

Hold-up: With a Vengeance*

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Abstract

When contracts are incomplete or unenforceable, inefficient levels of investment may occur due to hold-up. If individuals care for negative reciprocity these problems may be reduced, as revenge becomes a credible threat. However, negative reciprocity has this effect only when the investor holds the rights of control of the investment proceeds. We explore this issue analytically, deriving predictions for hold-up games which differ as regards assignment of rights of control. We also test and support these predictions in an experiment.

1 Introduction

The hold-up literature shows how relationship-specific investments and incomplete contracts combine to hurt partnership profitability.¹ The conclusions typically build on the assumption that agents selfishly maximize own

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¹The idea can be traced back at least to Williamson (1975, 1985) and Klein, Crawford & Alchian (1978). See Grout (1984) and Tirole (1986) for early formal theory, Tirole (1988, pp. 24-27, especially Example 1) and Hart (1995, pp. 73-85) for a textbook style introductions, and Che & Sakovics (2008) for a recent review covering much modern developments. Hold-up analysis is an Archimedean point for contract theorists who, starting with Grossman & Hart (1986) and Hart & Moore (1990), explain how organizational forms and contractual arrangements arise to reduce the underinvestment hold-up may cause.

income. However, hold-up scenarios involve opportunistic exploitation. Intuition as well as a wealth of evidence (cited in detail below) suggests exploited parties may get irritated and strike back. It may seem such negative reciprocity can deter exploitation and render hold-up less problematic.

We explore the issue analytically and experimentally. We show that whether or not negative reciprocity mitigates hold-up depends predictably on the nature of the investment. Contrasting two examples illustrates the key principle involved:

Example 1 *An artist (player 1) has been asked by a presumptive buyer (player 2) to paint a “beautiful portrait of 2.” 1 may disagree or agree. In the former case, 1 and 2 go separate ways. In the latter case, 1 spends \$2,000 worth of her time on the painting, and a contract says 2 should subsequently pay \$5,000 to 1. The value to 2 is \$8,000 but 2 may complain and claim (falsely) that the portrait is “rather ugly” and attempt to renegotiate offering a new price of \$1,000. Given the ambiguity of what constitutes beauty, 1 can’t enforce the \$5,000 payment and will have to accept or reject the new offer. 1 knows that no person other than 2 would pay to get the painting.*

Here, 2 could shoot himself in the foot by trying to renegotiate the price. 1 might become angry or, to use a phrase consistent with the intentions-based reciprocity theories of Rabin (1993) or Dufwenberg & Kirchsteiger (2004) (D&K), deem 2 unkind and desire to be unkind in return. 1 would then prefer to reject the renegotiated offer, and destroy (or disfigure and exhibit) the portrait. If 2 foresees this, then we have a case where negative reciprocity mitigates hold-up.

Our second example suggests that this insight only carries so far:

Example 2 *A professor (player 1) has been asked by a student (player 2) to extracurricularly teach 2 “how to use game theory to make a lot of money.” 1 may disagree or agree. In the former case, 1 and 2 go separate ways. In the latter case, 1 spends \$2,000 worth of his time talking to 2, and a contract says 2 should subsequently pay \$5,000 to 1. The value to 2 is \$8,000 but 2 may instead complain and claim (falsely) that the tutoring “was only good enough that she can make a moderate amount of money” and offer a renegotiated price of \$1,000. Given the ambiguity of what is “a lot,” 2 can’t enforce the \$5,000 payment and he will have to accept or reject the new offer.*

As strategic structure and monetary payoffs go, Example 2 may seem similar to Example 1. The sole difference is that if player 2 proposes to renegotiate the price, and if 1 rejects the offer, then 2 gains rather than loses. This reflects how education, unlike a portrait, comprises human capital which cannot be withheld. When players are vengeful this difference has repercussions for the entire strategic analysis. There is no way for player 1 to hurt player 2, therefore less to deter 2 from proposing a renegotiated price, and therefore less incentive for 1 to agree to the tutoring. Even if players are motivated by negative reciprocity, hold-up remains an issue.²

The key difference between Examples 1 & 2, however, is not whether a relation-specific investment concerns human capital. Rather, the issue concerns (to use a term of Grossman & Hart's, 1986) who has "residual rights of control" of the proceeds of the investment. Human capital may be a prominent source of residual rights of control, but other sources are possible too. Say, to make things concrete, that we had an example (suggested by Ben Hermalin) with a home-owner and a plumber who installs a new system of pipes & drains in the home-owner's bathroom. Whether this situation most resembles Example 1 or Example 2 depends on whether or not legislation makes it feasible for the plumber to pull out and destroy the pipes & drains if the home-owner tries to renegotiate a pre-agreed price.

