To trade, or not to trade, that is the question: New roles for incomplete contracts in dynamic settings*

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Abstract

We reexamine the role of contracts in a dynamic model of renegotiation that endogenizes the timing of investments and trade. The interaction between bargaining and investment significantly alters the lessons learned from static models. First, contracts that exacerbate the parties' vulnerability to hold-up can be desirable. Specifically, joint ownership of complementary assets can be optimal, an exclusivity agreement can protect the investments of its recipient, and trade contracts can facilitate purely cooperative investment. We also argue that the same type of contracts serve to ensure that the (most) efficient equilibrium is Pareto dominant, thereby providing an equilibrium selection role for them as well.

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1 Introduction

We have learnt from the theory of incomplete contracts that even if crucial terms – like relationship-specific investment – are not verifiable, writing a contract about the verifiable aspects of trade (property rights, exclusivity, quantity traded, etc.) can still be useful in providing better incentives. One of the main insights of this literature is that the power of these incentives depends on the comparison of net returns to different actions *conditional on trade taking place*. Consequently, incomplete contracts are generally evaluated according to how well they serve the purpose of improving these trade-contingent – often referred to as "marginal" – incentives.

In this paper we put forward alternative channels through which incomplete contracts can influence behavior in a dynamic set-up (modelled here as promoting *ex ante* investment in a situation exposed to hold-up). Our primary observation is that, despite the *ex post* efficiency of trade, there are realistic scenarios where – rather than the fear of under-investment, taking trade as given – the main concern is a deviation to *no* trade (and under-investment, of course).[1] In other words, it is the (absolute) level of exposure to hold-up that needs contractual attention.

The models in the literature[2] are static, in the sense that the investment phase is finished by the time (re)negotiation occurs. In many applications, however, the processes of investment and negotiation take place in a fluid and loosely structured way over time, with (incremental) investments being feasible as long as negotiation is not finished – with or without agreement/trade.[3] The dynamic model we present here captures this phenomenon,[4]

[1] In the standard models, relationship specificity implies that the parties are willing to trade whenever the trade-contingent incentive constraints are satisfied.

[2] A range of organizational and contract forms have been rationalized as safeguards against hold-up: Examples include vertical integration (Klein, Crawford and Alchian, 1978; Williamson, 1979), a property rights allocation (Grossman and Hart, 1986; Hart and Moore, 1990), contracting on renegotiation rights (Chung, 1991; Aghion, Dewatripont and Rey, 1994), option contracts (Nöldeke and Schmidt, 1995), and trade contracts (Edlin and Reichelstein, 1996; Che and Hausch, 1999).

[3] For instance, the Department of Defense may start negotiations to order a weapons system from a contractor, but it may decide to wait until the latter develops a better technology. A similar dynamic interaction between investment and bargaining arises in construction, or the development of advertising and software. The (original) editorial procedure at the B.E. Press can also be seen in this light. Here a submission was simultaneous to four vertically differentiated journals. Barring rejection, the author was offered a choice between immediate acceptance at a lower level, or, acceptance at a higher level, conditional on a substantial revision.

[4] Che and Sákovics (2004a) provided the original insight that if investment activity can continue after

encompassing a broad range of cases. At one extreme (infinitely impatient parties), it nests the standard/static model as a special case and our predictions confirm those of the existing theory. With sufficiently patient parties, the investment dynamics – and, as a result, the role of contracts in harnessing the power of expectations[5] – becomes important and a new insight on contract design emerges. As shown by Che and Sákovics (2004a), in such a scenario there exist multiple (subgame-perfect) equilibria, the most efficient of which is a constrained efficient outcome, when the parties are sufficiently patient. The constraint limiting efficiency is the parties' willingness to participate in the trade. This result shows that dynamics can serve as a substitute for standard incentive contracts, while it opens up new ways for contracts to foster efficiency.

We derive three general results. First, we show that a binding participation constraint can be relaxed by the provision of "punishments" for not trading *following efficient investment*. This is important and non-trivial, as it is often easier to affect these payoffs than the ones following a deviation to no investment, which are the ones that are explicitly present in the (trade) participation constraint. This result can be further sharpened when investments are fully relationship specific. In that case, the best way a contract can enable trade is by lowering the *aggregate* no-trade payoff (following efficient investment) of the parties. We call this result the *No-trade Payoff Minimization Principle*. It has been observed (c.f. Holmström and Roberts, 1998) that many large systems with complementary activities (satellite broadcasting – e.g. BSkyB –, software – e.g. Microsoft – biotechnology – e.g. Genentech) operate as an intricate network of contracts resisting the pressure for integration that the standard hold-up logic would require. Holmström and Roberts note that this "lack of integration" comes about despite the fact that the break-up costs of these networks would be very large. The No-trade Payoff Minimization Principle provides a ready answer to why this should not be surprising.

Second, we modify the use of incomplete contracts for improving the marginal incentives of an investing party. We show that in the dynamic model, the "leakage" effect of investment on the marginal exposure of the other party is diminished, or even absent. Thus, unlike the conclusions of Che and Hausch (1999) in a static model of cooperative investment, if the dynamics is important we would expect that contracts of the "usual" type should be

the negotiation has started, investment incentives may be enhanced, and the hold-up problem may be alleviated. The current model adapts their modeling framework so that it can explicitly handle contracts.

[5] When it is possible to make up in the future for under-investment today, whether the parties expect this to happen affects today's terms of trade, changing their incentives to invest.

beneficial – and thus observed – in situations where investments are cooperative, as long as they have some selfish component.

Our final general result addresses the issue of equilibrium selection, as the relevance of expectations results in multiple equilibria. If the efficient equilibrium happens to be Pareto dominant as well, this is not too problematic, as it is reasonable to expect that the parties should coordinate on it. However, when there are parties who prefer a non-efficient equilibrium – say, due to the relatively high cost of investment they face – multiplicity becomes a serious issue. Nonetheless, we show that by appropriately reducing the no-trade payoffs of the parties who do prefer the efficient equilibrium, we can always ensure that it becomes Pareto superior. Note that this is the same (type of) contract as the one identified for encouraging trade!

Next we turn to some specific applications. In particular, asset ownership, exclusivity of trading relationships, and the quantity or some aspects of quality of the traded goods/services. For each of these, we explore how such explicit contract terms can be designed to harness the power of expectation as a source of incentive. We obtain some surprising new insights: joint ownership of complementary assets can be optimal, an exclusivity agreement can protect the investments of its recipient, and trade contracts can facilitate purely cooperative investment, in contrast to the existing results.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 looks at the necessary and sufficient conditions that lead to the efficient investment in both the standard/static and our dynamic contract model and establishes the effects of contracts. Section 4 then applies the results to some well-known contracts. Section 5 reviews some further related literature and Section 6 concludes. The proofs not presented in the main part of the paper are collected in the Appendix.

2 The model

Two risk-neutral parties, 1 and 2, can create a surplus from some productive activity, that we simply label as "trade". The trade decision is an element in Q, a compact subset of $\mathbb{R}^n$, for some $n \in \mathbb{N}$, and there is a null trade $q_0 \in Q$ that yields a zero surplus (in normalization). The parties can increase the trade surplus by investing prior to the trade. The investment decision for party i is assumed to be binary, represented by an indicator function I_i, which takes the value 1 if i has invested and zero if she has not.[6] The cost of investment is $c_i > 0$ for party i.

Given investments $\mathbf{I} = (I_1, I_2)$, if the parties engage in a trade $q \in Q$, they jointly collect a surplus of $\Phi(q, \mathbf{I})$, gross of the investment cost. If they do not trade, however, they collect zero (gross) surplus, regardless of investments; i.e., $\Phi(q_0, \cdot) \equiv 0$. As it will become clear, it is useful to focus on the efficient trade decision conditional on the level of investment,

$$\phi(\mathbf{I}) := \max_{q \in Q} \Phi(q, \mathbf{I}).$$

We let $q^*(\mathbf{I})$ be its associated maximizer, which we assume is well defined. To make the problem interesting, we assume that investment by both parties is socially desirable:

Assumption 1. ***(Investment is efficient)*** *Letting* $\mathbf{I}^* := (1, 1)$,

$$\phi(\mathbf{I}^*) - \mathbf{c} \cdot \mathbf{I}^* > \phi(\mathbf{I}) - \mathbf{c} \cdot \mathbf{I} \quad \forall \mathbf{I} \in \{0,1\}^2, \mathbf{I} \neq \mathbf{I}^*,$$

where $\mathbf{c} = (c_1, c_2)$*.*

In keeping with the prevailing view of the contract literature, we assume that the parties cannot directly contract on investments. Rather, they can contract on other aspects, such as asset ownership, trade level, or exclusivity of trading relationships. These contracts take effect whenever they are not renegotiated. It is convenient to identify a contract by the payoffs it yields to the parties. Specifically, fix a contract μ. Then, the parties collect payoffs of $(\psi_1(\mathbf{I}; \mu), \psi_2(\mathbf{I}; \mu))$, henceforth referred to as *disagreement* or *no-trade payoffs*, in case they choose not, or fail, to renegotiate it (and trade).

Without specifying the precise nature of the contracts we consider, we make a few assumptions about the set of available contracts, $\mathcal{M}$. First, we assume that the contract payoffs are (weakly) increasing in the investments: for each $\mu \in \mathcal{M}$, $\psi_i(\mathbf{I}; \mu) \leq \psi_i(\mathbf{I}'; \mu)$ for any $\mathbf{I} < \mathbf{I}'$. Next, we assume that the investments are relationship specific in the following sense:

Assumption 2. ***(Specificity)*** *For each* $\mu \in \mathcal{M}$

(a) $\psi_1(0, \cdot; \mu) > \psi_1(1, \cdot; \mu) - c_1$ *and* $\psi_2(\cdot, 0; \mu) > \psi_2(\cdot, 1; \mu) - c_2$*;*

(b) $0 \leq \phi(\mathbf{I}) - \psi_1(\mathbf{I}; \mu) - \psi_2(\mathbf{I}; \mu) < \phi(\mathbf{I}') - \psi_1(\mathbf{I}'; \mu) - \psi_2(\mathbf{I}'; \mu)$ *for any* $\mathbf{I} < \mathbf{I}'$*.*

[6] The choice of binary investment is largely for simplicity. Allowing for a more general structure, such as continuous investments, makes it cumbersome to characterize the full equilibrium set. Our binary investment assumption does not alter the general thrust of the results, as has been shown by Che and Sákovics (2004a, 2004b).

