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Asset Ownership and Contractability of Interaction

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Asset Ownership and Contractability of Interaction

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Abstract

In a property-rights framework, we study how the organizational form and quantity contracts interact in generating investment incentives. Our model nests standard property-rights and hold-up models as special cases. We admit general message-dependent contracts but provide conditions under which non-contingent contracts are optimal. This allows to fully characterize optimal contracts. First, we contribute to the foundation of the property-rights theory by characterizing under which circumstances its predictions are correct even when trade is contractible. Second, we study how the two incentive instruments interact in our symmetric information framework depending on the environment which is in the spirit of the multitasking literature. Finally, our model has implications for future empirical test of the property-rights theory.

Keywords: Property Rights, Incomplete Contracts, Specific Investments.
JEL-Classification: D23, D82, L14, L22.

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1 Introduction

1.1 Motivation

The property-rights theory of the firm (PRT) addresses fundamental questions initially raised by Coase (1937): why are certain transactions conducted within firms and not in markets, and hence what determines the boundaries of the firm? Grossman and Hart (1986), Hart and Moore (1990) and Hart (1995) approached this question by defining a firm as a collection of non-human assets: they study how the allocation of ownership rights influences the incentives to engage in non-verifiable relationship-specific investments when only the allocation of property-rights can be specified in a contract. They derive optimal ownership structures endogenously, and their incomplete contracts approach has become a cornerstone of recent discussions about the boundaries of the firm. However, asset ownership often interacts with other instruments in generating investment incentives: an aspect which is neglected by the PRT but has been emphasized by e.g., Holmstrom and Roberts (1998) who argue that a theory of the firm should not ignore explicit and implicit contracts and that ownership patterns can often not be explained by property-rights considerations alone.[1] The literature on the hold-up problem provides support to this criticism: there, in a setting very similar to the PRT, simple trade contracts which specify trade quantities often suffice to induce first-best investments.[2] In these models the boundaries of the firm would be irrelevant because the parties would be able to sign the optimal quantity contract independent of the underlying ownership structure. In this light, it is somewhat surprising that some empirical studies, for example Elfenbein and Lerner's (2001) study of internet portal alliances, find support for the PRT even when contractual provisions regarding the level of activity are persuasive.[3]

Several questions emerge from this discussion. First, when are the predictions of the PRT correct even when trade, or more generally the degree of interaction, is contractible? This question about the foundation of the PRT is not only of theoretical interest because

[1]For related arguments, see Holmstrom and Milgrom (1994) and Holmstrom (1999). Some other criticisms which have been raised against the PRT are discussed in the conclusion.

[2]See e.g., Chung (1991), Hermalin and Katz (1993), Aghion, Dewatripont, and Rey (1994), Nöldeke and Schmidt (1995) and Edlin and Reichelstein (1996).

[3]We discuss Elfenbein and Lerner's (2001) study in more detail in Section 5.

an answer would lead to a better understanding of observed ownership patterns and would help to identify new empirical testing grounds for the PRT. Second, how does the contractability of trade change the predictions of the PRT? For example, are we more likely to observe integration when quantity contracts are feasible? And third, how do asset ownership and quantity contracts interact in generating investment incentives depending on the environment? For example, how do optimal quantity contracts between firms differ from quantity contracts within firms?[4]

Our paper addresses these questions: we study the interaction of asset ownership and quantity contracts in a setting of symmetric information which contains standard property-rights and hold-up models as special cases. In the model, two parties want to interact with each other in order to create a surplus where the degree of interaction, e.g., the trade quantity or the number of joint projects, is ex-ante contractible. The parties may trade simultaneously with each other and an outside-market, and we allow for spillovers between internal and external trade. We focus on ex-ante investments which are embodied in an asset: the investments might be physical themselves, e.g., a new plant, or they might increase the size of the market for the asset's product, e.g., marketing.[5] The parties sign a possibly message-dependent contract specifying the organizational form, the degree of interaction and a transfer payment. The purpose of the contract it is to generate investment incentives.

In this setting, we show in a preliminary step that under certain assumptions the parties can restrict themselves to message-independent (non-contingent) contracts if only one of the parties invests or if investments are transferable across parties, i.e., if it does not matter which of the parties makes the investment. Hart (1995, p. 69) argues that this is true for many investments in physical capital because such investments are frequently not specific to a particular individual. The restriction to non-contingent contracts allows to fully characterize optimal contracts and to study how the optimal use of the two incentive instruments, i.e., the organizational form and the degree of interaction, varies depending

[4]Holmstrom and Roberts (1998) provide examples of such "inside contracting."

[5]The literature has mostly focused on investments in human capital where the presence of the investor is necessary to recoup the returns of an investment. Our focus on investments in physical capital allows to fully characterize optimal contracts and to derive some interesting interaction results. If only one of the parties invests our results qualitatively also hold for an investment in human capital.

on the environment. Our main findings are as follows: (1) If only one of the parties invests the organizational form which the PRT predicts is optimal even when trade is contractible but other organizational forms which are suboptimal according to the PRT might be optimal as well. (2) If both parties invest the organizational form which the PRT predicts might in fact not be optimal. (3) Even when the right choice of organizational form is important the parties may sign a quantity contract which reduces or even eliminates the inefficiency which the property-rights approach suggests. Hence, while in the standard property-rights and hold-up literatures only one incentive instrument matters for generating investment incentives,[6] in our model both may be important. (4) More generally, we provide conditions when the right choice of both incentive instruments is important for investment incentives and when it is irrelevant which organizational form the parties choose. However, even when more than one organizational form is optimal (which is often the case) our model imposes restrictions on the optimal combinations of the incentive instruments, and hence the model can provide some guidance for future empirical work. (5) The model allows interesting comparative static exercises with respect to the contractability of interaction and with respect to the payoff functions of the parties. To illustrate this, we revisit the classic but meanwhile controversial Fisher-Body case and show how our model lends support to Klein's (2000)view that a large demand increase necessitated integration of Fisher-Body by General Motors in order to restore incentives for investments in physical capital. (6) Finally, based on the nature of the spillovers between internal and external trade, we discuss some more specific examples which provide guidance as to when the choice of organizational form is important even when trade is contractible.

What drives these results? If both parties profit from a higher value of the asset when trading with each other an investment by one party exerts a positive externality on the other party, and hence the investments are "cooperative" in the sense of Che and Hausch (1999):[7] in this case quantity contracts might not be very effective in generating

[6]With respect to the former, see e.g., Grossman and Hart (1986), Hart and Moore (1990), Hart (1995), DeMeza and Lockwood (1998), Chiu (1998) and Maskin and Tirole (1999a). With respect to the latter, see e.g., Aghion, Dewatripont, and Rey (1994), Nöldeke and Schmidt (1995) and Edlin and Reichelstein (1996).

[7]The model of Che and Hausch (1999) is a generalized version of the bilateral trading model of Edlin and Reichelstein (1996). The main focus of Che and Hausch (1999) is the value of trade contracts for

investment incentives: an investment by one party increases the threatpoint payoff of the trading partner from internal trade, and thereby reduces the available renegotiation surplus. This lowers the ex-post payoff of the investor, and consequently his expected marginal investment return. When trading externally this effect can be avoided if the investor owns the asset because then only he can use the asset for external trade. Hence, whether a quantity contract alone can generate sufficiently large incentives such that the choice of organizational form does not matter crucially depends on the degree to which each of the parties profits from an increase in the asset value. For example, we will show that if the effect on the asset value is very asymmetric across the parties the PRT may predict an organizational form which in fact is not optimal.

