Dynamic Investments and Contractual Remedies to the Hold-Up Problem

Yeon-Koo Che* József Sákovics†

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Abstract

An important theme in modern contract theory concerns the role contracts play in protecting the parties from the risk of hold up and thereby encouraging their relationship-specific investments. While this perspective has generated useful insights about various contracts, the underlying models abstract from realistic investment dynamics. We reexamine the role of contracts in a dynamic model of renegotiation that endogenizes the timing of investments and trade. The resulting interaction between bargaining and investment significantly alters the lessons learned from static models. We show that contracts that would exacerbate the parties' vulnerability to hold up – rather than those protecting them from the risk of 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, in contrast to the existing results – based on static models.

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*Economics Department, Columbia University, 420 West 118th Street, New York, NY 10027, USA. E-mail: yc2271@columbia.edu.

†University of Edinburgh, 50 George Square, EH8 9JY, Edinburgh, UK. E-mail: jozsef.sakovics@ed.ac.uk

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1 Introduction

The hold-up problem arises when a business partner makes relationship-specific investments that are susceptible to *ex post* expropriation by his associates. Examples of such investments include acquisition of firm-specific skills by workers, subcontractors' efforts to customize their parts to the special needs of manufacturers, and a firm's relocation of its plant adjacent to its trading partner's. These investments create more surplus within a relationship than without. Hence, absent any special safeguard, the fear of hold up may lead the parties to under-invest relative to the efficient level. As a result, an important theme of the modern contract literature is to look at how contracts can provide protection for the investors.[1]

While this literature has generated valuable insights about various contracts, the underlying models abstract from the realistic investment dynamics present in many business relationships. Specifically, the extant models of incomplete contracts assume that the partners make a single investment decision, after which the renegotiation of the contract commences. In practice, however, the timing of investment and bargaining is – at least to some extent – chosen endogenously by the parties, and the investment and bargaining stages are often intertwined. Crucially, trade can potentially be postponed in the expectation of further investment. For instance, the Department of Defense may negotiate to order a weapons system from a contractor based on his current technical knowledge, or it may decide to wait until the latter invests more in R & D and develops a better technology. A similar dynamic interaction of investment and bargaining arises in the development of new building construction, advertising pilots or software projects.[2]

In this paper, we study the effects of *ex ante* (incomplete) contracts in an environment where each party can make relationship-specific investments in every period until either the parties agree to trade or the negotiation breaks down – say, because trade ceases to be efficient. In our model, two risk-neutral parties initially sign a contract, that may specify

[1]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).

[2]Such dynamic interaction is also present in the publishing of academic articles. Consider the editorial procedure at the Berkeley Electronic Journals. Here submission is simultaneous to four vertically differentiated journals. Unless the initial submission is rejected, in principle, the author is offered a choice between immediate acceptance at a lower level or acceptance at a higher level conditional on a substantial revision (incremental investment after the negotiation has commenced).

various aspects of their relationship, such as asset ownership, future trade decisions or exclusivity of their trading relationship. This contract may be renegotiated over time, but it affects the outcome of renegotiation by determining its threat point. Once the contract is signed, the parties begin by (potentially) making a sunk investment of predetermined size, and then a randomly chosen proposer offers to his partner a share of the (gross) surplus that would obtain through trading given the current level of investment. If that offer is accepted, trade occurs according to the agreement, and the game ends. If the offer is rejected, then negotiation breaks down irrevocably with some given probability. In that case, the contract in place takes effect, assigning the payoffs to the parties. With the remaining probability, the game moves to the next period without trade, and the same process is repeated; i.e., either party who has not yet done so can invest, what is followed by a new bargaining round with a random proposer, and the game goes on until either trade occurs or the negotiation breaks down.

If investment is allowed to occur *only* in the first period – or equivalently, if breakdown is certain following disagreement – then, given risk neutrality, our model coincides with the majority of existing contract models, which use the Nash Bargaining Solution (NBS) with the contract payoffs serving as the threat point.[3] Our full-fledged model provides a natural dynamic extension of these that endogenizes the timing of investment and trade decisions. For this reason, the equilibrium results of our model are easily comparable to those in most of the incomplete contract literature.