Assumption 2-a implies that a party will not invest unless there is trade between the partners. In other words, investment is worthwhile only in the expectation of reaping its benefits through trade. Assumption 2-b means that the parties' investments are specific, in the *absolute* sense that they generate higher total surplus when the parties trade efficiently than when they disagree; and in the *marginal* sense that this difference increases with additional investment. These assumptions are sensible in the context of many applications. For instance, the disagreement outcome under any ownership may be inefficient since non-owners may not exert sufficient human capital input (as is assumed in Hart and Moore, 1990); a trade contract may not specify the efficient level of trade (as in Edlin and Reichelstein, 1996, and Che and Hausch, 1999); and external trading does not yield as much surplus as the efficient internal trading both under exclusive and nonexclusive regimes (see Segal and Whinston, 2000).

Assumption 2-b also implies that the disagreement outcome can never be efficient, so the social optimum can be characterized independently of the contract in place.

Our model is general enough to accommodate a broad set of circumstances in terms of the underlying environment and the allowed contracts/organizations. In particular, several well-known contracts are included.[7]

Example 1. ***(Asset Ownership)*** *The Grossman-Hart-Moore (GHM) model*[8] *of asset ownership deals with how different ways of allocating productive assets to the parties affects their incentives for relationship-specific investments. They postulate that asset ownership directly affects the disagreement payoffs of the parties when they negotiate, á la Nash Bargaining, the terms of the trade between them. This model is clearly subsumed in our current setup when* ψ_i *depends on the allocation of asset ownership.*

Example 2. ***(Exclusive Dealing)*** *An agreement prohibiting a trade partner from dealing with a third party is often justified by the protection that it may provide for relationship-*

[7] In principle, a more sophisticated contract, for example, one requiring exchanges of messages, can be incorporated into our model, with ψ_i interpreted as the equilibrium payoff of party i in that contract (sub)game. Of course, there is the issue of how these latter payoffs are determined and what contract payoffs are feasible. These are difficult questions to address even in the static model (as is well known from the debates on the incomplete contract paradigm). The more complex extensive form makes our dynamic model even less suitable for analyzing, let alone likely to offer any new insight on, these problems. For these reasons, we do not address the question of optimal contracts, limiting attention instead to some well-known contracts.

[8] See Grossman and Hart (1986), Hart and Moore (1990) and Hart (1995).

specific investments. Segal and Whinston (2000) investigate this hypothesis using an incomplete contract model where trade partners negotiate the terms of internal trade, and their disagreement payoffs depend on the presence of an exclusivity agreement. Our setup accommodates such a model, with the contract payoff $\psi_i(\cdot;\mu)$ varying with the extent, μ, to which one is allowed to trade with an external third party.[9]

Example 3. ***(Trade contracts with cooperative investment)*** *The parties may contract ex ante on the terms of trade, which may be later renegotiated. Many authors have analyzed the effects of such contracts on the incentives for specific investments (Edlin and Reichelstein, 1996; Che and Hausch, 1999, and Segal and Whinston, 2002, among others). Of particular interest is the case in which investments are cooperative in the sense that investors do not directly benefit from their investments, as such investments have been found particularly difficult to motivate via ex ante trade contracts (Che and Hausch, 1999). These models and the related questions can be reexamined in our dynamic context, when the disagreement payoffs are allowed to depend on the terms of trade initially agreed upon.*

Example 4. ***(Contracting in a complex environment)*** *Often parties to an ex ante contract trade in a complex environment, which makes it difficult for them to forecast the type of trade that will best harness their specific investments. Segal (1999) and Hart and Moore (1999) consider a model in which a seller and a buyer can trade one of n different types of "widgets." One of the different types becomes ex post optimal to trade, and the parties' investments raise the value of trading the special type of widget but no other types. They find ex ante trade contracts to be of little value when there are so many types that it is difficult to predict the special type of widget. This model again lends itself to our dynamic setup, with the disagreement payoffs allowed to depend on the type of widget that the parties may agree to trade initially.*

The previous authors studying these problems have employed the framework in which the parties invest first and then bargain over the terms of trade according to the Generalized Nash Bargaining Solution with bargaining powers (α_1, α_2) (henceforth GNBS), with the

[9] As this example illustrates, the absence of a contract is a special case of our model. In Che and Sákovics (2004a), where no contracts are allowed, the status quo payoffs are assumed to be zero. But this is just a normalization, and the reader should not interpret the current paper as assuming that the status quo payoffs will indeed rise as the parties sign some ex ante contract. As the exclusivity example illustrates, a contract may increase or decrease the parties' status quo payoffs.

contract payoffs $(\psi_1(\cdot;\mu), \psi_2(\cdot;\mu))$ serving as disagreement point.[10] For ease of comparison, it is useful to establish the resulting outcome as a benchmark. Suppose the parties choose investment pair $\mathbf{I}$, and subsequently bargain over the terms of trade according to the GNBS. Then, they will choose $q^*(\mathbf{I})$, and party $i = 1, 2$ will collect the payoff (gross of investment costs) of

$$\text{(GNBS)} \qquad U_i^0(\mathbf{I};\mu) := \alpha_i[\phi(\mathbf{I}) - \psi_{-i}(\mathbf{I};\mu)] + \alpha_{-i}\psi_i(\mathbf{I};\mu).$$

We consider a natural dynamic extension of this GNBS framework. The precise extensive form game is described as follows. We first fix a contract $\mu \in \mathcal{M}$, satisfying Assumption 2. The parties subsequently play an investment and bargaining game as follows. In period $t = 1$, they simultaneously make sunk investments, $\mathbf{I} = (I_1, I_2) \in \{0,1\}^2$. Party i is then chosen with probability $\alpha_i \in [0,1]$, $\alpha_1 + \alpha_2 = 1$, to make a proposal on the terms of trade, consisting of $q \in Q$ and a transfer t_i, $t_1 + t_2 = 0$. If the proposed terms are accepted by the responder, the game ends. If not, then with probability $1 - \delta \in (0,1]$ the bargaining breaks down for some exogenous reason, and the parties collect their contract payoffs, $(\psi_1(\mathbf{I};\mu), \psi_2(\mathbf{I};\mu))$. With probability δ, the game moves on to the next period, and the same process is repeated as in the first period, i.e., the parties may invest (if they haven't done so before) followed by (random-proposer) bargaining, and so on and so forth, until there is an agreement and trade or the bargaining breaks down. Our solution concept is that of Subgame Perfect Equilibrium (SPE).

If $\delta = 0$, the game ends after the first period, resulting in the standard two-stage investment-trade model. The unique SPE of our random-proposer bargaining procedure replicates the GNBS in that case, yielding (expected) payoffs $U_i^0(\mathbf{I};\mu)$ to the players.

3 The implementability of efficient investment

3.1 Efficiency under an arbitrary contract

Naturally, we are interested in the existence of an efficient SPE, where both parties invest in the first period. More precisely, we say that a contract μ ***implements*** $\mathbf{I}^* = (1,1)$ if $\mathbf{I}^*$

[10] Examples include Grossman and Hart (1986), Hart and Moore (1990), Edlin and Reichelstein (1996), Che and Hausch (1999), Hart and Moore (1999), Segal (1999), and Segal and Whinston (2000, 2002). The alternative approach treats contracts as affecting the outside option payoffs of non-cooperative bargaining (MacLeod and Malcomson, 1993; Chiu, 1998; De Meza and Lockwood, 1998).

is reached in the first period in some SPE of the game induced by μ.[11] An important step of the analysis is to evaluate the continuation payoffs following the investment decision. To this end, suppose first that both parties have invested. Since then there is no further investment opportunity for either party, the game becomes a pure bargaining game. In this cae, a standard argument shows that the continuation payoffs are uniquely determined:

Lemma 1. *For any $\mu \in \mathcal{M}$, in any subgame given efficient investment the SPE (continuation) payoffs are the GNBS payoffs: $U_i^0(\mathbf{I}^*; \mu)$, $i = 1, 2$.*

Proof: See the Appendix.

It is remarkable that the parties' equilibrium payoffs following efficient investment coincide with the static payoffs, irrespective of the probability of continuation. This clearly shows that the exposure to hold-up is not affected by the introduction of investment dynamics. As will be seen, however, this irrelevance result does not carry over to the incentives for investment. The next theorem characterizes the precise conditions under which a contract implements the efficient investment. It is useful to define, for any $\delta \in [0, 1)$ and contract $\mu \in \mathcal{M}$, a payoff function[12] for party i:

$$U_i^\delta(\mathbf{I}; \mu) := \alpha_i[\phi(\mathbf{I}) - (1 - \delta)\psi_{-i}(\mathbf{I}; \mu)] + \alpha_{-i}(1 - \delta)\psi_i(\mathbf{I}; \mu).$$

Notice that these payoffs coincide with those associated with the GNBS when $\delta = 0$, but differ from them when $\delta \neq 0$. Let $\mathbf{I}^*_{-i}$ be the investment pair arising when party $i = 1, 2$ unilaterally deviates from $\mathbf{I}^*$. That is, $\mathbf{I}^*_{-1} = (0, 1)$ and $\mathbf{I}^*_{-2} = (1, 0)$.

