Investing in a Relationship*

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March 2013

Abstract

A principal can make an upfront investment towards a repeated relationship with an agent, but the agent may appropriate the returns through ex-post bargaining. I study how this hold-up problem and efficiency depend on the contracting environment. When investment returns are observable, informal contracting environments ex post can be more efficient as they induce higher investment ex ante: the principal invests not only to generate direct returns, but also to improve relational incentives. Unobservability of returns increases the principal's ability to appropriate the returns, but reduces parties' ability to improve incentives. The optimal control of information depends on bargaining power.

JEL: C73, D82, L14

Keywords: ex-ante investments, hold-up problem, relational contracts, incomplete information, bargaining power

*I thank Yeon-Koo Che, Jean-Etienne de Bettignies, Wouter Dessein, Bob Gibbons, Oliver Hart, Ben Hermalin, Arijit Mukherjee, Steve Tadelis, Joel Watson, Ralph Winter, Jan Zabojnik, and seminar participants at MIT Sloan, Michigan State, Rochester Simon, UBC Sauder, and the Queen's School of Business for helpful comments.

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1 Introduction

Hold-ups arise when a party makes a relationship-specific investment that is not contractible. Depending on the allocation of bargaining power, her trading partner may then be able to appropriate the gains from the sunk investment, meaning that, ex ante, the party will invest at less than the socially efficient level.

The hold-up problem has been extensively studied in economics.[1] The literature however has considered hold-ups in the context of a single bilateral exchange, where some quantity of a good is traded following the investment. In reality, specific investments are often made at the beginning of a repeated, bilateral relationship, where ongoing effort must be induced for trade in each period following the investment. For example, consider a firm that invests in production assets to be used by workers, or a distributor that invests in specialized facilities to market a manufacturer's product. In each period after the investment is made, the parties negotiate a compensation for the agent (workers, manufacturer), and the agent exerts effort which generates output for the principal. The initial investment increases the productivity of the relationship; however, because the parties bargain after the investment is sunk, the investor may have to share the returns with the other party.

This paper studies the hold-up problem associated with an investment that takes place at the start of a repeated, principal-agent relationship. A natural question here is how investment and efficiency are affected by the contracting environment. The situation just described is rather straightforward if the agent's performance is contractible and the returns to the initial investment (i.e., total output) are observable. In such a case, first-best effort is implemented in each period in which the parties trade (under risk neutrality), but, unless the investing party has all the bargaining power, the initial investment is too low. I investigate how the results change when the agent's performance is noncontractible, so effort incentives are relational, and when the gains from the upfront investment are not commonly known.

[1] See Williamson (1975), Klein, Crawford, and Alchian (1978), Grout (1984), and Tirole (1986) for classical analyses, and Schmitz (2001) and Che and Sákovics (2008) for surveys. More recent work is discussed below.

The purpose of this paper is twofold. The first is to show how different contracting settings that are common in the real world may result in different levels of investment and efficiency. Because formally enforced contracts are typically unable to cover all relevant aspects of an agent's performance, parties often rely on informal incentives: the firm promises the workers a bonus for high production; the distributor promises the manufacturer a high price for high quality. These promises are not enforced by law but by the ongoing relationship between the parties. Likewise, the returns to a party's investment are rarely fully observable: workers cannot perfectly assess the firm's net profits; the manufacturer has incomplete information about the realized value to the distributor's facilities. Even when parties can observe their partner's investment, they may not perfectly observe the realized benefits.

The second goal is to understand how a contracting environment may be optimally shaped to induce high investment and efficiency. Parties to a relationship may be able to influence the scope of formal incentive contracts, for example through investing in monitoring technologies, or the extent to which information about the gains from their investments is available, for example through the use of audits or privacy rights. Previous work has noted that controlling the flow of information may be a worthy alternative to controlling bargaining power in dealing with the hold-up problem (see Gul 2001). Here I show that the optimal control of information critically depends on the nature of incentive contracts and the parties' bargaining powers.

The model considers a risk-neutral principal and agent who can trade for infinitely many periods. Before trade starts, the principal makes an investment that generates stochastic, fully persistent returns in each period in which the parties trade, but which has no value outside the relationship. Contracting is not feasible at this stage.[2] After the investment is made, each party receives the bargaining power with some positive probability. In each subsequent period, the party with the bargaining power makes a take-it-or-leave-it offer to the other,[3] specifying an enforceable fixed wage and a discretionary performance-contingent

[2]Pre-investment contracting may be particularly difficult when the investment is in new technologies. For an interesting example, see Duhigg and Bradsher (2012) on how a Chinese company became Apple's supplier after investing in glass screens for the iPhone.

[3]This is the simplest noncooperative bargaining game that, in a setting of complete information, is

payment for the agent. If the offer is accepted, the agent privately chooses effort, which determines his performance. The principal's output in each period depends on the returns to the initial investment and the agent's performance in that period.

As is well known, the set of subgame-perfect, (constrained) Pareto-optimal equilibria in repeated games can be large. This is especially problematic for the study of bargaining; absent sufficient structure, the allocation of bargaining power is meaningless. Following a large strand of the literature, I thus focus on a subset of the Pareto-optimal equilibria by placing restrictions on what parties can do in every contingency. As in Halac (2012), I assume the relationship may end if a party reneges on a promised payment, but remains on the Pareto-optimal frontier otherwise.[4] Thus, if information is complete, the party who makes the offers appropriates all the rents, including the returns to the investment.

I first show that when the returns to the initial investment are observable, the inability to formally contract on performance leads to higher investment, and possibly to higher overall efficiency. The logic is simple. Ex post, given a sunk investment, a relational contract induces an inefficiently low level of effort by the agent—while incentives would be first-best under contractible performance, relational incentives must be self-enforcing, and are thus limited by the value of the relationship.[5] Now, ex ante, this inefficiency in the provision of effort incentives helps reduce the inefficiency caused by the hold-up problem in the provision of investment incentives—because investment increases the expected value of the relationship, a higher investment benefits the principal (if she makes the offers) not only by increasing expected investment returns, but also, indirectly, by relaxing the enforcement constraint and increasing effort. Hence, the principal invests more when incentives are relational, and if investment returns are sufficiently important, total surplus results higher.

I next study the effects of investment returns being unobservable. Suppose the agent does

equivalent to the generalized Nash bargaining solution.

[4]That is, I postulate that a failure to honor a promised payment may lead to conflict and breakup, while an unexpected investment decision, an unexpected offer, or a rejection is not a credible excuse to walk away or impose similar punishments. See Section 5 for a discussion.

[5]See, among others, MacLeod and Malcomson (1989) and Levin (2003).

not observe whether the principal's investment has been highly successful and generates high returns in each period, so the principal is a "high type," or the investment has been less successful and generates low returns, so the principal is a "low type." I show that unless the future is heavily discounted, the agent cannot induce the principal types to separate when he makes the offers, as the high type wants to pretend to be a low type to appropriate future rents. Unobservability of returns then eliminates the hold-up problem: the agent cannot capture the returns to the principal's investment when he is unable to observe the realized returns. However, when incentives are relational, unobservability also weakens, and may even eliminate, the effects of investment on effort: the agent's effort responds less to an increase in the value of the relationship when the agent is unable to observe the realized value. I show that if the agent's bargaining power is high (i.e., the agent is likely to make the offers), the first effect dominates and efficiency increases when the gains from the investment are unobservable to the agent. Instead, if the principal's bargaining power is high, the latter effect dominates and efficiency goes down.

The analysis highlights the interaction between contracting, information, and bargaining. Absent contracting constraints, a principal's benefits from investing are the direct returns that the investment generates. The principal then invests more the less the agent can expropriate ex post, that is, when the agent cannot assess the gains from the investment or his bargaining power is low. When contracting constraints are present, on the other hand, investment also benefits the principal by increasing her commitment to the relationship, and relaxing these constraints as a result. Investment acts as a form of Williamson (1983)'s hostage giving: by investing, the principal gives a hostage (higher relationship value) as a means of committing to not renege on promises to make payments. This improves investment incentives and can increase total surplus; however, information has different effects here too. Private information increases the principal's ability to appropriate realized returns, but now it also reduces the parties' ability to relax contracting constraints. The optimal control of information depends on the net effect, and consequently on the parties' bargaining strengths.

Related literature

Several papers study how the hold-up problem depends on the information structure. Gul (2001) shows that the hold-up problem disappears when investment is unobservable and the noninvesting party makes frequently repeated offers. Different from the model below, Gul assumes that returns are a deterministic function of investment, so what is unobservable in his model is the investment itself. Hermalin and Katz (2009) and Skrzypacz (2005) consider an observable investment with stochastic, unobservable returns like I do; however, the former considers a static framework and the latter focuses on specific distortions that arise when investment affects the support of the distribution of returns. More importantly, none of these papers considers a principal-agent relationship nor studies relational contracting.

Within the relational contracts literature,[6] Levin (2003) characterizes optimal relational contracts under different forms of nonpersistent private information, including moral hazard as featured in the model below. Halac (2012) studies relational contracting when parties also have persistent private information about outside payoffs. The model is related to the setup with unobservable returns considered here; importantly, however, that model assumes an exogenous distribution of types, whereas here I allow for an upfront investment through which the principal endogenously chooses that distribution. To my knowledge, upfront investments in long-term relationships and their interaction with ex-post effort constraints has only been studied in Ramey and Watson (1997, 2001). Unlike the present paper, these articles focus on the effects of market frictions in matching markets, and do not consider a principal-agent setting nor study asymmetric information about the returns to investment.

Finally, the paper relates to previous work on the interaction between formal and informal contracts. Baker, Gibbons, and Murphy (1994) show that the presence of effective verifiable measures of performance can render optimal relational contracts infeasible because it improves a party's payoff after reneging.[7] In Bernheim and Whinston (1998), when some

[6] See MacLeod (2007) and Malcomson (2010) for surveys.