1.2 Related Literature

Our paper is closely related to the literature on the foundations of incomplete contracts:[8] building on work by Hart and Moore (1999) and Segal (1999), Maskin and Tirole (1999a) provide a foundation of the PRT based on the complexity of the environment. In their model, a buyer and a seller are ex-ante uncertain about which out of a large number of ex-ante describable widgets creates a surplus ex-post. Only one widget can be traded ex-post, and Maskin and Tirole (1999a) show that as the number of possible widgets goes to infinity the advantage from signing a quantity contract becomes negligible. In addition to providing a similar but somewhat stronger "irrelevance of quantity contracts"-result we fully characterize optimal contracts which allows to study the interaction of the incentive instruments. Whereas Maskin and Tirole (1999a) and most of the literature restrict attention to selfish investments,[9] in our model direct effects of investments on the trading partner play a crucial role. Hence, Che and Hausch (1999) is the paper most closely related to our work. However, Che and Hausch (1999) touch only very briefly on the issue of asset ownership. Especially, they do not explore the interaction of asset

solving the hold-up problem which was initially formalized by Hart and Moore (1988). Other papers that point out the reduced value of trade contracts when investments are cooperative are Che and Chung (1999), and in a more general, non-differentiable setting Schweizer (2000).

[8] For a critical discussion of the incomplete contract methodology, see Tirole (1999).

[9] I.e. investments from which only the investor benefits directly. Exceptions to this are e.g., Macleod and Malcomson (1993), Che and Chung (1999), Che and Hausch (1999) and Rosenkranz and Schmitz (1999).

ownership and quantity contracts which is the main focus of our paper.

The literature on multi-tasking and organizational form has provided important insights about the interaction of explicit contracts, implicit contracts and asset ownership in shaping incentives inside and across institutions. In contrast to the present model, in general these papers employ a moral hazard framework and assume that signals of the effort decisions are verifiable (see e.g., Holmstrom and Milgrom (1991) and Holmstrom and Tirole (1991)). More recently this framework has been extended to repeated interactions (see e.g., Baker, Gibbons, and Murphy (2001) and Baker, Gibbons, and Murphy (2002)). To keep the analysis tractable, attention is generally restricted to linear incentive contracts and to non-contingent assignments of ownership. In contrast, as the property-rights literature, we focus on relationships where the parties are symmetrically informed but no verifiable signals are available, and we allow for general message-dependent contracts.

Finally, while our paper focuses on the contractability of the degree of interaction some recent empirical and theoretical papers study the effects of shifts in the contractability of investments caused, for example, by developments in monitoring technologies. For example, Baker and Hubbard (2000) and Baker and Hubbard (2002) find that the adoption of on-board computers in the U.S. trucking industry led to patterns which reflect the importance of both incomplete contracts and measurement issues. For theoretical work in this area, see e.g., Hubbard (2001).

The remainder of the paper is structured as follows: In Section 2 we set up the model. In Section 3 we fully characterize optimal non-contingent contracts for the case that only one of the parties can invest, where we argue that the results qualitatively hold even when the investment is in human capital, and for the case of two-sided transferable investments which are interesting both from an theoretical and empirical point of view. In Section 4 we show that in the cases considered in Section 3 the parties cannot gain by considering more complicated, message-dependent contracts. In Section 5 we discuss implications of our model for future empirical work. In Section 6 we extend the model to allow for spillovers between internal and external trade. There, we discuss some examples which, based on the nature of the spillovers, provide additional guidance as to when the choice of organizational form matters even when trade is contractible. Section 7 concludes. All proof are relegated to an appendix.

2 The Model

2.1 Description of the Model

A downstream buyer (B) and an upstream seller (S), both of whom are risk-neutral, want to trade a variable quantity of a good. Even though we phrase the model in terms of a vertical supply relationship our results equally apply to horizontal relationships if one interprets the level of trade more generally as the level of interaction between the parties. The parties may simultaneously trade with each other (*internal trade*) and a competitive outside-market (*external trade*).[10] Beside their human capital the parties may use an asset A, for example a machine, for production and/or trade. The organizational form $O \in \{B, S, X\}$ determines which party has the residual rights of control over A: the asset may either be owned by the buyer (B) or by the seller (S). Because the residual rights of control will only matter for external trade it will play no role who owns the asset when the parties sign an exclusive dealing clause (X) which forbids both parties to trade externally.[11] Joint ownership of the asset where each party can block the other party from using A would be equivalent to an exclusive dealing clause, and hence we do not introduce it explicitly into the model. We assume that B and S have symmetric information and that they both observe all relevant variables and functions.

Sequence of events Figure 1 depicts the sequence of events. At *date 1* the parties sign a (non-contingent) contract $C = (O, q)$ which is registered with the courts. The contract specifies the organizational form $O \in \{B, S, X\}$ and the internal trade quantity $q \in [0, \overline{q}]$ where we assume that it is not possible to produce or trade an unlimited quantity internally. Only O, q, a transfer payment $t \in \Re$ from B to S at date 4 and messages which the parties might send between dates 2 and 3 are assumed to be verifiable by a court: because a fixed transfer payment will have no effect on incentives we set $t = 0$ without loss of generality. In Section 4 we show that given our assumptions below the parties cannot gain by considering more complicated message-dependent contracts like e.g., option contracts. We assume that the parties can only allow or forbid external trade

[10] Roider (2000) studies a related model where internal and external trade are mutually exclusive.

[11] We comment on exclusivity agreements which forbid only one of the parties to trade externally when we introduce the payoff functions below.

but that they are not able to regulate external trade in more detail: a court may be able to verify whether external trade takes place at all but given the large number of potential external trading partners it may not be possible to verify the exact external trading quantity. At *date 2* the buyer and the seller make relationship-specific investments $\beta \leq \overline{\beta}$ and $\sigma \leq \overline{\sigma}$ respectively in order to increase the value $a(\beta, \sigma)$ of the asset A, where a is continuously differentiable in both arguments. Hence, the investments are embodied in the asset but they need not necessarily be physical themselves: they might as well represent the effort which the parties expend to increase the market size for A's product. Since our results do not depend on the presence of ex-ante uncertainty about the ex-post state of nature, for ease of exposition, we do not introduce it into the model.[12] Denote the ex-post state of the world by $\theta \equiv (\beta, \sigma) \in \Theta \equiv [o, \overline{\beta}] \times [o, \overline{\sigma}]$. Because the parties have symmetric information we assume that they always renegotiate the initial contract to an ex-post efficient outcome at *date 3*.[13] We are more explicit on the renegotiations in Section 2.3 below. Finally, at *date 4* production, trade and payments take place.

Figure 1 here

Threatpoint payoffs If renegotiations fail the *threatpoint payoffs* $\hat{b}(O, q, a)$ and $\hat{s}(O, q, a)$ of the buyer and the seller respectively are determined by the initial contract $C = (O, q)$ where we assume that both payoff functions are continuously differentiable in all variables except O and non-decreasing in the asset value a. If $q > 0$ the contract obliges the parties to trade quantity q internally: we assume that $\hat{b}(X, q, a)$ and $\hat{s}(X, q, a)$ represent their respective threatpoint payoffs from internal trade where we suppose that $\hat{b}_a(X, q, a)$, $\hat{s}_a(X, q, a)$, $\hat{b}_{aq}(X, q, a)$, $\hat{s}_{aq}(X, q, a) \geq 0 \; \forall q, a$.[14] Moreover, if $O \in \{B, S\}$ they are free to trade with the outside-market, and consequently

[12] The model can easily be extended to the case that after investments but before renegotiations a continuously distributed random variable, which affects the payoffs of the parties, is realized. In this case, all of our results go through as long as Assumptions 3 and 4 below hold for all realizations of the random state and as long as Assumption 2 below holds in expected terms.

[13] Whether parties are able to commit not to renegotiate is discussed controversially (see e.g., Hart and Moore (1999) and Maskin and Tirole (1999b)). We do not deny that under certain circumstances the parties might be able to commit not to renegotiate but we want to consider renegotiation as a practical possibility.

[14] Throughout, subscripts denote partial derivatives.