Absent the possibility to invest, the unique subgame perfect equilibrium of this bargaining model replicates the NBS, just as in Binmore, Rubinstein and Wolinsky (1986).[4] Thus, our model can also be seen as a generalization of their model by making both the stake and the disagreement payoffs of bargaining endogenous through investment.

We show that allowing for investment dynamics yields a new insight on the effects of contracts. The recent contract literature has focused on the inappropriability of returns *at the margin* as a source of inefficiency and a rationale for contract intervention. More precisely, the literature has focused on how the parties' contract payoffs vary with investment.

[3]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).

[4]Binmore, Rubinstein and Wolinsky (1986) present the alternating-offer version of this model. They need to take the limit as the breakdown probability tends to zero in order to eliminate the first-mover advantage and to show the full equivalence with the NBS. Instead, we assume that in each bargaining round the proposer is chosen randomly, which – given risk neutrality – yields the same effect (see Binmore, 1987).

If an investor's contract payoff increases with her specific investment, it effectively reduces the specificity of her investment *at the margin*, thus reducing the exposure of her marginal investment return to expropriation. Such a contract thus improves her incentives to make the specific investment. Alternative contracts can be ranked along this logic: If a contract reduces the investor's marginal specificity exposure more than another contract, the former contract will protect her investment return better than the latter, thus inducing a higher level of investment. By the same token, if two contracts entail precisely the same *marginal* specificity, their effect on investment incentives will be precisely the same, even when they differ in terms of the investors' exposure to *absolute* specificity that they induce. Hence, the absolute degree of specificity investors are exposed to does not matter in the existing models. In our dynamic model, absolute specificity does matter (for a sufficiently low probability of breakdown). Roughly speaking, what happens is that for efficient investment to happen in equilibrium, two conditions need to be satisfied for each investor. One of them is an incentive compatibility constraint, which is easier to satisfy the higher the probability of continuation is. The other is an individual rationality constraint, which is independent of the break-down probability. For sufficiently low probability of continuation it is always the incentive constraint which is stricter and thus the intuition gained from the static model carries over. On the other hand, if the probability of continuation is sufficiently high the individual rationality constraint becomes the binding one. The way to relax this constraint is to choose the contract payoffs to be low. We call this general result the *Status Quo 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 say that this "lack of integration" comes about despite the fact that the break-up costs of these networks would be very large. The Status Quo Minimization Principle provides a ready answer to why this should not be surprising.

Our final general result concerns the alternative way the individual rationality constraint may be relaxed: by improving the marginal incentives of an investing party, just as in the standard model, but unlike in the standard model *without* having to worry about the "leakage" effect of investment on the marginal exposure of the other party. Thus, unlike the conclusions of Che and Hausch (1999) in a static model, if the dynamics is important we would expect that contracts of the "usual" type should be beneficial – and thus observed – in situations where investments are co-operative as long as they have some selfish component.

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 the 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 activities, simply labeled "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). They parties can raise the trade surplus by investing. The investment decision for party i is assumed to be binary, represented by an indicator function I_i which takes a value 1 if i has invested and zero if he has not invested.[5] The cost of investing 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 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 nontrivial, we assume that investment by each party 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 ownerships, trade level, or exclusivity of trading relationships. These contracts take effect whenever they are not renegotiated. It is convenient to identify a contract by

[5] The choice of binary investment is largely for simplicity, for allowing for 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).

the payoffs they yield to the payoffs. Specifically, fix a contract $\mu \in \mathcal{M}$, for some arbitrary set $\mathcal{M}$. Then, the parties collect payoffs of $(\psi_1(\mathbf{I};\mu), \psi_2(\mathbf{I};\mu))$, henceforth referred to as *disagreement* or *contract payoffs*, in case they choose not, or fail, to renegotiate it.

