AT-WILL RELATIONSHIPS: HOW AN OPTION TO WALK AWAY AFFECTS COOPERATION AND EFFICIENCY

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ABSTRACT. We theoretically and experimentally examine the effects from adding a simple, empirically relevant action to a repeated partnership, the option to walk away. Manipulating both the value of the outside option, and its relative distribution among the partners, we examine the strategies selected by human subjects in a simple prisoners-dilemma-like partnership. Our findings indicate that selecting between in-relationship punishments or walking-away are dictated by individual rationality. Moreover, where dissolution is used to punish bad outcomes, we find subjects commonly use a compound punishment, with a forgiving probation phase before termination is used. Where outside options for ex-partners are asymmetric, we find stark selection effects, with the potential for very high and very low efficiency, depending on how the division is determined, motivating further research into dissolution clauses for relational contracting.

1. INTRODUCTION

Dissolving a relationship is a familiar, easy-to-understand dynamic response, and can be readily incorporated as a future punishment threat to support cooperation today. It is clearly a force in many repeated scenarios of interest to economists: Workers quit firms that treat them badly, and are fired by firms that find them unproductive. Couples petition for divorce if their marriages become unhappy. Consumers stop patronizing businesses where they have had bad experiences, while firms refuse to deal with problem customer (schools expelling students, insurers denying renewals). But in these examples participants also have access to, and make use of, in-relationship punishments: Workers strike and conduct slow-downs, firms demote workers, cut back hours, or withhold bonuses. Couples argue, and atone for things they did not do. Businesses win back customers with steep discounts after bad service, while consumers can retain access to firms by paying more (a donation to the alumni fund, paying higher premiums). In environments where mistakes or bad outcomes are inevitable, despite the best efforts of all parties, in-relationship punishments allow for the possibility of forgiveness, and a return to cooperation, where leaving the relationship does not.

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Whether or not dissolution is preferable to in-relationship punishment for the individual depends on several factors: What is the in-relationship punishment’s expected value, can it recoordinate on an efficient outcome? How severe are the dissolution frictions (legal costs, losses on the sale of illiquid jointly held asset, reputation shocks, etc.)? What is the expected value from starting afresh in a new relationship (given equilibrium selection, and accounting for the population available to rematch)? Are outside options fixed, and commonly available, or do they depend on the way the relationship ends? Such environments have many moving parts, and the values to both remaining in the relationship and dissolving it are endogenous, leading to many possible equilibrium outcomes. To get a handle on such a complex problem, our paper uses a laboratory study to examine selected outcomes as we exogenously vary the outside-option value with exogenous, stationary rematching. Using a fixed in-relationship stage game—a prisoner’s dilemma (PD) game with imperfect public monitoring—our experimental treatments alter the possibility of/payoffs attained by walking away.

In the static PD game, and in finitely repeated play, we have an inefficient equilibrium outcome: both players defect, and the outcome is Pareto dominated by joint cooperation. However, where interactions are repeated indefinitely, more-efficient equilibria become possible. Folk theorems tell us that with patient enough participants, all individually rational payoffs can be supported in equilibrium (Fudenberg and Maskin, 1986)—each individual can condition their future behavior, and so any deviations from the intended path today will be punished tomorrow. The ensuing multiplicity in prediction has been addressed by a recent and growing body of experimental work analyzing equilibrium selection, finding strong support for conditional cooperation when players are patient enough. Moreover, in experimental implementations with imperfect monitoring—where actions in the stage game are unobserved, with outcomes providing an imperfect signal—results indicate subjects have an affinity for lenient and forgiving strategies (see Fudenberg et al., 2010). Subjects require multiple bad outcomes to enter a punishment phase (so they are lenient), while punishment durations are short followed by a return to cooperation (so they are forgiving). Because signals are imperfect, entering a punishment phase eventually is unavoidable, even with both parties cooperating. The selection of forgiving punishments therefore serves to increase efficiency, as the relationship will not become mired in an inefficient punishment. To these games, our paper adds an intuitive, empirically relevant punishment device, ending the relationship, where terminating a relationship precludes forgiveness.

Our first set of experiments examine symmetric environments, where each participant has access to the same in-relationship actions/payoffs and the same fixed outside option. Here the fundamental tension is the interplay between incentive compatibility and efficiency for the inside- and outside-the-relationship punishments. A slight strengthening of the folk theorem (weakly undominated, individually rational payoffs) implies termination should never be used when its value is lower than the expected value of the in-relationship minmax (in a PD game, joint defection). Though its presence might alter equilibrium selection, we should not see relationship dissolve along the path. In contrast, once the dissolution payoff exceeds the expected in-relationship minmax, the effect is to directly alter the individually rational payoff. Dissolved relationship are now expected to be observed along the path. Our experimental results are mostly in line with this hypothesis. When outside options are far below the in-relationship minmax (in which region, we can think of termination as a form of
costly punishment) we see very low rates of dissolution. When very high, we see much more substantial rates of dissolution. However, in contrast to the prediction, we observe large increases in termination use once outside options exceed the minimal realization attainable from the in-relationship minmax, rather than its expectation.

In terms of the types of strategies used we find two main results: First, the presence of termination increases the selection of initially cooperative strategies, even where termination is weakly dominated and is an unused action by most subjects. Second, as mentioned above, once the outside option exceeds the minmax realization, strategies using termination become the focal form of punishments. However, subjects utilizing termination punishments are more lenient in entering punishment phase, and just as forgiving as those subjects in treatments without termination or with much-lower outside options. This somewhat counter-intuitive result is explained by the frequent selection of a compound punishment, a form response we refer to as “probation” strategies. Here, the first part of the punishment is the probation period, using the in-relationship punishment. Successful outcomes in probation lead back to cooperation, so the punishment is potentially forgiving. On the other hand, continued bad outcomes in the probation phase lead to the second part of the punishment: dissolution. However, despite the selection of forgiving strategies, the rate at which initially cooperative strategies are used is mostly unchanged from other treatments. Though observed cooperation rates in ongoing relationships do increase in partnerships with higher outside options, this is mostly a selection effect, as relationships with consistently uncooperative partners are dissolved more frequently.

In terms of overall efficiency, our experimental results point to a non-monotonicity over the outside-option value. Through an increased selection of cooperative strategies, the presence of low-payoff outside options provides an initial boost to efficiency. From the lowest outside option levels, efficiency does increase slightly as outside options increase in value. Ending a relationship becomes a more-plausible threat as its value increases, but its actually use is infrequent. However, increasing the outside option too much, beyond the minimal realization from the in-relationship minmax, leads to much higher rates of termination. Because dissolution is (ex post) fairly inefficient and we do not observe increased cooperation rates, this leads to an efficiency drop. After this decline, subsequent increases to the outside option—from the minimal realization, through the expectation and beyond—increase efficiency. Though the rates of cooperation and dissolution remain flat, the ex post inefficiency after a relationship ends decreases in proportion to the outside option, leading to an observed increase in overall efficiency.

The first set of treatments address the size of the pie on dissolution, and provide a window into the effect of ex post frictions on ex ante outcomes. Our second set of treatments examines effects from changes to the relative distribution within the relationship on dissolution. Here we are motivated by relational contracts specifying how assets/costs are divided when relationships are dissolved. Examples range from prenuptial agreements in marriages to LLP’s incorporation documents, consumer mortgages and residential leases to joint-venture by firms, severance payments for terminated workers to non-compete clauses for ship-jumping employees. Contracting parties retain rights to unilaterally void the contract, subject to the costs/benefits specified for early termination. Our second treatment set examines three plausible asymmetric divisions on dissolution: i) an environment where the party terminating receives the larger amount; ii) an environment where the party who
is being terminated gets the larger amount; and iii) an environment where an independent arbitrator/judge diagnoses "blame" for the partnership's dissolution, and assigns a larger payoff to the more-cooperative party.

Our findings in these asymmetric environments are stark. Rewarding the party ending the relationship leads to a strong selection of termination from round one, despite expected outside options being Pareto dominated by the in-relationship minmax. Relationships with this type of division rarely seem to get off square one in our experiments. In contrast, in what seems to be a more-common arrangement in leases and labor contracts, an asymmetric division rewarding the party being terminated substantially reduces termination rates, though we do find reduced cooperation and fewer subjects using forgiving strategies relative to comparable symmetric treatments. Finally, our simulated-arbitrator treatment produces very high cooperation rates, leading to the most-efficient outcomes across the studied environments. Subjects select lenient strategies, with high initial cooperation rates, and where punishments exhibit similar forgiveness levels to the symmetric treatments. Because subjects are highly cooperative, and lenient towards bad outcomes, observed dissolution rates are lower than the symmetric treatments where termination punishments are selected at similar rates. Despite an average dissolution payoff comparable to our lowest-efficiency symmetric treatment, the asymmetric assignment on dissolution produces a useful marriage of properties for the punishment: plausibility of use by those doing the punishing, and punishment power for those being punished.

Below we briefly discuss the connection between our paper and a sample of the theoretical and experimental literatures. Section 2 describes our experimental design and explores some of the theoretical predictions in each of our seven treatments. Section 3 reports the results from the experiments, while Section 4 discusses the results and concludes.

1.1. Literature. The folk theorem for repeated games with discounting is articulated in Fudenberg and Maskin (1986), and shows that any feasible, individually rational payoff can be sustained in equilibrium when players are sufficiently patient.¹ The theorem is constructive and shows that cooperation can be supported by punishing deviations by minimizing the maximum amount deviators can obtain, over a number of punishment round. Repeated games with imperfect public monitoring were initially studied with respect to cartel behavior in dynamic Cournot-type competition. Firms receive imperfect signals of the other cartel members’ quantity decisions from the market via prices (Porter, 1983; Green and Porter, 1984), but monopoly quantities can be implicitly supported by the cartel under high prices, with market-flooding punishments (Cournot quantity choices) whenever the price gets too low. Further theory for imperfect monitoring is developed in Abreu et al. (1986, 1990), where the authors demonstrate the simple structures that can support optimal cooperation.

The closest theory paper to our environment is Radner et al. (1986), who study partnerships game with imperfect monitoring and positive discount rates.² Their finding is that the super-game equilibria are bounded away from full efficiency, uniformly over the discount. Fudenberg et al. (1994) subsequently extends the folk theorems to infinitely repeated games with imperfect public monitoring, articulating a condition (pairwise identification) on the

¹For earlier work see references within Fudenberg and Maskin (1986), in particular Friedman (1971).
²In this version of the partnership game, monitoring is two-sided imperfect. In contrast, in the principal-agent game in Radner (1985), imperfect monitoring is one-sided. See also Cole and Kocherlakota (2005) for characterization of symmetric public-perfect equilibria attainable with finite memory strategies.
monitoring technology for the folk theorem.\(^3\) The partnership game in Radner et al. (and the stage game in our experiments), fail this condition, and points on the feasible-payoff frontier are not attainable in equilibrium, even for \(\delta \to 1\).