Examples 1 & 2 were selected for pedagogical clarity, not because they were the economically most significant we could come up with. However, these cases are structurally similar to grander scenarios, with or without transfer from seller to buyer of residual rights of control. This could involve tailor-made multi-million dollar equipment for space-walks (where the seller keeps control) or expensive training-programs for key personnel in the oil industry (involving transfer of human capital), etc. In some cases the held-up party may be a firm and it is reasonable to wonder whether firms are as prone to reciprocation as individuals. We suggest so, since at the end of the day firms are run by individuals. Hart (2008) makes the same point, suggesting that "[l]arge corporations are run by individuals who have big egos and presumably therefore can have strong emotions."

This paper explores whether the intuitions outlined in connection with Examples 1 & 2 prove logically valid when a formal model (a D&K-modification)

²Our focus here, and in the remainder of the paper, concerns *negative* reciprocity, where unkindness breeds unkindness in return. Hold-up problems may also be affected by *positive* reciprocity, where kindness breeds kindness. In section 3, we discuss this further and make a case for not focusing on positive reciprocity.

of negative reciprocity is applied. They are, up to a caveat concerning twin equilibria. Theoretical stories, however intriguing per se, gain in value if they possess empirical relevance and in order to examine whether we can thus boost confidence in our predictions we also designed an experiment to test them. We report the results, which are supportive.

Several contributions (spanning theory and experiments) have suggested that fairness or reciprocity may be relevant to hold-up although they explore other topics than highlighting connections between residual rights-of-control and vengeance using intentions-based reciprocity theory.³ Most closely related are Ellingsen & Johannesson (2004a) and von Siemens (2009) who study hold-up games reminiscent of our Example 1 and examine, respectively, pre-play communication and forms of incomplete information. Our approach differs in style from some preceding studies (including Ellingsen & Johannesson, 2004a, and Fehr, Krehmelmer & Schmidt 2008) which start with some clever experimental design incorporating hold-up and then offer "behavioral explanations" or "a theoretical interpretation" (respectively: p. 407, p. 1263). We reverse the order, starting with behavioral theory (D&K) and then proposing an experimental test for empirical relevance. Moreover, some previous work (*e.g.* Fehr, Krehmelmer & Schmidt, p. 1277) suggest that formal models of intentions-based reciprocity make sense *but* are difficult to apply. We agree as regards the make-sense part, but somewhat disagree on the difficult-to-apply part and hope this paper will serve as proof-of-concept.

Section 2 develops a simple hold-up framework which embeds game forms corresponding to Examples 1 & 2, and derives predictions for selfish players. Section 3 elucidates the general economic relevance of vengeance, reviewing contributions which are not explicitly focused on hold-up but which indicate that vengeance is a powerful human motive (including experiments documenting how the presence of punishment options may have a dramatic impact on strategic interaction). Section 4 develops theory, section 5 reports experimental results, section 6 concludes.

³See Hackett (1994), Gantner, Guth & Konigstein (2001), Ellingsen & Johannesson (2004a, b), Sobel (2005, section 4.2.1), Sloof, Oosterbeek & Sonnemans (2007), Hart & Moore (2008), Fehr, Hart & Zehnder (2008), Hart (2008), Fehr, Krehmelmer & Schmidt (2008), and von Siemens (2009).

2 A simple hold-up model

The two examples in the introduction can be embedded in a simple hold-up framework: Two players, 1 and 2, have the opportunity to trade a unit of some investment good for which they have values v_1 and v_2 respectively. Assume that, prior to any moves, an implicit contract is formed under which the price of the investment good is p . Assume that investment is observable to both parties but not verifiable; each party can observe the investment decision, but it cannot be explicitly contracted upon *ex ante*. Furthermore, assume that $v_1 = 0$, so the investment good has no residual value to 1.

First, 1 chooses whether or not to invest. If not, then the players receive their reservation values of zero. Investment costs c . Upon observing 1's investment, 2 must decide whether or not to honor the implicit contract. If 2 does so, 1 receives a payoff of $p - c$ and 2 receives $v_2 - p$. If 2 chooses not to honor the implicit contract, he makes a take-it-or-leave-it offer t to 1. If 1 accepts this offer he receives a payoff of $t - c$ and 2 receives $v_2 - t$. If 1 does not accept then he must cover the investment cost so his payoff is $-c$ and 2 receives $(1 - \alpha)v_2$, where $\alpha \in [0, 1]$ is a measure of the residual control right to the investment held by 1. Full control over the investment proceeds by 1 is captured by $\alpha = 1$ while $\alpha = 0$ captures full control by 2. We assume that $v_2 > p > c > t > 0$ so investment is potentially beneficial to both parties. The two examples can now be accommodated by setting $(v_2, p, c, t) = (8, 5, 2, 1)$, where the numbers are measured in thousands of dollars. In Example 1, $\alpha = 1$ since the artist retains control over the painting. In Example 2, $\alpha = 0$ since the student retains control over his human capital.