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 $\mu \in \mathcal{M}$, $\psi_i(\mathbf{I};\mu) \le \psi_i(\mathbf{I}';\mu)$ 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) $0 \le \phi(\mathbf{I}) - \psi_1(\mathbf{I};\mu) - \psi_2(\mathbf{I};\mu) < \phi(\mathbf{I}') - \psi_1(\mathbf{I}';\mu) - \psi_2(\mathbf{I}';\mu)$ *for any* $\mathbf{I} < \mathbf{I}'$*.*

Assumption 2-a implies that a party will not invest unless there is internal 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 sense that they generate higher total surplus when the parties trade efficiently than when they disagree, both in the *absolute* and *marginal* senses. 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 with 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.[6]

[6] 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.

Example 1. ***(Asset Ownership)*** *The Grossman-Hart-Moore (GHM) model*[7] *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 status quo 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 *is allowed to depend 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-specific investments. Segal and Whinston (2000) investigate this hypothesis using an incomplete contract model wherein trade partners negotiate the terms of internal trade, and the status quo payoffs of the parties in negotiation depends on the presence of the 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.*

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 ex ante contracts on the incentives for specific investments (Edlin and Reichelstein, 1996; Che and Hausch, 1999, and Segal and Whinston, 2002, among others). The value of such an ex ante trade contract is crucial for the foundation of the incomplete contract paradigm. Of particular interest in this regard 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 status quo payoffs are allowed to depend on the terms of trade they 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 (party 1) and a buyer (party 2) 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 the status quo payoffs allowed to depend on the type of widget that the parties may agree to trade initially.*

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

As Example 2 illustrates, the absence of a contract is a special case of our model.[8] 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 shares (α_1, α_2) (henceforth GNBS), with the contract payoffs $(\psi_1(\cdot;\mu), \psi_2(\cdot;\mu))$ serving as status quo point. For ease of comparison, it is indeed 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 μ, chosen at time $t = 0$ from some set of contracts, $\mathcal{M}$, satisfying Assumption 1. The parties subsequently play an investment and bargaining game as follows. In period $t = 1$, the parties 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 recipient, the game ends. If not, then with probability $1 - \delta \in (0, 1]$, the bargaining breaks down, 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 $\delta = 0$, so the game must end by the end of the first period, then this game replicates the standard two-stage investment-trade model. The SPE of our extensive form in that case replicates the GNBS, yielding payoffs $U_i^0(\mathbf{I};\mu)$ to the players.

[8] 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.

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 $\mathbf{I}^*$ is reached in the first period in a SPE of the game induced by μ. 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. Hence, the standard argument shows that the continuation payoffs are uniquely determined:

Lemma 1. *Fix any $\delta \in [0,1)$. Given μ, in any SPE the continuation payoffs following $\mathbf{I}^* = (1,1)$ are given by the GNBS payoffs, $U_i^0(\mathbf{I}^*;\mu)$, $i = 1,2$.*

Proof. Once $\mathbf{I}^*$ is reached, the game essentially turns into a pure bargaining game since there is possible further investment to be made in the future. 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 $\mathbf{I} = (1,1)$. 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 $\overline{v}_i$ for 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 most $-i$ 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 for i 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 $\overline{v}_i = \underline{v}_i = U_i^0(\mathbf{I}^*;\mu)$. ∎

It is striking that – independent of the probability of continuation – the parties' equilibrium payoffs following $\mathbf{I}^*$ coincide with the GNBS payoffs. This clearly shows that the exposure to hold up is not diminished by the introduction of investment dynamics. As will be seen, however, this fact does not lead to the same condition or conclusion about the incentives for investment without the investment dynamics. The next theorem characterizes the precise condition under which an arbitrary contract implements the efficient investment $\mathbf{I}^* = (1,1)$. It is useful to define, for any given $\delta \in [0,1)$ and contract μ, a payoff function 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 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 $\mathbf{I}^*_{-2} = (1,0)$. We now present the characterization.

Theorem 1. *Given Assumptions 1 and 2, contract μ implements the investment $\mathbf{I}^* = (1,1)$ if and only if*

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

and

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

Proof: See the Appendix.

Theorem 1 identifies a pair conditions, (IR) and (IC), as necessary and sufficient for efficient investments under contract μ. Condition (IR) 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 by not investing and disagreeing indefinitely thereafter). This condition is implicit, but never binding, in the standard static model of hold-up.