$[\mathfrak{b}(O,q,a) - \mathfrak{b}(X,q,a)]$, $[\mathfrak{s}(O,q,a) - \mathfrak{s}(X,q,a)] > 0$ for $O \in \{B,S\}$ represent their respective threatpoint payoffs from external trade. For simplicity, we assume that the external threatpoint payoffs of the parties do not depend on the internal trade quantity, i.e., $\mathfrak{b}_q(O,q,a) - \mathfrak{b}_q(X,q,a) = 0 \; \forall O,q,a$, and analogously for the seller. This simplifying assumption is dropped in Section 6 where spillovers between internal and external trade are discussed. Finally, we assume that (i) internal payoffs are zero if no internal trade takes place, i.e., $\mathfrak{b}(X,0,a) = \mathfrak{s}(X,0,a) \; \forall a$, (ii) an owner has residual control rights over the asset, and hence he can block the non-owner from using it for external trade which implies that the external payoff of the non-owner does not vary in the asset value, i.e., $[\mathfrak{b}(S,q,a) - \mathfrak{b}(X,q,a)] = \mathfrak{b}(B,q,0) - \mathfrak{b}(X,q,0) \;\; \forall q,a$ and $[\mathfrak{s}(B,q,a) - \mathfrak{s}(X,q,a)] = [\mathfrak{s}(S,q,0) - \mathfrak{s}(X,q,0)] \; \forall q,a,$[15] and (iii) the possibility of external trade raises the marginal value of the asset for the owner, i.e., $\mathfrak{b}_a(B,q,a) > \mathfrak{b}_a(X,q,a)$ $\forall q,a$ and $\mathfrak{s}_a(S,q,a) > \mathfrak{s}_a(X,q,a) \; \forall q,a$.

2.2 The First-Best

We assume that it is ex-post efficient for the buyer and the seller to cooperate, and that by working together they create an ex-post surplus $\phi(a)$, possibly through internal and external trade, where $\phi_a(a) > 0$ and $\phi_{aa}(a) < 0 \; \forall a$. The ex-post surplus does not depend on the initial contract terms (O,q) because the buyer and the seller always agree on the ex-post efficient actions in renegotiations. Hence, the efficient best-response investment functions are given by:

$$\begin{aligned}
\beta^*(\sigma) &= \arg\max_{\beta \le \overline{\beta}} \; \{\phi(a(\beta,\sigma)) - \beta\}, \text{ and} \\
\sigma^*(\beta) &= \arg\max_{\sigma \le \overline{\sigma}} \; \{\phi(a(\beta,\sigma)) - \sigma\}.
\end{aligned}$$

The ex-ante efficient investment pair (β^*, σ^*) satisfies $\beta^*(\sigma^*) = \beta^*$ and $\sigma^*(\beta^*) = \sigma^*$, and the efficient asset value is given by $a^* \equiv a(\beta^*, \sigma^*)$ where we assume that a^* is unique and interior.

[15] This implies that under each $O \in \{B,S\}$ the external payoff of one party does not depend on a. Therefore, it is not necessary to explicitly consider one-sided exclusivity clauses which forbid only one of the parties to trade externally because such a clause would have the same effect on investment incentives as some $O \in \{B,S\}$.

2.3 Post-Renegotiation Payoffs and Investment Equilibrium

The surplus which is generated through renegotiating the initial contract is given by:

$$\Delta(O,q,a) \equiv \phi(a) - \hat{b}(O,q,a) - \hat{s}(O,q,a) \geq 0 \; \forall O,q,a,$$

and we assume that the seller and the buyer divide $\Delta(O,q,a)$ in Nash-bargaining in equal parts.[16] Hence, the post-renegotiation payoffs of the buyer and the seller net of investment costs are given by:

$$\hat{B}(O,q,a) \equiv \hat{b}(O,q,a) + \frac{1}{2}\Delta(O,q,a) = \frac{1}{2}\left[\phi(a) + \hat{b}(O,q,a) - \hat{s}(O,q,a)\right], \quad (1)$$

$$\hat{S}(O,q,a) \equiv \hat{s}(O,q,a) + \frac{1}{2}\Delta(O,q,a) = \frac{1}{2}\left[\phi(a) + \hat{s}(O,q,a) - \hat{b}(O,q,a)\right]. \quad (2)$$

respectively. Given the initial contract $C = (O,q)$, it follows from (1) and (2) that the best-response investment functions are defined by:

$$\beta(\sigma; C) = \arg\max_{\tilde{\beta}} \hat{B}(O,q,a(\tilde{\beta},\sigma)) - \tilde{\beta},$$

$$\sigma(\beta; C) = \arg\max_{\tilde{\sigma}} \hat{S}(O,q,a(\beta,\tilde{\sigma})) - \tilde{\sigma},$$

respectively, and an investment equilibrium $(\hat{\beta}(C), \hat{\sigma}(C))$ is implicitly defined by $\hat{\beta}(C) = \beta(\hat{\sigma}(C); C)$ and $\hat{\sigma}(C) = \sigma(\hat{\beta}(C); C)$. Hence, given a contract $C = (O,q)$, the net equilibrium surplus of the relationship between B and S is defined by:

$$\widetilde{W}(C) \equiv \phi(a(\hat{\beta}(C), \hat{\sigma}(C))) - \hat{\beta}(C) - \hat{\sigma}(C).$$

3 Analysis of the Model

In order to characterize optimal contracts, we first derive some properties of the post-renegotiation payoffs and introduce some assumptions. It directly follows from (1), (2)

[16] The surplus-splitting assumption is solely made for expositional clarity: the model could easily be generalized to allow for asymmetric bargaining powers, and all of our results would continue to hold qualitatively. Some papers, e.g., DeMeza and Lockwood (1998), have shown that the optimal ownership structure might depend on the nature of the bargaining game. In the present paper, the interaction of asset ownership and quantity contracts is at the center of attention, and therefore we neglect this aspect.

and the properties of the threatpoint payoffs that:

$$\hat{B}_a(O,q,a) = \phi_a(a) - \hat{S}_a(O,q,a) \ \forall O,q,a, \tag{3}$$

$$\hat{B}_{aq}(O,q,a) = -\hat{S}_{aq}(O,q,a) \ \forall O,q,a, \tag{4}$$

$$\hat{S}_a(S,q,a) > \hat{S}_a(X,q,a) > \hat{S}_a(B,q,a) \ \forall q,a, \tag{5}$$

$$\hat{B}_a(B,q,a) > \hat{B}_a(X,q,a) > \hat{B}_a(S,q,a) \ \forall q,a. \tag{6}$$

If an increase in q has a positive impact on the marginal investment return of the seller it automatically has a negative impact on the marginal investment return of the buyer, and vice versa. This arises from the fact that the payoffs of the parties depend on investments only through the asset value a. Moreover, because only the owner can use the asset for external trade the marginal investment returns can be unambiguously ordered across O. For the remainder of the paper, we maintain the following assumptions:

Assumption 1 *$a(\hat{\beta}(C), \hat{\sigma}(C)) > 0$, $\hat{\beta}(C) < \overline{\beta}$ and $\hat{\sigma}(C) < \overline{\sigma}$ for all C.*

Assumption 2 *$\hat{B}_{\beta\beta}(O,q,a(\beta,\sigma))$, $\hat{S}_{\sigma\sigma}(O,q,a(\beta,\sigma)) < 0 \ \forall O,q,\beta,\sigma$.*

Assumption 3 *For all O, either $\hat{S}_{aq}(O,q,a) > 0 \ \forall q,a$ or $\hat{S}_{aq}(O,q,a) < 0 \ \forall q,a$ holds.*

