \geq 1 - (1 - \bar{g})^\alpha, \tag{A.8}$$

where $\bar{V} \equiv \bar{u}/(1 - \delta)$.

Consider next the IE constraints for profile $\tilde{g}$ in the remaining periods. In periods $t \geq \tau + 1$, the IE constraints are exactly the same as (A.8). The IE constraints for all periods $\tau > t \geq (\sigma + 1)$ are also the same as (A.8), since x_τ is unchanged. The IE constraint for period σ is

$$\delta[\bar{V} - \tilde{V}_0] \geq 1 - (1 - g_\sigma)^\alpha. \tag{A.9}$$

Since $g_\sigma \leq \bar{g}$, the fact that (A.8) is satisfied implies that (A.9) is satisfied. Finally, the IE constraints for periods $t \leq (\sigma - 1)$ when $\tilde{g}_t = 0$ are

$$\delta[\tilde{V}_{t+1} - \tilde{V}_0] \geq 0. \tag{A.10}$$

Since the transfers are monotonically increasing, this inequality is satisfied: $\tilde{V}_{t+1} - \tilde{V}_0$ is nonnegative for all t. ∎

A.3 Proof of Proposition 3

To find V_0^*, it is possible to restrict attention to the optimal IE step profile, since from Proposition 2, for every IE transfer profile there is a step profile that yields weakly higher utility. I determine first the maximum utility from each σ-step profile. For a given σ, maximize $V_0 \equiv \delta^\sigma[u(g_\sigma) + u(\bar{g})\delta/(1-\delta)]$ subject to the enforceability constraint (A.8) for $t \geq (\sigma+1)$, (A.9) for $t = \sigma$, and (A.10) for $t \leq (\sigma - 1)$. Let the solution to this constrained maximization problem be $g_\sigma^*(\sigma,\delta)$ and $\bar{g}^*(\sigma,\delta)$.

If this solution yields the optimal IE utility level—that is, $V_0^* = \delta^\sigma[u(g_\sigma^*(\sigma,\delta)) + u(\bar{g}^*(\sigma,\delta))\delta/(1-\delta)]$—then it must be the case that $\bar{g}^*(\sigma,\delta) \geq g_\sigma^*(\sigma,\delta)$. Otherwise, by Proposition 1, there exists a step profile that yields higher utility.

If $g_\sigma^*(\sigma,\delta)$ and $\bar{g}^*(\sigma,\delta)$ yield the optimal level of utility, which implies $\bar{g}^*(\sigma,\delta) \geq g_\sigma^*(\sigma,\delta)$, then the constraint (A.8) on $\bar{g}^*(\sigma,\delta)$ must be binding. Setting (A.8) as an equality, solving for g_σ, and substituting into the objective function yields

$$V_0 = \frac{1}{1-\delta}u(\bar{g}) + \frac{1-(1-\bar{g})^\alpha}{\delta}. \tag{A.11}$$

The objective function is now independent of σ. Hence, the optimal IE levels of utility for any profile where $\bar{g}^*(\sigma,\delta) \geq g_\sigma^*(\sigma,\delta)$ are independent of σ. When $\sigma = 0$, $\bar{g}^*(0,\delta) \geq g_\sigma^*(0,\delta)$. Since agents discount utility, the optimal IE utility from the zero-step profile is the optimal IE level of utility: $V_0^* = u(g_\sigma^*(0,\delta)) + u(\bar{g}^*(0,\delta))\delta/(1-\delta)$. ■

A.4 Proof of Proposition 4

Since a cooperative PE profile must be constant over time and a cooperative IE profile cannot be constant over time, there does not exist a cooperative PE profile. To see that a cooperative PE must be constant over time, suppose not. Suppose a profile g with corresponding utility V_t in period t is PE and $u(g_\tau) > u(g_s)$ for some $s \neq \tau$. Since g is PE, the IE constraints in all periods are satisfied. Consider a pair deviating to a transfer profile g' with corresponding utility levels V_t', where $g_t' = g_t$ for all $t \neq \tau$ and $g_\tau' = g_s$. (All the transfers in g' are the same as the transfers in g except for the transfer in period s, which has increased to the level of g_τ.) Since $u(g_\tau) > u(g_s)$, this would be a profitable deviation. Moreover, both partners would be willing to deviate, given the strategies of the rest of the population. Since $V_t' \geq V_t$ in all periods t, and g is IE, the following inequality is satisfied in all t:

$$\delta[V_{t+1}' - V_0] \geq 1 - (1-g_t')^\alpha. \tag{A.12}$$

Hence, g is not PE. ■

A.5 Proof of Proposition 5

Consider a transfer profile g with corresponding utility V_t in period t. If g is PE, then in all periods s, $\tau > 0$, $u(g_t) = u(g_s)$. The proof is the same as in