[7] Similarly, in Kranton (1996), large markets with low search costs can destroy efficient reciprocal-exchange agreements because they make the punishment for reneging too low.

aspects of performance are nonverifiable, parties can benefit from leaving other aspects informal as well because that gives them recourse if a party reneges. In my model, the existence of verifiable measures of performance may also lower efficiency, although not because it increases a party's incentives to renege, but because it lowers a party's incentives to invest in the relationship. Note also that in these papers, relaxing the enforcement constraint is always beneficial; instead, here I show that it may cause investment and efficiency to fall.

Section 2 presents the model. Section 3 considers a benchmark with contractible performance. Section 4 studies relational incentive contracts when investment returns are observable and when they are unobservable. Section 5 analyzes complementarities between investment and effort and discusses the restrictions on strategies. Section 6 concludes.

2 The model

2.1 Setup

Consider a risk-neutral principal (she) who can trade with a risk-neutral agent (he) for infinite periods. Both parties have the same discount factor $\delta \in (0, 1)$. Before the relationship starts, the principal can make an investment that generates returns for the principal in each period in which the parties trade. Contracting is not feasible at this stage. The timing is as follows:

- In period $t = 0$, the principal chooses investment $I \in [0, \bar{I}]$ at private cost $k(I)$, where $k(0) = 0, k'(\cdot) > 0, k''(\cdot) > 0$. This investment choice is observable. Then both the principal and the agent (Section 4.1) or only the principal (Section 4.2) observe the investment success, $\theta \in \{\ell, h\}$. If $\theta = \ell$, investment returns are $r_t = \underline{r} \geq 0$ in each period t in which the parties trade; if $\theta = h$, returns are $r_t = \bar{r} > \underline{r}$. The probability that $\theta = h$ given investment I is $p(I) \in [0, 1)$, where $p(0) = 0$, $p'(\cdot) > 0, p''(\cdot) \leq 0$. If the parties do not trade, returns are zero.

- At the beginning of period $t = 1$, the allocation of bargaining power is exogenously

determined for $t = 1, 2, ...$ With probability $\lambda \in [0, 1]$ the principal receives the bargaining power, and with probability $1 - \lambda$ the agent does. The superscript $i \in \{A, P\}$ indicates the party who has received the bargaining power.

- In each period $t = 1, 2, ...$, the party with the bargaining power makes a take-it-or-leave-it offer to the other. The other party can accept or reject, where $d^j \in \{0, 1\}$, $j \in \{A, P\}$, denotes this decision. If the offer is accepted, the agent chooses effort $e_t \in [0, \bar{e}]$ at private cost $c(e_t)$, where $c(0) = 0, c'(\cdot) > 0, c''(\cdot) > 0$; this choice is the agent's private information. The agent's effort stochastically determines his performance, $q_t \in \{\underline{q}, \bar{q}\}$. The probability that $q_t = \bar{q}$ given effort e is $f(e) \in (0, 1)$, where $f'(\cdot) > 0, f''(\cdot) \leq 0$.[8] The agent's performance is observed by both the principal and the agent, but it cannot be verified by a third party. Finally, the principal receives output $y_t = r_t + q_t$.[9]

  If the offer is rejected, the principal and the agent receive their outside options, $\bar{\pi}$ and $\bar{u}$ respectively, in the current period (and investment returns are zero). If at any point the relationship ends, they receive their outside options in all periods from then on.

It is worth noting that the noncooperative bargaining game above leads to the generalized Nash bargaining solution if information is complete. That is, for the case where investment returns are observable, the results are unchanged if one assumes that in each period the parties split the gains from trading with each other with shares λ and $1 - \lambda$. Specifying a bargaining game, however, is necessary to deal with the case of incomplete information.

An offer is a compensation package for the agent, with the payoff to the principal being the difference between the surplus and the payment to the agent. The agent's compensation consists of a fixed wage w_t and a performance-contingent bonus b_t, where, without loss of generality, $b_t \in \{\underline{b}_t, \bar{b}_t\}$ corresponding, respectively, to $\underline{q}, \bar{q}$; $\underline{b}_t \leq 0$ and $\bar{b}_t \geq 0$. When not

[8] These conditions imply that the first-order approach for deriving the optimal contract is valid: the agent's incentive compatibility constraint for effort can be replaced with the first-order condition of his optimization problem.

[9] To simplify the analysis, I assume that investment increases the productivity of effort without affecting its marginal product. This allows for a cleaner characterization, as first-best effort and investment are then independent. See Section 5 for the case where investment and effort are complements.

confusing, a contract $\{w, b\}$ is simply denoted by b. The fixed wage is formally enforced, but, because performance is nonverifiable, the bonus is not. If $b_t > 0$, the principal has the decision whether to honor or renege on the bonus payment at the end of period t; if $b_t < 0$, the agent has this decision. (There is no limited liability.) Total compensation is denoted by W_t, where $W_t = w_t + b_t$ if contingent payments are honored and $W_t = w_t$ if they are not.

The ex-post per-period expected surplus in $t = 1, 2, ...$ given realized state θ and effort e is $s(\theta, e) \equiv \mathbb{E}[y - c|\theta, e] = r(\theta) + \mathbb{E}[q - c|e]$. I assume that the efficient levels of investment and effort are both strictly positive, and that effort is essential but high returns are not: $\max_e s(\ell, e) > \bar{\pi} + \bar{u} > s(h, 0)$. I also assume that the whole investment must be made in period $t = 0$, before a trading relationship is started.[10]

I multiply expected lifetime payoffs by $(1 - \delta)$ to express them as per-period averages. The principal and agent's expected payoffs at time t are, respectively,[11]

$$\begin{aligned}
\pi_t &= (1-\delta)\mathbb{E}\sum_{\tau=t}^{\infty}\delta^{\tau-t}\Big\{\mathbb{1}_\tau(\bar{\pi} - k(I)) + (1-\mathbb{1}_\tau)\big[d_\tau(y_\tau - W_\tau) + (1-d_\tau)\bar{\pi}\big]\Big\}, \\
u_t &= (1-\delta)\mathbb{E}\sum_{\tau=t}^{\infty}\delta^{\tau-t}\Big\{\mathbb{1}_\tau\bar{u} + (1-\mathbb{1}_\tau)\big[d_\tau(W_\tau - c(e_\tau)) + (1-d_\tau)\bar{u}\big]\Big\},
\end{aligned}$$

where $\mathbb{1}_\tau$ is equal to one if $\tau = 0$ and zero otherwise. The expected surplus is $S_t = \pi_t + u_t$.

2.2 Equilibrium concepts

In Section 4.1, where investment returns are observable and thus information is complete, I characterize Pareto-optimal contracts using the concept of perfect public equilibrium (PPE).[12] In Section 4.2, investment returns are not observable to the agent, so $\theta \in \{\ell, h\}$ is the principal's type (private information), and the agent forms a belief about this type. I characterize Pareto-optimal contracts in this setting using the concept of perfect public Bayesian equi-

[10] This assumption captures two ideas: first, an initial investment is necessary for trade to be feasible; second, investment is not fully divisible, and once an investment is chosen, adjustments are more costly.

[11] To simplify notation, I assume that in period $t = 0$, making an investment does not prevent the principal from receiving her outside option.

[12] See Fudenberg, Levine, and Maskin (1994).

librium (PPBE), which is the natural extension of PPE for dynamic Bayesian games.

A PPBE is a set of public strategies and posterior beliefs such that the strategies form a Bayesian Nash equilibrium in every continuation game given the posterior beliefs, and the beliefs are updated according to Bayes' rule whenever possible. Following Fudenberg and Tirole (1991), I require that beliefs be updated using Bayes' rule not only on the equilibrium path but also in continuation games reached with zero probability. Because Bayes' rule does not apply when beliefs are degenerate, an assumption such as Assumption 1 is needed (see Rubinstein 1985):

Assumption 1. *If, at any point, the agent's posterior belief assigns probability one to a given type, then his beliefs continue to do so no matter what happens.*

Even under the requirements of PPE and PPBE, the set of Pareto-optimal equilibria is very large. Inefficient levels of trade, as well as no-trade outcomes, can be supported in equilibrium, and thus be used by the parties as "punishments" for different behaviors. I concentrate on a subset of the Pareto-optimal equilibria by imposing restrictions on strategies and, hence, on these punishments:

Assumption 2. *If a party reneges on a payment at time t, the relationship ends with some probability $1 - \gamma_{t+1} > 0$ at time $t + 1$, and continues on the Pareto-optimal frontier with probability γ_{t+1}. If no party reneges, the relationship continues on the Pareto-optimal frontier with probability one.*

In Section 5, I show that the first part of this assumption (first sentence) is without loss of generality, and discuss the consequences of relaxing the second part. Importantly, in a setting where neither formal nor relational contracting is feasible at the investment stage, Assumption 2 ensures that investment incentives cannot be provided through variation in continuation payoffs, and, under complete information, the party who makes the offers appropriates all the rents.

2.3 First best

Suppose that pre-investment contracting is feasible and the investment success θ and output y_t are verifiable. Maximizing the total expected surplus at time $t = 0$ gives that the first-best levels of investment and effort are I^{fb}, e^{fb}, where (assuming $I^{fb} < \bar{I}$, $e^{fb} < \bar{e}$)

$$\begin{aligned} \frac{1-\delta}{\delta} k'(I^{fb}) &= p'(I^{fb})(\bar{r} - \underline{r}), \\ c'(e^{fb}) &= f'(e^{fb})(\bar{q} - \underline{q}). \end{aligned} \tag{1}$$

3 Contractible performance benchmark

As a benchmark, suppose that the agent's performance in each period is verifiable, so the parties use a formally enforced contract to provide effort incentives. Given risk neutrality, there exists a simple contract that implements first-best effort e^{fb}; for example, this contract specifies bonus payments $\underline{b} = 0$, $\bar{b} = \bar{q} - \underline{q}$. The proposed fixed wage depends on which party receives the bargaining power, and on whether total output—namely, the returns to the initial investment—can be observed by the agent.