Figure 1 below recasts Examples 1 & 2 as extensive game forms with monetary payoffs. Relative to the examples, we have normalized the payoffs (dividing by 1000, then adding constants of 2 to each payoff entry) and simplified choice labels. The games represent stylized hold-up problems, with different underlying assumptions regarding residual rights of control. The Low-game corresponds to the case where Player 1 retains control after investment (as in Example 1), while in the High-game Player 2 retains these rights (as in Example 2).

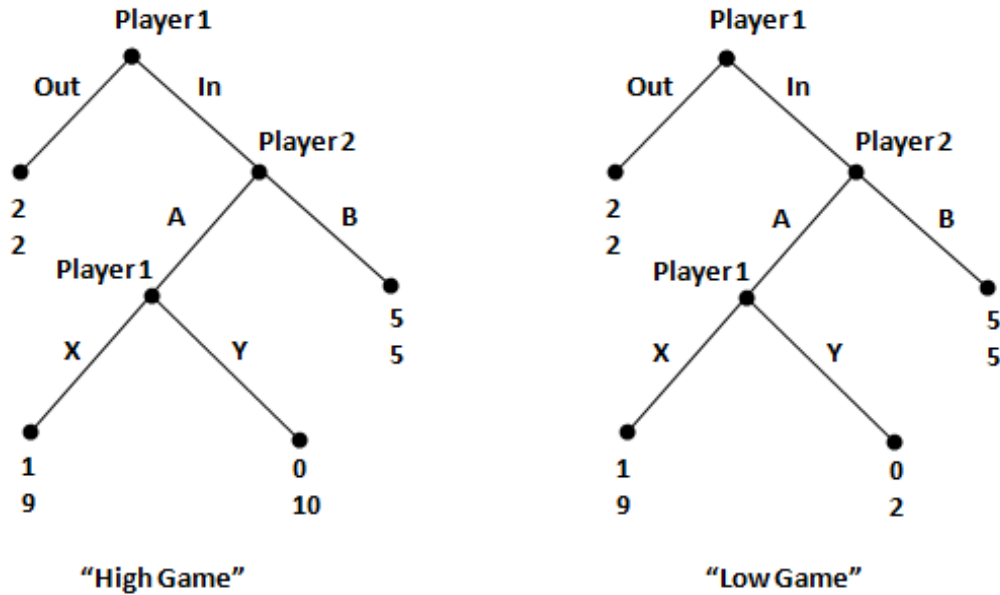


Figure 1: Two Hold-Up Games

The backward induction solution for selfish players is $((Out, X), A)$ in each game, with resulting inefficient payoffs $(2, 2)$. If the players are selfish, the hold-up problem is thus equally severe in each case. In section 4 we'll see that incorporating negative reciprocity will change this conclusion. However, before we proceed in behavioral directions we wish to point out an important issue which clarifies the connection between our exercise and the traditional hold-up literature:

Examples 1 & 2, and so the Low-game and the High-game, impose a special structure on renegotiation: player 2 makes a take-it-or-leave-it-offer to player 1 (20% of the originally agreed upon price). From the viewpoint of traditional hold-up theory this is a rather special case, and as noted by Che & Sákovics (2008, Remark 1) in their recent survey of the hold-up literature the "effects of alternative ownership structures may depend on the bargaining solution assumed". If, for example, players engaged in Nash bargaining, then the nature of a renegotiated deal would depend on the players' payoffs should they not strike a deal (the "threat points"), which in turn would depend on residual rights of control. As players anticipate bargaining outcomes, this could affect the likelihood of hold-up for reasons other than negative reciprocity. The purpose of our paper is not to comment on how to best

model renegotiation, however. Nor do we want any bargaining confound as we attempt to isolate the effects of negative reciprocity on hold-up as residual rights of control shift. We therefore, as seen in the Low-game and the High-game, assume a bargaining institution the outcome of which under selfish preferences is invariant to the assignment of residual rights of control.

3 The case for negative reciprocity

That vengefulness can be a powerful motive is reflected in popular culture which is filled with stories of good guys who get even. Our title makes reference to the 1995 movie *Die Hard: With a Vengeance*, starring Bruce Willis. Another example (disturbing and deeply touching) can be found in Cormac McCarthy's 2006 novel *The Road*, when the protagonist father decides to strip a thief of all he has (pp. 215-217). "I'm going to leave you the way you left us."