Given the endogenous endpoints in our experiments (choosing to end the relationship), our environment is more technically a dynamic or stochastic game (see Dutta, 1995). That is, we require an additional state variable (here whether or not a player has terminated before the current period) that determines the particular stage game played, and state transitions are endogenous, determined by players’ actions. In many dynamic games the focus is on Markov perfect equilibrium (Maskin and Tirole, 2001), a refinement where strategies are conditioned only on the current state variable. Given the simple binary nature of the state in our experiments, and the complete lack of agency in one state (inactive partnerships), our focus will instead be on a larger set of public-perfect equilibria (see Fudenberg and Tirole 1991).

Theoretical models for dividing surplus on dissolution have tended to focus on ex post division of the partnership’s assets (Cramton et al., 1987; Preston McAfee, 1992), where our focus is on ex ante efficiency.\(^4\) Related to this focus on overall efficiency, Comino et al. (2010) posit that firms might strategically omit more explicit termination clauses in relational contracts to ensure costly litigation on early termination, and increasing cooperation within the relationship (also see Li and Wolfstetter, 2010), which is borne out in our findings.

Early experiments on infinitely repeated games showed that cooperation is greater when it can be supported in equilibrium, but that subjects fail to make the most of the opportunity to cooperate (see Roth and Murnighan, 1978; Murnighan and Roth, 1983; Palfrey and Rosenthal, 1994). More recent experiments (Dal Bó, 2005; Aoyagi and Fréchette, 2009; Duffy and Ochs, 2009) have provided more detailed results on subject’s ability to support cooperation in infinitely repeated games. The theory on infinitely repeated games listed above does not generically provide sharp predictions—the folk theorems predict no specific payoffs within the individually rational set, without further refinement (for example, symmetry and efficiency). Experimental evidence has made a contribution to these equilibrium-selection questions. Dal Bó and Fréchette (2011) study the evolution of cooperation in infinitely repeated PD games, introducing a methodology for estimating the strategies used. They find that in treatments where cooperation cannot be supported in equilibrium, the use of cooperative strategies decreases with experience and eventually converges to a fairly low level. When cooperation can be supported in equilibrium, subjects fail to cooperate as much as they can, with Tit-for-Tat-like strategies becoming more prevalent at higher discount rates, where the gains from cooperation are highest.

Experiments have also studied noise/imperfect public monitoring in repeated games. Fudenberg et al. (2010) study repeated PD games with noise (implemented as a probability that a selected cooperate choice is implemented by the computer as defect, and vice versa) and find that successful strategies are “lenient” in not retaliating after a single deviation, and that many use “forgiving” strategies in order to return to cooperation after a punishment phase. In a different setting, Aoyagi and Fréchette (2009) examine imperfect public monitoring by

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\(^3\)Essentially the condition requires that players’ deviations can be statistically distinguished, so that punishment can be optimally used.

\(^4\)For an experimental examination of ex post dissolution see Brooks et al. (2010).
experimentally varying the quality of the public signal. Their main finding is a rise in cooperation levels with increased signal quality. Embrey et al. (2011) examine an environment with the most similar signal structure to our own paper, where their experiments manipulate the game through the addition/subtraction of a third intermediate action between the standard cooperate and defect. Their paper’s aim is to examine the empirical validity of alternative equilibrium concepts (in particular renegotiation proofness). Though they do not find much support for the renegotiation equilibrium, they do find that the concept helps predict the selection of more-forgiving strategies.

Experiments have also introduced punishments into the repeated PD game. Dreber et al. (2008) study the option for temporary and costly punishment, where they find that the existence of a punishment option substantially increases cooperation but not the average payoff of the group. In our treatments with symmetric but low outside options, termination is similar to costly punishment, though termination commits to an irreversible path and cannot be used to realign non-cooperative agents. However, for higher outside options, termination takes on a different role, and its presence raises equilibrium-selection questions.

Perhaps closest in motivation to our paper is Rand et al. (2011). They study cooperation in a structured network, where they examine the effects on the ability to change partners. Their paper examines termination and re-partnering as a punishment/selection device, but where the value of terminating is endogenously determined. They find that when subjects update their network connections frequently, cooperation is maintained at a much higher level through endogenous selection. Our own paper seeks to map out the effects of exogenous changes to the outside-option/punishment on cooperation, where we do not allow new links to form. Another related experimental paper is Hyndman and Honhon (2014), where they examines preferences for flexibility over termination options (though here in a coordination game). They find that subjects show a slight preference for flexibility in ending the relationship. However, subjects over-use the termination option, with too much sensitivity to short-term noisy outcomes. Our own paper indicates much more forgiveness, with subjects more willing to delay termination after a bad outcome.

2. Experimental Design and Theoretical Predictions

2.1. Repeated Partnership Game. Our experimental game has two players engaged in a repeated joint-production task with imperfect public monitoring, similar to that in Radner et al. (1986). In every round $t$ of their interaction, each partner $i$ simultaneously chooses a private action $a_i^t \in \{C, D\}$. Given the resulting action profile $a^t = (a_1^t, a_2^t)$, a public signal $Y^t \in \{\text{Success}, \text{Failure}\}$ is realized and observed by both players, alongside their round payoff $r_i(a^t_1, Y^t)$. The probability of a Success signal each round is a function of the selected actions, and the expected round payoff to partner $i$ given the action profile $(a_1, a_2)$ is

$$u_i(a_1, a_2) = \Pr \{S \mid (a_1, a_2)\} \cdot r_i(a_i, S) + (1 - \Pr \{S \mid (a_1, a_2)\}) \cdot r_i(a_i, F).$$

The partnership continues indefinitely under an exponential discount rate $\delta$, so that the discounted-average expected payoff for the partnership is

$$W_i \left( \{a_1^t, a_2^t \}_{t=1}^\infty \right) = (1 - \delta) \sum_{t=1}^\infty \delta^{t-1} u_i(a_1^t, a_2^t).$$
Table 1. Stage-game payoffs

|         | Payoff, \( r_i(a_i, y) \) | \( \Pr \{ \text{Success} | (a_i, a_j) \} \) | Expectation, \( u_i(a_i, a_j) \) |
|---------|---------------------------|---------------------------------|---------------------------|
|         | \( y: \)                  | \( a_j: \)                       | \( a_j: \)                  |
|         | Success | Failure | \( C \) | \( D \) | \( C \) | \( D \) |
| \( a_i: \) |         |         | 150 | 0 | 0.98 | 0.5 | 147 | 75 |
| \( a_i: \) |         |         | 250 | 100 | 0.5 | 0.1 | 175 | 115 |

Table 1 indicates the payoff realizations \( r_i(a_i, Y) \) and the conditional success rates \( \Pr \{ \text{S} | a \} \) chosen for our experiment, where the resulting expected payoffs make clear that the stage-game is a PD in expectation.\(^5\) The game can be thought of as two partners making choices over their individual effort levels into a jointly held venture (with \( C \) being high effort). The two partners equally split a $5 firm revenue on a success and $2 revenue on a failure. If either chooses to put in high effort they individually incur an additional $1 cost. Higher efforts increases the likelihood of a successful outcome: if both players expend effort there is a 98 percent chance the outcome is success; if both players put in low effort the probability of success is just 10 percent; if one exerts high effort and the other free rides the success probability is 50 percent.

Our main experimental treatments modify the repeated game above by adding a third action to the game, which allows either partner to unilaterally dissolve the partnership. If either party chooses this third action, \( T(\text{Termination}) \), no further action choices are made by either partner in subsequent rounds, and both parties receive a fixed payoff. Our experiments will focus on two types of termination: i) symmetric termination payoffs to each partner \((\pi_T, \pi_T)\); and ii) asymmetric payoffs on termination \((\pi, \bar{\pi})\), with the assignment of the the higher payment \((\pi > \bar{\pi})\) dictated by players’ actions.

2.2. Experimental Specifics. In a supplemental appendix we include more detailed instructions and screenshots of the interface used, but we here summarize the experimental design choices. The design is between subject: students are recruited for general economic experiments, and placed in sessions with exogenous and fixed assignment of treatment, the particular payoff on termination. Subjects participate in sessions of 12–16 subjects, at the start of which they are provided with instructions (a representative example of which is included in the appendix) which were read aloud.

As asking subjects to provide infinite choice sequences is infeasible, the experiment mirrors an infinitely-repeated game with exponential payoff discounting through an exogenous, stochastically determined end point. That is instead of scaling down the payoffs receive the next period and onward by a factor \( \delta = 4/5 \), we scale down the probability of obtaining any additional amount in the next and subsequent rounds, and retain the same stakes. After every round of the game where the partnership is still accumulating payment, there is a 1/5

\(^5\)The game is therefore a prisoner’s dilemma where outcomes are simple lotteries. Under constant relative risk-aversion there are no risk parameters that would reverse the PD ordering on the stage-game payoffs. Under constant absolute risk aversion, the risk aversion coefficient would need to be between 1.5 and 2.4 (for payoffs in cents) to induce a different ordinal game; consistent preferences at this level would require experimental subjects to take $50e for sure over an even gamble between zero and a million dollars.
probability that payment for the supergame will end, and \( \frac{4}{5} \) that it continues. The agents expected discounted-average payoff from the supergame is given by (1), as the probability of getting to round \( t \in \{1, 2, \ldots\} \) is given by \( \delta^{t-1} \). Subjects are paid the sum of their realized round payoffs \( r_i(a_i^t, Y^t) \) or (after a dissolution) their round termination payoffs \( \pi_T \), up to point where the partnership payment exogenously stops.

This method for implementing repeated games (exogenous stochastic termination) with no fixed horizon goes back to Roth and Murnighan (1978) and has been used extensively in experimental studies of dynamic behavior. One drawback to using a stochastic endpoint is that observed relationships can be very short, where such short interactions offer limited power to assess the strategies being used. To increase the length of the observed partnerships in the experiment, we use a block design (cf. Fréchette and Yuksel, 2013, for a methodological discussion). Subjects are only informed on when/whether the partnership payment has ended after every block of five rounds. That is, at the end of every round the computer rolls a 100-sided die, common to all subjects in a session. The first round where the die-roll exceeds 80 is the last round for which we pay subjects. However subjects only observe the outcomes from these rolls after rounds 5, 10, 15, etc.. If all five rolls are less than or equal to 80 the game continues to another block of five rounds, otherwise the partnership ends and payment is made on all rounds up to the first die-roll over 80.

We will refer to each experimental supergame, a repeated partnership with another fixed individual, as a “cycle.” At the end of each cycle, subjects are randomly and anonymously rematched, and they begin a new cycle. Sessions continue for at least an hour (excluding the time taken to read instructions). The first cycle to end after an hour is the end of the session. Two cycles are randomly chosen for payment. By design, each cycle in the experiment has the same duration for all participants, whether the partnership is dissolved or not. Subjects cannot influence their time in the laboratory, nor can they increase their payoffs by playing more cycles. However, one potential concern we had was that subjects might not use the termination option as they have no actions to take if they do. To mitigate this, our experimental design has each subject participating in two cycles concurrently (this method is also used in Hauk and Nagel, 2001). To facilitate these two concurrent partnerships, the matching protocol in each cycle randomly and anonymously forms subjects into a circle. The subjects’ two cycle partners are the session participants clockwise and counterclockwise from their position in the randomly formed circle. In this way, we minimize the ability a subject has to affect their clockwise partner through actions they take with their counterclockwise partner. In addition, all elements of the design are held constant across treatments except the treatment variable, the availability of termination, and its payoff when chosen.