Suppose first that the agent can observe how successful the principal's investment was, so he knows what the investment returns will be in each period. Then regardless of which party $i \in \{A, P\}$ receives the bargaining power, this party will capture all the surplus from the relationship, including the returns to the initial investment. Hence, given a sunk investment I and realized state θ, the principal proposes $w^{ofP} = \bar{u} - \mathbb{E}[b^{of} - c|e^{fb}]$ if she makes the offers, and the agent proposes $w_\theta^{ofA} = \mathbb{E}[y - b^{of}|\theta, e^{fb}] - \bar{\pi}$ if he makes the offers, where the superscript "of" stands for observable investment success and formal incentive contracting. Given this, the principal's investment decision problem at time $t = 0$ is:

$$\max_I \quad \lambda\delta\big[p(I)s(h, e^{fb}) + (1 - p(I))s(\ell, e^{fb})\big] - (1-\delta)k(I).$$

The first-order condition is:

$$\frac{1-\delta}{\delta}k'(I^{of}) = \lambda p'(I^{of})(\bar{r} - \underline{r}). \tag{2}$$

While the principal always pays the cost of investment, she captures the returns only when she obtains the bargaining power. Comparing equations (1) and (2), it thus follows that for $\lambda < 1$, the principal invests at an inefficiently low level. That is, a hold-up problem arises if ex post the agent may be able to appropriate the gains from the principal's sunk investment.

Suppose next that the agent cannot observe how successful the principal's investment was nor the realized returns in each period, so $\theta \in \{\ell, h\}$ is the principal's type. The agent observes the investment I and thus knows that the principal is a high type with probability $p(I)$ and a low type with probability $1 - p(I)$. As above, if the principal makes the offers, she captures all the surplus from the relationship; the question here is whether the agent can also capture all the surplus when he makes the offers. Note that to appropriate the investment returns, the agent must induce the principal types to separate.

It can be shown that if the agent induces separation of types, he does so through a rejection: one type of principal rejects while the other accepts the agent's offer.[13] Consider then the conditions for rejection. Suppose that the agent proposes a contract $\{w^A, b^A\}$ with expected payment $\mathbb{E}[W^A|e^{fb}]$, and the principal's type is fully revealed through rejection. Because the low type has a lower value of the relationship than the high type, it must be the low type who rejects, while the high type accepts. This means that if the offer is rejected, the agent proposes $\{w_\ell^{ofA}, b^{of}\}$ with expected payment $\mathbb{E}[W_\ell^{ofA}|e^{fb}] = \mathbb{E}[y|\ell, e^{fb}] - \bar{\pi}$ from then on. If the offer is accepted, the agent proposes $\{w_h^{ofA}, b^{of}\}$ with $\mathbb{E}[W_h^{ofA}|e^{fb}] = \mathbb{E}[y|h, e^{fb}] - \bar{\pi}$ from then on. Thus, the low type will indeed reject only if

$$(1-\delta)\mathbb{E}[y - W^A|\ell, e^{fb}] + \delta\bar{\pi} \leq \bar{\pi},$$

[13] This follows from the fact that if the agent offers a menu of contracts, an equilibrium where the two types separate by accepting different contracts does not exist. See the Appendix.

and the high type will indeed accept only if

$$(1-\delta)\mathbb{E}[y - W^A|h, e^{fb}] + \delta\bar{\pi} \geq \bar{\pi} + \delta(\bar{r} - \underline{r}).$$

Combining these two conditions, full separation of types through rejection is feasible only if

$$\delta \leq \frac{1}{2}.$$

This condition is also necessary for partial separation through rejection. In particular, if this condition does not hold, an equilibrium where the high type mixes between accepting and rejecting and the low type rejects does not exist.[14] A simple Coase-conjecture-like argument (Coase 1972) shows why. Under such strategies, after observing a number of rejections, the agent's belief becomes low enough that, if the principal again rejects, the agent optimally proposes $\{w_\ell^{ofA}, b^{of}\}$ from then on. But then, when that belief is reached, the high type rejects any offer that the low type rejects, so the agent proposes $\{w_\ell^{ofA}, b^{of}\}$ at that point. Continuing with this reasoning gives that the agent proposes $\{w_\ell^{ofA}, b^{of}\}$ in all periods.

Therefore, unless the future is heavily discounted, the agent cannot induce separation of types when he makes the offers: the high type has incentives to mimic the low type and reject in the present to enjoy rents in the future. As a consequence, the high type always keeps her rents, and the hold-up problem disappears.

Proposition 1. *Suppose that performance is contractible. Investment and total surplus are strictly below first-best for $\lambda < 1$ if the investment success is observable, while they are first-best if the investment success and returns are unobservable to the agent and $\delta > 1/2$.*

[14] An equilibrium where the high type accepts and the low type mixes between accepting and rejecting is not feasible either, as the high type would want to reject.

4 Relational incentives

Consider now a setting where the agent's performance in each period is observable but not verifiable, so incentives for effort must be self-enforcing.

4.1 Observable investment returns

Suppose first that the agent can observe how successful the principal's investment was, so he knows what the investment returns will be in each period. It follows from Levin (2003) that an optimal self-enforcing contract is stationary: given that state θ realized and party i received the bargaining power, in every period on the equilibrium path, $e_t = e(\theta)$, $(\underline{b}_t, \bar{b}_t) = (\underline{b}^i(\theta), \bar{b}^i(\theta))$, and $w_t = w^i(\theta)$. Thus, the principal and agent's expected payoffs in any period $t = 1, 2, ...$ are

$$\begin{aligned} \pi^i(\theta) &= \mathbb{E}[y - W^i(q,\theta)|\theta, e(\theta)], \\ u^i(\theta) &= \mathbb{E}[W^i(q,\theta) - c|\theta, e(\theta)]. \end{aligned}$$

For the compensation schedule to be self-enforcing, neither party can wish to renege on a promised payment. Since, here, no party ever reneges in equilibrium, it is without loss to assume that a default leads to termination of the relationship with probability one, which is the worst punishment (Abreu 1988). A self-enforcing contract then satisfies

$$\begin{aligned} \delta\pi^i(\theta) &\geq (1-\delta)\bar{b}^i(\theta) + \delta\bar{\pi}, \\ \delta u^i(\theta) &\geq -(1-\delta)\underline{b}^i(\theta) + \delta\bar{u}. \end{aligned}$$

Depending on the allocation of bargaining power, the fixed wage is adjusted and slack transferred from one constraint to the other. The two conditions above can thus be combined into a single enforcement constraint, (E(θ)). Given realized state θ, the optimal incentive contract maximizes expected surplus subject to an incentive compatibility constraint for

effort and (E(θ)):

$$\max_{e(\cdot),\underline{b}(\cdot),\bar{b}(\cdot)} s(\theta, e) = \mathbb{E}[y - c|\theta, e(\theta)]$$

$$\text{subject to} \quad e(\theta) \in \arg\max_{e} \; f(e)(\bar{b}(\theta) - \underline{b}(\theta)) - c(e), \qquad (\text{IC}_A(\theta))$$

$$\frac{\delta}{1-\delta}(s(\theta, e) - \bar{\pi} - \bar{u}) \geq \bar{b}(\theta) - \underline{b}(\theta). \qquad (\text{E}(\theta))$$

The solution is denoted by e_θ^{or}, b_θ^{or}, where "*or*" stands for observable investment success and relational incentive contracting. Note that unlike under contractible performance, here the first-best level of effort may not be implementable, as bonus payments are discretionary and hence the enforcement constraint must be satisfied. The enforcement constraint is tighter the lower the discount factor and the higher the parties' outside options. For the analysis to be interesting, I assume that for $\theta \in \{\ell, h\}$, parameters are such that (E(θ)) binds but some bonus scheme is enforceable. Given that the party making the offers will capture all the surplus, the optimal contract implements an effort e_θ^{or} (below first-best level) by specifying b_θ^{or} with

$$\begin{aligned} \bar{b}_\theta^{or} &= \frac{\delta}{1-\delta}\tilde{\lambda}(s(\theta, e_\theta^{or}) - \bar{\pi} - \bar{u}), \\ \underline{b}_\theta^{or} &= -\frac{\delta}{1-\delta}(1-\tilde{\lambda})(s(\theta, e_\theta^{or}) - \bar{\pi} - \bar{u}), \end{aligned}$$

where $\tilde{\lambda}$ is equal to one if the principal has the bargaining power and zero otherwise. The wage is $w_\theta^{orP} = \bar{u} - \mathbb{E}[b_\theta^{or} - c|e_\theta^{or}]$ if the principal has the bargaining power and $w_\theta^{orA} = \mathbb{E}[y - b_\theta^{or}|\theta, e_\theta^{or}] - \bar{\pi}$ if the agent does.

It is clear that, given a sunk initial investment I and realized state θ, the inability to formally contract on performance reduces the ex-post expected surplus that the parties can generate. But, how does this affect the principal's ex-ante investment decision? At time

$t = 0$, the principal solves:

$$\max_{I} \quad \lambda\delta\big[p(I)s(h, e_h^{or}) + (1 - p(I))s(\ell, e_\ell^{or})\big] - (1 - \delta)k(I).$$

The first-order condition is:

$$\frac{1-\delta}{\delta}k'(I^{or}) = \lambda p'(I^{or})\Big[\bar{r} - \underline{r} + \Big(\mathbb{E}[q - c|e_h^{or}] - \mathbb{E}[q - c|e_\ell^{or}]\Big)\Big]. \tag{3}$$

As in the case of contractible performance, the principal captures the benefits from her investment only if she receives the bargaining power, with probability λ. But here, the marginal benefit of investment has two components. First, as above, there is a direct effect: a higher level of investment increases expected future returns. Second, there is now also an indirect effect: by increasing expected returns, investment increases the expected future value of the relationship, which relaxes the expected enforcement constraint and causes expected incentives and effort, and thus expected performance net of effort costs, to increase. (This effect is shown by the term in parenthesis on the right-hand side of equation (3), which is strictly positive.) As a result, comparing (2) and (3), it follows that the principal always invests more than when performance is contractible. In fact, comparing with equation (1), we see that the principal may invest more than the first-best level.