The first two assumptions are of technical nature: Assumption 1 ensures that the equilibrium investment of at least one of the parties is strictly positive. Assumption 2 ensures that the investment equilibrium can be characterized by the appropriate first-order conditions: unfortunately, if the threatpoint payoffs of both parties vary in a this is not guaranteed automatically even if $a(\cdot)$, $\phi(\cdot)$, $\hat{B}(\cdot)$ and $\hat{S}(\cdot)$ are well-behaved in β and σ. Finally, Assumption 3 implies that, for each organizational form O, the nature of the incentive problem does not vary across q and a: to illustrate this point, recall from (4) that $sign\{\hat{B}_{aq}(O,q,a)\} \neq sign\{\hat{S}_{aq}(O,q,a)\} \ \forall O,q,a$, and note that $\hat{S}_{aq}(O,q,a) > 0 \Leftrightarrow \hat{s}_{aq}(O,q,a) > \hat{\theta}_{aq}(O,q,a)$. Hence, for both parties, Assumption 3 rules out the case that for some (q,a)-pairs an investment has a large selfish and a small cooperative effect while the opposite is true for other (q,a)-pairs. Given these assumptions, we show in Section 4 that in the cases which we consider below, independent of the contractability of trade, the parties cannot achieve a higher net equilibrium surplus by employing more complicated, message-dependent contracts, like e.g., option contracts.[17] Hence, if one argues that there is an (arbitrarily small) cost of writing more complex contracts our restriction to non-contingent contracts seems to be justified. For a more detailed discussion of this issue, see Section 4. The focus on non-contingent contracts allows to pin down the equilibrium decisions and to fully characterize optimal contracts.[18] Finally, in accordance with the property-rights theory we assume that the external threatpoint payoffs of both parties are relatively unresponsive to increases in a because, when trading externally, the parties do not have access to the other party's human capital:

Assumption 4 $[\hat{s}_a(S,q,a) - \hat{s}_a(X,q,a)],\ [\hat{b}_a(B,q,a) - \hat{b}_a(X,q,a)] < \phi_a(a)\ \forall q, a.$

Optimal contracts An optimal contract $\tilde{C} = (\tilde{O}, \tilde{q})$ solves the following problem:[19]

$$\tilde{C} \in \arg\max_{C} \widetilde{W}(C). \tag{C}$$

Since the optimal contract is in general not unique we denote the set of optimal organizational forms by $\Omega \equiv \{O \in \{B, S, X\} \ / \ O = \tilde{O} \text{ for some } \tilde{C}\}$. Assumption 3 ensures that, for a given O, the optimal trade quantity is unique. Note that, if $X \in \Omega$, it does not matter whether the asset is given to the buyer or the seller because in this case the optimal exclusive quantity contract can be signed regardless of the underlying ownership structure. Hence:

Definition 1 *We say that it is relevant who owns A if $\Omega = \{B\}$ or $\Omega = \{S\}$, otherwise it is irrelevant who owns A. Similarly, we say that quantity contracts are relevant if $\tilde{q} > 0$, otherwise quantity contracts are irrelevant.*

[17] For this result, Assumption 1 has to hold for all possible message-dependent contracts. This result is robust to the possibility of randomization across organizational forms.

[18] The main ideas of the paper still go through even if the restriction of attention to non-contingent contracts is not possible. In Roider (2000) this is the case because there our Assumption 3 does not hold. While in that setting it is not possible to fully characterize optimal contracts, Roider (2000) provides sufficient conditions under which it is optimal to sign no trade contract. There, it is illustrated how asset ownership might interact with simply contingent trade contracts, i.e. contracts where the parties agree to trade a fixed quantity at a fixed price but, by paying some privately stipulated damages, one of the parties has the right to withdraw from the contract.

[19] Note that under the optimal contract there exist ex-ante payments which induce participation by both parties. Because these payments would not affect investment incentives they are not introduced explicitly.

Main effects If trade is non-contractible, because the good to be traded cannot be described in sufficient detail or has yet to be developed, (C) is solved under the constraint $q \equiv 0$ (property-rights approach): in this case the optimal organizational form is generically unique because the first-best cannot be achieved.[20] But why might the choice of organizational form be relevant even when trade is contractible? In the following, we illustrate that investments in physical capital may give rise to externalities which reduce investment incentives. The contract terms q and O influence the extent of these externalities. First, consider the effect of agreeing on a certain q in the initial contract. For the sake of illustration, suppose that $\hat{s}_{aq}(O,q,a), \hat{b}_{aq}(O,q,a) > 0\ \forall O,q,a$: it is obvious from (2) that, on the one hand, a larger trade quantity leads to higher investment incentives for the seller because $\hat{s}_a(O,q,a)$ increases. On the other hand, since the buyer profits as well from a higher value of the asset there is a countervailing effect: a larger q leads to a larger threatpoint payoff for the buyer, and hence to a lower renegotiation surplus. Thereby, the post-renegotiation payoff of the seller is reduced.[21] If the latter effect is relatively strong this externality might overcompensate the direct selfish effect on the seller, and the investment incentives for the seller, which can be created through the right choice of q, may be limited.[22] Second, the investment returns of the parties can be unambiguously ordered across O because only the owner can use the asset for external trade, and hence only the external threatpoint payoff of the owner does depend on a (see (5) and (6)). The following notation will be useful:

$$\begin{aligned} n(q,a) &\equiv \hat{s}(X,q,a) - \hat{b}(X,q,a)\ \forall q,a, \\ \hat{s}^e(a) &\equiv \hat{s}(S,q,a) - \hat{s}(X,q,a)\ \forall q,a, \\ \hat{b}^e(a) &\equiv \hat{b}(B,q,a) - \hat{b}(X,q,a)\ \forall q,a, \end{aligned} \tag{7}$$

where $n_a(q,a)$ is a measure of the net selfish effect of an investment by S which arises through internal trade, where $\hat{s}^e_a(a)$ ($\hat{b}^e_a(a)$) denotes the marginal change in the external

[20] If one extends Assumption 1 to hold for all message-dependent contracts, this holds true even if attention is not restricted to non-contingent contracts and even if one allows for randomization across organizational forms.

[21] If the parties do not share the renegotiation surplus in equal parts but asymmetrically the countervailing effect is the larger the larger the share of the investor.

[22] In Section 6, we consider the effects of q on both the internal and the external threatpoint payoffs of the parties.

threatpoint payoff of the seller (buyer) when he owns the asset, and where $\widehat{s}^e_a$ and $\widehat{b}^e_a$ are independent of q by assumption.

3.1 One-Sided Investment Case

In this subsection, we focus on the case that only the seller is able to make an investment, i.e., $\beta \equiv 0$. For simplicity, we assume $a = \sigma$.[23] If one interprets $O = S$ as two separate firms and $O = B$ as an integrated firm in which B procures the good internally from S,[24] the property-rights approach predicts that two separate firms will be formed, i.e., $(S, 0)$ is the solution to (C) under the constraint $q \equiv 0$ (see Proposition 1(vi) below). Hence, $\Omega = \{S\}$ but the first-best cannot be reached. Does this sharp prediction still hold when trade is contractible?

Intuition Note that, because inequality (5) holds and because $\widehat{S}_a(O, q, a)$ is continuous in q, we still have $S \in \Omega$ when trade is contractible. However, ownership by the seller is *uniquely* optimal only if $\widehat{S}_a(X, \overline{q}, a^*) - 1 < 0 \Leftrightarrow n_a(\overline{q}, a^*) < \phi_a(a^*)$ because if this condition does not hold then even under an exclusive contract, i.e., independent of who owns the asset, the first-best could be achieved. Hence, even when the cooperative effect of σ on $\widehat{b}(X, q, a)$ is relatively weak a sufficiently low $n_a(\overline{q}, a^*)$ may result such that the choice of organizational form is relevant. With respect to optimal trade quantities, note that if $\Omega = \{S\}$ it is optimal to maximize investment incentives by setting $\widetilde{q} = \overline{q}$ or $\widetilde{q} = 0$ as long as the first-best is not achieved. If, for a certain O, a quantity $q = \overline{q}$ would induce overinvestment the parties will reduce the contracted trade quantity accordingly. If more than one organizational form is optimal it immediately follows from (5) that the first-best is reached and that the optimal trade quantities are related as stated in the proposition below.

To ease the exposition of the result, define $\sigma^{q=0} \equiv \sigma(\beta = 0; C = (S, 0))$, $\sigma^{q=\overline{q}} \equiv \sigma(\beta = 0; C = (S, \overline{q}))$, and, for each O, define q^O implicitly by $\widehat{S}_a\left(O, q^O, a^*\right) = 1$. The threshold values in the proposition below are defined as follows: $v^1 \equiv 2 - \phi_a(\sigma^{q=0}) - \widehat{s}^e_a(\sigma^{q=0})$, $v^2 \equiv 1 - \widehat{s}^e_a(a^*)$ and $v^3 \equiv 1 + \widehat{b}^e(a^*)$.