2.3. Termination Institutions. Theoretically, endogenous dissolution introduces a state variable into the partnership, that can be either Active or Inactive, where the transitions between states are determined by participants’ choices. Our experimental game is therefore a stochastic game with imperfect information. However, because the Inactive state is absorbing (once a partner terminates the game never returns to the Active state) and degenerate (no players have any available choices over their actions here) this particular stochastic game

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6Referred to as Partnership Red and Partnership Blue within the experiment, both partnerships are affected by session-wide realizations for the exogenous end of payment. However, the probability of Success and Failure in each partnership depends only on the partnership-specific actions chosen, and are independent of all other outcomes in the experiment.
is fairly simple. We will focus on examining choices in the Active state, and we will use standard infinitely repeated game concepts for our analysis.7

**Symmetric Termination Payoffs.** Our first set of treatments consider an institution where the two partners receive the same payoff $\pi_T$ if the partnership is dissolved. Interpretations for this are a partnership with assets having a net value of $2 \cdot \pi_T$ on dissolution, where the partners equally split the proceeds, or that each partner anonymously re-enters some stationary matching market for new partnerships with an expected outcome net rematching costs of $\pi_T$. The effects from the addition of the termination option to the partnership game is to change the sets of feasible and individually rational (IR) payoffs. Generically, the feasible payoffs are the convex hull of the expected stage-game outcomes in the Active state and the termination payoff vector $(\pi_T, \pi_T)$.

In terms of individual rationality, the addition of termination complicates things. Because termination can be unilaterally imposed there are weak Nash equilibria of the game where both parties terminate in round one, regardless of the value $\pi_T$.8 Because of this, our focus here will be on a refinement: individually rational outcomes of the game attainable in weakly undominated strategies.

Given the weakly undominated restriction we will examine two cases: when $\pi_T < u_i(D,D)$ and $\pi_T \geq u_i(D,D)$, where the extra-relationship payoff is below and above the in-relationship minmax. In the first case, any strategy involving termination is weakly dominated by the same strategy with $D$-forever after replacing any termination action. In the second case, because termination can be unilaterally imposed any discounted-average payoff less than $\pi_T$ is not individually rational. So, weakly undominated individual rationality yields the following testable hypotheses:

**Hypothesis 1.** When $\pi_T < u_i(D,D)$, termination is not used and the expected discounted-average payoff vector satisfies $(W_1, W_2) \geq (u_1(D,D), u_2(D,D))$

**Hypothesis 2.** When $\pi_T \geq u_i(D,D)$, the expected discounted-average payoff vector satisfies $(W_1, W_2) \geq (\pi_T, \pi_T)$

Hypothesis 1 is slightly more amenable to experimental tests than Hypothesis 2, as it precludes termination as an observed action choice, whereas the defect action can still be chosen along the path when $\pi_T \geq u_i(D,D)$ (but only in transition to playing $C$ again, or where the other player uses termination). Hypothesis 2 does have a complementary prescription, that both players cannot play Always Defect after any history.9

These two hypothesis are illustrated graphically in Figure 1. In each subfigure the lighter gray polygon represents the set of feasible discounted-average expected payoffs, while the darker-gray region is the set of weakly undominated, individually rational expected payoffs. The first subfigure (A) illustrates the partnership game without a termination option, subfigure (B) the game with a termination payoff of $\pi_T < u_i(D,D)$ (in particular $\pi_T = 0.75$), while subfigure (C) illustrates the case where $\pi_T > u_i(D,D)$ (in particular $\pi_T = 1.25$).

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7.N.B. The only pure-strategy Markov perfect equilibria for this dynamic game involves always defecting or always terminating, depending on the termination payoff $\pi_T$.

8.Note, this does require a fixed division of the termination payoff. If, for example, the person who initiates dissolution gets a lower value $\pi$, the $(T,T)$ equilibrium will not hold.

9.N.B. For all values of $\pi_T > u_i(D,D)$ the asymmetric strategy pairing (Always Terminate, Always Defect) constitutes a weakly undominated equilibrium outcome.
Figure 1. Feasible, Weakly-Undominated-Individually-Rational and Equilibrium Payoffs.

(a) No Termination

(b) Termination lower than joint defection

(c) Termination higher than joint defection

(d) No Termination
In addition to the IR payoffs, Figure 1 also indicates the expected payoffs possible from all symmetric equilibria using 3-state machines (with further details provided in section 2.4 below).

Given that the expected discounted-average payoff from joint defection is $1.15 in our stage game, our main symmetric treatments focus on termination values of $\pi_T = 0.75$ and $\pi_T = 1.25$, which we label as $S-75$ and $S-125$ respectively, where we run three independent experimental sessions for each. To contrast the behavior when termination is available we also conduct three sessions where the termination action is not available (a treatment we will refer to as $\text{No T}$). In addition, to understand substitution between termination and defection as a punishment we run one session each for $\pi_T \in \{0.85, 0.95, 1.05, 1.15, 1.35\}$, (with the treatment labels $S-100 \cdot \pi$). In Section 2.4 we specify further restrictions over strategies, however, we first introduce our asymmetric treatments.

Asymmetric Termination Payoffs. Our second set of treatments examine the same repeated partnership game with a dissolution option, however the two partners here receive different payoffs on termination. One partner receives a high payoff amount $\pi$, while the other gets the low payoff, $\pi$. Which partner gets which payoff is decided by the actions preceding termination. All of our treatments with ties on the assignment-rule break them with a fair coin, so the expected payoff on a tie is $\hat{\pi} = \frac{1}{2} \pi + \frac{1}{2} \pi$ for both players.

In general, the asymmetric division could depend on the entire available history $\{a_1^t, a_2^t, y^t\}_{t=1}^T$ up to the point of termination. There is subsequently a huge constellation of asymmetric division rules. Our focus will be on the three rules and parametrizations, which to our minds, are both strategically interesting and policy relevant.\(^{10}\)

Asymmetric First: this treatment assigns a higher payoff to the party ending the relationship, and the lower payment to the party being terminated, where we label this treatment $A$-First. The treatment is motivated by partnerships where parties that exit first are best prepared, or where last-movers are left stuck with large debts/costs. There are recent examples of law and accountancy firms, incorporated as partnerships, which upon hitting hard times saw large-scale partner defections to rival firms (one would assume bringing with them many of their previous firms’ clients).\(^{11}\) The treatment mirrors this tension, a strong belief that the other will leave the partnership makes leaving yourself a best response.

Unlike the symmetric cases, joint-termination cannot be removed by appealing to weak dominance for any $\pi > \pi$. Each partner strictly prefers to end the relationship if they believe the other is going to do it. In particular, we will examine the case where the discounted-average value of joint termination, $\hat{\pi} = \frac{1}{2} \pi + \frac{1}{2} \pi$, is lower than $1.15$. The treatment therefore alters the weakly undominated individually rational point to $(\hat{\pi}, \hat{\pi})$, an equilibrium outcome that is Pareto-dominated by the in-relationship minmax.

The addition of this inefficient equilibrium might not matter if subjects are able to coordinate on different equilibrium strategies. However, asymmetric division with a first-mover

\(^{10}\)An interesting institution which we have not pursued is asymmetric fixed division, where player one gets $\pi$ with certainty on dissolution. Theoretically, this is not too different from the symmetric division discussion above, but can allow for ‘abusive’ equilibria where player one uses the threat of termination to produce asymmetric outcomes such as $(D, C)$.

\(^{11}\)For instances: Arthur Andersen LLP, saw huge partner defections after the Enron accounting scandal broke; Howrey LLP, a global law firm dissolved itself in 2011, but witnessed extensive partner defections to competing firms before this point.
advantage has another negative effect compared with comparable partnership games with symmetric outside options. Per the above, the set of weakly undominated IR payoffs in the symmetric game is \( \{ \text{Feasible} \} \cap \{ (u', u'') | u', u'' \geq \max (\hat{\pi}, u_i(D, D)) \} \). However, because of the asymmetric division and absorbing nature of dissolution, any feasible payoff outside of \( \{ (\hat{\pi}, \hat{\pi}), (\pi, \pi), (\pi, \pi) \} \) involves some positive probability of both players not terminating. As such, any expected payoffs to the player in \((\hat{\pi}, \pi)\) cannot be enforced, as terminating in the first round would produce a strictly better outcome. Where \( \pi > u_i(D, D) \), the asymmetric division has the effect of removing any equilibria which rely on punishment phases with continuations in \((u_i(D, D), \pi)\), any pure-strategy equilibria of the game using termination must do so jointly.

Given the above, our parametrization for this treatment chooses dissolution payoffs of \( \pi = $1.25 \) and \( \overline{\pi} = $0.75 \). Joint-termination in round one is Pareto dominated by Always Defect, but \( \pi > u_i(D, D) \), so the high termination payoff creates a meaningful restriction on the equilibrium set as Always Defect cannot be an equilibrium punishment. However, the chosen parametrization does allow for equilibria with initial cooperation supported by joint-termination on failure.

**Hypothesis 3.** In the A-First treatment the discounted-average payoff vector either satisfies \((W_1, W_2) > (\pi, \pi)\) or involves joint termination in round 1 and \((W_1, W_2) = (\hat{\pi}, \hat{\pi})\).

**Asymmetric Last:** Our second asymmetric treatment A-Last is the mirror of A-First, assigning the higher payoff to the party who has been terminated, and the lower payoff to the partner choosing to terminate. Individual rationality is now dictated by the point max \( \{ \pi, \min \{ \pi, u_i(D, D) \} \} \). Each player can guarantee themselves the higher of: i) the lower termination payoff \( \pi \) if they choose to end the game themselves, or ii) if they switch to defect forever, the other partner can force them to take the minimum of the joint-defection payoff or the high termination value \( \pi \).

This treatment is designed to mirror contract clauses that specify the party initiating early termination incur additional costs. Many employment contracts allow for severance payments ("golden parachutes" for executives) if the firm voids the relationship. If the contract is voided by the employee this severance payment is not made (in the other direction, employees who walk away might have to adhere to non-compete agreements, reducing their outside options). This might induce employees in faltering relationships to seek termination by the other party, rather than quitting themselves.\(^{12}\)

Unlike the A-First treatment, A-Last does not have joint-defection as an equilibrium outcome, as each partner does strictly better by defecting if they believe the other will terminate. Cooperation cannot be supported by joint termination, and so equilibrium punishments must use some defection by at least one player. When \( \pi < U_i(D, D) \), the weakly undominated IR set is identical to the symmetric termination games with \( \pi_T < U_i(D, D) \).