The difference in total expected surplus relative to the contractible performance benchmark is:

$$\begin{aligned} S^{or} - S^{of} \quad = \quad & \delta\Big[p(I^{or})\mathbb{E}[q - c|e_h^{or}] + (1 - p(I^{or}))\mathbb{E}[q - c|e_\ell^{or}] - \mathbb{E}[q - c|e^{fb}]\Big] \\ & + \Big[\delta(p(I^{or}) - p(I^{of}))(\bar{r} - \underline{r}) - (1 - \delta)(k(I^{or}) - k(I^{of}))\Big]. \end{aligned}$$

The first term in square brackets is the difference in surplus due to different effort levels. Because effort is inefficiently low when incentives are relational, this term is strictly negative. The second term in square brackets is the difference in surplus due to different investment

levels. Because investment is higher when incentives are relational, this term may be strictly positive.[15] Moreover, if the returns to investment are sufficiently important, this term may more than compensate for the first one, in which case total surplus is higher under relational contracts.

Proposition 2. *Suppose that the investment success is observable. Investment is higher when performance is noncontractible and thus incentives are relational than when performance is contractible. Moreover, there exist parameters, with* $0 < \lambda < 1$*, such that total expected surplus is also higher.*

Figure 1 illustrates this result with an example.[16] This proposition says that if pre-investment contracting is infeasible, agency relationships may be more efficient in environments where effective, verifiable measures of performance are not available, or legal institutions and thus formal contract enforcement are weak. Parties will then rely on relational contracts, where the constraints in the provision of effort incentives ex post increase the parties' incentives to invest in the relationship ex ante.

Proposition 2 also implies a substitution between investment in monitoring and investment in the relationship. That is, ex ante, the principal may choose either to invest in monitoring technologies to increase formal enforcement of incentive contracts, or to invest in the productive relationship, thus increasing relational enforcement of incentive contracts.[17] Proposition 2 shows that investing in the relationship may be preferred.

The literature on relational incentive contracts stresses that efficiency depends on how binding the enforcement constraint is. In particular, the higher the discount factor and the lower the parties' outside opportunities, the less tight this constraint, and the higher the levels of effort and total surplus that can be sustained (see, e.g., Levin 2003). A corollary of Proposition 2 is that this result may be reversed when ex-ante investments are important.

[15] This term may also be negative; this can occur if $I^{or} > I^{fb}$.

[16] See the proof of Proposition 2 for details.

[17] As in the case of productive investments, the principal may have to decide how much to invest in monitoring ex ante; making further investments or switching to formal contracts ex post may be more difficult, and parties may then face higher implementation costs.

Intuitively, as the enforcement constraint is relaxed and relational incentives become more efficient ex post, the indirect effect of investment on effort becomes smaller, so the principal's incentives to invest fall.

Corollary 1. *Suppose that the investment success is observable. Consider a change in parameters that relaxes the enforcement constraint and thus increases efficiency given a sunk investment (e.g., a decline in $\bar{\pi}+\bar{u}$). There exist parameters such that investment and overall efficiency fall following this change.*

An illustrative example is provided in Figure 2.[18]

4.2 Unobservable investment returns

Consider next the effects of the gains from the principal's investment being unobservable to the agent. Suppose the agent cannot observe how successful the principal's investment was nor the realized returns in each period, so $\theta \in \{\ell, h\}$ is now the principal's type. The agent observes the investment I and thus knows that with probability $p(I)$, the principal is a high type and returns under trade are $r_t = \bar{r}$, and with probability $1-p(I)$, the principal is a low type and returns are $r_t = \underline{r}$.

This setting is arguably more complex.[19] As shown above, when incentives are relational, effort depends on how valuable the relationship is. Now, when the gains from the investment are unobservable to the agent, the value of the relationship is not commonly known; hence, as I show next, effort depends on whether information about the value of the relationship is revealed, and on how this revelation of information occurs.

I relegate some parts of the formal analysis to the Appendix. Here, I focus on how the informational asymmetry, by affecting continuation play, affects the principal's investment,

[18] See the proof of Corollary 1 for details.

[19] This setting is similar to the one studied in Halac (2012), where the principal's outside option is her private information. An important difference is that, here, there is an initial investment stage and a potential hold-up problem. Through the initial investment, the principal chooses the probability with which her type is high instead of low, whereas this probability is exogenous in Halac (2012).

and how overall efficiency compares to the case of observable returns. The next lemma, which follows from the results in Halac (2012), simplifies the analysis.

Lemma 1. *Suppose that the investment success and returns are unobservable to the agent. If separation of types occurs in a Pareto-optimal equilibrium, it occurs through a rejection if the agent has the bargaining power, and through a default if the principal has the bargaining power. No separation occurs through the principal's choice of contract.*

Given Lemma 1, the case where the agent receives the bargaining power is analogous to that described in Section 3 for contractible performance. To induce separation of types, the agent must propose a contract that the high type is willing to accept while the low type rejects.[20] But, as shown, if the discount factor is high enough, the high type wants to pretend to be a low type to capture future rents, and separation of types is not feasible. As a result, the hold-up problem disappears. However, when incentives are relational, this also has implications for the agent's effort: if the agent can capture only the value of the relationship with the low type when he has the bargaining power, incentives in that case must correspond to the low type's symmetric-information incentives b_ℓ^{or}, and hence effort in each period is e_ℓ^{or}.

Lemma 2. *Suppose that the investment success and returns are unobservable to the agent, and the agent has the bargaining power. If $\delta > 1/2$, the agent cannot induce separation of types, and $\{w_\ell^{orA}, b_\ell^{or}\}$ is implemented in every period.*

Consider next the case where the principal receives the bargaining power. Here, in contrast with the case above, it is the low type who wants to misrepresent her type—she wants to pretend to be a high type to provide high-powered relational incentives to the agent.

[20]Note that when the agent has the bargaining power, no informal payments from the principal to the agent can be enforced; that is, $\bar{b} = 0$ in any contract. The argument is as follows. Suppose that a contract with bonus $\bar{b} > 0$ is implemented. Then the low type reneges (in finite time), as the low type's expected payoff within the relationship is weakly lower than $\bar{\pi}$. So it must be that the high type honors. Thus, if no default occurs, the agent learns that the principal's type is high, and offers contract $\{w_h^{orA}, b_h^{or}\}$ which gives the high type an expected payoff of $\bar{\pi}$. But then the high type also reneges, which gives a contradiction.

The principal's proposed contract may induce pooling or separation of types. Note that (given Assumption 2) the principal can always choose to act as if her type were low and obtain a payoff $\pi^P(\theta|b_\ell^{or}) \equiv s(\theta, e_\ell^{or}) - \bar{u}$, regardless of the agent's beliefs. Hence, if no separation is induced, $\{w_\ell^{orP}, b_\ell^{or}\}$ is implemented in each period, as this is the best the principal can do under no information revelation. Moreover, if separation is induced, both types's payoffs must be above $\pi^P(\theta|b_\ell^{or})$, so the separating equilibrium Pareto-dominates the pooling one.

By Lemma 1, we only need to consider separation through default, where both types of principal offer the same contract and one type reneges on the promised bonus payment while the other honors it. Also, for the purpose of this analysis, it is sufficient to consider separating equilibria in pure strategies, where the principal either honors or reneges with probability one and the relationship ends if she reneges.[21] Consider the conditions for default. Suppose that a contract $\{w^P, b^P\}$ is implemented and the principal's type is fully revealed through default. Because the low type has a lower value of the relationship than the high type, it must be the low type who reneges. This means that if no default occurs, $\{w_h^{orP}, b_h^{or}\}$ is implemented from then on. Thus, the high type will indeed honor only if

$$\delta\pi^P(h|b_h^{or}, 1) \geq (1-\delta)\bar{b}^P + \delta\bar{\pi}, \tag{E$_h$}$$

and the low type will indeed renege only if

$$\delta\pi^P(\ell|b_h^{or}, 1) \leq (1-\delta)\bar{b}^P + \delta\bar{\pi}, \tag{D$_\ell$}$$

where $\pi^P(h|b_h^{or}, 1) \equiv s(h, e_h^{or}) - \bar{u}$, and $\pi^P(\ell|b_h^{or}, 1)$ is the low type's continuation value when the agent believes that she is a high type with probability one. Note that, given such belief, the low type's optimal strategy is to renege on $\bar{b}_h^{or}$ when performance is high, so that:

$$\pi^P(\ell|b_h^{or}, 1) = s(\ell, e_h^{or}) - \bar{u} + \left[\frac{\delta f(e_h^{or})}{1-\delta(1-f(e_h^{or}))}(\bar{r} - \underline{r})\right].$$

[21] I discuss the case of mixed strategies in the Appendix.

Given the conditions for default, the next step is to determine whether the principal will offer a contract that induces default. As explained above, the principal must receive a payoff at least as large as her pooling payoff, $\pi^P(\theta|b_\ell^{or})$. Now, because the low type has a positive option to renege, her payoff under separation is always larger than $\pi^P(\ell|b_\ell^{or})$ if the high type's payoff is larger than $\pi^P(h|b_\ell^{or})$. Thus, we can concentrate on the high type's problem. Given a belief $p(I)$, the next program finds b^P, e^P that maximize the high type's expected payoff subject to an incentive constraint for effort (IC$_A$), the conditions for default (E$_h$), (D$_\ell$), and the agent's participation constraint, which is incorporated in the high type's payoff below:[22]

$$\max_{b^P,e^P} \ \pi^P(h|b^P,p) = \frac{(1-\delta)[s(h,e^P)-\bar{u}-f(e^P)(1-p(I))\bar{b}^P]+\delta f(e^P)\pi^P(h|b_h^{or},1)}{1-\delta(1-f(e^P))}$$

$$\text{subject to} \quad e^P \in \arg\max_e \ f(e)p(I)\bar{b}^P - c(e), \tag{IC$_A$}$$

$$\delta\pi^P(h|b_h^{or},1) \geq (1-\delta)\bar{b}^P + \delta\bar{\pi}, \tag{E$_h$}$$

$$\delta\pi^P(\ell|b_h^{or},1) \leq (1-\delta)\bar{b}^P + \delta\bar{\pi}. \tag{D$_\ell$}$$

Let b^{P*}, e^{P*} denote the solution. Then a Pareto-optimal equilibrium that induces separation of types exists if and only if $\pi^P(h|b^{P*},p) \geq \pi^P(h|b_\ell^{or})$, or equivalently,[23]

$$(1-\delta)(s(h,e^{P*})-s(h,e_\ell^{or}))+\delta f(e^{P*})(s(h,e_h^{or})-s(h,e_\ell^{or})) \geq (1-\delta)f(e^{P*})(1-p(I))\bar{b}^{P*}.$$

This condition says that the principal induces separation of types if and only if the benefits outweigh the costs when she is a high type. The benefits come from the ability to provide stronger incentives and generate a higher surplus when separation occurs. The costs are in the form of a compensation to the agent for the risk of default. If the probability that the principal is a high type $p(I)$ is high enough, the benefits exceed the costs and separation of types is induced. Otherwise, the high type prefers to offer the pooling contract $\{w_\ell^{orP}, b_\ell^{or}\}$.