[23] If only the buyer is able to invest our results hold with obvious modifications.

[24] This interpretation is common in the empirical literature on vertical integration. For a critical discussion of this literature, see Whinston (2001).

Proposition 1 *Take Assumptions 1-4 as given and suppose that only the seller invests. Then Ω, the set of optimal organizational forms, and the respective optimal quantities $\hat{q}$ are given by:*

(i)	$\Omega = \{S\}$	*iff* $n_a(\overline{q}, a^*) < 1$	$\Rightarrow$	$\hat{q} = 0$ *if* $n_a(\overline{q}, \sigma^{q=0}) < v^1$,
				$\hat{q} = q^S$ *if* $n_a(\overline{q}, a^*) \geq v^2$,
				$\hat{q} = \overline{q}$ *otherwise,*
(ii)	$\Omega = \{S, X\}$	*iff* $1 \leq n_a(\overline{q}, a^*) < v^3$	$\Rightarrow$	$\hat{q} = q^O$ *where* $q^S < q^X$,
(iii)	$\Omega = \{S, X, B\}$	*otherwise*	$\Rightarrow$	$\hat{q} = q^O$ *where* $q^S < q^X < q^B$,

(iv) *In cases (i)($\hat{q} = q^S$), (ii) and (iii) the first-best is achieved while in cases (i)($\hat{q} = 0$) and (i)($\hat{q} = \overline{q}$) equilibrium investment is given by $\hat{a}(\hat{C}) = \sigma^{q=0} < \sigma^*$ and $\hat{a}(\hat{C}) = \sigma^{q=\overline{q}} \leq \sigma^*$ respectively,*

(v) $q^O > 0$ *and generically* $q^O < \overline{q}$ $\forall O$*. Hence,* $q = \overline{q}$ *generically implies* $\hat{a} < \sigma^*$*,*

(vi) *In the special case of non-contractible trade, the uniquely optimal contract, i.e., the contract which solves (C) subject to the constraint $q \equiv 0$, is given by $\hat{C} = (S, 0)$ which leads to $\hat{a}(\hat{C}) = \sigma^{q=0} < \sigma^*$.*

Foundations of the property-rights theory Proposition 1 contributes to the foundation of the property-rights theory of the firm: (1) In the one-sided investment case the contractability of trade has no impact on the optimality of $O = S$ which is a strength of the property-rights approach because the PRT derives this prediction under the assumption that $q \equiv 0$, and hence in a simpler framework. (2) It has been argued, e.g., by Holmstrom (1999), that the ability of the property-rights approach to rule out suboptimal arrangements is perhaps even more important than identifying optimal once. We show that if trade is contractible the PRT may fail on this account because X or even B may be optimal, i.e., in contrast to the prediction by the PRT the optimal organizational form may not be unique. Especially, the choice of organizational form is irrelevant if $n_a(\overline{q}, a^*) \geq 1$ holds. Note that ($\hat{O} = S, \hat{q} = 0$) is optimal iff $n_{aq}(q, a) < 0$ $\forall q, a$ holds. (3) While previous foundations of the PRT describe environments where it is optimal to write no quantity contract at all and where consequently only the allocation of ownership matters, we provide conditions under which the PRT is well founded, i.e., $\Omega = \{S\}$ even when trade is contractible, but the parties additionally sign a quantity contract which reduces or even eliminates the inefficiency which the PRT suggests.

Contractability and organizational form Proposition 1 has implications beyond the foundation issue: (1) If only the seller invests ownership of the asset by the buyer, i.e., in the context of a vertical relationship an integrated firm, can only be optimal if trade is contractible: if $\Omega = \{S, X\}$ in addition to integration the parties need to sign an exclusive dealing contract while if $\Omega = \{S, X, B\}$ integration is optimal with and without an exclusive clause. (2) Suppose that trade is initially non-contractible (such that $O = S$ is uniquely optimal) but subsequently becomes contractible, for example due to standardization after an development phase. In this case, the model suggest that a change of organizational form is not necessary. Note that, as we will show below, this holds not necessarily true in the two-sided investment case.[25]

Interaction between organizational forms and quantity contracts Proposition 1 implies that even when the model allows only limited or no predictions regarding O it still imposes restrictions on the optimal combinations of O and q: (1) Once we observe more than one organizational form $q^S < q^X < q^B$ has to hold, i.e. if in a vertical context both separate and integrated firms are observed the contracted quantities should be higher in the latter than in the former. (2) However, if the parties sign an exclusive dealing contract, i.e., $O = X$, the model predicts the same trade quantities independent of who owns the asset. (3) Trade contracts can only be irrelevant, i.e., $\hat{q} = 0$, if $\Omega = \{S\}$. Hence, the lack of a quantity contract can only be optimal *between* firms. Moreover, if $(\hat{O} = S, \hat{q} = 0)$ is observed empirically the model predicts that the optimal organizational form is unique: hence, in all relationships identical to the one under consideration only $\hat{O} = S$, i.e., only separate firms, should be observed.

Efficiency By observing certain contract terms one can draw inference about the efficiency of the relationship: (1) Whenever $q = 0$ or $q = \overline{q}$ is observed we know that generically the first-best is not achieved. Moreover, it follows from Proposition 1 that in this case the optimal O is unique, i.e. $\Omega = \{S\}$, and hence no other organizational form should be observed empirically. (2) Conversely, if we observe (a) more than one organizational form, (b) that the parties sign an exclusive dealing contract, or (c) an

[25]The model also allows interesting comparative static exercises with respect to the payoff functions of the parties (for example, changes due to cost or demand shocks). This is illustrated by means of the Fisher-Body case in Section 3.2 below.

interior trade quantity the model implies that the first-best is achieved.

To summarize, we have shown that the set of optimal organizational forms crucially depends on $n_a(\overline{q}, a^*)$: if the non-investor profits sufficiently from an increase in the value of the asset, for example because a better asset allows a higher quality product or because the investment increases the size of the market for the assets product, then, even if trade is contractible, we have $\Omega = \{S\}$ as under the property-rights approach. Nevertheless, the parties may still find it worthwhile to sign a quantity contract to generate additional investment incentive. Finally, one can show that all of the above results extend to the case of a one-sided investment in *human capital*: in this case, the non-investor only benefits from an improvement in the human capital of the investor if both parties interact with each other but he does not benefit if he trades with the outside-market.

3.2 Transferable Investments

When both parties may invest the model allows additional insights. For example, we will show that, in contrast to the one-sided case, it is possible that an integrated firm is strictly optimal when trade is non-contractible while two separate firms are strictly optimal when trade is contractible. Hence, in the two-sided case the property-rights approach may give a misleading prediction with respect to optimal organizational forms. While this problem exist in general we restrict attention to the case of two-sided transferable investments for the remainder of this section:

Assumption 5 $a(\beta, \sigma) \equiv \beta + \sigma$.

Transferable investments are interesting from an applied point of view, and they possess some useful analytical properties: (1) Investments are transferable in many contexts: for example, Hart (1995, p. 69) argues that investments in physical capital are often not specific to a particular party but are transferable in the sense that while they are relationship-specific it does not matter which of the parties to a relationship invests. Furthermore, in many horizontal relationships, as for example in horizontal production joint ventures, the parties contribute a homogenous input to the venture. Similarly, in marketing alliances the parties often just contribute money which might nevertheless be difficult to verify.[26] In all of these cases, only the total amount invested matters. (2) From a theoretical perspective, we will show in Section 4 that with transferable investments the restriction of attention to simple contracts of the form (O, q) for some $O \in \{B, S, X\}$ and $q \in [o, \overline{q}]$ is justified because this restriction does not lead to an efficiency loss.[27] When both parties make *non-transferable* investments the parties can in general gain by randomizing over organizational forms which complicates the analysis considerably, and, from a theoretical point of view, there is no obvious reason why randomization in the initial contract should be ruled out.[28] (3) Finally, in the case of transferable investments one can isolate how the optimality of a contract depends on its impact on the threatpoint payoffs of the parties which is the main focus of the present paper. In general, the form of an optimal contract also depends on the exogenously given importance of each investment for increasing total surplus. When investments are transferable both investments are equally important by definition, and the later consideration is irrelevant.