Real-world evidence is abundant too. Interview studies with business leaders, including that of Bewley (1999), conclude that an important reason for downward wage rigidity in times of recession is the perception that wage cuts would be perceived by employees as unkind measures to which the reaction would be less conscientious on-the-job effort.⁴ The economic consequence may be nationwide involuntary unemployment, as firms prefer layoffs to wage cuts if the fired personnel can't strike back. Firing personnel can have negative-reciprocity repercussions too though, as fired personnel have been known to engage in sabotage such as messing up computer systems before they leave their office.⁵

Businessmen can be vengeful too. Donald Trump, in his recent book *Think Big & Kick Ass* (Trump & Zanker, 2008) which teaches how to be successful in business and life beyond, devotes an entire chapter to the importance of revenge. Part of the message reflects repeated-game or reputation concerns, but part is clearly reflecting an innate joy of getting even. The following passage illustrates (p. 198):

Most business writers won't be so blunt and honest with you about getting even. They know it's the truth, but won't tell you

⁴See Dufwenberg & Kirchsteiger (2000) for more references and a theoretical account.

⁵This last example is taken from Sobel (2005, p. 393).

because they want people to think of them as a “nice person.” I don’t like to mince words. When you are wronged and do nothing about it, you aren’t “nice” you’re a schmuck. That is why I say when you are wronged, go after the those people, because it’s a good feeling ... I love it.

Of course, the hold-up literature is concerned with interaction between businessmen (say CEOs or self-employed independent contractors); Trump’s advice underscores the relevance of negative reciprocity in this connection.

Further documentation of the relevance of vengeful motivation to human decision making comes from studies of experimental games. Lopsided offers get rejected in ultimatum games, costly punishment options are exercised in public goods contexts, and low wage offers are met with low effort in wage-effort gift-exchange games, for example. We refer to Fehr & Gächter (2000a) for a discussion of much of the evidence and its interpretation with respect to reciprocity. Particularly telling evidence includes Bolton & Zwick’s (1995) comparison of ultimatum games and impunity games (which look like ultimatum games except the responder can only reject the part of a proposal meant for him, so there can’t be punishment), and several studies that compare various games with and without added punishment options (*e.g.* Fehr & Gächter, 2000b, 2002; Falk, Fehr, & Fischbacher, 2005).

Theorists have responded to the evidence by developing formal models of reciprocity. Rabin (1993) is a pioneer; other papers include D&K, Falk & Fischbacher (2004), Segal & Sobel (2007), and Cox, Friedman & Sadiraj (2008).⁶ There is also a literature which establishes that negative reciprocity preferences can be given evolutionary foundations. The key idea is that genes which instill an inclination for costly revenge may make others back off, which may increase one’s rewards and so one’s fitness. See Guth & Yaari (1992), Huck & Oechssler (1995), and Friedman & Singh (2008) for different approaches.

Reciprocity has two faces; negative reciprocity involves vengeance, while positive reciprocity involves rewarding kindness. Most previous discussions of reciprocity treat both forms alongside, but we focus on negative reciprocity. Our intuitions concerning Examples 1 & 2 involved retribution only, and our goal is to see how incorporating a taste for vengeance changes conclusions

⁶We focus on approaches that link reciprocity to intentions; we do not emphasize the complementary approach where players care about forms of inequity of distributions. Fehr & Schmidt (2003) and Sobel (2005) discuss also such models.

relative to a traditional hold-up analysis. Positive reciprocity may be an important human motivation,⁷ but so may a host of other concerns like anxiety, guilt, disappointment, regret, fear, hope, altruism, and inequity aversion. In order to highlight the effect of negative reciprocity, we abstract away from all these other sentiments, including positive reciprocity.

4 Theory

Rabin (1993) highlights key qualitative aspects of reciprocity in games. However, as he notes himself (p. 1296), his normal form construction is inadequate for applications to games with a non-trivial dynamic structure (like our Low- and High-games) which require a description of how kindness conceptions get updated through a game tree. D&K therefore develop a model for extensive form games, which considers both positive and negative reciprocity. As explained in section 3, we wish to focus solely on negative reciprocity and propose a modification of D&K’s theory which achieves this. We first recall D&K’s theory (sketchily; for the unabridged version with its formal details we refer to D&K), then introduce the negative-reciprocity-only modification, and finally apply this theory to our games.