Proposition 4. Therefore, all PE profiles are zero-step profiles with a transfers g_0 in period 0 and a transfer $\bar{g}$ in all periods $t \geq 1$. ■

A.6 Proof of Proposition 6

The proof defines two critical transfer values, then establishes five preliminary results about the optimal PE profile, Lemmas A.1–A.5, that are used to prove the central result.

Let g_0^{**} be the transfer that maximizes utility in the first period: $\rho(g_0)^\alpha + (1 - g_0)^\alpha$. Solving for g_0^{**} yields

$$g_0^{**} = \frac{1}{1 + \left(\frac{1}{\rho}\right)^{\frac{1}{1-\alpha}}}. \tag{A.13}$$

Notice that $\rho(g_0)^\alpha + (1 - g_0)^\alpha$ is increasing for $g_0 < g_0^{**}$.

Let $\hat{g}$ be the transfer that maximizes the "net incentive to cooperate" in subsequent periods—that is, the continuation payoffs from cooperating minus any gains from cheating. The IE constraint in periods $t \geq 1$ is

$$\frac{\delta}{1-\delta} u(\bar{g}) - \delta V_0 \geq 1 - (1 - \bar{g})^\alpha. \tag{A.14}$$

The net incentive to cooperate is then

$$\frac{\delta}{1-\delta} u(\bar{g}) - 1 + (1 - \bar{g})^\alpha. \tag{A.15}$$

Solving for $\hat{g}$ yields

$$\hat{g} = \frac{1}{1 + \left(\frac{1}{\delta}\right)^{\frac{1}{1-\alpha}}} \tag{A.16}$$

Notice that the net incentive to cooperate is increasing for $\bar{g} < \hat{g}$ and for $\delta < 1$, $\hat{g} < 1/2$. Notice also that if $\rho \leq \delta$, $g_0^{**} \leq \hat{g}$.

Lemma A.1. If $g = (g_0, \bar{g})$ is PE, then $\bar{g} \geq \hat{g}$.

Proof. Suppose not. Suppose $\bar{g} < \hat{g}$. Then there exists $\bar{g}' \in (\bar{g}, \hat{g})$ such that, since $\hat{g} < 1/2$, $u(\bar{g}') > u(\bar{g})$. And since $\bar{g} < \hat{g}$,

$$\frac{\delta}{1-\delta} u(\bar{g}') - 1 + (1 - \bar{g}')^\alpha > \frac{\delta}{1-\delta} u(\bar{g}) - 1 + (1 - \bar{g})^\alpha. \tag{A.17}$$

Hence,

$$\delta \left[\frac{1}{1-\delta} u(\bar{g}') - V_0 \right] \geq 1 - (1 - \bar{g}')^\alpha. \tag{A.18}$$

The PE constraint on $\bar{g}$ is not satisfied: a pair of players would have an incentive to deviate to such a transfer $\bar{g}' \in (\bar{g}, \hat{g})$ in any period $t \geq 1$. ■

Lemma A.2. If $g = (g_0, \bar{g})$ is PE, then either $\bar{g} = 1/2$ or the IE constraint on $\bar{g}$ is binding.

Proof. Suppose not. Suppose $\bar{g} \neq 1/2$ and

$$\delta[u(\bar{g}) - \rho(g_0)^\alpha - (1 - g_0)^\alpha] > 1 - (1 - \bar{g})^\alpha. \tag{A.19}$$

Both the left- and right-hand sides of (A.19) are increasing in $\bar{g}$. By Lemma A.1, $\bar{g} \geq \hat{g}$. Hence, there exists a $\bar{g}' > \bar{g} \geq \hat{g}$ such that:

$$\delta\left[u(\bar{g}') - \rho(g_0)^\alpha - (1 - g_0)^\alpha\right] > 1 - (1 - \bar{g}')^\alpha, \tag{A.20}$$

which implies that the deviation to $\bar{g}'$ is supportable:

$$\delta\left[\frac{1}{1-\delta}u(\bar{g}') - V_0\right] \geq 1 - (1 - \bar{g}')^\alpha. \tag{A.21}$$

Since $\bar{g}' \in (\bar{g}, 1/2)$, $u(\bar{g}') > u(\bar{g})$. Hence, the PE constraint on is not satisfied; a pair of players would have an incentive to deviate to a transfer $\bar{g}' \in (\bar{g}, 1/2)$ in any period $t \geq 1$. ■

Lemma A.3 If $g = (g_0, \bar{g})$ is PE, then $g_0 \leq g_0^{**}$.