Investment equilibrium If investments are transferable then, for a given investment σ by the seller, the buyer will invest up to the point where $\hat{B}_a(O, q, \beta + \sigma) = 1$. Hence, the investment best-response functions are given by $\beta(\sigma; C) = \max\{a^B(C) - \sigma, 0\}$ and $\sigma(\beta; C) = \max\{a^S(C) - \beta, 0\}$ where $a^B(C) \equiv \arg\max_a\{\hat{B}(O, q, a) - a\}$ and where $a^S(C)$ is defined analogously. Hence, the investment equilibrium $(\hat{\beta}(C), \hat{a}(C))$ is given by (i) $(a^B(C), 0)$ if $a^B(C) > a^S(C)$, (ii) $(0, a^S(C))$ if $a^B(C) < a^S(C)$ and (iii) (β, σ) such that $\beta + \sigma = a^B(C)$ otherwise. Note that generically only one of the parties will invest in equilibrium which eases the analysis considerably. Total equilibrium investment is given by $\hat{a}(C) \equiv \max\{a^B(C), a^S(C)\}$. Note that since the $a^j(C)$'s are continuous in q, $\hat{a}(C)$ is continuous in q as well. The properties of the investment equilibrium are illustrated in Figure 2 below.

Figure 2 here

[26] Laffont and Tirole (1993, p. 88) highlight that due to "creative accounting" opportunities even monetary contributions might be hard to verify. For example, if the money is used to buy certain inputs or services the investor might collude with the provider of the input in order to overstate its price.

[27] For a more detailled discussion of this issue, see Section 4.

[28] However, as the proof of Proposition 3 shows, even in the non-transferable case, the parties cannot gain by signing message-dependent contracts.

Intuition We will show below that if investments are transferable and trade is *non-contractible* the optimal organizational form is generically unique but it depends on the parameter values whether $\Omega = \{S\}$ or $\Omega = \{B\}$.[29] Why might the maximization of (C) subject to $q \equiv 0$, i.e., the property-rights approach, fail to identify the optimal organizational form when trade is contractible? Recall from (4) that $B_{aq}(O,q,a) = -S_{aq}(O,q,a)\ \forall O,q,a$. Hence, if the investment incentives of one party are decreasing in q they are automatically increasing in q for the other party. In the one-sided case, because of (4), this observation had no impact on the optimality of $O = S$. In the following, for definiteness, we focus on the case that $O = B$ is optimal when trade is non-contractible.[30] Then, if trade is contractible, because of (4), it is perfectly possible that the incentives of S are increasing in q and that it is optimal to raise the incentives of S even further by giving him ownership of the asset. Note that *in equilibrium* generically only one of the parties will invest, and that inequalities (5) and (6) hold. Hence, the above observations imply that the choice of organizational form is only relevant, i.e., $X \notin \Omega$, if, for both parties, specifying a large trade quantity in the initial contract generates only relatively low incentives: a case which arises if the internal gains from increases in the asset value are relatively similar for both parties. However, even if the choice of organizational form is relevant, i.e., if $\Omega = \{S\}$ or $\Omega = \{B\}$, it is still possible that the first-best is achieved.

With respect to optimal trade quantities, note that generically $\overline{q}$ can only be optimal if the first-best is not achieved. Hence, to agree on $\overline{q}$ can generically only be optimal if the ownership structure is relevant, i.e., if $\Omega = \{S\}$ or $\Omega = \{B\}$. Similar to the one-sided case, if $\Omega = \{B\}$ when trade is non-contractible then if trade is contractable $q = 0$ can only be optimal if $\Omega = \{B\}$ still holds. Hence, quantity contracts are irrelevant if and only if $\Omega = \{B\}$ and the investment incentives of the buyer are decreasing in q. Whenever more than one organizational form is optimal it depends on the identity of the investing party under which organizational form the accompanying trade quantity is larger: it follows from (5) and (6) that the optimal trade quantity is lower when the investor owns

[29] While joint ownership of the asset, i.e., $O = X$, may in general be optimal when investments are in physical capital this is not the case when investments are transferable. This has previously been shown by Rosenkranz and Schmitz (2001) who study transferable investments in a dynamic property-rights framework.

[30] We choose this case because it fits the Fisher-Body example which we present below. For the alternative case that $O = S$ if trade is non-contractible the results are completely analogous.

the asset than when he does not own it.

The following notation will be useful for the exposition of the result. The result is illustrated in Figure 3 below:[31] In cases (ii)-(iv) of Proposition 2 below q^O is implicitly defined by $\widehat{B}_a\left(O, q^O, a^*\right) = 1$ while in cases (v)-(vii) q^O is implicitly defined by $\widehat{S}_a\left(O, q^O, a^*\right) = 1$. Define $q^M \equiv \overline{q}$ if $\widehat{B}_a(B, q, a)$ is increasing in q, and $q^M \equiv 0$ otherwise. Define $a^S \equiv a^S(S, \overline{q})$ and $a^B \equiv a^B(B, 0)$. The threshold values as used in the proposition are defined by: $t^1 = -1 - \widehat{s}^e_a(a^*)$, $t^2 = -1$, $t^3 \equiv -1 + \widehat{b}^e_a(a^*)$, $t^4 \equiv -2 + \phi_a\left(a^B\right) + \widehat{b}^e_a\left(a^B\right)$, $t^5 = -2 + \phi_a\left(a^S\right) + \widehat{b}^e_a\left(a^S\right)$, $t^6 \equiv 1 - \widehat{s}^e_a(a^*)$, $t^7 = 1$, $t^8 = 1 + \widehat{b}^e_a(a^*)$.

Proposition 2 *Take Assumptions 1-5 as given.*

(i) In the special case of non-contractible trade, $\Omega = \{S\}$ ($\Omega = \{B\}$) if $\widehat{b}^e_a\left(a^B(B,0)\right) < (>) \widehat{s}^e_a\left(a^B(B,0)\right)$, and only party S (B) invests in equilibrium.

For definiteness, suppose that $\Omega = \{B\}$ when trade is non-contractible. Then, if trade is contractible, the optimal organizational forms and the accompanying optimal trade quantities are given by:

(ii)	$\Omega = \{B, X, S\}$	*iff* $n_a(\overline{q}, a^*) \leq t^1$	$\Rightarrow$	$\widehat{q} = q^O$ *where* $q^B < q^X < q^S$,
(iii)	$\Omega = \{B, X\}$	*iff* $t^1 < n_a(\overline{q}, a^*) \leq t^2$	$\Rightarrow$	$\widehat{q} = q^O$ *where* $q^B < q^X$,
(iv)	$\Omega = \{B\}$	*iff* $n_a(\overline{q}, a^*) > t^2$	$\Rightarrow$	$\widehat{q} = q^B$ *if* $n_a(\overline{q}, a^*) < t^3$,
		and $n_a\left(q^M, a^S\right) < t^5$		$\widehat{q} = 0$ *if* $n_a\left(\overline{q}, a^B\right) > t^4$,
				$\widehat{q} = \overline{q}$ *otherwise,*
(v)	$\Omega = \{S\}$	*iff* $n_a\left(q^M, a^S\right) > t^5$	$\Rightarrow$	$\widehat{q} = \overline{q}$ *if* $n_a(\overline{q}, a^*) < t^6$,
		and $n_a(\overline{q}, a^*) < t^7$		$\widehat{q} = q^S$ *otherwise,*
(vi)	$\Omega = \{S, X\}$	*iff* $t^7 \leq n_a(\overline{q}, a^*) < t^8$	$\Rightarrow$	$\widehat{q} = q^O$ *where* $q^S < q^X$,
(vii)	$\Omega = \{S, X, B\}$	*iff* $n_a(\overline{q}, a^*) \geq t^8$	$\Rightarrow$	$\widehat{q} = q^O$ *where* $q^S < q^X < q^B$,

(viii) $q^O > 0$ and generically $q^O < \overline{q}$ for each $O \in \Omega$,

(ix) The first-best is achieved iff either $n_a(\overline{q}, a^*) \leq t^3$ or $n_a(\overline{q}, a^*) \geq t^6$ holds. In cases (ii)-(iv) only B invests in equilibrium while in cases (v)-(vii) only S invests in equilibrium.