Theorem 1. *Given Assumptions 1 and 2, contract μ implements the efficient investment if and only if*

$$(P) \qquad U_i^0(\mathbf{I}^*; \mu) - c_i \geq \psi_i(\mathbf{I}^*_{-i}; \mu), \text{ for } i = 1, 2$$

and

$$(IC) \qquad U_i^\delta(\mathbf{I}^*; \mu) - c_i \geq U_i^\delta(\mathbf{I}^*_{-i}; \mu) - \alpha_{-i}\delta c_i, \text{ for } i = 1, 2.$$

[11] We do not require unique implementation here. In Section ? we will argue that there exist contracts that ensure that the (most) efficient equilibrium is indeed Pareto efficient, so it is reasonable to expect players to coordinate on it.

[12] These are not actual equilibrium payoffs and therefore do not have a straightforward interpretation.

Proof: See the Appendix.

Theorem 1 identifies a pair of conditions for each party, (P) and (IC), as necessary and sufficient for efficient investments under contract μ. Condition (P) states that party i's equilibrium payoff from efficient investments (as identified in Lemma 1) must be no less than her contract payoff (which she could collect, in equilibrium, by not investing and disagreeing indefinitely thereafter). In other words, it is her Participation constraint for trade to occur. This condition is implicit, but never binding, in the standard static model of hold-up.[13]

Condition (IC) captures the need for a "marginal" benefit associated with investment on the equilibrium path: party i must not gain from under-investing and bargaining efficiently – and therefore, by Assumption 2-b, trade – from that point onward. This condition is understood better when compared with the corresponding condition in the static model ($\delta = 0$):

$$(1) \qquad U_i^0(\mathbf{I}^*; \mu) - c_i \geq U_i^0(\mathbf{I}_{-i}^*; \mu), \ \forall i = 1, 2.$$

When $\delta > 0$, (IC) becomes easier to satisfy than (1). To see this, first let $\Delta_i \phi := \phi(\mathbf{I}^*) - \phi(\mathbf{I}_{-i}^*)$ and $\Delta_i \psi_j(\mu) := \psi_j(\mathbf{I}^*; \mu) - \psi_j(\mathbf{I}_{-i}^*; \mu)$ denote respectively the changes in the trade surplus and in the contract payoffs that result from party i's investing, i.e., a shift from $\mathbf{I}_{-i}^*$ to $\mathbf{I}^*$. Then, rewrite (IC) in terms of these marginal effects:

$$(IC\prime) \qquad \Delta V_i^\delta(\mu) := \alpha_i[\Delta_i \phi - (1-\delta)\Delta_i \psi_{-i}(\mu)] + \alpha_{-i}(1-\delta)\Delta_i \psi_i(\mu) - (1 - \alpha_{-i}\delta)c_i \geq 0.$$

Differentiating with respect to δ we obtain

$$\frac{d\Delta V_i^\delta(\mu)}{d\delta} = \alpha_i \Delta_i \psi_{-i}(\mu) + \alpha_{-i}\left(c_i - \Delta_i \psi_i(\mu)\right) > 0,$$

where the inequality follows by Assumption 2-a. In other words, the (IC) constraint is the easier to satisfy the larger δ is. Since (P) does not depend on δ, the following is immediate.

Corollary 1. *If μ implements $\mathbf{I}^*$ for δ, then it implements $\mathbf{I}^*$ for all $\delta' > \delta$.*

In particular, for any given contract there are stronger incentives for investment in our dynamic model with $\delta > 0$ than in a static model ($\delta = 0$). Where do the extra incentives come from? As noted following Lemma 1, on the equilibrium path the parties share the returns on investment in precisely the same way as when $\delta = 0$. The incentives come

[13] To see this in our set-up, Corollary 2 below will show that, when $\delta = 0$, (IC) implies (P).

from the equilibrium dynamics, which influence the way in which the parties split the surplus off-the-equilibrium path, *when a party under-invests.* In particular, if following his deviation a party is expected to invest in the next period (if there is no breakdown), then the pie will grow next period if no agreement is reached this period, so the investor's partner will demand a bigger share of the current pie to forego that (probabilistic) option. Essentially, the forecasted investment dynamics worsens the party's bargaining position following a deviation, which leads to the under-investor receiving a share smaller than under the GNBS. This creates a stronger investment incentive, which in turn confirms the belief that investment will be made in the future, making it self-fulfilling. The dynamics – in combination with the aggrieved party's sense of entitlement (based on rational expectations) – thus generates more incentives for investment.

The relative importance of conditions (P) and (IC) varies as δ changes. When the probability of continuation is small, the investment dynamics does not matter much, so the current model is qualitatively similar to the static model where only (IC) matters. By contrast, when δ becomes large, (IC) becomes easy to satisfy, so (P) looms more important. This observation is made more precise below.

Corollary 2. *For any contract μ, there exist $\delta_i^* \in (0,1)$, $i = 1, 2$, such that, if $\delta \leq \min\{\delta_1^*, \delta_2^*\}$, (IC) is sufficient for μ to implement $\mathbf{I}^*$ and that, if $\delta \geq \max\{\delta_1^*, \delta_2^*\}$, (P) is sufficient for μ to implement $\mathbf{I}^*$.*[14]

Proof: See the Appendix.

Next, we investigate how investment dynamics affects the comparison of alternative contracts.

3.2 The effects of contracts

The key factor in static models is the extent to which a contract enables a party to appropriate her investement returns, or equivalently, to reduce her exposure to hold-up "at the (investment) margin". In our model, this effect is captured by the terms $\Delta_i\psi_j(\mu)$, for investor $j = i$ and non-investor $j = -i$. Specifically, $\Delta_i\psi_i(\mu)$ represents the marginal return of investment that investor i appropriates, and $\Delta_i\psi_{-i}(\mu)$ reflects the marginal return of i's investment "leaked" to the non-investor, $-i$. The former protects the investor from, while the latter exposes her to, the hold-up problem at the margin. Indeed, as can be seen from

[14] In between these two values, for each party a different constraint is stricter.

($IC\prime$), condition (IC) can be written solely in these marginal terms and conform to the standard insight.

The same is not true for (P), however. To see this, rewrite (P) as:

$$(P\prime) \qquad \alpha_i(\phi(\mathbf{I}^*) - \Psi^*(\mu)) + \Delta_i\psi_i(\mu) \geq c_i,$$

where $\Psi^*(\mu) := \psi_1(\mathbf{I}^*;\mu) + \psi_2(\mathbf{I}^*;\mu)$ denotes the parties' aggregate disagreement payoff under contract μ with efficient investment. The first term is the proportion retained from the (efficient) trade surplus $(\phi(\mathbf{I}^*) - \Psi^*(\mu))$ – the degree to which a party is exposed to hold-up in the *absolute* sense (that is, taking investment as given). The added term is the investor's marginal return, $\Delta_i\psi_i(\mu)$, which relaxes her ($P\prime$). Note that the "leakage" of her investment returns, $\Delta_i\psi_{-i}(\mu)$, does not affect the participation constraint of either party. Due to these differences, ($P\prime$) yields a distinct new insight on the role of contracts – whenever it is the stricter constraint.

Thus, the crucial question is which of the two conditions is binding. As shown in Corollary 2, (IC) implies (P) when δ is close to zero, in which case the role of contracts will conform to the standard insight. By contrast, only (P) matters if δ is sufficiently large. The following terminology proves useful for our formal presentation of the results.[15]

Definition 1. (i) *Contract μ'* ***weakly dominates*** *contract μ if μ' implements $\mathbf{I}^*$ whenever μ implements it. A contract $\mu \in \mathcal{M}$ is optimal in $\mathcal{M}$, if it weakly dominates all other contracts in $\mathcal{M}$.*

(ii) *Contract μ'* ***dominates*** *contract μ if μ' weakly dominates μ and there exists (c_1, c_2) such that the former implements $\mathbf{I}^*$ but not the latter.*

(iii) *Contracts μ and μ' are* ***equivalent*** *if μ' implements $\mathbf{I}^*$ if and only if μ implements it.*

We can now state our result formally:

Proposition 1. *Consider any pair of contracts μ', μ.*

a) *If $\left(\Delta_i\psi_i(\mu'), -\Delta_i\psi_{-i}(\mu')\right) \geq \left(\Delta_i\psi_i(\mu), -\Delta_i\psi_{-i}(\mu)\right)$, $i = 1, 2$,[16] then there exists $\tilde{\delta} \geq 0$*

[15] The following definitions are made relative to the first-best investment. Given the binary nature of investment this seems the natural way to proceed.

[16] We display a stronger sufficient condition, independent of the possible compensation between the marginal and the leakage effects, for clarity. A weaker sufficient condition is

$$\alpha_{-i}\Delta_i\psi_i(\mu') - \alpha_i\Delta_i\psi_{-i}(\mu') \geq \alpha_{-i}\Delta_i\psi_i(\mu) - \alpha_i\Delta_i\psi_{-i}(\mu).$$

such that contract μ' weakly dominates contract μ for any $\delta \leq \tilde{\delta}$. If at least one (vector) inequality is strict, then μ' dominates μ.

b) *If $\Delta_i \psi_i(\mu') - \alpha_i \Psi^*(\mu') \geq \Delta_i \psi_i(\mu) - \alpha_i \Psi^*(\mu)$, $i = 1, 2$, then there exists $\hat{\delta} < 1$ such that contract μ' weakly dominates contract μ if $\delta \geq \hat{\delta}$. If at least one inequality is strict, then μ' dominates μ.*

Proof. See the Appendix.

Thus, we find the standard insight to be robust to introducing a small probability of continuation. In other words, for a small δ, the extent to which contracts influence the investors' exposure to hold-up "at the margin" explains the relative performance of contracts well. The same cannot be said, however, when δ is large. In this case, bargaining may continue after under-investment, permitting the expectation of future investment to matter. The possible investment dynamics changes the incentives of the parties and, more importantly, the way contracts influence these. In particular, (IC) is no longer important, for it is satisfied regardless of the underlying contract. Only (P), or equivalently $(P\prime)$, matters, resulting in the effects explained following $(P\prime)$.