[22]Note that when the principal has the bargaining power, no informal payments from the agent to the principal can be enforced; that is, $\underline{b} = 0$ in any contract.

[23]This condition is derived here under the restriction of pure strategies. However, as discussed in the Appendix, the analysis can be extended to mixed strategies without affecting the qualitative results.

Lemma 3. *Suppose that the investment success and returns are unobservable to the agent, and the principal has the bargaining power. There exists $\widehat{p} \in (0,1)$ such that if $p(I) \geq \widehat{p}$, the principal induces separation of types through default. If $p(I) < \widehat{p}$, no separation is induced and $\{w_\ell^{orP}, b_\ell^{or}\}$ is implemented in every period.*

Having solved for the continuation equilibria when the agent makes the offers (Lemma 2) and when the principal does (Lemma 3), I now turn to the principal's initial investment decision. In what follows, I assume $\delta > 1/2$. The principal's problem at time $t = 0$ is:

$$\max_I \quad \lambda\delta\big[p(I)\pi^P(h|b^{ur}, p) + (1 - p(I))\pi^P(\ell|b^{ur}, p)\big] + (1-\lambda)\delta p(I)(\bar{r} - \underline{r}) - (1-\delta)k(I),$$

where "ur" stands for unobservable investment success and relational incentive contracting. The analysis above shows that if the agent receives the bargaining power, or if the principal does but her investment implies a probability $p(I)$ low enough, no separation of types is induced. Hence, in this case, $\{w^{urP}, b^{ur}\} = \{w_\ell^{orP}, b_\ell^{or}\}$, and the principal's benefits from investing are $\bar{r} - \underline{r}$ regardless of bargaining power. It follows that the principal invests at first-best level; however, because the agent's effort is $e_\ell^{or} < e^{fb}$, total surplus is always strictly less than first-best. Furthermore, note that effort corresponds to that induced given a known low type, e_ℓ^{or}, regardless of the investment success. Thus, unlike in the contractible performance benchmark, here total surplus under unobservable returns may be strictly less than under observable returns. This result depends on the allocation of bargaining power: because the hold-up problem is eliminated, unobservability of returns increases efficiency when high bargaining power is on the agent's side (i.e., when λ is low), but, because the effects of investment on effort are also eliminated, unobservability of returns lowers efficiency when high bargaining power is on the principal's side (i.e., when λ is high).

Lastly, Lemma 3 shows that if the principal receives the bargaining power and her investment implies a probability $p(I)$ sufficiently high, separation of types is induced, with the low type reneging on a promised payment. In this case, the principal's ex-ante expected payoff

conditional on receiving the bargaining power, $p(I)\pi^P(h|b^{ur},p) + (1-p(I))\pi^P(\ell|b^{ur},p)$, is:

$$\frac{(1-\delta)[p(I)s(h,e^{ur}) + (1-p(I))s(\ell,e^{ur}) - \bar{u}] + \delta f(e^{ur})[p(I)(s(h,e_h^{or}) - \bar{u}) + (1-p(I))\bar{\pi}]}{1-\delta(1-f(e^{ur}))}.$$

From an ex-ante perspective, the rent that the principal makes when she is a low type and reneges is cancelled by the compensation for the risk of default that the principal must pay to the agent. Given an investment I, private information then reduces the principal's ex-ante expected payoff conditional on making the offers by lowering effort when she is a high type and requiring inefficient termination when she is a low type. The principal's ex-ante incentives to invest may be higher as a result; yet, as above, total surplus cannot be larger than under observable returns if the principal's bargaining power is high enough, as the principal invests efficiently in that case.

Proposition 3. *Suppose that the investment success and returns are unobservable to the agent and $\delta > 1/2$. Total expected surplus is always strictly below first-best. Moreover, there exists $\widehat{\lambda} \in (0,1)$ such that if $\lambda \leq \widehat{\lambda}$, total surplus is higher than when the investment success is observable, while if $\lambda > \widehat{\lambda}$, total surplus is lower.*

The analysis highlights the role of information and how it affects the value of repeated agency relationships. Limiting the flow of information can be a useful tool to increase ex-ante investment incentives if a hold-up problem is present and parties care enough about the future. However, limiting information can also hurt ex-post effort incentives and overall efficiency if commitment to the relationship is important. The results show that the net effect, and thus the optimal control of information, depend on the parties' bargaining powers.

5 Discussion

Below I extend the results to a setting where investment and effort are complements and discuss the restrictions on strategies.

5.1 Complementarities

The model assumes that investment increases the productivity of effort but not its marginal product. This formulation is consistent with many applications; for example, a firm's investment that lowers the fixed costs of production, for any quantity produced, or a distributor's investment that reduces the cost of transporting a manufacturer's product, for any quality of such product. Note that as assumed in the paper, in these examples and in many contracting settings, an agent's performance may be observable even when the principal's total profits, and thus the gains from her upfront investments, are not.

An alternative formulation is one where investment increases the marginal product of effort. For instance, let output be $y_t = q_t(1 + r_t)$.[24] Unlike above, in this case, first-best effort depends on the investment's success, so a higher investment leads to higher effort even if performance is contractible. Yet, while the analysis becomes more cumbersome, the main insights of the paper can be shown to remain unchanged. In particular, when the gains from the initial investment are commonly known, informal contracting settings ex post may increase overall efficiency by inducing higher investment ex ante.

Proposition 4. *Consider an alternative model where investment increases the marginal product of effort: $y_t = q_t(1 + r_t)$. Suppose that the investment success is observable. There exist parameters, with $0 < \lambda < 1$, such that total expected surplus is higher when performance is noncontractible and thus incentives are relational than when performance is contractible.*

The effects of the returns to the investment being unobservable to the agent are also as shown above. The main difference is that, here, an agent with bargaining power may be able to induce the principal types to separate either by accepting different contracts or through a rejection, and he may be able to do so for a discount factor larger than one half. However, in either case, separation still requires that the future be sufficiently discounted; otherwise, the high type of principal has incentives to mimic the low type. Therefore, if the parties

[24] Equivalently, let $y_t = q_t r_t$, but, since trade is profitable regardless of the realization of θ, assume $\underline{r}$ is strictly greater than zero.

care enough about the future, unobservability of returns eliminates the hold-up problem. At the same time, as in Section 4, unobservability reduces, or even eliminates, the effects of investment on effort. The net effect depends on the distribution of bargaining power.

Proposition 5. *Consider an alternative model where investment increases the marginal product of effort:* $y_t = q_t(1 + r_t)$. *Suppose that the investment success and returns are unobservable to the agent and incentives are relational. There exist* $\bar{\delta} \in (0, 1)$ *and* $\bar{\lambda} \in (0, 1)$ *such that for* $\delta > \bar{\delta}$*, total surplus is higher than when the investment success is observable if* $\lambda \leq \bar{\lambda}$*, while it is lower if* $\lambda > \bar{\lambda}$.

5.2 Strategies

The first part of Assumption 2 states that following a default, the parties end the relationship with positive probability, and continue on the Pareto-optimal frontier otherwise. This is without loss of generality: if a Pareto-optimal equilibrium exists, there exists a Pareto-optimal equilibrium that satisfies this assumption and gives the same expected payoffs to all the parties. This is immediate if no default occurs in equilibrium, as the worst punishment for default is then optimal. Now suppose the principal's type is unobservable to the agent and a default occurs in equilibrium. If trade continues with probability one after the default, the two types of principal would have the same incentives to renege; hence, assuming termination with some positive probability is without loss. Further, suppose that following default, the relationship ends with probability $1 - \gamma$ and continues on an inefficient path with probability γ. Then we can show that for some γ', there exists an equilibrium where, following default, the relationship ends with probability $1 - \gamma'$ and continues on an efficient path with probability γ', and where the parties' expected payoffs are weakly higher.

The second part of Assumption 2 states that, if no default occurs, the relationship always remains on the Pareto-optimal frontier. This means that the parties cannot end the relationship or switch to an inefficient level of trade following an unexpected investment

decision, an unexpected offer, or a rejection.[25] This assumption is not without loss; there exist Pareto-optimal equilibria with expected payoffs to the parties that cannot be replicated when this assumption is imposed.

The main motivation for assuming Pareto-optimal play provided no default has occurred is to consider situations where bargaining power matters. In particular, I am interested in studying situations where parties have to make investment decisions before they can negotiate with trade partners, and where, importantly, their gains from the investment depend on the outcome of those future negotiations. For example, a firm must decide how much to invest in production assets prior to contracting with workers, knowing that workers may later capture part of the benefits through wage bargaining. In such situations, parties' ex-post rents, and thus their ex-ante incentives to invest, naturally depend on the allocation of bargaining power. But in a repeated game where contracting is self-enforcing and Assumption 2 is not imposed, bargaining power needs not affect the distribution of rents—by threatening to cease trade following certain histories of play, any distribution of rents can be sustained. In fact, if threats can be made contingent on past investment, a party can always be given efficient incentives to invest. This results unrealistic, however, as it is then required that ex post parties punish decisions taken ex ante before their interaction had started.