4.1 D&K

D&K consider finite multi-stage games with observed actions and without nature (this includes our Low- and High-games). *Ecco* player i ’s utility:

$$u_i = \underbrace{\pi_i}_{\text{material payoff}} + \underbrace{\sum_j (\theta_{ij} * \kappa_{ij} * \lambda_{iji})}_{\text{reciprocity payoff}} \quad (1)$$

Player i ’s material payoff π_i simply reflects his dollar earnings. $\theta_{ij} * \kappa_{ij} * \lambda_{iji}$ is i ’s reciprocity payoff with respect to player j : $\theta_{ij} \geq 0$ is a parameter reflecting i ’s sensitivity to reciprocity (D&K use Y_{ij} instead of θ_{ij}). κ_{ij} is i ’s kindness to j ; this term is negative (positive) if i is unkind (kind) to j . λ_{iji} describes how kind i perceives j to be; in analogy with kindness, this term is negative or positive. Reciprocity is captured as, *ceteris paribus*, i wants to match the sign of κ_{ij} and λ_{iji} , to make the product $\kappa_{ij} * \lambda_{iji}$ positive.

⁷Some experiments suggest that negative reciprocity is more important than positive reciprocity though. See Charness (2004), Charness & Rabin (2002), Offerman (2002).

κ_{ij} is actually a real-valued function of i 's strategy and "first-order beliefs" about other players' strategies; κ_{ij} is the difference between the material payoff i believes j gets and the average of the maximum and minimum material payoffs that i believes j could have gotten had i chosen differently.⁸ Perceived kindness λ_{iji} is defined analogously, except that its arguments – i 's first-order belief about j 's strategy and i 's "second-order beliefs" about j 's first-order beliefs – appear one level higher in i 's belief hierarchy.

This *Reader's Digest* presentation of D&K's theory warrants a few more comments: D&K define a solution concept called *sequential reciprocity equilibrium (SRE)*. The SRE concept imposes that players optimize at all histories, for beliefs which are 'correct'. This involves that strategies and beliefs at any history reflect probability 1 choices along the path that lead to that history; this is how D&K model intentionality and updating of kindness as play proceeds. Since i 's utility u_i includes beliefs as arguments, D&K's model fits the framework of psychological games (Geanakoplos, Pearce & Stacchetti, 1989; Battigalli & Dufwenberg 2009).

4.2 Vengeance equilibrium

We now modify D&K's theory to reflect negative reciprocity only. Rather than operating with perceived kindness function λ_{iji} , we simply define $\lambda_{iji}^- := \min\{\lambda_{iji}, 0\}$. Rather than maximizing u_i , player i maximizes his utility v_i (v for "vengeance") defined by:

$$v_i = \underbrace{\pi_i}_{\text{material payoff}} + \underbrace{\sum_j (\theta_{ij} * \kappa_{ij} * \lambda_{iji}^-)}_{\text{vengeance payoff}} \quad (2)$$

Define a *Vengeance Equilibrium (VE)* just like a SRE, except that i 's utility is v_i rather than u_i . Note two properties of the VE: First, a VE exists for any game within the considered class; D&K's proof applies directly, *mutatis mutandis*. Second, neither SRE nor VE is a refinement of the other concept. To see this, consider the game in Figure 2:

⁸More precisely, the calculation of the minimum is defined with respect to what D&K call i 's "efficient" strategies. See D&K for details. The qualification is irrelevant for analyzing our High- and Low-games, so we neglect this somewhat complicated issue here.

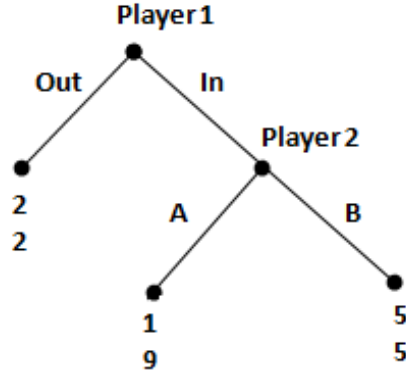


Figure 2: VE vs. SRE

It can be verified that if θ_{12} and θ_{21} are high enough then the unique SRE is (In, B) while the unique VE is (Out, A) .

4.3 Hold-up with vengeance

We are now ready to solve our two hold-up games for their VEs, paying special attention to the cases where θ_{12} and θ_{21} are large numbers so that concern for getting even is important. We start with the High-game where the prediction is unambiguous:

Observation 1 *Regardless of θ_{12} and θ_{21} , the unique VE of the High-game is $((Out, X), A)$.*

To verify Observation 1, check incentives through the game: *At the root*, given equilibrium beliefs, player 1 believes player 2's kindness is zero ($\lambda_{121} = 0$), as 2 does not affect material payoff if 1 chooses *Out*. Therefore, at the root, 1 will maximize his material payoff. He'd get a payoff of 1 choosing *In* (since play would proceed *A* then *X*), while *Out* gives him $2 > 1$ *Next, look at 2's node*: Given (updated) equilibrium beliefs, $\lambda_{212} > 0$ so $\lambda_{212}^- = 0$, so 2 will maximize her material payoff. Since player 1 chooses *X* if given the chance, 2's best response is *A*. ... *Finally, after history (In, A)*: 1's reciprocity and material payoffs are aligned; 1's material reward is higher if he chooses *X* rather than *Y*, and since 2's choice *A* is unkind 1's reciprocity payoff is also maximized by choice *X* which minimizes 2's material payoff.