Condition (IC) captures the "marginal" benefit associated with investment on the equilibrium path, i.e., that party i must not gain from under-investing and bargaining efficiently from that point onward. This condition is understood better when compared with the corresponding condition in the static model:

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

One may recall that (1) is precisely the condition for a contract μ to implement the efficient outcome in the standard "static" model. Interestingly, our (IC) collapses to (1), as $\delta \to 0$. When $\delta > 0$, though, (IC) departs from, and 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:

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

from which it follows that

$$\Delta V_i^{\delta'}(\mu) = \Delta V_i^\delta(\mu) + (\delta' - \delta)\left[\alpha_i\Delta_i\psi_{-i}(\mu) + \alpha_{-i}(c_i - \Delta_i\psi_i(\mu))\right].$$

By Assumption 1-(a), the terms inside the square brackets are non-negative, so if $\delta' > \delta$, $\Delta V_i^{\delta'}(\mu) \geq \Delta V_i^\delta(\mu)$. In other words, the (IC) constraint is the easier to satisfy the larger δ is. Since (IR) does not depend on δ, the following is immediate.

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

Proof. If μ implements $\mathbf{I}^*$ for δ, then by Theorem 1, (IR) and (IC) must hold at δ. The latter means $\Delta V_i^\delta(\mu) \geq 0$. Since (IR) does not depend on δ and $\Delta V_i^{\delta'}(\mu) \geq \Delta V_i^\delta(\mu)$ for $\delta' > \delta$, the result follows from Theorem 1. ▮

In particular, for any given contract there are more incentives for investment in our dynamic model with $\delta > 0$ than in a static model (which coincides with our model with $\delta = 0$). Where do the extra incentives come from? As noted in 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 from the equilibrium dynamics, which influence the way in which the parties split the surplus *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 toughens the partner's bargaining position following a deviation, which leads to the investor receiving a share smaller than the one under the GNBS if he under-invests relative to the target. 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 thus generates more incentives for investment.

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

Corollary 2. *For any contract μ, there exist $\tilde{\delta} \geq 0$ and $\hat{\delta} < 1$ such that, if $\delta < \hat{\delta}$, (IC) is sufficient for μ to implement $\mathbf{I}^*$ and that, if $\delta \geq \hat{\delta}$, (IR) is sufficient for μ to implement $\mathbf{I}^*$.*

Proof. We already observed that (IC) converges to (1) as $\delta \to 0$. Further, the RHS of (1) is no less than $\psi_i(\mathbf{I}^*_{-i}; \mu)$, by Assumption 1-(b). It then follows from the continuity of $U^{[\cdot]}$ that there exists $\tilde{\delta} \geq 0$ such that (IC) implies (IR) for $\delta \leq \tilde{\delta}$. Hence, the first statement is proven.

To prove the second statement, 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 strictly implied by the efficiency of investment (i.e., Assumption 1), (IC) is satisfied for any $\delta \geq \hat{\delta}$ for some $\hat{\delta} < 1$. ▮

We next investigate how the investment dynamics affects comparison of alternative contracts.

3.2 The effects of contracts

The central insight from the static models concerns the extent to which a contract in question enables the investor to appropriate his return, or equivalently, reduce his exposure to hold up, "at the margin." This effect is fully captured by the terms $\Delta_i\psi_j(\mu)$, for the investor $j = i$ and the non-investor $j = -i$. Specifically, $\Delta_i\psi_i(\mu)$ represents the marginal return of investment that the 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 him to, the hold-up problem at the margin. Indeed, as can be seen from (IC'), condition (IC) can be written solely in these marginal terms and conform to the standard insight.

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

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

where $\Psi^*(\mu) := \psi_1^*(\mathbf{I}^*; \mu) + \psi_2^*(\mathbf{I}^*; \mu)$ denote the parties' aggregate status quo payoff under contract μ with efficient investments from both parties. Notice that, in addition to the marginal return on investment $\Delta_i\psi_i(\mu)$, the condition also depends on the aggregate level of quasi rents $(\phi(\mathbf{I}^*) - \Psi^*(\mu))$ — i.e., the degree to which the parties are jointly exposed to hold up in the *absolute* sense. In addition, the investor's own marginal return (i.e., $\Delta_i\psi_i(\mu)$) relaxes (IR), but the "leakage" of her investment returns, $\Delta_i\psi_{-i}(\mu)$, does not affect (IR). Due to these differences, (IR') yields a distinct new insight on the role of contracts whenever it matters.