In order to focus on the tension between ending the relationship oneself vs having the other player terminate, our treatments use the parametrization \( \pi = $1.25 \) and \( \overline{\pi} = $1.35 \). Given this, unilaterally dissolving the partnership is better than joint-defection forever, but each partner strictly prefers that the other party is the one terminating. Individual rationality is therefore defined by the low-termination payoff of $1.25, where the weakly undominated IR

\(^{12}\)An alternative non-equilibrium interpretation is that the party firing/quitting/jilting the other does so publicly. This public signal could plausibly affect their ability to recruit new partners/gain subsequent employment when rematching, so forcing the other party to leave is preferable.
set is the same as the S-125 treatment. However, the equilibrium sets do differ, which we discuss in more detail below.

**Hypothesis 4.** In the A-Last treatment the discounted-average payoff vector satisfies \((W_1, W_2) \geq (\bar{\pi}, \bar{\pi})\)

Asymmetric-Judge: Our final asymmetric treatment is motivated by arbitration-hearings after a relationship ends. A judge/arbitrator (through some perfect, possibly costly, forensic process) obtains access to the complete history \(\{a^k_1, a^k_2, y^k\}_{k=1}^t\), not just the public history. She assigns the higher dissolution payoff to the party that cooperated most. That is, once one player chooses termination in round \(t\), the judge examines the action sequence \(\{a^k_1, a^k_2\}_{k=1}^t\), and assigns the higher termination payoff to player \(i\) and the lower payoff to player \(j\) if

\[
\sum_{k=1}^{t} \left(1 \{a^k_i = C\} - 1 \{a^k_j = C\}\right) > 0.
\]

We will call this our A-Judge treatment, and it is intended to mirror an institution where a third party chooses a division of assets, taking into account the partners’ behavior. Examples of this institution are: divorce settlements, where judges might take into account the behavior of each party when dividing assets and custody of children, and labor arbitration hearings, where firms and workers abide by the third-party’s decision.

The institution has the intuitive effect of increasing the outside option for cooperating players, and decreasing it for deviators. Termination punishments therefore make deviations more costly, while entering the punishment is more palatable to cooperators. However, in-relationship punishment becomes less useful, as resorting to it can be detrimental, as those being punished can cooperate, and then and seek arbitration.

Technically, this treatment induces a somewhat complex stochastic game, with an imperfectly observed, endogenous state, the cooperation-difference \(\omega_t = \sum_{k=1}^{t-1} 1 \{a^k_i = C\} - 1 \{a^k_j = C\}\). Each agent observes their private history \(\{a^k_i, Y^k\}_{k=1}^{t-1}\), from which they update their beliefs about \(\omega_t\), which influences their expected payoff from taking the action \(a^t_i = T\). For a patient enough player, individual rationality can be shown to be arbitrarily close to \(\pi\). However, it is beyond the scope of the present work to examine the game for arbitrary \(\delta\). Our focus will be on the strategies human subjects use in this environment, and whether they can be rationalized. We think this environment is well motivated both by observed institutions, and through the highly cooperative play we will document within it. However, as we mention below, none the simple set of strategies we will examine (nor non-trivial extensions) are equilibria of the A-Judge game.

**Hypothesis 5.** In the A-Judge treatment the discounted-average payoff vector satisfies \((W_1, W_2) \geq (\bar{\pi}, \bar{\pi})\).

2.4. Equilibrium Strategies. The above outlines fairly broad hypotheses using just weak dominance and individual rationality to produce lower-bound predictions on the payoffs possible in any equilibrium of the game, for arbitrary \(\delta\). We now look more constructively for simple equilibria of these games under \(\delta = 4/5\). Our focus will be on the following restricted,

\[\text{Each player can specify a strategy that cooperates initially. After every period it calculates the probability of the observed sequence of outcomes under the null that the other play is cooperating. The strategy terminates if the probability of the observed sequence drops below some pre-specified confidence level } \alpha^{*}.\]
but cognitively simple set of equilibria: weakly undominated, symmetric, stationary, public-perfect equilibria (wSSPPE), which can be represented as finite machines. That is, we will look for strategies of the game that depend only on the public signal in the last round $Y^{t-1}$ and a finite number of internal states. The machine’s chosen action at each point in time is dictated by its internal state, and the transition between these states depends only on public signal ($S$ or $F$) and the internal state last round. For simplicity, we here examine only those machines with three internal states $C$, $D$ and $T$, where the three states are connected to the actions cooperate, defect, and terminate, respectively. By discussing only the strategies that fall into this small category we hope to illustrate the broad effects on the types of equilibria possible from changes to the outside option. In our data analysis, we will consider a larger constellation of machines, and asymmetric pairings between them.

Because termination is an absorbing state by construction, the set of 3-state machines in our setting has 81 distinct entries.\textsuperscript{15} In terms of theoretical prediction, from those 81 possible machines, just three form wSSPPEs when the symmetric outside option $\pi_T$ is less than $\$1.15$ (or when dissolution is not present). These three machines are depicted in the Figure 2, and correspond to the strategies (A) \textit{Always Defect}, (B) the \textit{Grim Trigger}, and (C) the \textit{Monotone} strategy, where we have highlighted the most-efficient starting state in gray.\textsuperscript{16} When the value of termination is strictly greater than $\$1.15$ the set of equilibria changes, \textit{Always Defect} is now replaced by the strategy (D) \textit{Always Terminate} as an equilibrium, while

- **(A) Always Defect**
- **(B) Grim trigger**
- **(C) Monotone**
- **(D) Always Terminate**
- **(E) One-Strike**
- **(F) Probation**

\textbf{Figure 2. Simple three-state machines with Termination}

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\textsuperscript{14}N.B. We present here the hypothesis for $\delta \to 1$. When $\delta = 4/5$ the individual rational payoff is strictly lower, between $[101.7,115.0]$. Given arbitrary strategies $\sigma_i$ and $\sigma_j$ for the two players, and expected discounted-average payoff of $W_i(\sigma_i,\sigma_j)$. The two bounds on $\min_{\sigma_i} \max_{\sigma_j} W_i(\sigma_i,\sigma_j)$ come from: $101.7 = \min_{\sigma_i} \max_{\sigma_j} W_i(\sigma_i,\sigma_j)$ for the player strategy $\delta_i$ which plays two periods of initial cooperation then terminates after the first failure; and $115.0 = \max_{\sigma_i} W_i(\sigma_i,\delta_j)$ for the strategy $\delta_j$ of \textit{Always Defect}.

\textsuperscript{15}The $C$ and $D$ states each have two edges, with three possible destinations, so there are $3^4 = 81$ possible machines, where the machines can start in any state.

\textsuperscript{16}If we look at the set of all two-state machines without termination (allowing for asymmetric matchings between different machines) there are four equilibria (unique up to state relabelings): symmetric \textit{Always Defect}, symmetric \textit{Mono} starting in either the \textit{Cooperate} or \textit{Defect} state, and symmetric \textit{Grim Trigger}.
the *Grim Trigger* is replaced by its termination complement (*E*), which we will refer to as *1-strike*. However, the forgiving *Mono* machine remains a symmetric equilibrium so long as the value of termination is not too much greater than $1.15$. As the termination value increases past $1.24$, *Mono* stops being an equilibrium—the continuation value in the *D* state falls below the dissolution option $\pi_T$, so the punishment is no longer sub-game perfect. As the value of termination increases further still (beyond $1.31$) the *1-strike* strategy drops from the equilibrium set too, as defecting in the *C* state becomes profitable as the dissolution punishment lacks power.\(^{17}\)\(^{18}\)

Other than *Mono*, of the 81 machines we consider there are no other forgiving wSSPPEs for any termination value $\pi_T$—strategies capable of returning to cooperation after entering a punishment phase.\(^{19}\) The only forgiving machine with incentive-compatible cooperation using both dissolution and the *D* action in the punishment path is the *Probation* strategy illustrated in Figure 2(F).\(^{20}\) However, despite the punishment supporting cooperation, the strategy is not a wSSPPE as the punishment phase is not incentive compatible. Best-responding agents will deviate to play *C* (or *T* if $\pi_T$ is large enough) where the strategy specifies the *D* action. This is because of a much higher probability of returning to the high-payoff cooperation state if they deviate to *C* (a 50 percent chance) as opposed to *D* (a 10 percent chance). Other simple forgiving strategies such as *Win-stay-lose-shift* (WSLS) and the unconditional one-round-punishment (*T11*) lack incentive compatibility for cooperation, as continuation values in the in-relationship punishment are too high.\(^{21}\)

The asymmetric-division treatments have similarly stark predictions. For *A-First* just two of the three-state machines are wSSPPE: *Always Terminate* and *1-Strike*. In the *A-Last* treatment, none of these 81 machines are symmetric equilibria, though asymmetric combinations such as *Always Defect/Always Terminate* and *Grim/1-Strike* are w(no S)SPPEs. Finally, in the *A-Judge* treatment, none of the 81 machines, nor any asymmetric pairing are PPEs of the game. The *A-Judge* game requires much more sophisticated asymmetric strategies to form an equilibrium outcome (in particular mixed strategies with a corresponding belief update rule over the game state $\omega_t$).

\(^{17}\)Moreover, once the value of termination crosses $1.32$, the *only* perfect equilibrium of any form for $\delta = 4/5$ is *Always Terminate*.

\(^{18}\)In addition to the existence of differing equilibria, when termination increases in value past $1.15$, the comparable risk-dominance orderings of the equilibria change. Introduced in Blonski and Spagnolo (2004) and applied by Dal Bō and Fréchette (2011), risk dominance has been a useful measure to predict subjects’ response in perfect monitoring environments. Among the three equilibrium strategies for $\pi_T < 1.15$ (*Grim*, *Mono* and *Always Defect*), we find that *Always Defect* risk dominates *Grim*, which in turn risk dominates *Mono*. Where $\pi_T \geq 1.15$, *Mono* and *1-strike* both risk dominate *Always Terminate*, which dominates *Always Defect*.

\(^{19}\)No "lenient" strategies are possible without allowing for additional states that play the *C* action.

\(^{20}\)A variant of the Probation strategy which exchange the *Success* and *Failure* arrows in the *D*-state is also not an equilibrium, though here because cooperation is not incentive compatible when the termination value is weakly greater than $1.15$, and for lower values the termination action is weakly dominated.