Observation 1 shows that the High-game embodies inefficiency due to hold-up whether or not players are vengeful. Observation 2, by contrast, shows that vengefulness may mitigate hold-up in the Low-game:

Observation 2 *If θ_{12} and θ_{21} are large enough, there are two VE's of the Low-game:*

- (i) $((In, Y), B)$ and
- (ii) $((Out, Y), A)$

Case (i) captures our intuitions regarding Example 1 from the introduction: *At the root*, $\lambda_{121} > 0$ i.e. $\lambda_{121}^- = 0$, so 1 will maximize his material payoff. He is happy with his *In* choice, since $5 > 2$ *At 2's node*, she chooses *B*. To see why, note that given equilibrium beliefs, $\lambda_{212} > 0$ so $\lambda_{212}^- = 0$. Thus 2 will maximize her material payoffs, and by choosing *B* she gets 5 rather than 2. ... *Finally, after history (In, A)*, player 1 is motivated by negative reciprocity to choose *Y*; at that history $\lambda_{121}^- = \lambda_{121} < 0$, so with θ_{12} high enough *A* will minimize *B*'s material payoff.

Take a moment to reflect on the following 'irony' concerning the VE of Case (i) as compared to the unique VE of the High-game: The Low-game differs from the High-game in that a player's payoffs goes *down* (a 10 becomes a 2), but in VE both players' material payoffs go up!

However, the strategy profile $((In, Y), B)$ is not the only VE-possibility in the Low-game. Case (ii) adds an intriguing, gloomy possibility. The strategy profile $((Out, Y), A)$ is also a VE. We like to think of this strategy profile as a "miserable" VE. This time, we discuss what's going on starting below the root:

In the subgame starting at 2's node (off the equilibrium path) the two players indulge in being unkind to one another. Given (updated) equilibrium beliefs, each player perceives the other as unkind, and strikes back to minimize the co-player's payoff. For player 1, the argument is just like in Case (i). For player 2, the behavior could be thought of as 'reciprocation-in-anticipation,' as 1 makes the choice that hurts 2 *after* 2 makes the choice that hurts 1. This is allowed by the theory; given (updated) equilibrium beliefs, at 2's node, she believes that 1 believes he will willingly minimize her material payoffs; $\lambda_{212}^- = \lambda_{212} < 0$, so 2 is happy to minimize 1's material payoff by choosing *A*. ... *Finally, going back to the root*, given equilibrium beliefs, 1 realizes that strategies (In, Y) and (Out, Y) both give player 2 a material payoff of 2, so κ_{12} is the same for both strategies. Since the material payoff from choosing *Out* is higher, this breaks what in terms of reciprocity payoff is a tie in favor of (Out, Y) .

It is natural to wonder whether the conclusions we have obtained here for our High- and Low-games are robust with respect to changes in the under-

lying parameters. The answer is *yes*: If one returns to the broader hold-up framework presented at the start of section 2, derives game forms for parameterizations such that $v_2 > p > c > t > 0$, adds a component of reciprocity in the form of any $\theta_{12} > 0$, then one can show (proof available on request) that if α is low [high] enough Observation 1 [2(i)] has a counterpart.

5 Experiment

Our work falls in the category of "applied theory". It should primarily be evaluated according to how intriguing and novel is our examination of connections between vengeance and residual-rights-of control for hold-up. Nevertheless theoretical stories, however intriguing, gain some value if they also possess empirical relevance. Against this background we ran an experiment to test the predictions of section 4. This section explains what we found.

5.1 Testable predictions

As seen in section 4.3, incorporating negative reciprocity does not change conclusions regarding the severity of hold-up in the High-game, as $((Out, X), A)$ is its unique VE regardless of θ_{12} and θ_{21} (Observation 1). However, in the Low-game, if θ_{12} and θ_{21} are high enough, *every choice may flip*, in the sense that $((In, Y), B)$ is a VE (Observation 2, Case (i)). It is thus natural to test whether, on balance, the choices In , Y , and B are more common than Out , X , and A in the Low-game than in the High-game.

One potential counter-force to this prediction is the additional VE pointed out in Case (ii) of Observation 2: $((Out, Y), A)$. The existence of this VE increases the possibility that we may not be able to reject the hypotheses that the behavior in the two games, at each decision node, is the same. In other words, if our subjects are attracted to the miserable equilibrium behavior across treatments will look similar even if subjects are vengeful. On the other hand, if we do get rejection it will support the idea that negative reciprocity can mitigate hold-up mainly in cases where the investing party maintains residual rights of control, as well as the empirical relevance of the $((In, Y), B)$ VE in the Low-game.