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

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 $(\Delta_i\psi_i(\mu')), -\Delta_i\psi_{-i}(\mu')) \geq (\Delta_i\psi_i(\mu), -\Delta_i\psi_{-i}(\mu))$, $i = 1, 2$, then there exists $\tilde{\delta} \geq 0$ such that contract μ' weakly dominates contract μ for any $\delta \leq \tilde{\delta}$. If at least one inequality is strict, then μ' dominates μ.*

b) *If $\alpha_i[\Psi^*(\mu') - \Psi^*(\mu)] \leq \Delta_i\psi_i(\mu') - \Delta_i\psi_i(\mu)$, $i = 1, 2$, 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.

A few points are worth noting. First, we find the standard insight to be robust to introducing a small δ. 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 is likely to continue after initial disagreement, permitting a future investment plan to matter more. Such a possible investment dynamics changes the incentives of the parties and, more importantly, the way contracts influence them. In particular, (IC) is no longer important for it is satisfied regardless of the underlying contract if $\delta \approx 1$. Only (IR), or equivalently

(IR'), matters. As mentioned above, a contract affects (IR') differently than it affects the incentives in the traditional model, in two ways. First of all, as can be seen from (IR') the "leakage" $\Delta_i\psi_{-j}(\mu)$ of investment returns to the non-investor does not have an adverse effect on the incentive. Second and more important, the extent to which the contracts affect an investor's exposure to holdup "in absolute terms" matter.

This latter point can be seen most clearly, 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 ($IC$) will be the same for all contracts, i.e., they will be indistinguishable with regard to this condition. Yet, they are not same with respect to (IR'). In particular, the extent to which contracts expose the parties to hold up in absolute level — $\Psi^*(\mu)$ — matters. Note that the absolute exposures of the parties are perfect substitutes, independent of their bargaining powers. Strikingly, (IR') tells us that 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. ***(Status quo minimization principle)*** *Suppose* $\Delta_i\psi_j(\mu) = \Delta_i\psi_j(\mu')$, $i, j = 1, 2$, *and*

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

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

Proof. By Proposition 1b), contract μ' dominates μ for any $\delta > \hat{\hat{\delta}}$ for some $\hat{\hat{\delta}} < 1$, and Proposition 1a) implies that the two contracts are equivalent for any $\hat{\delta} < \tilde{\delta}$ for some $\tilde{\delta} > 0$. To prove $\hat{\delta} = \tilde{\delta}$, 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') is the same under both contracts but that μ' satisfies (IR') 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 (IR') and (IC') but μ fails (IR'). By Corollary 1, for any $\delta' > \delta$, μ' still satisfies the two conditions at c but μ still fails (IR') (since it does not depend on δ). ∎

Any two contracts that have the same "marginal" features are equivalent for low values of δ, but not for high values of δ. In the latter case, a contract exacerbating the investors' (aggregate) exposure to hold up performs well.

Further, the leakage of investment returns has an adverse effect only for a 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 $\hat{\delta} \in (0, 1)$ *such that i)* μ *dominates* μ', *if* $\delta < \hat{\delta}$, *and ii) contract* μ' *and contract* μ *are equivalent if* $\delta \geq \hat{\delta}$.

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

To illustrate the new insight, consider a simple example in which only party 1 has a (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 the equal bargaining power with $\alpha = \frac{1}{2}$, then the standard hold-up model would predict the three contracts to perform exactly the same. 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 status quo payoff. Under contract μ'', investing improves her status quo payoff by 1, but this is "offset" by the concomitant improvement in her opponent's status quo 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').[9] They are all different, though, in terms of the extent to which they satisfy (IR'). A shift from μ to μ' relaxes

[9]The LHS of (IC') becomes

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

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

the constraint since μ' reduces the joint status quo 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 concommitant leakage has no effect on (IR') (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.