6 Concluding remarks

Parties often have to make specific, noncontractible investments before starting a trade relationship. This paper has studied how investments and efficiency are affected by the relationship parties form in a general principal-agent framework. I showed that when the returns to a party's investment are commonly known, informal, more restrictive contracting environments ex post give parties higher incentives to invest ex ante. Parties invest not only

[25] This type of restriction on the punishments that parties can impose appears in models where parties can renegotiate after a disagreement. For example, Ramey and Watson (2002) and Miller and Watson (2010) make assumptions about the bargaining stage and the consequences of disagreement at that stage that are similar to those made here. Because all transfers are made at such stage, though, inefficient termination never occurs in their settings.

to generate direct returns, but also to increase their commitment to the relationship and relax contracting constraints. As a consequence, when investment is subject to a hold-up problem, informal relationships can be more productive.

Unobservability of investment returns can eliminate the possibility of hold-up, thus increasing efficiency if contracting is formal. When incentive contracting is informal, unobservability improves efficiency if the noninvesting party's bargaining power is high and thus hold-up problems are important, but it lowers efficiency if the investing party's bargaining power is high and thus commitment to the relationship is more important. The results of this paper show that while controlling the flow of information, for example through the use of audits or privacy rights, can be a useful tool, the net effects, and thus the optimal control, critically depend on the nature of incentive contracts and the parties' bargaining powers.

Figure 1: Total surplus under observable returns

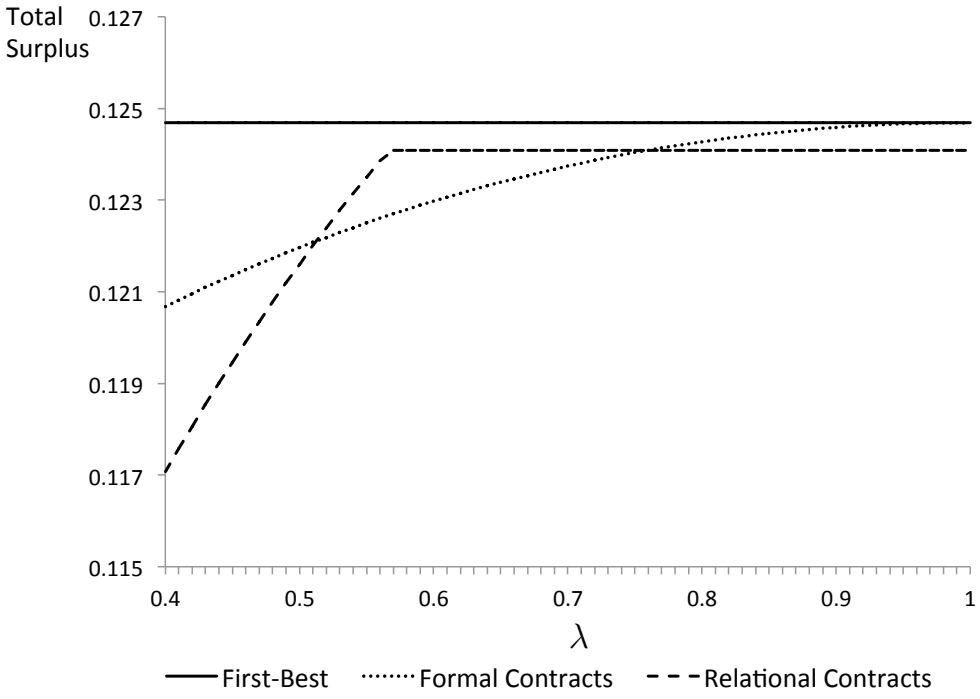
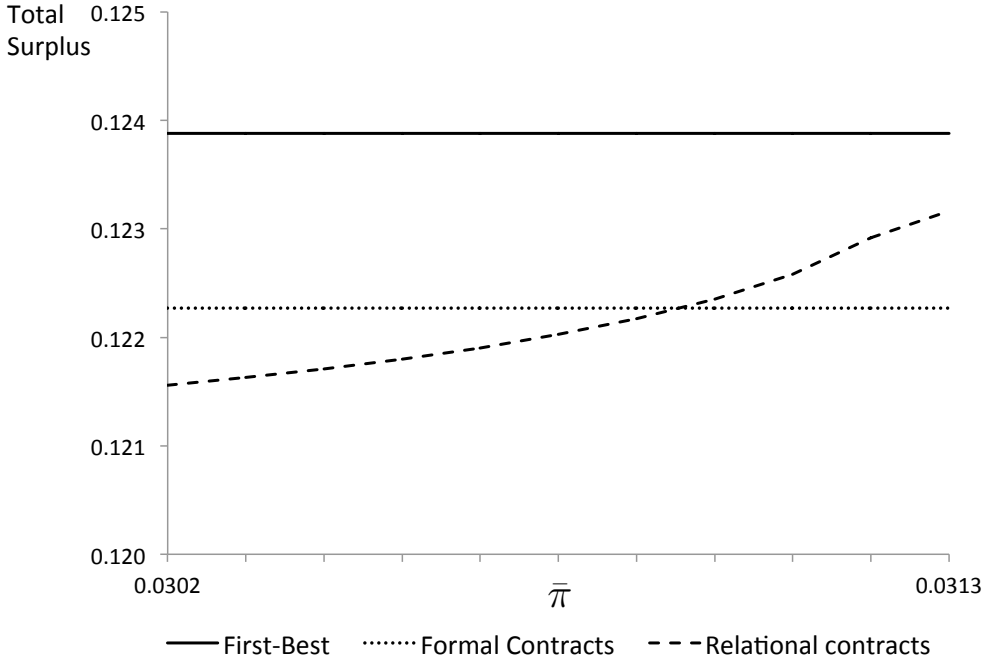


Figure 2: Total surplus and outside options



Appendix

Proof of Proposition 1. The first part of the proposition, referring to the case of observable investment success, is immediate from the analysis in the text. For the second part, suppose that the investment success and returns are unobservable to the agent. I proceed by proving three claims.

Claim 1. *Suppose that the agent receives the bargaining power. A PPBE where separation of types occurs through the principal's choice of contract does not exist.*

Suppose by contradiction that there exists a PPBE where, in some period t, the agent offers a menu of contracts and types ℓ and h accept different contracts. Let $\{w_1, b_1\}$ be $\ell's$ contract and $\{w_2, b_2\}$ h's contract. Let e_1, e_2 be the effort levels that solve the agent's incentive compatibility constraint given b_1, b_2. After this period t, the continuation play is the symmetric-information equilibrium, with the agent offering contract $\{w_\ell^{ofA}, b^{of}\}$ following acceptance of $\{w_1, b_1\}$ and contract $\{w_h^{ofA}, b^{of}\}$ following acceptance of $\{w_2, b_2\}$. But then if $\mathbb{E}[q - W_2|e_2] > \mathbb{E}[q - W_1|e_1]$, ℓ wants to deviate to $\{w_2, b_2\}$, and if $\mathbb{E}[q - W_1|e_1] \geq \mathbb{E}[q - W_2|e_2]$, h wants to deviate to $\{w_1, b_1\}$. Contradiction.

The claim extends immediately to mixed strategies. If h mixes between $\{w_1, b_1\}$ and $\{w_2, b_2\}$ while ℓ accepts $\{w_1, b_1\}$, the agent offers $\{w_h^{ofA}, b^{of}\}$ following acceptance of $\{w_2, b_2\}$. For h to mix, it must thus be that $\mathbb{E}[q - W_2|e_2] > \mathbb{E}[q - W_1|e_1]$, but then ℓ wants to deviate to $\{w_2, b_2\}$. Finally, if ℓ mixes between $\{w_1, b_1\}$ and $\{w_2, b_2\}$ while h accepts $\{w_2, b_2\}$, it must be that $\mathbb{E}[q - W_1|e_1] = \mathbb{E}[q - W_2|e_2]$, but then h wants to deviate to $\{w_1, b_1\}$.

Claim 2. *Suppose that the agent receives the bargaining power and $\delta > \frac{1}{2}$. The Pareto-optimal PPBE is pooling and implements $\{w_\ell^{ofA}, b^{of}\}$ in every period.*

By Claim 1, separation of types through the principal's choice of contract is not feasible. Since the principal only accepts or rejects when the agent has the bargaining power, consider separation of types through rejection. Immediate full separation through rejection is not feasible because, as shown in the text, any contract that induces ℓ to reject also induces h

to reject when $\delta > \frac{1}{2}$. Gradual separation through rejection is not feasible either. First note that a PPBE where ℓ mixes between accepting and rejecting and h accepts with probability one does not exist, as again h wants to reject. Consider then a PPBE where h mixes between accepting and rejecting and ℓ rejects with probability one. Given a prior p at time t, the agent offers some contract $\{w^A(p), b^A(p)\}$. If the principal accepts, the agent learns that $\theta = h$ and offers $\{w_h^{ofA}, b^{of}\}$ from then on. If the principal rejects, the agent updates his belief. Then there exists a period t' where the posterior p' is low enough that the agent optimally offers $\{w_\ell^{ofA}, b^{of}\}$ from then on. But then, at $t'' = t' - 1$, h rejects any offer that ℓ rejects. In turn, at t'', the agent optimally offers $\{w_\ell^{ofA}, b^{of}\}$. But then, at $t''' = t'' - 1$, h rejects any offer that ℓ rejects. Continuing with this reasoning gives that separation is not feasible if immediate separation is not feasible.

Hence, the equilibrium must be pooling, and the Pareto-optimal equilibrium implements contract $\{w_\ell^{ofA}, b^{of}\}$ in every period.