\(^{21}\)There are many asymmetric equilibria when $\pi = 1.15$, involving combinations of *Defection* and *Termination*. Once the termination value increases to $1.25$ all conditionally cooperative asymmetric equilibria combining the 81 machines involve at least one player using a variant of *1-strike*. For example, one player use the *Suspicious 1-strike* that starts at *Defect*, moves to *Terminate* on a failure, and to the standard *1-Strike Cooperation* state on a success; and the other player can use *Suspicious-Grim* (replace the *T* action in *Suspicious 1-strike* with *Always D*).
### Table 2. Experiment Summary

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sessions</th>
<th>Subjects</th>
<th>Cycles</th>
<th>Cycle Length</th>
<th>Activity $t \geq 2$</th>
<th>Active Choice Freq. $C$</th>
<th>not $C$</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Avg.</td>
<td>Max</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-75</td>
<td>3</td>
<td>14,16,13</td>
<td>21,23,24</td>
<td>4.3</td>
<td>21</td>
<td>0.936</td>
<td>0.580</td>
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<tr>
<td>S-85</td>
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<td>16</td>
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<td>7.8</td>
<td>17</td>
<td>0.940</td>
<td>0.494</td>
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<tr>
<td>S-95</td>
<td>1</td>
<td>16</td>
<td>24</td>
<td>4.6</td>
<td>17</td>
<td>0.867</td>
<td>0.739</td>
</tr>
<tr>
<td>S-105</td>
<td>1</td>
<td>16</td>
<td>23</td>
<td>4.4</td>
<td>9</td>
<td>0.699</td>
<td>0.583</td>
</tr>
<tr>
<td>S-115</td>
<td>1</td>
<td>16</td>
<td>18</td>
<td>2.4</td>
<td>6</td>
<td>0.778</td>
<td>0.537</td>
</tr>
<tr>
<td>S-125</td>
<td>3</td>
<td>12,16,14</td>
<td>18,20,17</td>
<td>5.1</td>
<td>20</td>
<td>0.624</td>
<td>0.607</td>
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<tr>
<td>S-135</td>
<td>1</td>
<td>16</td>
<td>21</td>
<td>5.0</td>
<td>21</td>
<td>0.572</td>
<td>0.536</td>
</tr>
<tr>
<td>No T</td>
<td>3</td>
<td>14,15,14</td>
<td>17,23,23</td>
<td>4.3</td>
<td>21</td>
<td>1.000</td>
<td>0.409</td>
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<tr>
<td>A-First</td>
<td>2</td>
<td>16,11</td>
<td>19,16</td>
<td>4.5</td>
<td>25</td>
<td>0.096</td>
<td>0.415</td>
</tr>
<tr>
<td>A-Last</td>
<td>2</td>
<td>14,15</td>
<td>24,20</td>
<td>6.0</td>
<td>13</td>
<td>0.775</td>
<td>0.519</td>
</tr>
<tr>
<td>A-Judge</td>
<td>2</td>
<td>11,16</td>
<td>13,20</td>
<td>5.7</td>
<td>25</td>
<td>0.790</td>
<td>0.834</td>
</tr>
</tbody>
</table>

Note: Number of cycles are given for each session, cycle lengths are in terms of payment rounds, observed rounds are nearest multiple of five above the final payment round.

### 3. Results

We have conducted 20 sessions at the Pittsburgh Experimental Economics Laboratory. A total of 291 subjects, recruited from the University of Pittsburgh general subject pool participated in the experiment. For each session we recruited 18 subjects and ran with at most 16 from those attending the session, with an average of 14.6 subjects per session. Subjects earnings ranged from a minimum of $5 to a maximum of $77.75, where this includes a $5 guaranteed show-up payment. Table 2 summarizes the experiments carried out and subject numbers per session.

#### 3.1. Choices and Efficiency

We first examine aggregate choice behavior through some simple sample-averages, to illustrate broad patterns in the data. To start we look at the choice proportions within each treatment, aggregating over sessions, subjects, cycles and rounds. We then examine the within-session evolution of behavior, analyzing subject behavior as subjects gain experience with the environment. Next, we illustrate the patterns for within-cycle dynamics, comparing the cooperation and relationship activity in the first and fifth rounds of each cycle. Finally, we illustrate how these choices affect final outcomes, examining payoff efficiency across treatments, and comparing this to the hypotheses produced from weak dominance and individual rationality.

**Aggregates Choices and Relationship Activity.** The last three columns in Table 2 summarize sample averages for a nested series of binary outcomes. The *Activity* column summarizes the fraction of rounds $t \geq 2$ where the state is *Active*, where neither player has yet dissolved the partnership (all rounds are active by design in round 1). Where the state is *Inactive*, subjects had no choices to make, so the next two columns present choices conditional on the round being active. The penultimate column presents the cooperation
rate in active partnerships. Finally, conditioning on both the round being active and that the subject chose not to cooperate, the last column illustrates the fraction of non-cooperative choices that terminate the relationship, with the residual being defections.

Aggregating all the symmetric treatments with the termination option available, subjects choose to cooperate 59 percent of the time, where the sample probability of cooperating varies mostly between 50 and 60 percent (the single S-95 session is an outlier at 74 percent). Using session-level averages for Active Cooperation, we fail to reject equivalence using Mann-Whitney tests across the symmetric treatments. Rather than raw cooperation rates, the main change across the symmetric treatments is over which non-cooperative action is selected. This is seen in the table through an increased termination rate as \( \pi \) heads past $1.00 (and a matching reduction in activity). In treatments with \( \pi_T > 1.00 \) subjects who have chosen not to cooperate end the relationship 10-15 percent of the time. In comparison, for dissolution payoffs between $0.75 and $0.95, the uncooperative subjects end the relationship between one and seven percent of the time. Examining session-level averages, all three S-75 treatments have lower termination rates (and higher activity rates) than the three S-125 treatments, so we can reject equivalence at the five percent level (\( p = 0.050 \)).

However, a part of Hypothesis 1 (produced through risk-neutrality, weak dominance and individual rationality) proscribes termination as an observed action whenever \( \pi_T < 1.15 \). Because this is a boundary prediction, the quantitatively small termination rates in S-75 and S-85 might be attributable to choice errors. However, given the size of the errors in S-75–85, the observed termination behavior in the S-95 and S-105 sessions are statistically larger (\( p = 0.066 \)). With enough risk-aversion, one could rationalize observed termination in S-105, however, for S-95 the termination payoff is lower than the minimal realization from choosing D, a payoff of $1.00, so the Termination action is stochastically dominated by defecting forever.

In contrast to the S-X treatments, in No T, where termination is not an available action, the cooperation rate is significantly lower at 40 percent. We can reject equivalence in cooperation between No T and the symmetric-termination treatments S-75–135 (\( p = 0.011 \)). Given the absence of a termination option in No T, all non-cooperative actions are necessarily defections, so there are no useful comparisons beyond cooperation.

The last three rows in Table 2 present the same data for the asymmetric treatments. In the A-First treatment the most obvious difference to the symmetric treatments is the very low activity rate (and correspondingly high use of termination). Indeed, the two A-First sessions—where the partner who terminates gets a constant $1.25 round payment to their partner’s

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22 All remaining tests in this section are one-sided Mann-Whitney tests using session averages against the small-sample \( U \)-distribution. We use this fairly conservative test to illustrate patterns, though for some comparisons the test is underpowered and cannot reject at the 10 percent level (any 3 session vs 2 session test), and so we will here examine tests against sessions from contiguous S-X treatments.

23 For instance, we fail to reject a null of equivalence between S-75 and S-125 (three session observations for each), while there is no significant relationship between treatments with outside options lower than $1.15 and treatments with values equal or greater than or equal to $1.15 (six and five sessions, respectively).

24 Cooperation rates are also significantly lower in the No-T treatment compared to the symmetric treatment blocks where the weakly undominated IR hypotheses differ, S-75–105 and S-115–135 (\( p = 0.048 \) and \( p = 0.018 \), respectively). However, the test fails to reject when comparing the three sessions of No-T against the three sessions of S-75 (\( p = 0.200 \)), as the minimally cooperative session from S-75 is smaller than the maximally cooperative session from No-T.
$0.75—have the two lowest activity rates across the 20 experimental sessions. The observed activity rates drops below ten percent. Testing equivalence for termination/activity against any four other sessions (for instance, S-125–135), we reject in favor of greater termination and inactivity in A-First ($p = 0.066$). Though the overall cooperation rate in the Active state does not seem very low, at just over 40 percent, this figure oversamples pairs of cooperators who manage to get to an active round 2, where the vast majority enter Inactivity in round two onward. The raw termination rate in the very first round of each cycle is approximately 70 percent here. Given the round-one termination rate and independent matching, this explains the approximately 90 percent inactivity rate in rounds two and beyond, as $1 - (1 - 0.7)^2 \approx 0.9$.

In contrast, for A-Last, where those terminating receive the smaller payoff of $1.25, compared to their partner’s $1.35, the observed activity rates are much higher. In fact both sessions have a higher activity rates than any session from S-125–135. The small asymmetry in termination payoffs leads to relationships with longer durations. However, the institution does not have increased cooperation. In fact the average active cooperation rate is lower than both S-125 and S-135 (though not significantly so).

Finally, the last row in Table 2 provides data for the A-Judge treatment. Here we find the highest cooperation rates across all of our sessions, where 83 percent of the time the chosen action in an active partnerships is to cooperate (underpowered with $p = 0.101$ for tests against the S-75/S-125/No-T in isolation, but $p = 0.018$ against the nine session from the three treatments pooled together). Activity rates also indicate more-active partnerships ($p = 0.066$) than the symmetric treatments with high termination values S-125–135, and lower rates (again, $p=0.066$) than the low-termination-value treatments S-75–95.

**Result Summary 1.** Results at the aggregate level indicate:

- As symmetric termination rates increase there is no significant effect on cooperation, but activity (termination) rates decrease (increase) with the outside option $\pi_T$.
- The presence of dissolution increases cooperation.
- Asymmetric treatments that reward players ending the relationship produce very high termination rates, while those that reward the player being jilted lead to low termination rates.
- The asymmetric division that favors the more cooperative player leads to very high cooperation rates and relatively low inactivity.

**Session Dynamics.** We here summarize the dynamics within sessions, providing more detail in a supplemental appendix for interested readers.

**Result Summary 2.** Across sessions the data indicates:

- Reduced cooperation in No-T relative to the symmetric termination treatments emerges quickly.
- Cooperation rates fall across all treatments’ sessions except A-Judge, which exhibits increased cooperation.
- The direction of the trend in termination use depends on the outside option $\pi_T$. When above (below) the lower-bound realization for joint defection ($\$1$), the termination rate increases (decreases) across the session.

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25Termination rates are statistically lower (higher activity) when compared to the four pooled sessions of S-125–135.
Figure 3. Actions and Activity across Cycles

— Subjects converge quickly within the session toward dissolution in round one of the A-First cycles.

Cycle Dynamics. Figure 3 illustrates the general patterns in response across cycles, comparing behavior in round one (the gray markers) and round five (white markers) within each cycle. The gray triangles indicate the average cooperation rate in round one (active in all cycles), while gray circles illustrate the termination rate in round one (with the residual being defection choices). This behavior in round one of the cycle can be contrasted with the white shapes, indicating inactivity (white diamonds) and the active cooperation rate (white squares) by the cycle’s fifth round. In addition, a table in the appendix provides greater detail on across-cycle response by providing the five-most-popular sequences of action-outcome pairs across cycles.