4 Applications

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

4.1 The Grossman-Hart-Moore 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: $\mu_N := (\{a_1\}, \{a_2\})$;[10] (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 he/she can generate by exercising his/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.

[10]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).

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 $A_i^{\mu} \subset A_i^{\mu'}$.

To highlight our new insight in comparison with 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 person'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 more important how the asset values are characterized in "marginal" terms; i.e., by the way in which raising investments affects the status quo payoffs:[11]

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*

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

[11] 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.

Invoking Proposition 1, a series of observations follow.

Proposition 2. 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 2-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 δ of continuance 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 status quo 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 his interpretation of a vertically integrated structure as integration in the GHM setup is somewhat *ad hoc*, as 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 does apply, vertical integration is often better described as a merger and thus corresponds to a joint ownership structure![12]

In a similar vein, Hart (1995) also argues that cooperatives and partnerships should not be thought of as joint ownership regimes, as decisions are usually taken by majority rule. However, the majority rule no longer applies when a break-up is being considered. In this case, a consensus must be reached for an agreement, implying that joint ownership is a better description.

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 on 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 future 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.

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

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 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 3. 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.

[Any real example? What evidence De Meza and Salvaggi provide?? What about the Matouschek??] De Meza and Selvaggi (2006) 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

Much of modern organization theory rests on the assumption that some crucial decisions such as specific investments are difficult to contract on. Such an incompleteness can often be overcome indirectly through contracting on the price and quantity of ex post trading. However, a number of scenarios have been identified in which the underlying incompleteness is such that 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, seller (party 1) and 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 $\hat{q}$ 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 for our purpose is the situation in which the investments are fully cooperative, in the sense 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 nontrivial 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 nontrivial 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 4. *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 5. *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 (IR). The status quo 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 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 (1981??), 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 Status Quo Minimization Principle applies in his set-up depends on the available gains to trade.

There is an interesting interpretation of our model along the lines of Hart and Moore (2007). They assume that the partners have a sense of entitlement fixed by the (extremes of a loose) ex ante contract, which will lead them to an ex post non-Coasian bargaining *within* the limits of the old contract, because 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. We could incorporate their assumption into our model, with the difference that the behavioral motives only kick in if our renegotiation breaks down. That is, aggrievement only sets in if the “harmony” of the relationship is perturbed.[13] In that case – but in only that one –, the continuation game is no longer efficient. Then, signing a contract which is “loose” – and thus leads to less efficient bargaining within it – would lead to a low status quo 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.

Finally, in Che and Sákovics (2004a) we analyze a dynamic hold-up model much like[14] the current one, but *without* the possibility of breakdown – and therefore, effectively *in the absence of contracts*. The role of contracts in providing incentives to invest is the focus of the current study.

6 Concluding Remarks

We have shown that allowing for a simple and plausible investment dynamics in a hold-up model produces much different implications on the design of important contracts and organizations than have been suggested in the literature. The novel theme in our prediction is that the incentives for 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, 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 a concern in the static models, since the individual rationality constraint is never binding there, but it is an important consideration in our dynamic model since the steeper incentives provided by investment dynamics may cause the latter constraint to be binding.

A shift of emphasis from how organizations affect the extent to which investments alleviate 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 absolute degree of hold up matters, our

[13] 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 can be directly associated with a loss of such an intrinsic motivation.

[14] There we model impatience by exponential discounting instead of probabilistic breakdown.

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 deviation. 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.

[We are pushing a little too much below....]

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,[15] the GHM theory is difficult to test, 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.

7 Appendix

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 an option of avoiding trade. It follows that

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

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

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 (IR).

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 (IR) and (IC), this strategy profile, along with the optimal bargaining behavior, forms a SPE. This can be seen by the fact that, given (IR), 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 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 $i = 1, 2$,

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

Hence, 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 $\mathbf{I}^*$. Hence, 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 $\hat{\hat{\delta}} < 1$ such that, for any $\delta > \hat{\hat{\delta}}$, only condition (IR) matters. Fix any such δ, and suppose the hypothesis is true. Then, since (IR') 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 (IR') holds only for μ'. Hence, μ' dominates μ. ▮

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Myerson and Satthertwaite

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