It is interesting to look at the extreme case, when the parties' investments are totally relationship specific so that a failure to consummate trade leads to the parties being unable to appropriate any investment returns. In this case, for all μ, $\Delta_i \psi_j(\mu) = 0, i, j = 1, 2$. Then, condition (IC) is the same for all contracts: they are indistinguishable with regard to this condition. Yet, they are not same with respect to $(P\prime)$. In particular, the extent to which contracts expose the parties to hold-up in absolute level – $\Psi^*(\mu)$ – is the only thing affected by the contract that matters. Strikingly, $(P\prime)$ tells us that – independently of the distribution of the aggregate disagreement payoff and of the bargaining powers – a contract maximizing the parties' (aggregate) exposure to hold-up is the one that relaxes the constraint the most! The same insight applies if investments are not totally relationship specific, but the alternative contracts provide the same marginal protection to the investors from the hold-up problem:

Corollary 3. ***(No-trade Payoff Minimization Principle)*** *Suppose*

$$\Psi^*(\mu') < \Psi^*(\mu).$$

Then, there exists $\hat{\delta} \in (0, 1)$ such that i) μ' dominates μ, if $\delta > \hat{\delta}$, and ii) if $\Delta_i \psi_j(\mu) = \Delta_i \psi_j(\mu')$, $i, j = 1, 2$, then contracts μ' and μ are equivalent if $\delta \leq \hat{\delta}$.

Proof: See the Appendix.

For high values of δ, any contract exacerbating the parties' returns on investment (in the absence of trade) performs well. At the same time, any two contracts that have the same "marginal" features are equivalent for low values of δ. In fact, as long as the marginal effects of the contracts go in the right way (c.f. Proposition 1a), reducing the no-trade payoff weakly incentivizes investment for any time preference.

Further, the leakage of investment returns has an adverse effect only for low values of δ.

Corollary 4. ***(Irrelevance of Leakage)*** *Suppose* $\Delta_i\psi_i(\mu) = \Delta_i\psi_i(\mu')$, $i = 1, 2$, $\Psi^*(\mu') = \Psi^*(\mu)$ *and*

$$\Delta_i\psi_{-i}(\mu) < \Delta_i\psi_{-i}(\mu'), \;\; i, j = 1, 2.$$

Then, there exists $\widetilde{\delta} \in (0, 1)$ *such that i)* μ *dominates* μ'*, if* $\delta < \widetilde{\delta}$*, and ii) contract* μ' *and contract* μ *are equivalent if* $\delta \geq \widetilde{\delta}$*.*

Proof. See the Appendix.

To illustrate the new insight, consider a simple example in which (only) party 1 has a fully relationship specific (binary) investment decision. The efficient payoff (excluding investment costs) as well as contract payoffs under three contracts μ, μ', μ'' are as follows:

payoffs	ϕ	$(\psi_1(\mu), \psi_2(\mu))$	$(\psi_1(\mu'), \psi_2(\mu'))$	$(\psi_1(\mu''), \psi_2(\mu''))$
not investing	2	$(1, 1)$	$(\frac{1}{2}, \frac{1}{2})$	$(0, 0)$
investing	5	$(1, 1)$	$(\frac{1}{2}, \frac{1}{2})$	$(\frac{1}{2}, \frac{1}{2})$

Assume the cost c_1 of investing is less than 3, the social investment return, so it is socially desirable for party 1 to invest. If the parties have equal bargaining powers, then the standard hold-up model would predict the three contracts to perform equally. None of the contracts lower the investor's exposure to hold-up at the "margin." Specifically, under contracts μ and μ', investing never improves that party's no-trade payoff. Under contract μ'', investing improves her no-trade payoff by $\frac{1}{2}$, but this is "offset" by the concomitant improvement in her opponent's no-trade payoff (i.e., the leakage of the investment return). In the static model, since the investor (party 1) internalizes only half of the return $\frac{1}{2}(5-2) = 1.5$, these contracts will implement the efficient outcome if and only if $c_1 \leq 1.5$.

In our dynamic model, however, these contracts are not equivalent, provided that $\delta \geq 2 - \frac{3}{c_1}$. For such a value of δ, all three contracts satisfy $(IC\prime)$.[17] They are all different, though, in terms of the extent to which they satisfy $(P\prime)$. A shift from μ to μ' relaxes the constraint since μ' reduces the joint no-trade payoff (Corollary 3); a shift from μ' to μ'' further relaxes the constraint since μ'' reduces the investor's exposure to holdup at the margin and the concomitant leakage has no effect on $(P\prime)$ (Corollary 4). In fact, for a sufficiently high δ, contract μ'' dominates μ', which in turn dominates μ. For instance, fix any $\delta \geq \frac{1}{2}$. Then, if $c_1 \in (1.5, 2]$, contract μ can never implement the efficient outcome but contracts μ' and μ'' can. If $c_1 \in (2, \frac{3}{2-\delta}]$, then only contract μ'', but not the other two, can implement the efficient outcome.

3.3 Equilibrium selection

The dynamic model has the unwelcome feature that it has multiple equilibria. Of particular note is that no investment continues to be an equilibrium outcome for any value of δ. It is therefore of interest to see whether the parties can coordinate on the (most) efficient equilibrium. When the equilibria are Pareto ranked, it is sensible to assume that they will indeed act in their collective interest.[18] However, for an arbitrary contract, the equilibria need not be Pareto ranked. We now show that in that case, by manipulating the no-trade payoffs of the parties the efficient equilibrium can be made Pareto superior without sacrificing the No-trade Payoff Minimization Principle.

Proposition 2. *Assume that investment is an equilibrium and $U_1^0(\mathbf{I}^*;\mu) - c_1 > U_1^0((0,0);\mu)$ but $U_2^0(\mathbf{I}^*;\mu) - c_2 \leq U_2^0((0,0);\mu)$. In that case, there exists μ' such that investment is still an equilibrium and $U_i^0(\mathbf{I}^*;\mu') - c_i > U_i^0((0,0);\mu')$, $i = 1, 2$. One such μ' can be generated from μ by decreasing $\psi_1(\mathbf{I}^*;\mu)$ and $\psi_1(\mathbf{I}^*_{-1};\mu)$ by the (same) appropriate amount.*

Proof: See the Appendix.

In other words, we can adhere to the No-trade Payoff Minimization Principle by reducing only the more willing party's no-trade payoff upon investment and complement it with a

[17] The LHS of $(IC\prime)$ becomes

$$\tfrac{1}{2}(5-2) - (1 - \tfrac{1}{2}\delta)c_1,$$

which is nonnegative if $\delta \geq 2 - \frac{3}{c_1}$.

[18] Note that, by Assumption 1, when they are Pareto ranked, the equilibrium with investment is preferred by both parties.

(no smaller) decrease in her no-trade payoff following her deviation to no investment, and we achieve equilibrium selection at the same time as we encourage investment.

4 Applications

In what follows, we explore how the new insights apply to several well-known problems. In particular, we illustrate how investment dynamics influences the prescriptions for organizational design.

4.1 The Grossman-Hart-Moore (GHM) model of asset ownership

Suppose there are two assets, $A = \{a_1, a_2\}$. An ownership structure, μ, is then represented by a pair of disjoint subsets of A, (A_1^μ, A_2^μ), where $A_i^\mu \subset A$, $i = 1, 2$, stands for the asset(s) party i owns under ownership structure μ. There are four alternative structures: (1) separate ownership or non-integration: $\mu_N := (\{a_1\}, \{a_2\})$;[19] (2) common ownership (or integration) by party 1: $\mu_1 := (\{a_1, a_2\}, \emptyset)$; (3) common ownership (or integration) by party 2: $\mu_2 := (\emptyset, \{a_1, a_2\})$; and (4) joint ownership $\mu_J := (\emptyset, \emptyset)$.

According to the GHM theory, a party's contract payoff, $\psi_i(\mathbf{I}; \mu)$, represents the revenue that she can generate by exercising her residual rights in the event of disagreement, so the payoff depends on the assets owned by that party. This set-up easily lends itself to analysis in our dynamic model in which, following the choice of asset ownership, the parties play our investment-trading game. Following Hart (1995), we make a few assumptions. First, a party's contract payoff depends only on the asset he owns: i.e., $\psi_i(\cdot; \mu) = \psi_i(\cdot; \mu')$ if $A_i^\mu = A_i^{\mu'}$. Second, owning more assets can only raise one's contract payoff: $\psi_i(\mathbf{I}, \mu) \leq \psi_i(\mathbf{I}, \mu')$ if $A_i^\mu \subset A_i^{\mu'}$, for all $\mathbf{I}$. Last, the investments are interpreted as acquisition of human capital not embodied in the assets, so it is reasonable to assume that one's contract payoff does not depend on his *partner*'s investment: $\Delta_i \psi_{-i}(\mu) \equiv 0$. That is, there is no leakage of investment returns.

The crucial element in the GHM theory is the extent to which each ownership structure determines one's exposure to hold up *at the margin*. Hence, it is important for alternative ownership structures to be well ordered in this respect, which is accomplished by assuming that additional assets owned reduce this exposure: $\Delta_i \psi_i(\mu) \leq \Delta_i \psi_i(\mu')$ if $A_i^\mu \subset A_i^{\mu'}$.

[19] We ignore $(\{a_2\}, \{a_1\})$, for simplicity and consistency with GHM. Actually, "cross ownership" might be an additional safeguard against opportunism. See, for example, Heide and John (1988).

To highlight our new insightrelative to the existing one, we define two salient cases of interest in terms of how asset ownership affects the parties' overall exposure to the hold-up problem.