For S-75–95 we observe reduced active cooperation across the cycle, but the vast majority of cycles are still Active in round five. In contrast, for S-105–135 the pattern is reversed: the active cooperation rate increases across the cycle, but 40–50 percent of the cycles Inactive by this point. In comparison to the symmetric termination treatments, the No T treatment starts out with lower cooperation, and the drop-off in cooperation across the cycle is comparable to that in S-75–95.

For our asymmetric treatments, the clearest effect is the very high termination rate in the first round of A-First cycles (70.1 percent), and low initial cooperation rate (24.3 percent). Matching this we find very high inactivity by the fifth round (94.6 percent), though for those partnerships which do survive to the fifth round, the cooperation rate is fairly substantial (84.0 percent cooperation for the 50 partnerships still active in round five). Second, within A-Last, despite observing similar initial cooperation rates to the comparable symmetric

26 The active cooperation rate within-cycle differences are significantly smaller ($p = 0.016$) when comparing S-75–95 to S-105–135, however, the relationship is not significant when comparing just S-75 and S-125 ($p = 0.200$).
treatments ($S-125-135$), we observe the opposite within-cycle response: many more cycles are still Active in round 5, and the active cooperation rate drops across the cycle. Finally, the A-Judge treatment has very high cooperation rates in active relationships, with little dropoff across the cycle. However, compared to the symmetric treatments where termination is frequently used ($S-105-135$), the A-Judge treatment has a substantially lower fraction of Inactive cycles by round five.

Result Summary 3. Within cycle we find:

— Decreasing active cooperation rates for treatments where termination is not used ($S-75-95$, No-T).
— Where termination is used ($S-105-135$), active cooperation increase across the cycle, though this is potentially driven by selection, as uncooperative relationships become inactive.
— In asymmetric treatments, A-Judge sustains high cooperation across the cycle, while A-Last is the only treatment with substantial termination use where the active cooperation rate falls across the cycle.

Payoff Efficiency. We now examine payoff efficiency and the hypotheses from individual rationality and weak dominance detailed in section 2.4. Our efficiency measure will be the sample discounted-average payoff for cycles in the experimental treatment, relative to the discounted-average payoff from the in-relationship minmax ($\$1.15$). This is then normalized by the difference in discounted-average payoffs between mutual cooperation and mutual defection ($\$1.47 - \$1.15 = \$0.32$). The payoff efficiency for a particular subject-cycle is therefore

$$\Upsilon \left( \{a_{t1}, a_{t2}\}_{t=1}^{T} \right) = \frac{\hat{W}_i \left( \{a_{t1}, a_{t2}\}_{t=1}^{T} \right) - W_i (\{D, D\}_{t=1}^{\infty})}{W_i (\{C, C\}_{t=1}^{\infty}) - W_i (\{D, D\}_{t=1}^{\infty})},$$

where

$$\hat{W}_i \left( \{a_{t1}, a_{t2}\}_{t=1}^{T} \right) = \frac{(1-\delta)/(1-\delta_T)}{\sum_{t=1}^{T} \delta^{t-1} u_i (a_{t1}, a_{t2})}$$

for cycles that end (exogenously) in round $T$.

Taking sample averages for $\Upsilon$ across all subject-cycles we illustrate the payoff efficiency by treatment in Figure 4. For each treatment, the figure indicates the discounted payoff efficiency across all cycles as the larger gray diamond, where the error bars indicate a 95-percent confidence region for this mean. In addition to the overall discounted average, we illustrate the average payoff efficiency for round one on its own, and rounds five onward as white circles and triangles. Payoff components from Hypotheses 1–5 (alongside an upper-bound from the best wSSPPE efficiency attainable, per section 2.4) are illustrated as the shaded region. Examining the lower and upper bounds on efficiency, all of our treatments except $S-135$ fall within the identified region (for the discounted-average, as well as in rounds one and rounds four onward). With the exception of $S-135$, we therefore fail to reject any of the IR hypotheses.\textsuperscript{27}

\textsuperscript{27}Given $\delta = \frac{4}{5}$, the unique equilibrium payoff in $S-135$ (all equilibria involve at least one player terminating in the first round) coincides with the IR payoff, producing a payoff efficiency of 62.5 percent. The sample-average efficiency in the $S-135$ session is significantly lower at 56.5 percent, where a bootstrap indicates values greater than the IR prediction with probability 0.043. However, examining the discounted-average payoff from rounds five onward, the average efficiency in $S-135$ is 60.8 percent, with a 0.362 probability the mean is larger than 62.5 percent. Rounds two–four drive the lower average, and the discounted-average
Figure 4. Payoff Efficiency by treatment

Note: Shaded areas represent lower-bound from individual rationality hypotheses (achievable with Always Defect or Always Terminate in majority of treatments), and upper bound from best symmetric pure-strategy memory 1 wSSPPE. For A-Judge, the indicated region represents a lower bound on the IR level at $\delta = \frac{1}{2}$, upper bound indicated at full efficiency. Error bars indicate 95 percent confidence region for mean payoff-efficiency calculated with a bootstrap of size 5,000.

For the symmetric termination treatments, five out of seven generate significantly higher efficiency than No-T: S-75 — 95, S-125 and S-135 when we examine averages over all subject-cycles. The pattern in the figure indicates increasing efficiency as the outside option increases from 75 to 95, stemming from increased cooperation. However, a sharp drop in efficiency occurs at S-105, as subjects begin to use the (here highly inefficient) termination action more frequently. From here efficiency increases with the termination value, where this is driven by increasing payoffs from termination, rather than increased cooperation rates (seen by greater slope of the shaded region lower bound).

For the asymmetric treatments, the lower-bound efficiency in A-First is negative, as symmetric Always Defect Pareto dominates symmetric Always Terminate. Moreover, as we have detailed, termination from the very first round is both an equilibrium outcome and the modal experimental response. As such this treatment generates the worst outcomes among all our treatments. The A-Last treatment performs similarly in efficiency terms to the comparable symmetric treatments (S-125 and S-135). However, where most other treatments start out with higher efficiency and decrease consistently over the cycle, the A-Last treatment initially falls, then begins to increases again once the partnership is old enough. Finally, A-Judge generates the highest efficiency among all our treatments, however it also generates the highest drop-off in efficiency across the cycle.

efficiency across these three rounds is 44.8 percent, reflecting a high degree of $(C, D)$ and $(D, D)$ choices (expected efficiencies of 31.3 percent and 0 percent, respectively).

28However, there is substantial variation at both the session and subject-levels.
Result Summary 4. In terms of efficiency we find:

- Across all treatments except S-135 we fail to reject our weakly undominated, individually rational hypotheses.
- In total efficiency terms, the best treatment is A-Judge and the worst is A-First.
- Efficiency is not monotone in the outside option, where a middle region where termination is frequently used (but highly inefficient) reduces welfare.
- The majority of the symmetric treatments (S-75–95 and S-125–135) are more efficient than No T.
- Efficiency falls as the cycle progresses in almost all treatments.

3.2. Strategy Estimation. This section investigates the strategies adopted by subjects within each treatment. We use the methods detailed in Dal Bó and Fréchette (2007), referred to as the Strategy Frequency Estimation Method (SFEM, also used in Fudenberg et al. 2010; Embrey et al. 2011). To use the SFEM method we specify a set of 38 strategies, motivated both by theory and the previous experimental literature. Given the strategy-set restriction, and an econometric error term (an independent probability of mistakes when implementing a strategy), we estimate the proportions of play for each strategy with a maximum likelihood approach, using data from the last six cycles in each experimental session. Appendix A outlines the method in more detail and reports full estimation results over the 38 strategies. We focus here on providing the broad families of strategy used, and the modal strategy selections.

Table 3 reports the proportion of estimated strategies that exhibit: i) initially cooperative behavior; ii) the possibility for ongoing cooperation; iii) lenience in response to failure; iv) forgiving punishment phases; and v) punishment phases with termination components. In addition to these broad groupings, the table also indicates the three most-popular strategies in each treatment, and their estimated incidence.

In No T, where termination is not an option, the most-common strategies are always defect (All-D), the grim-trigger (Grim), and the monotone strategy (Mono). Just ten percent of the selected strategies exhibit lenience (All-C and the Sum-2 strategy that cooperates if more successes have been observed than failures), while 27 percent are forgiving (primarily the Sum-2, Mono and WSLS strategies). However, just over half of the responses are initially cooperative, while 58.4 percent of the selected strategies are capable of sustaining cooperation.

In comparison to No T, the S-75 treatment adds termination as an available action, but theory indicates its use is weakly dominated. Here the SFEM estimates indicate just 7 percent of selected strategies use termination, where this figure is much higher than the figures suggested by a reduced-form approach. The reason for the differing incidence is that the terminating strategies indicated by SFEM are the conditionally cooperative 2- and 3-Strike responses. These lenient strategies require two or three failures to trigger dissolution,
and otherwise cooperate. As such, termination is used less frequently along the path, despite a higher incidence of subjects selecting strategies with termination as a punishment.

The S-75 treatment is more cooperative than No T (both initially, and in selecting strategies capable of ongoing cooperation) and has greater lenience, and so is more likely to remain at cooperation. The primary driver for this is a much larger proportion of subjects assessed as using the most cooperative strategy from the 38 specified, the All-C strategy. Always cooperate is selected at the expense of two forgiving strategies, the suspicious variants of Mono and WSLS (termed S-Mono and S-WSLS in the appendix estimation tables) that start out in the defection state. Because All-C has no punishment phase it is not classified as a forgiving strategy. Potentially, what has been classified here as All-C, are in fact just very lenient, conditionally cooperative strategies. Because of the excessive lenience, the particular paths of play may not identify the punishment, and subsequently whether the punishment is forgiving or not. As such, below the Forgiving row we also provide the fraction of forgiving strategies including All-C.

Increasing the outside option from $0.75 to $1.25 has the effect of substantially increasing the selection of terminating strategies. Fifty-four percent of selected strategies use termination along the path, where the most-common termination strategy is a Probation variant. Labeled Probation-21, this initially cooperative strategy is lenient with an additional cooperation state after the first failure, and a round of defection after the second failure, but terminating on the third failure. Success in any of the probation parts of the punishment moves the state back into the first cooperation state. As such the strategy is both cooperative, lenient, forgiving and terminating. The estimates reflect an approximately 21 percent incidence of the 1-, 2- or 3-strike strategies, where the most commonly chosen of the three is the (lenient) 2-strike at 11.5 percent. Our estimates indicate that S-125 is in fact more lenient and more forgiving (weakly if we include All-C as forgiving) than either No T or S-75, where forgiveness is driven by the 17 percent selection of Probation-21.

For the asymmetric treatments, the clearest selection is also obvious from the aggregate levels, the heavy use of Always-T in the A-First sessions, with 93 percent of subjects consistent with this strategy. In A-Judge, where active cooperation rates and efficiency are highest, the threat of arbitration induces high frequency of selection for All-C (27.9 percent)
and a very lenient and forgiving monotone-strategy variant (Mono-31), with three cooperation states and a final defect state after four sequential failures. The vast majority of selected strategies are initially cooperative, and 89 percent are capable of sustaining cooperation given successes. Of the small minority that do play non-cooperative strategies, the most common are the false cooperator (C-AllD) which cooperates in round one, and then switches to always defect, the standard All-D, and the strategy which alternates between C and D regardless of the public outcome (CDCD), with each strategy selected at a three to four percent incidence. The majority of selected strategies are lenient and (if including All-C) forgiving.