5.2 Procedures

All lab sessions were conducted in the Economic Science Laboratory at the University of Arizona. Subjects were undergraduate students recruited via E-mail from our online subject database. Twelve subjects participated in each session, six subjects were randomly assigned to the Low-treatment and the rest were assigned to the High-treatment. In the Low-treatment, subjects played the Low-game. In the High-treatment, subjects played the High-game. Five sessions were conducted.

Upon arriving at the lab, subjects were checked-in and randomly assigned to individual computer carrels (the computer software was programmed using ECONPORT). Half of the subjects found high treatment instructions when they arrived at their carrel and the other half found low treatment instructions. The instructions are available in the appendix.

After reading the instructions on their own, the experimenter answered any questions subjects had privately. The same experimenter was present at each of the sessions. After all the questions had been answered the experiment began. Subjects were randomly assigned by the computer to be either "Player 1" or "Player 2" for the duration of the experiment.

Our games are complicated enough that we thought it wise to let each subject play several times, to allow for some learning and possible gravitation towards equilibrium. At the same time, to maintain the one-shot nature of the interaction presumed by the theory and to avoid creating a repeated game we employed a random-matching format. In each treatment subjects played the game for 5 rounds. In each round each subject was randomly and anonymously matched with one of the other players in their group. All of this information was given to subjects in the instructions.

Subjects recorded their per-round payoff on a summary sheet and were privately paid their cumulative profit at the end of the session. No exchange rate was used. Sessions typically lasted about 30 minutes. No subject participated in more than one session.

5.3 Results

The theoretical analysis suggests that subjects' choices would gravitate towards strategy profile $((Out, X), A)$ in the High-game, and towards strategy profile $((In, Y), B)$ in the Low-game to the extent that the Case (i) VE is relevant. Comparing these two strategy profiles we get the across-treatment

prediction that *every choice should flip*. We accordingly perform three one-sided tests to examine whether each of the respective choices In , B , and Y occur more frequently in the High-treatment than in the Low-treatment.

Taking a conservative approach to the data analysis, we average the number of In , B , and Y observations for each group at every session. This gives us a total of five independent observations at each of the three information sets for each treatment. Since the number of independent observations is small with this approach, we employ non-parametric statistical tests.

At each of the three information sets, we use the Mann-Whitney test (see Siegel & Castellan 1988). We conduct three separate tests to determine whether the two treatments have the same mean percentage of In , B , and Y moves. For each test, the alternative hypothesis is that the mean percentage is higher for the Low-treatment. This gives us three directional tests for our research hypotheses.

We present the results from the different stages of the game in ‘backward’ order, starting with the stage after Player 1 has chosen In and Player 2 has chosen A . Player 1 now has the choice of X or Y . Recall that the key difference between the two treatments as regards material payoff occurs at this stage: By choosing Y rather than X player 1 gives up a material payoff of 1 in both treatments, while player 2’s material payoff is thereby reduced (from 9 to 2) in the Low-treatment and increased (from 9 to 10) in the High-treatment. Our research hypothesis at this stage is that *the mean percentage of Y choices is higher in the Low-game than in the High-game*. The following table records mean percentage data for the 5 independent sessions:

Final Stage Choices (Fraction Y):

Treatment	Session 1	Session 2	Session 3	Session 4	Session 5
Low	0.1250	0.4444	0.2500	0.5714	0.6000
High	0.000	0.0000	0.0000	0.0000	0.0000

A casual look at the data confirms the willingness of subjects to engage in costly punishing once play had reached the third stage. Under the null, the probability of observing a sample as extreme as this one is 0.0027. We therefore clearly reject the associated null. This willingness to punish, even to the detriment of ones’ own payoff, after player 2 chose action A supports the idea of a negative reciprocity motivation.

The second stage of the game is when player 2 chooses B or A , following player 1's choice of In . Our research hypothesis at this stage, following the discussion in sections 4.3 and 5.1, is that *the mean percentage of B choices is higher in the Low-game than in the High-game*. The following table records mean percentage data for the 5 independent sessions:

Second Stage Choices (Fraction B):

Treatment	Session 1	Session 2	Session 3	Session 4	Session 5
Low	0.0000	0.2500	0.4286	0.2222	0.6000
High	0.0000	0.1111	0.1429	0.2000	0.0000

Under the null, the probability of observing this sample, or one as extreme, as this one is 0.0362. We thus reject the null. In other words, we find support for the idea that conditional on Player 1 playing In , the efficient equal-split is more likely in the Low-game than the High-game.