Definition 2. *The assets are* ***substitutive*** *if*

$$\psi_1^*(\mu_J) + \psi_2^*(\mu_J) \leq \psi_1^*(\mu_i) + \psi_2^*(\mu_i) < \psi_1^*(\mu_N) + \psi_2^*(\mu_N),\ i = 1, 2.$$

The assets are ***complementary*** *if*

$$\psi_1^*(\mu_i) + \psi_2^*(\mu_i) > \psi_1^*(\mu_N) + \psi_2^*(\mu_N) \geq \psi_1^*(\mu_J) + \psi_2^*(\mu_J),\ i = 1, 2.$$

Suppose the assets are substitutive. Then, starting from separate ownership, if a party gains an asset, his status quo value does not rise as much as the other party's status quo payoff declines. In this sense, the assets are more valuable (outside the relationship) when owned separately than when owned under a common ownership. In the same sense, complementary assets are more valuable (outside the relationship) when owned by the same party than when they are owned separately.

In the GHM theory, it is crucial how the asset values are characterized in "marginal" terms; i.e., by the way in which raising investments affects the status quo payoffs:[20]

Definition 3. *The assets are* ***marginally substitutive*** *if*

$$\Delta_i\psi_i(\mu_i) = \Delta_i\psi_i(\mu_N) > \Delta_i\psi_i(\mu_{-i}) = \Delta_i\psi_i(\mu_J),\ i = 1, 2.$$

The assets are ***marginally complementary*** *if*

$$\Delta_i\psi_i(\mu_i) > \Delta_i\psi_i(\mu_N) = \Delta_i\psi_i(\mu_{-i}) = \Delta_i\psi_i(\mu_J),\ i = 1, 2.$$

Invoking Proposition 1, a series of observations follow.

[20] The following definitions originate from Hart (1995), but he labels them differently. We changed the terms to be more cohesive with the alternative notions, defined above. Note also that Definition 2 is a little more general than the "absolute payoffs" counterpart of the Definition 3:

$$(*) \qquad \psi_i^*(\mu_i) = \psi_i^*(\mu_N) > \psi_i^*(\mu_{-i}) = \psi_i^*(\mu_J),\ i = 1, 2.$$

$$(**) \qquad \psi_i^*(\mu_i) > \psi_i^*(\mu_N) = \psi_i^*(\mu_{-i}) = \psi_i^*(\mu_J),\ i = 1, 2.$$

Clearly, $(*)$ and $(**)$ imply the assets to be substitutive and complementary, respectively, as defined in Definition 2.

Proposition 3. **a)** *If assets are marginally substitutive, then separate ownership of the assets dominates their common ownership by either party, which in turn both dominate joint ownership, for any* $\delta < \tilde{\delta}_1$ *for some* $\tilde{\delta}_1 > 0$.

b) *If assets are marginally complementary, then common ownership of assets by either party dominates both separate and joint ownership for any* $\delta < \tilde{\delta}_2$ *for some* $\tilde{\delta}_2 > 0$.

c) *If assets are substitutive, then there exist* $M > 0$ *and* $\hat{\delta}_1 < 1$ *such that common ownership of the assets by either party dominates their separate ownership, if* $\delta > \hat{\delta}_1$ *and* $\Delta_i \psi_i(\mu) < M$, $\forall i, \mu$.

d) *If assets are complementary, then there exist* $M > 0$ *and* $\hat{\delta}_2 < 1$ *such that separate ownership of assets dominates their common ownership by either party, if* $\delta > \hat{\delta}_2$ *and* $\Delta_i \psi_i(\mu) < M$, $\forall i, \mu$.

e) *There exist* $M > 0$ *and* $\hat{\delta}_3 < 1$ *such that joint ownership is optimal if* $\delta > \hat{\delta}_3$ *and* $\Delta_i \psi_i(\mu) < M$, $\forall i, \mu$.

Proposition 3-a) and -b) find the robustness of the GHM prescription that marginally substitutive assets should be owned separately and marginally complementary assets should be owned together, to introducing a small probability of continuation of bargaining and possible investment dynamics. On the other hand, parts c), d) and e) show results of the "opposite flavor" to hold, if δ is sufficiently large. They show, for instance, that complementary assets should be owned separately and that joint ownership, where neither party has firm control over assets, and thus any appreciable residual right, is optimal, when δ is large. This surprising result again is traceable to the No-trade Payoff Minimization Principle: the parties' incentives to shirk can be controlled better when they can credibly put themselves in a position vulnerable to hold up.

As the predictions of the static and dynamic models are so starkly different, it is worth relating them to the actually observed organizational structure. Hart (1995) alludes to the evidence – Joskow (1985), Stuckey (1983) – that complementary assets are usually vertically integrated as proof in favor of the superiority of asset integration. We believe that this evidence is subject to interpretation. In these examples it is unclear whether within the vertically integrated firm we still have two parties making relationship-specific, non-contractible investments. In fact, a principal-agent relationship is more likely. In the cases where the GHM paradigm clearly applies, vertical integration is often better described as a merger and thus corresponds to a joint ownership structure.[21]

4.2 Exclusive Dealing

An agreement to deal with a partner at the exclusion of others has been the subject of much debate. Antitrust authorities have either banned or held in suspicion any exclusive practices that may foreclose competition. Others suggested that the voluntary nature of such agreements may reflect some efficiency benefits they might bring. One such hypothesis is that the security of the trading relationship such an agreement brings can motivate the partners to make relationship specific investments: in other words, exclusivity may protect the partners from hold-up.

Whether this hypothesis holds true can be studied within the framework of the current model. Suppose two parties, 1 and 2, can realize the trading benefit of $\Phi(\mathbf{I})$, given their investment $\mathbf{I}$. If they fail to reach an agreement to trade, they can collect the payoffs of $\psi_i(\mathbf{I};\mu)$, depending on the contractual arrangement μ. There are four possibilities in this regard, as exclusivity may be granted to either 1 or 2 or to both, or to neither. Let X_i denote an agreement for party $i = 1, 2$ not to engage in external trade, X_b the agreement for both parties not to trade externally, and NX means no such agreement. Thus $\mathcal{M} = \{X_1, X_2, X_b, NX\}$. It is reasonable to assume that the opportunity to trade externally is valuable:

$$\psi_1(\cdot;NX) + \psi_2(\cdot;NX) > \psi_i(\cdot;X_i) + \psi_{-i}(\cdot;X_i) > \psi_1(\cdot;X_b) + \psi_2(\cdot;X_b), i = 1, 2.$$

There are several cases of potential interest. The first is one where the specific investments are *not transferable* to trading outside the current relationship. For instance, a specialized investment tailored to his partner may be lost when one changes his partner. This implies that $\Delta_i\psi_j(\mu) = 0$ for all $\mu \in \mathcal{M}$ and $i, j = 1, 2$. Segal and Whinston (2000) found the exclusivity agreement to be of no value in promoting investments in this situation.

Next is the case where investment is transferable but in a way that benefits only the investor, in the sense that $\Delta_i\psi_i(NX) = \Delta_i\psi_i(X_{-i}) > 0 = \Delta_i\psi_{-i}(X_i) = \Delta_i\psi_{-i}(NX)$. That is, there is no leakage of investment returns to the partner. This is a reasonable assumption

[21] See Whinston (2003) for a discussion on the little guidance that the empirical literature can give us regarding the applicability of the GHM paradigm.

in most trading relationships. The last focal case is one where the investment benefits only the trading partner: $\Delta_i\psi_i(NX) = \Delta_i\psi_i(X_{-i}) = 0 < \Delta_i\psi_{-i}(X_i) = \Delta_i\psi_{-i}(NX)$. Such "leakage" of investment is an issue for sports clubs and entertainment agencies, which often discover, train and groom their talents, only to see them switching to different teams or different agencies, taking with them the human capital and marketing assets cultivated by the original partner. Invoking Corollary 3 and Proposition 1, the following series of results hold.

Proposition 4. a) *Suppose the investments are non-transferable in the sense that* $\Delta_i\psi_j(\mu) = 0$ *for all* $\mu \in \mathcal{M}$ *and* $i, j = 1, 2$. *Then, there exist* $\tilde{\delta} \in [0, 1)$ *such that, for* $\delta \leq \tilde{\delta}$, *all arrangements in* $\mathcal{M}$ *are equivalent but, for any* $\delta > \tilde{\delta}$, X_b *dominates* X_i, $i = 1, 2$, *which in turn dominate* NX.

b) *Suppose* $\Delta_i\psi_i(NX) = \Delta_i\psi_i(X_{-i}) > 0 = \Delta_i\psi_{-i}(X_i) = \Delta_i\psi_{-i}(NX)$. *Then, there exist* $\tilde{\delta} \geq 0$ *and* $\hat{\delta} < 1$ *such that, for any* $\delta \leq \tilde{\delta}$, NX *dominates* X_i *which in turn dominates* X_b, *but for any* $\delta > \hat{\delta}$, X_b *dominates* X_i, *which in turn dominates* NX *if* $\Delta_i\psi_{-i}(X_i) = \Delta_i\psi_{-i}(NX)$ *is sufficiently small.*

c) *Suppose* $\Delta_i\psi_i(NX) = \Delta_i\psi_i(X_{-i}) = 0 < \Delta_i\psi_{-i}(X_i) = \Delta_i\psi_{-i}(NX)$. *Then,* X_b *dominates* X_i, *which in turn dominates* NX.