Finally, examining A-Last, the small asymmetry in dissolution payoffs ($1.25 vs $1.35) leads to a much smaller incidence of terminating strategy selection. With the exception of A-First, the A-Last treatment has the lowest selection of cooperative strategies and the least forgiving responses. Always defect is selected 36.0 percent of the time, with the next most common strategy being the non-lenient, non-forgiving Grim. Comparing the selected strategies to S-125, we see a drop from just over half of strategies selected using termination to approximately one in ten. Of the terminating strategies that are selected, the most common is to terminate in the very first round (All-T at 5.8 percent) followed by the D-2-strike strategy at 3.4 percent (play D until two failures are observed, after which terminate).\textsuperscript{31} Though the selected strategies are less likely to be terminating ones, the lack of lenience or forgiveness in the selections mean that dissolution is triggered more often. To illustrate this, the table indicates close to two and half times the incidence of terminating strategy selection for A-Judge over A-Last. But the inactivity rate for rounds two and beyond in A-Last exceeds that of A-Judge.

4. Conclusion

We experimentally investigate a series of prisoners’ dilemma games with imperfect monitoring. Introducing a termination option into the PD stage game that can unilaterally end the relationship, our experiments manipulate the outside options available to the players. Our first set of treatments examine the effect from varying the outside option symmetrically, where each partner receives the same payoff if the relationship dissolves. Here we contrast the observed outcomes to an imperfect-monitoring environment without a dissolution option. Our findings suggest that the use of termination as a punishment is directly related to the outside option’s value: if remaining in an uncooperative relationship stochastically dominates walking away, subjects rarely end the relationship. However, the presence of a dissolution option does increase both cooperation, and the lenience of the strategies used. Without a termination option, the cooperative strategies selected are rarely lenient, with punishment phases triggered by a single failure. In contrast, the selection of lenience increases by a factor of three to four in our main symmetric treatments with a termination option.

Moreover, we do not observe drops in the selection of forgiving strategies. Where outside-options dominate the in-relationship punishment, we do see a majority of subjects using

\textsuperscript{31}A war-of-attrition style mixed-strategy wSSPPE exists for A-Last where each player defects with probability 0.758 and terminates with probability 0.242 with a discounted-average value of $1.262. Moreover, a Grim-like cooperative wSSPPE exists where this mixed-strategy is used as the punishment path following a failure.
terminating strategies. Despite the use of the intrinsically unforgiving termination action, forgiveness does not decrease. The reason for this is a large proportion of subjects combining both in-relationship and dissolutions punishments. The selected probation strategies initially use in-relationship defections to punish, and in this phase are capable of returning to cooperation. The second-stage of the punishment uses termination only after continued bad outcomes. By using more sophisticated combinations of punishments, subjects retain the ability to forgive and therefore return to the cooperative path.

Our results do differ slightly from hypotheses generated from weak dominance and individual rationality. Ending a relationship is a weakly dominated action whenever the outside-option value is lower in expectation than the in-relationship minmax. However, we begin to observe termination use at significant frequencies below this level. Our results suggest a substitution toward terminating strategies whenever outside options are not stochastically dominated by staying within the relationship. Once the outside option exceeds the lowest individually-rational realization (as opposed to its expectation), we see higher rates of termination and relationship inactivity, increasing through sessions as subjects learn to use termination more often. Below this level, we see much-reduced termination use and inactivity, and this decreases over sessions. This leads to a non-monotonicity in observed efficiencies with respect to outside options. As outside options increase, their plausibility as punishments increases, which helps increase cooperation and therefore efficiency. However, because the termination rate increases so much at the minimal realization, we see large welfare losses: subjects are using a very costly form of punishment. Further increases to the outside option, decrease the costs of the termination punishment, and we again see increasing welfare. The results suggest an optimal friction for the dissolution process (incompleteness in contracts, costs in trials, etc.). These costs should be small enough to make the punishment just plausible enough to be a threat, but large enough to make the vast majority unwilling to use this option in all but the most extreme cases.

Our second set of treatments make payoffs on dissolution asymmetric, with one partner getting a higher payoff depending on the choices made while the partnership was active. Three simple institutions are analyzed: the party that terminates gets a higher payoff; the party being terminated gets a higher payoff; and, finally, the party that was more cooperative in the partnership gets the higher payoff. The effect from changing the asymmetric institutions are striking. Where first-movers have a payoff advantage, we see almost all subjects move towards termination in the very first round. Partnerships are very unlikely to get off the ground. The precise dissolution payoffs chosen actually result in outcomes Pareto dominated by the in-relationship minmax (itself dominated by mutual cooperation). In contrast, where the party being terminated receives a higher payoff, we observe a large drop in the fraction of subjects using termination, relative to comparable symmetric treatments. The quantitatively small asymmetry in dissolution payoffs leads to lower initial cooperation rates, and selected strategies selected that are less forgiving and lenient that those in the comparable symmetric treatments. Neither of these two asymmetric treatments indicate an efficiency gain from contracts specifying unequal divisions on dissolution.

However, our final asymmetric payoff treatment, A-Judge, is the most successful among all of our treatments. Selected strategies are mostly cooperative, forgiving and lenient, resulting in the high efficiency levels. This institution determines who receives the higher and lower dissolution payoffs by determining who cooperated the most within the relationship while it
was active, and treatment mirrors an arbitrator or judge determining how to distribute payoffs (through some moral remit to assign it to the more-deserving party). In our experiments this judge player is automated and has access to a perfect forensic process. Future research might examine the extent to which the highly efficient outcomes we observe are retained when the arbitrator is a human subject without a set division rule and/or with imperfect information on the two player’s actions. Such extensions will help gauge the robustness of this result, and may help guide remits for arbitration. Further to the discussion above, ex post inefficiencies can be useful to increase ex ante efficiency, and our A-Judge treatment has an expected dissolution payoff across the partners equal to the lowest realization for the in-relationship minmax. This low efficiency ex post allows for potentially very costly arbitration discovery hearings. Unlike the symmetric treatment with a comparable average dissolution payoff (S-105, representing comparable dissolution frictions), asymmetric division and assignment to the more-cooperative player combines a highly plausible threat, with far-greater punishment effect on deviators. The effect is large gains in cooperation rates, and reduced need to use the punishment. These gains are more than enough to offset the large costs when dissolution does occur.

References


Embrey, Matthew, Guillaume Fréchette, and Ennio Stachetti, “Renegotiation in Repeated Games: An Experimental Study,” 2011.

Fréchette, Guillaume R and Sevgi Yuksel, “Infinitely Repeated Games in the Laboratory: Four Perspectives on Discounting and Random Termination,” February 2013. NYU working paper.


Fudenberg, Drew and Jean Tirole, Game Theory 1991.


Hyndman, Kyle and Dorothée Honhon, “Flexibility in Long-Term Relationships: An Experimental Study,” 2014. University of Texas working paper.


Appendix A. Strategy Frequency Estimation (For Online Publication)

We will briefly describe the econometric model adopted in SFEM, discuss about the set of strategies we include in the estimation and then report the estimated frequency of strategies for each of the treatments. To use SFEM, we assume that each subject chooses a fixed strategy for the last six cycles (the supergames). These chosen strategies are implemented with the possibility of independent mistakes, where another choice than the intended action is made. In this section, we report the results from our SFEM estimations. We first briefly describe the econometric model adopted and then report the estimated strategy weights for each of the main treatments.

Denote the choice made by subject $i$ in round $t$ of cycle $m$ by $c_{imt}$. We specify a priori a set of $K$ possible public perfect strategies $\Phi = \{\phi_1, \ldots, \phi_K\}$, where the choice of the strategy $\phi_k$ prescribes the choice $s_{imt}^k = \phi(y_{jm1}, \ldots, y_{jm(t-1)})$ following the public history $(y_{jm1}, \ldots, y_{jm(t-1)})$. Each subject is assumed to follow a particular strategy $\phi_k$, but they make independent mistakes each round with a probability $(1 - \beta)$, and chose the prescribed action with probability $\beta$. Given three actions ($C$, $D$ and $T$) a random uniform choice is represented by $\beta = 1/3$, while a perfect match with a strategy by $\beta = 1$. The econometric model assumes a mixture model across the available strategies, so that strategy $\phi_k$ is selected with probability $q_k$.

Define the indicator, $I_{imt}^k = 1\{c_{imt} = s_{imt}^k\}$, which assigns a value of one if the observed subject choice matches the strategy choice $\sigma_k$ match. The likelihood that the observed choices for subject $i$ were generated by the strategy $\phi_k$ are given by

$$\Pr_i(\phi_k; \beta) := \prod_{m \in M_i} \prod_{t=1}^{T_{im}} \beta^{I_{imt}^k} (1 - \beta)^{1 - I_{imt}^k},$$

where $M_i$ is the set of cycles, and $T_{im}$ the set of active rounds. Combining across all subjects in a treatment we obtain the following likelihood function:

$$\sum_{i \in I} \ln \left( \sum_{\phi_k \in \Phi} q_k \Pr_i(\phi_k; \beta) \right)$$

for the specified set of strategies $\Phi$ and summing the log-likelihoods across all subjects $I$ in the treatment. The parameters to be estimated by maximum likelihood are the vector of probabilities $q = (q_1, \ldots, q_K)$ and the strategy-match probability $\beta$, under constraints that $\beta \in [1/3, 1]$, and that the vector of probabilities $q$ lies in the probability $K$-simplex. The numerical maximization, and bootstrapping of the results, was completed in Mathematica using a differential-evolution constrained-optimization algorithm, using starting points for the estimation obtained following the same techniques followed in Dal Bó and Fréchette (2011).\(^{32}\)

In total we allow for 38 different strategies, motivated by theory and the previous experimental literature. Many of the important strategies are defined in the main text, but a full list and definition of each strategy are available from the authors by request.