Note that in the knife-edge case $n_a\left(q^M, a^S\right) = t^4$ we have $\Omega = \{B, S\}$. In Appendix C we provide a simple numerical example which illustrates that all cases of Proposition 2

[31] It is straightforward to show that the order of the threshold values is exactly as shown in Figure 3.

may indeed occur. In the following, we highlight which differences and additional insights relative to the one-sided case arise in the two-sided case:

Foundations of the property-rights theory (1) In contrast to the one-sided investment case, Proposition 2 (v) shows that if both parties invest the property-rights approach may wrongly predict that some ownership structure is optimal which, given that trade is contractible, is not the case. However, this case cannot arise if the investment incentives of the seller are decreasing in q which is equivalent to $n_{aq}(0,0) < 0$. Note that in the case of Proposition 2 (vi) ownership of the asset by the buyer is still optimal as long as it is accompanied by an exclusive dealing contract. (2) Besides providing the exact conditions under which the property-rights approach is well founded, i.e., when $\Omega = \{B\}$, the above proposition shows that the choice of ownership structure is relevant over a larger parameter range, namely when $n_a(\overline{q}, a^*) \in (-1, 1)$: if this condition is satisfied then $X \notin \Omega$, and hence the choice of ownership structure matters.

Figure 3 here

Contractability and organizational form (1) While the optimal organizational form is generically unique when trade is non-contractible this is in general not true with contractible trade, and in contrast to the one-sided investment case it is even possible that the sets of optimal organizational forms for contractible and non-contractible trade respectively do not overlap: for example, if Proposition 2 (v) applies then, in a vertical relationship, integration is strictly optimal when trade is non-contractible while two separate firms are strictly optimal when quantity contracts are feasible. (2) In contrast to the one-sided case, if investments are transferable and trade becomes contractible at a certain point in time a change in organizational form may be necessary: for example, if Proposition 2 (vi) applies the parties need to additionally sign an exclusive quantity contract, while if Proposition 2 (v) applies an outright move from integration to separate firms is necessary.

Efficiency and investing party Proposition 2(ix) predicts that generically only one of the parties invests in equilibrium, and that for all $O \in \Omega$ it is the same party who invests. Moreover, whenever the non-owner invests the ownership structure is generically irrelevant, and hence the first-best is achieved. This is true because giving this party ownership would even increase her incentives. Hence, the initial arrangement could not be optimal if it would not induce the first-best. Moreover, by observing empirically which of the parties invests one can draw inference about which contract terms are consistent with equilibrium.

Interaction between organizational forms and quantity contracts (1) In contrast to the one-sided case, when investments are transferable it depends on the model parameters whether the contracted quantities are larger in integrated or in separate firms. However, the above results allow the prediction that if only the seller (buyer) invests in equilibrium the contracted quantities should be lower (higher) between separated firms than within an integrated firm. (2) As in the one-sided case, quantity contracts can only be irrelevant, i.e., $q = 0$ can only be optimal, if the same organizational form as under non-contractible trade turns out to be uniquely optimal when quantity contracts are feasible. Hence, in the setting of Proposition 2 the lack of a quantity contract can only be optimal within an integrated firm. (3) Finally, Proposition 2 completely characterize when the choice of both incentive instruments is relevant.

Comparative Statics: Fisher-Body revisited The model also allows interesting comparative static exercises: for example, one can explore how the optimal organizational form, quantity contracts, the efficiency of the relationship and the identity of the investing party evolve due to exogenous shocks on the payoff functions of the parties. To illustrate this point, we revisit the classic Fisher-Body (FB) case which has attracted considerable attention in the transaction cost and property-rights literatures. While there are rivaling interpretations of the case,[32] our model provides support to Klein's (2000) view that the refusal by FB to invest in a new plant following a substantial increase in demand for closed automobile bodies necessitated full vertical integration of FB by General Motors (GM) in 1926 after which GM build the plant itself.[33] Since 1919 the two had operated under a supply contract which obliged GM to buy all of its automobile bodies from FB

[32]For example, while Coase (2000) denies that a hold-up occured prior to integration, Casadesus-Masanell and Spulber (2000) and Freeland (2000) argue that integration was caused by human specificity considerations.

[33]The 1925-26 period exhibited very rapidly growing GM sales and a dramatic shift from open to closed autobodies which led to an increase of FB closed body sales to GM of about 200% (Klein (2000, p. 113)). For GM's investment, see Klein (2000, p. 118).

but allowed FB to trade externally,[34] where the fact that the contract included explicit price terms gives some evidence that trade was contractible in our sense. In the period prior to 1926, FB had built several plants to meet GM's needs.[35] In terms of our model, this could be expressed as that, prior to 1926, $(O = S, q = \overline{q})$ was observed which in 1926 changed to $(O = B, q = 0)$ because no explicit quantity contract was in place after that date.[36] Our model can rationalize this switch: note, that these two contracts correspond to neighboring parameter regions in Figure 3 and that the boundary between these parameter regions is defined by:

$$\phi_a\left(a^S\right) - \hat{s}_a\left(X, q^M, a^S\right) + \hat{\theta}_a^e\left(a^S\right) + \hat{\theta}_a\left(X, q^M, a^S\right) - 2 = 0 \tag{8}$$

As long as the left-hand side of (8) is negative, $(O = S, q = \overline{q})$ is optimal. Arguably, an exogenous increase in demand would have made trade, and hence a new plant more valuable for GM which would have caused an upward shift in its (marginal) payoff functions $\hat{\theta}_a(\cdot)$ and $\hat{\theta}_a^e(\cdot)$. Because the shift was relatively large the left-hand side of (8) turned positive, and hence $(O = B, q = 0)$ became optimal. Note, that the observed investment behavior is consistent with Proposition 2(ix).[37] Hence, our model contributes to the explanation of the Fisher-Body case: while Klein (2000) argues informally that, due to insufficient reputational capital, the rise in demand shifted the initial supply contract outside its "self-enforcing range" he remained unsure what exactly it was "about the large, unexpected demand increase by GM that caused Fisher to take advantage of the imperfect body supply regime."[38] Our model suggests that the rise in demand increased the contractual externality of the investment, and thereby led to the suboptimality of the supply contract regime. More generally, the above example illustrates that our model can

[34] In 1919, when signing the supply contract for a horizon of 10 years, GM also acquired a 60% interest in FB. However, as both Coase (2000, p. 22f.) and Klein (2000, p. 107ff.) argue this did not provide GM with control of FB, and FB was still run as an independent firm by the Fisher Brothers after 1919. Summaries of the contract terms can be found at the same references.

[35] See Klein (2000, p. 110).

[36] Again, we interpret $O = S$ as two separate firms.

[37] Our results build on the assumption that $\Omega = \{B\}$ when trade is non-contractible. In the Fisher-Body case, this is consistent with the observed contracts: suppose to the contrary that $\Omega = \{S\}$ when trade is non-contractible. In this case, an analogous argument to Proposition 2 implies that $(O = B, q = 0)$ could not be optimal when trade is contractible.

[38] Klein (2000, p. 129).

provide guidance as to when large specific investments and incomplete contracts indeed necessitate vertical integration.