Proof. Suppose not. Suppose $g_0 > g_0^{**}$. Then a pair of players would have an incentive to deviate to g_0^{**} in period 0. This would increase expected utility in period 0: by definition, $\rho(g_0^{**})^\alpha + (1 - g_0^{**})^\alpha > \rho(g_0)^\alpha + (1 - g_0)^\alpha$. Individuals also have less incentive to cheat: since $g_0^{**} < g_0$, $1 - (1 - g_0^{**})^\alpha < 1 - (1 - g_0)^\alpha$. Hence,

$$\delta\left[\frac{1}{1-\delta}u(\bar{g}) - V_0\right] \geq 1 - (1 - g_0^{**})^\alpha. \tag{A.22}$$

The PE constraint on g_0 is not satisfied. ■

Lemma A.4. If $g = (g_0, \bar{g})$ is PE and $g_0 < g_0^{**}$, then the IE constraint on g_0 is binding.

Proof. Suppose not. Suppose $g_0 < g_0^{**}$, and

$$\delta[u(\bar{g}) - \rho(g_0)^\alpha - (1 - g_0)^\alpha] > 1 - (1 - g_0)^\alpha. \tag{A.23}$$

Then a pair of players would have an incentive to deviate to a transfer $g_0' \in (g_0, g_0^{**})$ in period 0. Since $1 - (1 - g_0)^\alpha$ is increasing in g_0, there exists a $g_0' \in (g_0, g_0^{**})$ such that

$$\delta\left[\frac{1}{1-\delta}u(\bar{g}) - V_0\right] = 1 - (1 - g_0')^\alpha. \tag{A.24}$$

Since $g_0 < g_0^{**}$, $\rho(g_0')^\alpha + (1 - g_0')^\alpha > \rho(g_0)^\alpha + (1 - g_0)^\alpha$. And the PE constraint on g_0 is not satisfied. ■

Lemma A.5. If $\rho \leq \delta$ and $g = (g_0, \bar{g})$ is PE, then $g_0 = g_0^{**}$.

Proof. From Lemma A.3, $g_0 \leq g_0^{**}$. Suppose $g_0 < g_0^{**}$. From Lemma A.4, the IE constraint on constraint on g_0 is binding. Since the IE constraints on g_0

and $\bar{g}$ are both satisfied, this implies

$$1-(1-g_0) \geq 1-(1-\bar{g}), \tag{A.25}$$

which in turn implies $g_0 \geq \bar{g}$. By hypothesis, then, $g_0^{**} > g_0 \geq \bar{g}$. From Lemma A.1, $\bar{g} \geq \hat{g}$. Together these imply $g_0^{**} > \hat{g}$. But if $\rho \leq \delta$, $g_0^{**} \leq \hat{g}$. ■

With lemmas A.1–A.5, we can prove Proposition 6:

Existence: Set $g_0 = g_0^{**}$. Set $\bar{g}$ such that either $\bar{g} = 1/2$ or the maximum $\bar{g}$ so that the IE constraint on $\bar{g}$ is binding. This implies that both the IE and the PE constraint on $\bar{g}$ are satisfied. In addition, it must be that $\bar{g} \geq \hat{g}$. (If not, $\bar{g}$ could be increased while loosening the IE constraint on $\bar{g}$). Since $\rho \leq \delta$, $g_0^{**} \leq \hat{g}$. Hence, $\bar{g} \geq g_0^{**} = g_0$. Since the IE constraint on $\bar{g}$ is satisfied and $\bar{g} \geq g_0$, the IE constraint on g_0 is also satisfied. Finally, since $g_0 = g_0^{**}$, the PE constraint on g_0 is clearly satisfied.

Uniqueness: From Lemma A.5, if $\rho \leq \delta$ and $g = (g_0, \bar{g})$ is PE, then $g_0 = g_0^{**}$. And from Lemma A.2, if $g = (g_0, \bar{g})$ is PE, then either $\bar{g} = 1/2$ or the IE constraint on $\bar{g}$ is binding. Hence, if $\rho \leq \delta$, no other transfer profile is PE. ■

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