\(^{32}\)We also conducted the same exercise in Matlab using modified code provided by Guillaume Fréchette, obtained qualitatively similar results. However, the Mathematica numerical routines seemed to be slightly better at attaining a global solution.
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*Note:* Bootstrapped standard errors (across sessions, subjects and cycles) in parentheses. Significance indicated by: ***=1 percent level; **=5 percent level; *-=10 percent level.
B.1. **Within-Session Dynamics.** Examining subjects’ initial response in the experiment—the first round of the very first cycle, before they have interacted with other subjects—we do not see a stark cooperation differences across treatments. Across all sessions the median initial cooperation rates is 70 percent, with an interquartile range of 64–73 percent.\textsuperscript{33} Expanding beyond this very first choice in the experiment, and analyzing the first six cycles in the sessions, the cooperation rate in active rounds in symmetric treatments is generally within the 60–70 percent range. For the other treatments, outliers in initial cooperation are the No T treatment, with an already much-lower active cooperation rate of 50 percent, and the A-Judge treatment with 76.5 percent cooperation.\textsuperscript{34}

As the session progresses, the active cooperation rate decreases by approximately 10 percent in each treatment, with the exception of A-Judge and A-First. Looking at the final six cycles in each session, the symmetric treatments have active cooperation rates of 50–55 percent (with a single outlier in the S-95 session). No T decreases to 40.5 percent active cooperation, while A-Last has a similar ten percent decrease to 46.8 percent. For A-First, the cooperation rate slide is much larger, decreasing to just 9.6 percent active cooperation in the final six cycles, with a matched increase in inactivity across the session. Finally, A-Judge is the only treatment which shows an increase in cooperation across session. The

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{cooperation_and_inactivity.png}
\caption{Cooperation and Inactivity across Sessions}
\end{figure}

\textsuperscript{33}Extreme outliers for initial cooperation in cycle-one-round-one are one session of No T and one for S-75 on the low side (36 and 46 percent, respectively), and one session of S-75 and one for S-125 on the high (89 percent and 92 percent).

\textsuperscript{34}No T is significantly lower ($p = 0.030$) and A-Judge is significantly higher ($p = 0.051$) than the symmetric treatments S-75–135. A-First also has significantly lower initial cooperation than the symmetric treatments ($p = 0.051$), however the difference is quantitatively smaller, at 57 percent active cooperation.
final six-cycles in \textit{A-Judge} have active cooperation rates of 87.0 percent, while activity rates remains fairly constant across the sessions at approximately 94 percent.\textsuperscript{35}

For the symmetric treatments with termination, the activity-rate trend across sessions is more varied. All sessions for \textit{S-75-95} show increased relationship activity (and reduced termination rates) in the last six cycles when compared to the first six, as subjects move away from using the termination action as the session progresses. In contrast, every session from \textit{S-105-135} shows decreased relationship activity (increased termination) in the final six cycles (though the activity drop in the single \textit{S-115} session is quantitatively small).

\section*{B.2. Conditional Response.} To examine aggregate strategic responses, Figure 6 illustrates the proportion of action choices (either \textit{C}, \textit{D} or \textit{Terminate}) conditioned on the previous round’s history in our multi-session treatments (similar graphs for the single-session symmetric treatments are provided in the supplemental figures appendix). Given the imperfect monitoring environment, subject \(i\) observes the sub-history \((a_{i}^{t-1},y_{i}^{t-1})\) for all rounds \(t \geq 2\), her own previous action choice and the public outcome, and the empty history \(\emptyset\) in the very first round. Each figure indicates the proportion of choices in \textit{Active} rounds over the last six cycles in the session.\textsuperscript{36} The main square in each figure represents all active rounds in rounds two and onward, while the thinner bar to the left indicates the actions chosen in the first round. The set of all active rounds is then sub-divided horizontally to indicate the previous round’s history. The square is therefore divided into at most four regions, as all active rounds have a sub-history in \(\{C,D\} \times \{S,F\}\). The proportion of active rounds with the relevant sub-history is given by the area covered by each of these four bands, here proportional to their width. For instance, in the \textit{No-Termination} treatment the modal action-outcome pair in the previous round was \((D,F)\), while the least common was \((C,F)\). In contrast, for \textit{S-125}, the most common action-outcome the previous round was \((C,S)\), though it should be noted that only 54.5 percent of the relevant rounds in this treatment are active.\textsuperscript{37} Each history-specific band (including the first round empty-history band) is itself divided up vertically into three regions, indicating the proportion of actions chosen, given the last period’s sub-history. The bottom gray region reflects the proportion of defection choices, the top white region reflects cooperation choices, while the black middle region indicates termination choices. Examining the \textit{No-Termination} treatment, the figure indicates that the initial action choice in the first round is to play \(a_{1} = C\) in 52 percent of the time, with \(D\) played 48 percent of the time, with no termination decisions (by design).

After the first round, conditional on cooperating and getting a successful outcome last round, the \((C,S)\) sub-history, subjects continue to cooperate 75 percent of the time in \textit{No T}, while for every other sub-history defection is the more common response (with defection rates between 75–80 percent). In fact, the modal response to successful cooperation last

\textsuperscript{35}Figure 5 in the appendix illustrates the activity and cooperation across sessions by treatment.

\textsuperscript{36}Given \(M\) total cycles in a session, all analyses referring to the last six cycles use session cycles \(M - 3\) to \(M - 1\), dropping the last cycle in the session to remove an end-session effect stemming from some subjects realizing the session was about to end where the hour had elapsed. For each cycle, each subject has two distinct partnerships, so we have a total of six distinct cycles.

\textsuperscript{37}For all treatments except \textit{No Termination}, we provide the activity rate for all rounds other that the first one in the treatment label.
each plot indicates the proportion of actions chosen in the very first round.

Diagrams: The band into three regions: D in gray, at the bottom; C in white from the top, and the \( \text{terminate} \) action in black. The bars to the left in each plot show the proportion of action choices following each history and are represented by \( \left( 1 - \beta_t 1_{t \geq 2} \right) \). The proportion of active rounds with the relevant \( \beta_t \) is then divided horizontally into the proportion of action choices following each history and are represented by \( \left( 1 - \beta_t 1_{t \geq 2} \right) \). The bar to the left in each plot indicates the proportion of actions chosen in the very first round.

Figure 6. Conditional response in last five cycles, \((a)\) A-Judge, \((b)\) A-Last, \((c)\) S-125, \((d)\) A-First, \((e)\) A-Late, \((f)\) No Termination.
round is to cooperate again across all of our treatments, and at higher rates than No T.\textsuperscript{38} The highest cooperation rate following the (C, S) sub-history is for A-Judge, where subjects continue to cooperate 93 percent of the time, though this is closely followed by S-75 at 91 percent. The large efficiency differences between A-Judge and S-75—67.1 percent vs. 42.3 percent payoff efficiency overall, and 69.6 percent vs 32.7 percent in the last six cycles—are mostly attributable to greater first-round cooperation in A-Judge.

The figures partially illustrate leniency and forgiveness through the cooperation rates after histories other than (C, S). In terms of symmetric memory-one strategies, cooperating after the history (C, F) indicates lenience (a willingness to delay entering a punishment phase) while cooperation following (D, F) and (D, S) indicates forgiveness (attempts to enter a new cooperative phase from punishment). Across treatments, the most lenient and forgiving treatment using this rubric is A-Judge. In comparison to No T, S-75 and S-125—where defection is the modal response to every sub-history bar (C, S)—the A-Judge treatment has cooperation as the modal response regardless of previous round’s history. The treatment with the least lenient behavior is No T, with 29 percent cooperative decisions following (C, F) the previous round. In contrast, cooperation rates following (C, F) in symmetric treatments with termination are 42 percent in S-75 and 49 percent in S-125. The presence of a dissolution option therefore increases the selection of lenient responses.\textsuperscript{39}

In contrast to lenience, the presence of an unused, low-payoff termination option has a negative effect on forgiveness. Pooling the decisions where (D, F) and (D, S) occurred the previous round, the cooperation rate is 20 percent in No T compared to just 13 percent in S-75. Where termination is present and utilized, the raw cooperation rate after a defection the last round increases in S-125 to 27 percent, so forgiveness seems to increase. In this situation however, the reduced-form figure is harder to parse, as selection effects through partnership dissolution are more pronounced. Because many more cycles are dissolved in the punishment phase, those that are not are over-sampled. We address this in the paper body through the SFEM analysis.

Examining the black shaded regions in each figure, the termination action is primarily used either: i) as a decision to opt out in the very first round; ii) as a punishment following failed cooperation, (C, F); or iii) to exit an inefficient relationship following failed-defection, (D, F). In addition to A-First—where 90 percent of first-round actions are termination and subsequently 99 percent of partnerships in the last six cycles end in round one—round-one dissolution is most common in the S-105–135 treatments (with 7–8 percent round-one termination) and A-Last (7.5 percent). Outside these treatments, round-one termination is rare (less than 0.5 percent across S-75–95 and 1.2 percent in A-Judge).

Conditional on being in an active relationship past round one, the highest dissolution rates follow failed cooperation, and can thus be interpreted as unforgiving punishments. The incidence of termination following (C, F) varies from low rates in S-75 and S-85 (4.5 percent and 1.6 percent, respectively), to middling rates in A-Last (9.5 percent), to the more substantial in S-95–135 and A-Judge (mostly in the 20–25 percent range, with two-outliers S-115 at 14.6 percent and S-135 at 45.8 percent). Termination is rarely used following

\textsuperscript{38}The No T cooperation rate following (C, S) is matched by A-First, though we will mostly ignore this treatment for much of the discussion as there are only four Active-state observations in rounds two and onward in the last six cycles, due to very high termination rates in round one.

\textsuperscript{39}The other symmetric termination treatments mostly have cooperation rates following (C, F) of 43–53 percent, with the one outlier being S-135 with 33 percent cooperation.
successes last round, and termination rates are generally lower than 0.5 percent after either $(C, S)$ or $(D, S)$.\(^\text{40}\) Finally, termination rates are non-negligible following a failed defection the previous round. However, in all treatments but $A$-Last the termination rate following $(D, F)$ is a fraction of that following $(C, F)$, and matches the idea that the participant shares more of the blame for the observed failure, given their defection.

\(^\text{40}\)The only notable exceptions are termination rates of 2.0 and 3.5 percent following the $(D, S)$ history in $S$-125 and $S$-135, respectively.
### Appendix C. Supplemental Figures and Instructions (For Online Publication)

#### Table 5. Most Common Sequences

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**Note:** Five most frequent sequences of the form \( \{(a_1^i, y_1^i), \ldots, (a_5^i, y_5^i)\} \), where each cell indicates the action sequence \( a_1^5 a_2^5 a_3^5 a_4^5 a_5^5 \), where \( a_t^i \) represents \( y_t^i = \text{Success} \), \( a_t^i \) represents \( y_t^i = \text{Failure} \), and \( \tilde{a}_t^i \) indicates the relationship state became/was Inactive in period \( t \). The number \( N_{5} \) indicates the total number of subject-cycles for the five most popular sequences, while figures in parentheses indicate the fraction of the total subject-cycles represented by the sequence/top-five sequences.
Figure 7. Conditional response in last five cycles, \( a \) t i | \((a_{t-1}^{i}, y_{t-1}^{i})\). Note: For each treatment the horizontal axis indicates the proportion of active rounds \( t \geq 2 \) in the last five cycles given the relevant \((a_{t-1}^{i}, y_{t-1}^{i})\). The vertical axis indicates the proportion of each of the three possible actions: \( D \) in gray, \( C \) in white, and the \( \text{Terminate} \) action in black.

The bar on the left of each plot provides the proportion of actions chosen at the empty history (round 1).
Figure 8. Screenshot of Experimental Interface