At the first stage player 1 chooses whether or not to trust player 2; In or Out . In the Low-game, player 1 knows he has a punishment mechanism if player 2 chooses A . Our research hypothesis, following the discussion in sections 4.3 and 5.1, is that *the mean percentage of In choices is higher in the Low-game than in the High-game*. The following table records mean percentage data for the 5 independent sessions:

Root Choices (Fraction In):

Treatment	Session 1	Session 2	Session 3	Session 4	Session 5
Low	0.5333	0.8000	0.9333	0.6000	0.9333
High	0.2667	0.6000	0.4667	0.3333	0.3333

Under the null hypothesis that the two samples come from the same distribution, the probability of observing this outcome, or one that is more extreme, is 0.0102. We therefore reject the null. It is plain that in all five sessions the mean percentage of In choices was higher in the Low-treatment than in the High-treatment.

We noted in section 3.4 that to the extent that the miserable VE described there would have been relevant to the Low-game, negative reciprocity could have been an important motivational force even if there wouldn't have been

much of a difference in the nature of play between the High-game and the Low-game. In light of the data, this point now seems moot. All in all, we take the support for our research hypotheses as reinforcing the idea that negative reciprocity can mitigate hold-up mainly in cases where the investing party maintains the residual rights of control.

6 Concluding remarks

The back cover of the *JPE* once recalled a hold-up story about a rich woman in Savannah where, between the lines, we see negative reciprocity at work:⁹

Some years ago she ordered a pair of iron gates for her house. They were designed and built especially for her. But when they were delivered she pitched a fit, said they were horrible, said they were filth. “Take them away,” she said, “I never want to see them again!” Then she tore up the bill, which was for \$1,400 – a fair amount of money in those days.

The foundry took the gates back, but didn’t know what to do with them ... there wasn’t much demand for a pair of ornamental gates exactly that size. The only thing they could do was sell the iron for its scrap value. So they cut the price from \$1,400 to \$190. Naturally, the following day the woman sent a man over to the foundry with \$190, and today those gates are hanging on her gateposts where they were originally designed to go.

The story may seem puzzling. Why would the woman send a man to the foundry rather than just make a take-it-or-leave-it offer herself? Part of the answer may be that she feared a counter-offer, but another part is that she might otherwise irritate the foundry’s owner who may retaliate by refusing to sell her the gate. On this interpretation, we thus have a situation where a proper understanding of an economic outcome involves reference to negative reciprocity. And if we modify the situation to make the foundry less naive, i.e., so that they could see through the woman’s ploy, the situation would structurally resemble our Example 1, or our Low-game!

⁹See *Journal of Political Economy* 107(1), February 1999. The excerpt is from John Berendt’s 1994 novel *Midnight in the Garden of Good and Evil*. It was suggested to the *JPE* by Oliver Hart, and to us by Tore Ellingsen.

Classical hold-up theory typically assumes that the involved parties selfishly maximize own income. We have argued that this perspective may be to limited; negative reciprocity may plausibly play a role too. Injured parties may have an inclination to strike back if they are treated badly (even if this is costly), and if this is anticipated the problems due to hold-up are mitigated. We have shown, however, that it would be premature to draw the blanket conclusion that hold-up is not a serious concern. Rather, this depends in predictable ways on details of the situation. Namely, hold-up is a less serious concern if the investing party retains residual rights of control than if the other party does. This conclusion is supported by a D&K-based theory of negative reciprocity which we apply to two hold-up games (which vary the residual right of control), and through a related experimental test.

Under certain conditions our conclusions accord well with those that come out of traditional hold-up analysis. If one assumes (as we did not) that renegotiations take the form of Nash bargaining, then if the non-investing party holds the residual rights of control he has a favorable threat point which however serves him badly since the other party may shun a deal for fear of hold-up. Assuming Nash bargaining and incorporating negative reciprocity may thus have similar consequences, a fascinating insight since Nash's bargaining theory is not motivated with reference to vengeance. To properly gauge the seriousness of hold-up one may independently assess how details of an economic situation affect bargaining power as well as the incentives for decision makers inclined to get even.

The insights of this paper may matter not only to theorists, but also to practitioners who conduct industry analysis with the aim of assessing optimal responses to market conditions. Evaluating hold-up problems (upstream and downstream) may be important to schemata such as "Porter's Five Forces".¹⁰ We have not seen any reference in strategy textbooks to negative reciprocity, and its link to residual rights of control.

¹⁰See Porter (1980) or, for more recent textbook guidance that devotes considerable attention to hold-up, Besanko, Dranove, Shanley & Schaefer (2007; pp. 123-130). See also Besanko et al's scorecard items that concern "relation-specific investments" in the appendix to chapter 10, and question 10 in their chapter 3 which inspired our Examples 1 and 2 although we added the focus on residual rights of control.

7 References

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