Part a) contrasts the differences between the cases with small δ and large δ. In the former case, exclusive dealing has no effect on the investment incentives, as it was found by Segal and Whinston (2000), since exclusivity affects the scope of the hold-up problem only in absolute terms. With a large δ, this latter effect matters, however, and exclusivity does promote the investment, the more so with exclusivity imposed on both parties than just on one party. Part b) deals with the case in which the investments transferable to the investors in their external trade. In this case, the possibility of external trade actually improves the incentives at the margin, so with small δ, exclusivity is undesirable. With large δ, however, the opposite result holds as long as the extent of the transferability is small. Part c) concerns the case of "leakage" of investment returns. In this case, exclusivity promotes investments regardless of δ. Leakage of investment returns undermines the incentives, which can be avoided by removing the partner's access to external trade. For instance, suppose $\Delta_1\psi_2(NX) > 0$, with $\Delta_i\psi_j(NX) = 0$ for all $(i, j) \neq (1, 2)$. Then, granting exclusivity to party 1, which prohibits party 2's external trade, promotes the former's investment for δ small. If δ is close to 1, however, the leakage by itself does not pose a problem, but the parties' aggregate exposure to the holdup becomes important. Exclusivity increases the exposure, which increases their ability to punish, and thus improves the incentives even of those who grant the exclusivity clause.

De Meza and Selvaggi (2007) also find that exclusive dealing may promote specific investment, but in a markedly different model. In addition to a buyer and a seller, they explicitly model a third party (another buyer), who makes no investment but can either trade with the seller directly or can buy the good off the other buyer – when this is efficient. If the investing buyer has exclusivity protection, the second buyer can only participate in an eventual resale. Their result and ours complement each other towards establishing a positive role exclusivity may play in promoting specific investments.

4.3 Trade contracts

The inability to contract on investment can often be overcome indirectly, through contracting on the price and quantity of *ex post* trade. However, a number of scenarios have been identified in which a trade contract does not deliver full efficiency. We will discuss two of these. Both scenarios recognize the renegotiability of contracts as an important ingredient to obtain this result. In addition, they require some assumptions about the nature of specific investments: either cooperativeness or unpredictability of investment benefit, which will be described more fully below. Again, our extensive form is well suited to subsume these scenarios.

4.3.1 Cooperative Investments

Two parties, a seller (party 1) and a buyer (party 2), have an opportunity to trade $q \in Q \subset \mathbb{R}_+$ units of a good, which will cost party 1 $c(q, \mathbf{I})$ but generate a surplus of $v(q, \mathbf{I})$ to party 2, if they invest $\mathbf{I}$. The efficient surplus is then $\phi(\mathbf{I}) = \max_q[v(q, \mathbf{I}) - c(q, \mathbf{I})]$. The parties can initially sign a contract $(\hat{q}, \hat{t}) \in Q \times \mathbb{R} =: \mathcal{M}$ which obligates them to trade $\hat{q}$ at the payment $\hat{t}$, unless they renegotiate. The set $\mathcal{M}$ includes the possibility of the null contract, $(\hat{q}, \hat{t}) = (0, 0)$, with an associated outcome $v(0, \cdot) = c(0, \cdot) = 0$.

The parties initially agree on the trade contract. They then make specific investments $\mathbf{I}$. At the same time, they renegotiate the terms of the contract, and possibly add more investments until they agree to trade, all according to our extensive form. In particular, if they disagree and the bargaining breaks down (which occurs with probability $1 - \delta$), then the contract takes effect and they trade $\hat{q}$ and collect the payoffs, $\psi_1(\mathbf{I}; \hat{q}, \hat{t}) = \hat{t} - c(\hat{q}, \mathbf{I})$

and $\psi_2(\mathbf{I}; \hat{q}, \hat{t}) = v(\hat{q}, \mathbf{I}) - \hat{t}$, respectively. We are interested in how alternative contracts in $\mathcal{M}$ compare in implementing $\mathbf{I}^*$ in a Subgame Perfect equilibrium. We say a contract $\mu \in \mathcal{M}$ is *optimal* if it weakly dominates all other contracts in $\mathcal{M}$.

Of particular interest are purely cooperative investments, such that investors do not directly benefit from their investments: $c(\cdot, \mathbf{I}) \equiv c(\cdot, \cdot, I_2)$ and $v(\cdot, \mathbf{I}) \equiv v(\cdot, I_1, \cdot)$. Given this property of investment, it is easy to see that

$$\Delta_i \psi_i(\mu) = 0 < \Delta_i \psi_{-i}(\mu), i = 1, 2$$

for any $\mu = (\hat{q}, \hat{t})$ with $\hat{q} > 0$, whereas $\Delta_i \psi_j(0, 0) = 0, \forall i, j = 1, 2$. In other words, any non-trivial contract increases one's exposure to hold-up at the margin. Accordingly, Che and Hausch (1999) find that in the static model the null contract dominates any non-trivial trade contract.

Whether this conclusion holds true in the current dynamic model depends on whether there exists an (excessive) trade level that will generate a loss (and therefore a lower aggregate contract payoff than the null contract). Suppose

$$\hat{q}^+ \in \arg\min_{q \in Q} [v(q, \mathbf{I}^*) - c(q, \mathbf{I}^*)].$$

If $v(\hat{q}^+, \mathbf{I}^*) - c(\hat{q}^+, \mathbf{I}^*) < 0$, then a contract to trade $\hat{q}^+$ can be optimal for a sufficiently large δ. Again, our Proposition 1, Corollaries 3 and 4 deliver the following implications.

Proposition 5. *Suppose investments are purely cooperative.*

a) *The null contract is optimal, for all $\delta \leq \tilde{\delta}$ for some $\tilde{\delta} \geq 0$.*

b) *If $v(\hat{q}^+, \mathbf{I}^*) - c(\hat{q}^+, \mathbf{I}^*) \geq 0$, then the null contract is optimal, regardless of δ.*

c) *If $v(\hat{q}^+, \mathbf{I}^*) - c(\hat{q}^+, \mathbf{I}^*) < 0$, then a contract to trade $\hat{q}^+$ is optimal, for any $\delta > \hat{\delta}$ for some $\hat{\delta} \in [\tilde{\delta}, 1)$.*

The optimality of the null contract found by Che and Hausch may extend to our dynamic model, but it requires an additional condition.

4.3.2 Complexity (the "widget model")

Suppose a seller (party 1) and a buyer (party 2) can trade one of n different types of "widgets." Let the set Q^n be the set of all feasible types of widgets, with $|Q^n| = n + 1$, and

$q \in Q^n$ represents a particular type of widget and $q = 0 \in Q^n$ represents no trade. After the parties make investments $\mathbf{I} = (I_1, I_2)$, they learn one of the widget types to be special in that it generates higher joint surplus. Each widget has equal chance of becoming special. The special widget, regardless of its type, costs party 1 $c(\mathbf{I})$ and and yields the surplus of $v(\mathbf{I})$ to party 2. If widget q is ordinary, then it costs c_q to party 1 and yields the surplus of v_q to party 2, with $v_0 = c_0 = 0$. We assume $\Phi(\mathbf{I}) := v(\mathbf{I}) - c(\mathbf{I}) > v_q - c_q$, $\forall \mathbf{I} \in \{0,1\}^2$ and $\forall q \in Q^n$, so that it is efficient for the parties to trade the special widget.

Notice that the investments need not be cooperative here, but their value is realized only when the special good is traded. This latter property entails the same sort of difficulties with *ex ante* contracts in generating incentives. Specifically, the parties may sign a contract that requires them to trade a particular type $\hat{q} \in Q^n$ of widget for some transfer payment $\hat{t}$. The disagreement payoffs for parties 1 and 2 are random, since the type $\hat{q}$ becomes special with probability $\frac{1}{n}$ and ordinary with the remaining probability. Segal (1999) and Hart and Moore (1999) considered such a model. Of special interest is the limiting case in which the environment gets complex in the sense that $n \to \infty$. Let $Q = \lim_{n\to\infty} Q^n$. We consider this limiting case. Assume Q is compact. (Alternatively, we could start with a set Q that contains infinitely many types of widgets.)

Suppose the parties contract to trade any particular type $\hat{q}$. There is zero probability that that type will be special, so the contract payoffs are $\psi_1(\mathbf{I}; \hat{q}, \hat{t}) = \hat{t} - c_{\hat{q}}$ and $\psi_2(\mathbf{I}; \hat{q}, \hat{t}) = v_{\hat{q}} - \hat{t}$, respectively for parties 1 and 2. Notice that these payoffs do not depend on the investments at all. Hence, $\Delta_i \psi_j(\mu) = 0$, for all $\mu \in \mathcal{M} := Q \times \mathbb{R}$. Again, it is useful define the level of trade,

$$\hat{q}^+ \in \arg\min_{\hat{q}\in Q} [v_{\hat{q}} - c_{\hat{q}}],$$

that would lead to the worst joint payoff unless renegotiated. We obtain a result similar to that with the cooperative investment.

Proposition 6. *It is optimal for the parties to contract to trade* $\hat{q}^+$.

The intuition behind this result is clear. Observe that all different types of contracts are indistinguishable based on the marginal features, since $\Delta_i \psi_j(\mu) = 0$, for all $\mu \in \mathcal{M}$, so they are equivalent with respect to (IC). Hence, alternative contracts can be only be differentiated by (P). The No-trade Payoff Minimization Principle in Corollary 3 then suggests that the contract to trade the worst type of widget is optimal. Of course, such a contract may boil down to the null contract:

Corollary 5. *The null contract is optimal if and only if* $v_{\hat{q}^+} - c_{\hat{q}^+} \geq 0$.

Hence, our results from both cases suggest that the foundations of incomplete contracts can sometimes be justified in the dynamic setting but require some qualifications.

5 Related Literature

Several papers have developed somewhat similar insights, though in differing modelling contexts. Halonen (2002) shows in a repeated-game model that joint ownership of an asset strictly dominates single ownership for intermediate values of the players' discount factor, δ, since the former can make the repeated game punishment more severe. Baker et al. (2001, 2002) also demonstrate that the absolute payoff levels can affect the efficiency ranking of different ownership structures in a repeated trade setting. This is because the set of self-enforcing contracts that are sustainable depend on the (absolute) payoffs one gets from breaching the contract, which in turn vary with the ownership structure. Thus, in order to make the best relational contract possible a specific way of allocating the assets may be superior.