Claim 3. *Suppose that $\delta > \frac{1}{2}$. Then investment and total expected surplus are first-best.*

By Claims 1 and 2, the agent cannot induce separation of types when he receives the bargaining power. Thus, at time $t = 0$, the principal solves

$$\max_I \quad \delta p(I)(\bar{r} - \underline{r}) - (1 - \delta)k(I).$$

The solution is $I = I^{fb}$ and the total expected surplus is thus $S = \delta[p(I^{fb})s(h, e^{fb}) + (1 - p(I^{fb})s(\ell, e^{fb}))] - (1 - \delta)k(I^{fb}) = S^{fb}$. □

Proof of Proposition 2. The first part follows from comparison of equations (2) and (3). For the second part, consider the following example: $r \in \{0, \frac{1}{32}\}, q \in \{0, 1\}, I \in [0, \bar{I}]$ with $1 < \bar{I} < \frac{9}{8}$, $e \in [0, 1]$, $\delta = \frac{8}{9}$, $\bar{\pi} = \frac{1}{32}$, $\bar{u} = 0$, $p(I) = \frac{8}{9} I^{\frac{9}{10}}$, $k(I) = \frac{I^2}{10}$, $f(e) = \frac{e}{2}$, $c(e) = \frac{e^2}{2}$. First-best investment and effort are $I^{fb} = 1$, $e^{fb} = \frac{1}{2}$. Under contractible performance, $I^{of} = \lambda^{\frac{10}{11}}$, $e^{of} = e^{fb}$. When performance is noncontractible, $e_h^{or} = \frac{1}{2}$, $e_\ell^{or} = \frac{1}{4}$, and $I^{or} = (2\lambda)^{\frac{10}{11}}$ if

$\lambda \leq \frac{1}{2}\bar{I}^{\frac{11}{10}}$, $I^{or} = \bar{I}$ otherwise. Letting $\bar{I} = \frac{28}{25}$, one can immediately verify that $S^{or} > S^{of}$ for $\lambda \in [0.52, 0.75]$. Figure 1 depicts S^{fb}, S^{of}, and S^{or} for $\lambda \in [0.4, 1]$. □

Proof of Corollary 1. Consider the example in the proof of Proposition 2 with $\bar{r} = \frac{1}{32} - \frac{1}{960}$. Consider lowering $\bar{\pi}$ from $\bar{\pi} = \frac{1}{32}$ to $\bar{\pi}' = \frac{1}{32} - \frac{1}{960}$. For $\lambda = 0.6$, Figure 2 shows that this change lowers total surplus. □

Proof of Lemma 1. Suppose that the investment success and returns are unobservable to the agent. I proceed by proving four claims.

Claim 1. *Suppose that the agent receives the bargaining power. If separation of types occurs in a PPBE, it occurs through a rejection.*

This claim follows from the fact that separation of types through the principal's choice of contract is not feasible. The proof is analogous to the one above when performance is contractible (Claim 1 in the proof of Proposition 1, where here Assumption 2 ensures that continuation play after separation is given by the symmetric-information equilibria) and is thus omitted.

Claim 2. *Suppose that the principal receives the bargaining power. A PPBE where full separation of types occurs through the principal's choice of contract does not exist.*

Suppose by contradiction that there exists a PPBE where ℓ and h offer different contracts in some period t. Let $\{w_1, b_1\}$ be ℓ's contract and $\{w_2, b_2\}$ h's contract. Denote by $\pi^P(\theta|b, p)$ the payoff to type θ given that the principal has the bargaining power, the implemented bonus is b, and the agent's belief is p. By Assumption 2, after this period t, the continuation play is the symmetric-information equilibrium, with payoff to the principal $\pi^P(\ell|b_\ell^{or}, 0) = s(\ell, e_\ell^{or}) - \bar{u}$ if $\theta = \ell$, and $\pi^P(h|b_h^{or}, 1) = s(h, e_h^{or}) - \bar{u}$ if $\theta = h$. Let e_1, e_2 be the effort levels that solve the agent's incentive compatibility constraint given b_1, b_2 and the agent's beliefs. Suppose

first that both $\{w_1, b_1\}$ and $\{w_2, b_2\}$ are such that the agent accepts, so in equilibrium both types honor the payments and the relationship ends if a party reneges. Then,

$$\pi^P(\ell|b_1, 0) = (1-\delta)(\underline{r} + \mathbb{E}[q - W_1^P|e_1]) + \delta(s(\ell, e_\ell^{or}) - \bar{u}),$$
$$\pi^P(h|b_2, 1) = (1-\delta)(\bar{r} + \mathbb{E}[q - W_2^P|e_2]) + \delta(s(h, e_h^{or}) - \bar{u}).$$

Now if h deviates to $\{w_1, b_1\}$, she obtains

$$\pi^P(h|b_1, 0) = (1-\delta)(\bar{r} + \mathbb{E}[q - W_1^P|e_1]) + \delta(s(h, e_\ell^{or}) - \bar{u}) = \pi^P(\ell|b_1, 0) + (\bar{r} - \underline{r}), \quad \text{(A1)}$$

and if ℓ deviates to $\{w_2, b_2\}$, she obtains

$$\begin{aligned}\pi^P(\ell|b_2, 1) \;=\; & (1-\delta)(\underline{r} + \mathbb{E}[q - W_2^P|e_2]) \\ & + \max\left\{\delta\pi^P(\ell|b_h^{or}, 1), f(e_2)\left[(1-\delta)\bar{b}_2 + \delta\bar{\pi}\right] + (1 - f(e_2))\delta\pi^P(\ell|b_h^{or}, 1)\right\},\end{aligned}$$

where $\pi^P(\ell|b_h^{or}, 1)$ is ℓ's continuation value when the agent's posterior belief is one. As shown in the text,

$$\pi^P(\ell|b_h^{or}, 1) = s(\ell, e_h^{or}) - \bar{u} + \left[\frac{\delta f(e_h^{or})}{1 - \delta(1 - f(e_h^{or}))}(\bar{r} - \underline{r})\right].$$

Note that ℓ gains from the option of being able to renege. Hence,

$$\pi^P(\ell|b_2, 1) > \pi^P(h|b_2, 1) - (\bar{r} - \underline{r}). \quad \text{(A2)}$$

A PPBE where full separation occurs through the principal's contract offer exists if and only if for $\delta \in (0, 1)$, we have that $\pi^P(\ell|b_1, 0) \geq \pi^P(\ell|b_2, 1)$ and $\pi^P(h|b_2, 1) \geq \pi^P(h|b_1, 0)$. But equations (A1) and (A2) imply that one of these two incentive compatibility constraints is always violated. Contradiction.

Suppose next that $\{w_1, b_1\}$ or $\{w_2, b_2\}$ or both are such that the agent rejects. If $\{w_1, b_1\}$ is rejected, ℓ has incentives to deviate to b_ℓ^{or}, which (by Assumption 2) is always accepted and

gives ℓ a continuation value at least as high as $\{w_1, b_1\}$. If $\{w_2, b_2\}$ is rejected, the argument above is strengthened, since the difference between $\pi^P(\ell|b_2, 1)$ and $\pi^P(h|b_2, 1) - (\bar{r} - \underline{r})$ increases.

Claim 3. *Suppose that the principal receives the bargaining power. A PPBE implementing contracts b' and $b'' < b'$ where partial separation of types occurs through the principal's choice of contract exists only if there exists a PPBE implementing b' where separation occurs only through default.*

Step 1: Suppose there exists a PPBE where contracts b', b'' are implemented and partial separation occurs through the principal's contract offer. Suppose no type reneges in equilibrium. Then it must be that $b' = b'' = b_\ell^{or}$; otherwise, regardless of beliefs, some type would want to deviate. But then no separation occurs. Contradiction.

Step 2: Suppose there exists a PPBE where contracts b', b'' are implemented and partial separation occurs through the principal's contract offer. Suppose h offers contract b'' and ℓ mixes between b'' and b'. Let p'' be the agent's belief when contract b'' is offered and p' when contract b' is offered. Then in equilibrium $\pi^P(h|b'', p'') \geqslant s(h, e_\ell^{or}) - \bar{u}$ (otherwise, h would deviate to b_ℓ^{or}), and thus $b' > b_\ell^{or}$. Now since $p' = 0$, $\pi^P(\ell|b', p') < s(\ell, e_\ell^{or}) - \bar{u} = s(h, e_\ell^{or}) - \bar{u} - (\bar{r} - \underline{r}) \leqslant \pi^P(h|b'', p'') - (\bar{r} - \underline{r}) \leqslant \pi^P(\ell|b'', p'')$. But then ℓ is not willing to mix between b'' and b'. Contradiction.

Step 3: By Steps 1 and 2, in any PPBE with partial separation through the principal's contract offer, ℓ offers some contract b', h mixes between b' and some $b'' < b'$, ℓ reneges on b' with positive probability, and h honors b' and b'' with probability one. Now note that if h offers b' with probability $g'_h \in (0, 1)$, $p' = pg'_h/[pg'_h + (1 - p)] < p$, and thus given a probability with which ℓ honors the contract $\rho_\ell \in [0, 1)$, the probability that b' is honored is $p' + (1 - p')\rho_\ell < p + (1 - p)\rho_\ell$, so $e(b', p') < e(b', p)$. But then $\pi^P(\theta|b', p') < \pi^P(\theta|b', p)$ for $\theta \in \{\ell, h\}$. Therefore, if there exists a PPBE where both types offer b' given belief p', there exists a PPBE where both types offer b' given belief p.

Claim 4. *Suppose that the principal receives the bargaining power. If separation of types occurs in a Pareto-optimal PPBE, it occurs only through default.*

By Claim 2, we only need to consider a PPBE with separation through default and a PPBE with partial separation through the principal's contract offer. Suppose a PPBE with partial separation through the principal's contract offer exists. Then by Claim 3, a PPBE where separation occurs only through default (with both types offering the same contract) also exists. Moreover, it is immediate from the proof of Claim 3 (Step 3) that a PPBE where separation occurs exclusively through default Pareto-dominates the PPBE where separation also occurs through the principal's contract offer. The claim follows. □

Proof of Lemma 2. Suppose that the investment success and returns are unobservable to the agent, $\delta > \frac{1}{2}$, and the agent has the bargaining power. By Claim 1 in the proof of Lemma 1, separation of types must involve a rejection. By an analysis analogous to that in the text for contractible performance, immediate full separation through rejection is not feasible. Moreover, the argument in the proof of Proposition 1 shows that gradual separation through rejection is then not feasible either. Hence, separation of types cannot be induced, and the agent optimally offers the symmetric-information contract of the low type, $\{w_\ell^{orA}, b_\ell^{or}\}$, in every period. □

Proof of Lemma 3. Suppose that the investment success and returns are unobservable to the agent. I proceed by proving two claims.