The repeated trade opportunities assumed in these papers make the folk theorem of repeated games applicable, which implies that an efficient outcome is sustainable as $\delta \to 1$, irrespective of the underlying organizational arrangements. In this sense, the organizational issues become irrelevant for a sufficiently large δ in these papers. By contrast, the parties have a single trading opportunity in our model (just as in the standard hold-up problem), which makes the folk theorem inapplicable. Indeed, contract design remains relevant even when $\delta \approx 1$ in our model.

Matouschek (2004) studies the effects of *ex ante* contracts on the *ex post* trading (in)efficiencies when the parties have two-sided asymmetric information *à la* Myerson and Satterthwaite (1983), but have no opportunity to invest. Similarly to our results, contracts inducing low disagreement payoffs increase the probability that agreement is reached when it is efficient. However, they prove more costly when agreement fails to obtain. As a result, whether the No-trade Payoff Minimization Principle applies in his set-up depends on the available gains to trade.

Hviid (1996) proposes the idea that default rules could be used for equilibrium selection in the context of a game of renegotiation with asymmetric information, but again without investments. His idea, however does not involve managing expectations, as once the desired default rule is in place there is a single equilibrium remaining.

In the context of incentive contracts, Baker et al. (1994) suggest that when some performance measure is non-verifiable it may be advantageous to make even some of the verifiable measures implicit in the contract. While on the face of it, this looks very similar to – some of – what we are proposing, the underlying logic is completely different. In their case, not making the verifiable part explicit confers a power of retaliation on the principal, in case the agent shirks on the non-verifiable part.

Finally, this paper is related to Hart and Moore (2008), who develop the idea that contracts may serve as reference points. Their contracting parties have a sense of entitlement fixed by the – extremes of a loose – *ex ante* contract, which will lead them to ex post non-Coasian bargaining *within* the limits of the old contract, if they feel shortchanged (relative to what they feel entitled to). The inefficiency could be just subjective, but they assume that it is realized via a shading of the quality of *ex post* performance.[22] The current paper can be seen as developing a "dual" view. Like theirs, our point of departure is that contracts fix the expectations of the parties. But instead of these acting as the source of efficiency loss, they become a source of incentives in our model. Also, while the sense of entitlement in their model is psychological, it is rational in our model, supported by the equilibrium belief.

6 Concluding remarks

We have shown that allowing for a simple and plausible investment dynamics in a hold-up model produces new implications on the design of important contracts and organizations. The novel theme in our prediction is that the incentives for relationship-specific investments depend not just on how a contract affects the investor's exposure to hold-up *at the margin* – the focus on the recent contract/organization literature – but, sometimes more importantly, on how the contract affects the investor's exposure to hold-up in *absolute* terms. Absolute exposure to hold-up *per se* was never been a concern in the static models, since the (trade) participation constraint is never the binding one there, but it is an important consideration in our dynamic model since the steeper incentives provided by investment dynamics may cause it to be binding.

A shift of emphasis from how organizations affect the extent to which investments al-

[22] This approach is in line with the one taken by Kreps (1997), Benabou and Tirole (2003), Besley and Ghatak (2005) and others, where some *intrinsic* motivation of the workers to perform well is incorporated into a principal-agent model. The aggrievement of Hart and Moore (2008) can be directly associated with a loss of such an intrinsic motivation.

leviate the hold-up problem at the margin to how they affect their exposure to hold-up directly takes us back to the original "transaction cost analysis" (TCA) authors (Klein et al., 1978; Williamson 1979, 1985, 1996), who were largely concerned about the absolute level of hold-up parties are subject to as the source of inefficiencies and the rationale for organizational interventions. While we agree that the absolute degree of hold-up matters, our specific predictions differ from these authors as well. Our theory predicts that contracts that would exacerbate the parties' vulnerability to hold-up – rather than those protecting them from it (as proposed by the TCA authors) – can be desirable. As discussed in the paper, this view throws a more positive light on a variety of "hostage taking" or "hands-tying" arrangements such as exclusivity agreements, joint ownership of assets, and trade contracts compelling parties to trade excessive amounts. These contracts/organization forms can perform well in our dynamic model since they can create a strong equilibrium punishment for under-investment. The TCA paradigm has often been criticized (c.f. Holmström and Roberts, 1998) about the fact that it ignored two empirically relevant features of an economic relationship: the cost of relationship-specific investments and the asymmetry of (bargaining) power between the parties. Our results remedy both of these weaknesses. As it is clear from (IR') our implementability condition incorporates both of these factors.

Real-world contracts are full of vague language and difficult-to-verify terms. Terms such as "good faith," "best efforts," "due diligence" and "commercially reasonable" are commonplace in any commercial contract (see Scott and Triantis, 2006). The parties signing a contract may clearly understand what these terms mean in the context of their relationship; it is unlikely, however, that courts share the same understanding and can enforce them the way the parties have intended. We argue that the ubiquity of seemingly unenforceable terms belies an important role contracts play: *to coordinate and manage the parties' expectations about their partners' behavior*. We postulate that stipulating a contract obligation for a party (promisor) gives his partners (promisees) *a sense of entitlement* to the former's fulfilling that obligation. Such a sense of entitlement alone – namely, holding a promisor to the expectation of performance – can create incentives for her performance, even when there are no explicit legal sanctions that support that expectation. Scott and Triantis (2006), analyze the trade-off between front-end (contract writing) and back-end (litigation, evidence production) costs. They argue that the use of "unnecessarily" vague terms in a contract may be the rational outcome of resolving this trade-off. The No-trade Payoff Minimization Principle reinforces and complements their findings. By including vague terms, the parties increase the back-end costs,[23] thereby providing the necessary penalty in case litigation indeed occurs. The actual back-end costs are of course a function of the courts' behavior. The issue of the ability of the courts for actually penalizing the parties for deferring the gap-filling to them was first raised by Ayres and Gertner (1989). They advocate the use of *penalty default rules* as a means of incentivizing information revelation in an asymmetric information setting. Their suggestion was challenged by Maskin (2006) and Posner (2006). The first of these argues that there is a superior way of providing the incentives, while the latter claims that such default rules are not used in practice. We would like to resurrect the idea of penalty default rules, though under a different guise. We claim that they can be useful not to encourage information revelation, rather to incentivize non-contractible investment. Such an interpretation does not fall foul of the Maskin critique. At the same time, we have a good reason to argue why such rules are not often applied in practice – at least, under Common Law. Observe, that the penalty default rule serves its purpose by providing the appropriate ex ante incentives. If the case reaches the court, there is no longer any point in imposing the penalty with respect to the current litigation. Thus, there is a serious problem of time inconsistency. The judge suffers from a present bias, not taking into account the effect of her decision on future cases. As a result, in countries whose legal system is based on Case Law, it is difficult to encourage the use of a penalty default rule. The situation would be different under Statute/Civil Law, where, at least in principle, such a rule could be written into the statutes. See Anderlini et al. (2014) for an insightful comparison of the two systems from this perspective.

Finally, the fact that our predictions are largely based on the absolute level of quasi-rents could also make them more empirically testable. As Whinston (2003) points out, the GHM theory is difficult to test,[24] since the (marginal) effects of investment on the disagreement payoffs are difficult to estimate, especially since most feasible levels of investment are not made in equilibrium. By contrast, hypotheses pertaining to the effects of absolute degree of asset specificities can be tested without observing payoff consequences of all investment choices, especially when investments are totally specific.

[23] This is consistent with the Hart and Moore (2008) argument. Signing a contract which is "loose" – and thus leads to less efficient bargaining within it – would lead to a low disagreement payoff, enhancing investment incentives. In a sense this is exactly what happens in the case of joint ownership: if the parties get into a row during renegotiation it is very difficult to sort the mess out if individual property rights are not clearly defined.

[24] Though see Baker and Hubbard (2004).

7 Appendix

Proof of Lemma 1: Let $\overline{v}_i$ and $\underline{v}_i$ be the supremum and infimum payoffs of party $i = 1, 2$ attainable in any SPE, immediately following $\mathbf{I}^*$. Then, for each $i = 1, 2$,

$$\begin{aligned}
\overline{v}_i &= \alpha_i[\phi(\mathbf{I}^*) - \delta\underline{v}_{-i} - (1-\delta)\psi_{-i}(\mathbf{I}^*;\mu)] + \alpha_{-i}\left[\delta\overline{v}_i + (1-\delta)\psi_i(\mathbf{I}^*;\mu)\right], \\
\underline{v}_i &= \alpha_i[\phi(\mathbf{I}^*) - \delta\overline{v}_{-i} - (1-\delta)\psi_{-i}(\mathbf{I}^*;\mu)] + \alpha_{-i}\left[\delta\underline{v}_i + (1-\delta)\psi_i(\mathbf{I}^*;\mu)\right].
\end{aligned}$$

The supremum payoff $\overline{v}_i$ is explained as follows. Upon reaching $\mathbf{I}^*$, party i is chosen with probability α_i to propose a share to his partner $-i$. If the latter rejects that proposal, then, with probability δ, the game continues with $\mathbf{I}^*$ as the state next period, from which $-i$ can earn at least $\underline{v}_{-i}$ by definition; with probability $1-\delta$, the negotiation breaks down, and $-i$ collects $\psi_{-i}(\mathbf{I}^*;\mu)$. In other words, the least $-i$ can get from rejecting i's offer is $\delta\underline{v}_{-i} + (1-\delta)\psi_{-i}(\mathbf{I}^*;\mu)$. Hence, the most i can earn is $\phi(\mathbf{I}^*)$, the maximum surplus that can be generated from trading with $-i$, minus this amount. This explains the first term. With probability $\alpha_{-i} = 1-\alpha_i$, party i becomes the receiver of $-i$'s offer. In this case, the most she can earn is $\delta\overline{v}_i + (1-\delta)\psi_i(\mathbf{I}^*;\mu)$, which explains the second term. The infimum payoff is explained analogously.

Solving this system of four equations for $\{\overline{v}_i, \underline{v}_i\}_{i=1,2}$ such that $\overline{v}_i \geq \underline{v}_i$ yields $\overline{v}_i = \underline{v}_i = U_i^0(\mathbf{I}^*;\mu)$. ∎

Proof of Theorem 1: (Necessity) By Lemma 1, in any efficient investment SPE, party $i = 1, 2$ must obtain a payoff of $U_i^0(\mathbf{I}^*;\mu) - c_i$. Suppose now party i deviates unilaterally by not investing. There are only two possible subgame perfect continuations following the deviation: either the deviator will make the investment in the following period or never, in case no agreement is reached in the current period. Consider the latter case, i.e., without investment in the next period. Let $\underline{w}_i$ be the infimum of party i's subgame perfect equilibrium payoff attainable in any subgame following $\mathbf{I}_{-i}^*$. Then,

$$\underline{w}_i \geq \delta\underline{w}_i + (1-\delta)\psi_i(\mathbf{I}_{-i}^*;\mu),$$

since party i has the option to avoid trade. It follows that

$$\underline{w}_i \geq \psi_i(\mathbf{I}_{-i}^*;\mu).$$

Since party i earns at least $\psi_i(\mathbf{I}_{-i}^*;m)$ from deviating, the efficient investment equilibrium can be supported only if

$$U_1^0(\mathbf{I}^*;\mu) - c_i \geq \psi_i(\mathbf{I}_{-i}^*;m),$$

as is required by (P).

Consider next a deviation followed by party i investing in the subsequent period in case no agreement is reached in the current period. If the next period is indeed reached, the associated continuation payoffs for i and $-i$ are respectively $U_i^0(\mathbf{I}^*;\mu) - c_i$ and $U_{-i}^0(\mathbf{I}^*;\mu)$, by Lemma 1. Hence, party i's payoff from such a deviation must be at least

$$\begin{aligned} &\alpha_i[\phi(\mathbf{I}_{-i}^*) - \delta U_{-i}^0(\mathbf{I}^*;\mu) - (1-\delta)\psi_{-i}(\mathbf{I}_{-i}^*;\mu)] \\ &+\alpha_{-i}[\delta(U_i^0(\mathbf{I}^*;\mu) - c_i) + (1-\delta)\psi_i(\mathbf{I}_{-i}^*;\mu)]. \end{aligned} \tag{2}$$

Since such a deviation should not be profitable,

$$\begin{aligned} & U_i^0(\mathbf{I}^*;\mu) - c_i \\ \geq\ & \alpha_i[\phi(\mathbf{I}_{-i}^*) - \delta U_{-i}^0(\mathbf{I}^*;\mu) - (1-\delta)\psi_{-i}(\mathbf{I}_{-i}^*;\mu)] + \alpha_{-i}[\delta(U_i^0(\mathbf{I}^*;\mu) - c_i) + (1-\delta)\psi_i(\mathbf{I}_{-i}^*;\mu)] \\ & \Leftrightarrow U_i^\delta(\mathbf{I}^*;\mu) - c_i \geq U_i^\delta(\mathbf{I}_{-i}^*;\mu) - \alpha_{-i}\delta c_i, \end{aligned}$$

as is required by (IC).

(Sufficiency) To show that these conditions are sufficient for existence of an efficient investment SPE, consider the following investment strategy profile: "Each party invests whenever he has not invested previously." This simple investment strategy profile clearly implements the efficient investment. Further, given (P) and (IC), this strategy profile, along with the optimal bargaining behavior, forms a SPE. This can be seen by the fact that, given (P), any unilateral single-period deviation by party 1, say, gives him precisely the payoff in (2), which is dominated by his equilibrium payoff, as is guaranteed by (IC). ∎

Proof of Corollary 2: Note that both constraints can be written as an upper bound on c_i, so they are comparable. We have already observed that (IC) converges to (1) as $\delta \to 0$. Further, the RHS of (1) is more than $\psi_i(\mathbf{I}_{-i}^*;\mu)$, by Assumption 2-b, so (IC) implies (P). It then follows from the continuity of $U^{[\cdot]}$ and the monotonicity of (IC) in δ – as shown by the proof of Corollary 1 – that there exists $\tilde{\delta}_i \geq 0$ such that $(IC) \Leftrightarrow (P)$ for $\delta \leq \tilde{\delta}_i$.

To see that $\delta_i^* < 1$, it suffices to show that (IC) is satisfied for sufficiently large $\delta < 1$. To this end, observe that, as $\delta \to 1$, (IC) converges to $\alpha_i\phi(\mathbf{I}^*) - c_i \geq \alpha_i\phi(\mathbf{I}_{-i}^*) - \alpha_{-i}c_i$, or, $\phi(\mathbf{I}^*) - c_i \geq \phi(\mathbf{I}_{-i}^*)$. Since this latter condition is implied – with strict inequality – by the efficiency of investment (Assumption 1), (IC) is satisfied for any $\delta \geq \hat{\delta}$ for some $\hat{\delta} < 1$. Finally, note that for $\delta \in [\hat{\delta}_i, \tilde{\delta}_i]$ both constraints are satsified – since (IC) implies (P) – so we can claim that (P) implies (IC). Consequently, $\delta_i^* = \min\{\hat{\delta}_i, \tilde{\delta}_i\}$ satisfies the claim. ∎

Proof of Proposition 1: a) It follows from Corollary 2 that (IC) is sufficient for any two contracts μ and μ' to implement $\mathbf{I}^*$ when $\delta \leq \tilde{\delta}$ for some $\tilde{\delta} \geq 0$. Fix any such δ and suppose that μ implements $\mathbf{I}^*$. Then, contract μ must satisfy (IC), so $\Delta V_i^\delta(\mu) \geq 0$, $i = 1, 2$. Given the hypothesis, it follows that, for $i = 1, 2$,

$$(3)\ \ \Delta V_i^\delta(\mu') - \Delta V_i^\delta(\mu) = (1-\delta)\left\{\alpha_{-i}(\Delta_i\psi_i(\mu') - \Delta_i\psi_i(\mu)) - \alpha_i(\Delta_i\psi_{-i}(\mu') - \Delta_i\psi_{-i}(\mu))\right\} \geq 0.$$

Therefore, we must have $\Delta V_i^\delta(\mu') \geq 0$, $i = 1, 2$, so μ' satisfies (IC). Since (IC) is sufficient, μ' must also implement $\mathbf{I}^*$. Consequently, μ' weakly dominates μ, proving the first statement. If one of the vector inequalities is strict, then the LHS of (3) is strictly positive for either $i = 1$ or $i = 2$. Hence, there exists (c_1, c_2) such that $\Delta V_i^\delta(\mu') \geq 0$, for $i = 1, 2$, but that $\Delta V_i^\delta(\mu) < 0$ for some i. In this case, μ' implements $\mathbf{I}^*$ but μ cannot. Hence, μ' dominates μ, proving the second statement.

b) By Corollary 2, for any pair of contracts μ, μ' there exists $\hat{\delta} < 1$ such that, for any $\delta > \hat{\delta}$, only condition (P) matters. Fix any such δ, and suppose the hypothesis is true. Then, since $(P\prime)$ is sufficient for a contract to implement $\mathbf{I}^*$, whenever μ implements $\mathbf{I}^*$, so does μ'. Hence, μ' weakly dominates μ. If the inequality is strict for at least for one party, then there exists (c_1, c_2) such that $(P\prime)$ holds only for μ'. Hence, μ' dominates μ. ▮

Proof of Corollary 3: By Proposition 1b), contract μ' dominates μ for any $\delta > \hat{\delta}$ for some $\hat{\delta} < 1$, and Proposition 1a) implies that the two contracts are equivalent for any $\delta < \tilde{\delta}$ for some $\tilde{\delta} > 0$. To prove that $\hat{\delta} = \tilde{\delta}$, it suffices to show that if μ' dominates μ at any δ, the same is true for a higher δ. To see this, observe first that $(IC\prime)$ is the same under both contracts but that μ' satisfies $(P\prime)$ whenever μ does, for any value of δ. It follows that μ' weakly dominates μ. Next, fix δ and suppose μ' dominates μ at that δ. This means there exists c for which μ' satisfies both $(P\prime)$ and $(IC\prime)$ but μ fails $(P\prime)$. By Corollary 1, for any $\delta' > \delta$, μ' still satisfies the two conditions at c but μ still fails $(P\prime)$ (since it does not depend on δ). ▮

Proof of Corollary 4: By Proposition 1a), contract μ' dominates μ for any $\delta > \widetilde{\delta}$ for some $\widetilde{\delta} < 1$, and Proposition 1a) implies that both contracts are equivalent for any $\delta < \delta'$ for some $\delta' > 0$. That $\delta' = \tilde{\delta}$ can be shown by an argument analogous to that in the proof of Corollary 3. ▮

Proof of Proposition 2: By Assumption 1 and the hypothesis, $U_1^0(\mathbf{I}^*; \mu) - c_1 - U_1^0((0,0); \mu) > U_2^0((0,0); \mu) - (U_2^0(\mathbf{I}^*; \mu) - c_2)$: the gain of the willing party exceeds the loss of the unwilling one. As $\frac{dU_1^0(\mathbf{I};\mu)}{d\psi_i(\mathbf{I};\mu)} = -\frac{dU_2^0(\mathbf{I};\mu)}{d\psi_i(\mathbf{I};\mu)}$, we can decrease $\psi_1(\mathbf{I}^*; \mu)$ by the appropriate amount, to achieve Pareto superiority of investment. To see that equilibrium incentives can be maintained, note that by decreasing $\psi_1(\mathbf{I}^*_{-1};\mu)$ by the same amount, we do not affect the equilibrium payoffs but keep both parties' investment incentives (IC) constant while their trading incentive (P) improves. ▮

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