Claim 1. *Suppose that the principal receives the bargaining power. A pooling PPBE always exists, and any such PPBE implements* $\{w_\ell^{orP}, b_\ell^{or}\}$ *in all periods.*

For existence, consider this PPBE: the agent's belief upon the principal offering b_ℓ^{or} is $p(I)$, his belief upon the principal offering $b \neq b_\ell^{or}$ is zero, and his belief upon the principal offering b_ℓ^{or} and then making any payment W is $p(I)$; the principal offers b_ℓ^{or} (with fixed wage w_ℓ^{orP}) in every period; the agent accepts and chooses e_ℓ^{or}; both types always honor; if the principal

reneges, the relationship ends. Clearly, beliefs are consistent, the agent's participation and effort decisions are optimal, and the principal's payment decision is optimal. To see that offering b_ℓ^{or} is optimal for the principal, note that for $\theta \in \{\ell, h\}$, $\pi^P(\theta|b_\ell^{or}) = s(\theta, e_\ell^{or}) - \bar{u}$; $\pi^P(\theta|b', 0) < s(\theta, e_\ell^{or}) - \bar{u}$ for any $b' < b_\ell^{or}$ because the agent then chooses $e' < e_\ell^{or}$; and $\pi^P(\theta|b'', 0) < s(\theta, e_\ell^{or}) - \bar{u}$ for any $b'' > b_\ell^{or}$ because the agent rejects, or accepts and chooses $e'' = 0$. Finally, since both types follow the same strategy, no information is revealed.

To show that any pooling PPBE implements b_ℓ^{or}, note that such PPBE cannot implement $b' < b_\ell^{or}$; regardless of beliefs (given Assumption 2), both types can increase their expected payoffs by deviating to b_ℓ^{or}. Further, any PPBE that implements $b'' > b_\ell^{or}$ induces separation. Otherwise, either both types always renege or both always honor. But if both types renege, the agent exerts no effort, so b'' cannot be optimal. And since $b'' > b_\ell^{or}$, ℓ optimally reneges.

Claim 2. *Suppose that the principal receives the bargaining power. There exists $\widehat{p} \in (0, 1)$ such that a PPBE that induces separation of types exists if and only if $p(I) \geq \widehat{p}$.*

The analysis of separating equilibria in the text can be extended to allow for mixed strategies. In such equilibria, ℓ initially mixes between honoring and reneging, until in some finite period t she reneges with probability one, and the relationship ends with positive probability if the principal reneges. A program similar to the one presented in Section 4.2 (but allowing for mixed strategies) can be derived, and such program gives a necessary and sufficient condition for the existence of a PPBE with separation through default which is analogous to the condition given in the text. It then follows directly from inspection of these conditions that there exists $\widehat{p} \in (0, 1)$ such that the conditions hold if and only if $p(I) \geq \widehat{p}$. The reader is referred to Proposition 2 in Halac (2012) for details.

Finally, by Lemma 1 and Claim 1, we only need to consider PPBE where separation occurs only through default and the pooling PPBE implementing b_ℓ^{or}. By Claim 2, there exists $\widehat{p} \in (0, 1)$ such that if $p(I) \geq \widehat{p}$, a separating PPBE exists, which also implies that both types prefer this PPBE to the pooling PPBE. If $p(I) < \widehat{p}$, a PPBE where separation occurs through a default does not exist, which (by Claim 3 in the proof of Lemma 1) implies

that the pooling PPBE is unique, and thus Pareto optimal. □

Proof of Proposition 3. The first part of the proposition is immediate. For the second part, suppose first that investment is such that $p(I) < \widehat{p}$, with $\widehat{p}$ defined in Lemma 3. Then $S^{or} - S^{ur}$ is equal to

$$\delta\big[p(I^{or})(\mathbb{E}[q-c|e_h^{or}] - \mathbb{E}[q-c|e_\ell^{or}])\big] + \big[\delta(p(I^{or}) - p(I^{fb}))(\bar{r} - \underline{r}) - (1-\delta)(k(I^{or}) - k(I^{fb}))\big],$$

where I^{or} is given by condition (3). For $\lambda \to 0$, $I^{or} \to 0$, so $p(I^{or}) \to 0$ and thus $S^{or} - S^{ur} < 0$. Note also that if $I^{or} = I^{fb}$, then $S^{or} - S^{ur} > 0$. But for λ high enough, I^{or} maximizes S^{or}, and thus it must be that $S^{or} - S^{ur} > 0$.

Suppose next that $p(I) \geq \widehat{p}$, and a Pareto-optimal separating equilibrium when the principal makes the offers implements e^{ur}. Assume without loss $\bar{u} = 0$. Then $S^{or} - S^{ur}$ is equal to

$$\frac{\delta\lambda}{1-\delta+\delta f(e^{ur})}\left\{\begin{array}{c}(1-\delta)\Big[p(I^{or})s(\ell,e_h^{or}) + (1-p(I^{or}))s(\ell,e_\ell^{or}) - s(\ell,e^{ur})\Big] \\ +\delta f(e^{ur})\Big[p(I^{or})s(\ell,e_h^{or}) + (1-p(I^{or}))s(\ell,e_\ell^{or}) - \bar{\pi} - p(I^{ur})\big(s(\ell,e_h^{or}) - \bar{\pi}\big)\Big]\end{array}\right\}$$
$$+\,\delta(1-\lambda)p(I^{or})\big(s(\ell,e_h^{or}) - s(\ell,e_\ell^{or})\big) + \delta\big(p(I^{or}) - p(I^{ur})\big)(\bar{r} - \underline{r}) - (1-\delta)\big(k(I^{or}) - k(I^{ur})\big).$$

It is immediate that for λ low enough, $S^{or} - S^{ur} < 0$. Also, note that if $I^{or} = I^{ur}$, with $p(I^{ur}) \geq \widehat{p}$, then $S^{or} - S^{ur} > 0$. But for λ is high enough, I^{or} maximizes S^{or}, and thus it must be that $S^{or} - S^{ur} > 0$. □

Proof of Proposition 4. Consider parameter values as in the proof of Proposition 2. Let $r \in \{0, \frac{1}{7}\}$. First-best investment and effort are $I^{fb} = \left(\frac{60}{49}\right)^{\frac{10}{11}}$, $e_h^{fb} = \frac{9}{16}$, $e_\ell^{fb} = \frac{1}{2}$. Under contractible performance, $I^{of} = \left(\frac{60}{49}\lambda\right)^{\frac{10}{11}}$, $e_\theta^{of} = e_\theta^{fb}$ for $\theta \in \{\ell, h\}$. When performance is noncontractible, $e_h^{or} = \frac{1}{2}$, $e_\ell^{or} = \frac{1}{4}$, and $I^{or} = \left(\frac{4(1+2\sqrt{2})}{7}\lambda\right)^{\frac{10}{11}}$ if $\lambda \leq \frac{7}{4(1+2\sqrt{2})}\bar{I}^{\frac{11}{10}}$, $I^{or} = \bar{I}$ otherwise. Letting $\bar{I} = \frac{28}{25}$, one can immediately verify that $S^{or} > S^{of}$ for $\lambda \in [0.46, 0.68]$. □

Proof of Proposition 5. Suppose that the agent received the bargaining power. It is easy to see that if the agent cannot induce separation of types through rejection, he cannot induce separation of types through the principal's choice of contract (i.e., through h accepting a different contract than ℓ), as rejection maximizes the difference between the two types' payoffs. Consider then the conditions for rejection. Suppose that the agent proposes a contract $\{w^A, b^A\}$ with expected payment to the agent $\mathbb{E}[W^A|e^A]$, and the principal's type is fully revealed through rejection. Because ℓ has a lower value of the relationship than h, it must be ℓ who rejects, while h accepts. Thus, if the offer is rejected, the agent proposes $\{w_\ell^{orA}, b_\ell^{or}\}$ from then on, where b_ℓ^{or} solves the program in Section 4.1 with the new output function (and $\theta = \ell$) and w_ℓ^{orA} is such that $\mathbb{E}[W_\ell^{orA}|e_\ell^{or}] = \mathbb{E}[y|\ell, e_\ell^{or}] - \bar{\pi}$. If the offer is accepted, the agent proposes $\{w_h^{orA}, b_h^{or}\}$, where w_h^{orA} is such that $\mathbb{E}[W_h^{orA}|e_h^{or}] = \mathbb{E}[y|h, e_h^{or}] - \bar{\pi}$. Hence, ℓ will indeed reject only if

$$(1-\delta)\mathbb{E}[y - W^A|\ell, e^A] + \delta\bar{\pi} \leq \bar{\pi},$$

and h will indeed accept only if

$$(1-\delta)\mathbb{E}[y - W^A|h, e^A] + \delta\bar{\pi} \geq \bar{\pi} + \delta\left(\mathbb{E}[y|h, e_\ell^{or}] - \mathbb{E}[y|\ell, e_\ell^{or}]\right).$$

Combining these two conditions, full separation of types through rejection is feasible only if

$$\frac{\delta}{1-\delta}\mathbb{E}[q|e_\ell^{or}] \leq \mathbb{E}[q|e^A].$$

Since $\mathbb{E}[q|e_\ell^{or}] > 0$, there exists $\bar{\delta} \in (0,1)$ such that this condition is violated for $\delta > \bar{\delta}$. Finally, a similar argument as the one used in the proof of Proposition 1 shows that gradual separation through rejection is not feasible if immediate full separation through rejection is not feasible. The rest of the analysis is analogous to that in the main text and thus omitted. □

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