4 Non-Contingent Contracts Suffice

In this section, we show that given our assumptions the parties cannot gain by considering more complicated contracts which might depend on messages θ^B and θ^S which the buyer and the seller respectively send between dates 2 and 3.[39] To prove this, we follow the mechanism design with renegotiation approach as advanced by Maskin and Moore (1999) and invoke the revelation principle which allows to restrict attention to direct revelation mechanism under which both parties have an incentive to report the ex-post state of the world truthfully. In the more general setting considered in this section, we define a contract C as a mapping $(O, q, t) : \Theta^2 \rightarrow \{B, S, X\} \times [0, \overline{q}] \times \Re$. The best-response investment functions, given this more general class of contracts, are defined in the proof of the proposition below. We build on results by Segal and Whinston (2002) who provide conditions under which every sustainable investment equilibrium can be sustained by a non-contingent contract which *randomizes* over organizational forms. We extend their results in two ways: first, by focussing on the set of optimal contracts, we strengthen their results to non-randomizing contracts. Second, if investments are transferable investment equilibria are in general not interior, and we extend Segal and Whinston (2002) to accommodate this case:[40,41]

[39] Note that option contracts may improve upon non-contingent contracts if parties invest sequentially (see e.g., Nöldeke and Schmidt (1998) and Edlin and Hermalin (2000)).

[40] The result below is robust to the possibility of randomization across organizational forms. If both parties make non-transferable investments, by applying results of Segal and Whinston (2002), one can show that, as long as all investment equilibria are interior, the restriction to message-independent contracts which randomize over organizational forms does not lead to an efficiency loss. However, non-randomizing contracts are in general not optimal in this case. In the absence of a randomizing device the results of Segal and Whinston (2002) are not directly applicable because in this case one of the decisions, namely O, would be discrete. Whether in this case the restriction of attention from arbitrary contracts of the form $(O(\cdot), q(\cdot), t(\cdot))$ to non-contingent contracts (O, q, t) does not lead to an efficiency loss awaits future research.

[41] With two-sided investments in human capital, the results of Segal and Whinston (2002) are not applicable: while the internal payoffs of the parties might depend on the investments of both parties, a party has only access to its own human capital when trading externally. Hence, in general the investments cannot be aggregated into one dimension in the decision-dependent parts of the post-renegotiation payoffs as required by Condition A in Segal and Whinston (2002).

Proposition 3 *Take Assumptions 2-4 as given and suppose that Assumption 1 holds for any message-dependent contract C as defined above. If only one party can invest or if investments are transferable across parties, i.e., $a(\beta, \sigma) \equiv \beta + \sigma$, the set of optimal contracts always contains a non-contingent contract of the form (O, q, t) for some $O \in \{B, X, S\}$, $q \in [0, \overline{q}]$ and $t \in \Re$.*

Segal and Whinston (2002) have shown that if one allows for arbitrary message-dependent mechanisms the equilibrium pre-renegotiation decisions $\hat{O}$ and $\hat{q}$ are in general indeterminate in the sense that starting from any incentive-compatible mechanism one can always change the equilibrium decision and subsequently modify the equilibrium transfers in a way such that the equilibrium payoffs remain unchanged and the incentive-compatibility conditions still hold. Hence, only if one imposes certain restrictions on the set of possible contracts one can make predictions regarding the equilibrium decisions. In the setting of Proposition 3, the restriction of attention to non-contingent contracts seems to be justified if one assumes that there is an (arbitrarily) small cost of writing more complex contracts.[42]

5 Implications for Empirical Testing

Our model has implications for the growing empirical literature on the PRT (see e.g., Baker and Hubbard (2001), Elfenbein and Lerner (2001), Hanson (1996), Woodruff (1996)). First, our model may shed some light on the puzzle why some empirical studies, like Elfenbein and Lerner's (2001) recent study of internet portal alliances, support the PRT even though in this line of business alliance agreements contain on average two quantity provisions relating to project output which suggests that interaction is contractible in our sense. Many internet portal alliances are marketing alliances, and hence seem to fit in the framework of Section 3.2.[43] Elfenbein and Lerner (2001) find that in

[42]Note that non-contingent contracts are a special case of continuous contracts in which the decisions are continuous in the messages of the parties. Segal and Whinston (2002) show that under some assumptions the expected decision in any optimal continuous contract is equal to the decision in the optimal non-contingent contract. Unfortunately, the assumptions which underlie this result, e.g., a one-dimensional decision space (see Segal and Whinston's (2002)Condition S), are not satisfied in our model.

[43]In a recent paper, Rosenkranz and Schmitz (2001) argue that the joint provision of internet portals is an especially valuable field for marketing alliances. While Elfenbein and Lerner's (2001) sample contains

promotional agreements in general one of the parties provides most of the effort, and they report a significant relationship between the identity of this party and the allocation of ownership rights which they interpret as support for the PRT. However, they are puzzled by a varying degree of completeness of the contracts with respect to quantity provisions. Our model suggest that, given transferability of investments, the optimal organizational form, quantity provisions and the identity of the investing party are all determined endogenously, and that the choice of ownership structure is only relevant under certain circumstances.[44] Elfenbein and Lerner (2001) do not examine the relationship between the observed ownership patterns and the completeness of the contracts with respect to quantity provisions. Hence, in future work, it might be interesting to revisit Elfenbein and Lerner's (2001) data set in light of our theory. Second, in contrast to the PRT, our model suggest that frequently more than one organizational form will be optimal. This poses the problem that the theoretical prediction might not be unique. Hence, it seems to be promising to look at industries which experience a shift in underlying parameter values, e.g., in the demand or costs structure, such that a certain organizational form is only optimal before the shift.[45] Third, Whinston (2001) emphasizes that the informational requirements of empirical test of the PRT are high since, in principle, marginal contributions have to be observed. Our model imposes joint restriction on potentially observable variables, like the organizational form, the contracted level of interaction and the identity of the investing party, which may allow informationally less demanding indirect test of the theory. Finally, our model suggest that settings where the investments of the parties are embedded in an asset can serve as a valuable empirical testing ground independent of the contractability of interaction, and that one need not confine attention to situations where interaction is not contractible.

both marketing and technology alliances one of their leading examples concerns an advertising and promotional agreement between Autoweb.com and Yahoo! in 1998.

[44]This observation hints at possible endogeneity problems if one runs regressions of the ownership structure on the identity of the investing party.

[45]This would be similar to the approach by Baker and Hubbard (2002) who utilize shifts in the informational environment.

6 Extension: Spillovers Between Internal and External Trade

Until now, we have assumed that the threatpoint payoffs which the parties obtain from external trade are independent of the internal trade quantity. In this section, we drop this assumption, and hence $[\hat{\vartheta}(O,q,a) - \hat{\vartheta}(X,q,a)]$ and $[\hat{s}(O,q,a) - \hat{\vartheta}(X,q,a)]$ might vary in q. In this more general setting, one can show that all propositions continue to hold: only the threshold values in Propositions 1 and 2 have to be redefined appropriately.[46]

Definition 2 (Spillovers) *We speak of positive (negative) spillovers from internal on external trade for the buyer if* $\hat{\vartheta}^e_{aq}(q,a) > (<) 0 \; \forall q, a$ *holds. Analogously, we speak of positive (negative) spillovers for the seller if* $\hat{s}^e_{aq}(q,a) > (<) 0 \; \forall q, a$ *holds.*

If spillovers are negative then, in the presence of intense internal interaction, the asset can only be less profitably employed externally. For example, this might arise if the parties have less time to look for external trading partners or if internal trade reduces their marginal utility from external trade. Positive spillovers might arise if, by trading internally, the parties get better at trading externally: for example, the seller might learn how to produce cheaper for the external market. In general, spillovers might be positive for one party and negative for the other. The presence of spillovers allows to provide some easily interpretable examples where the model predicts that the optimal organizational form is unique even though quantity contracts are feasible. The conditions in these examples have the interpretative advantage that, in contrast to the conditions in the above propositions, they do not rely on derived entities such as a^S or a^*. Recall that $n_{aq}(q,a) > (<) 0 \Leftrightarrow \hat{s}_{aq}(X,q,a) > (<) \hat{\vartheta}_{aq}(X,q,a) \; \forall q, a$. Moreover, note that in the presence of spillovers it might depend on O whether $\hat{\vartheta}_{aq}(O,q,a)$ is increasing or decreasing in q, and the subsequent examples make use of this feature. In the examples below, we assume that both parties may make transferable investments, and we maintain the assumption that $\Omega = \{B\}$ if trade is non-contractible. Given Assumption 3 and Proposition 2, the proof that the examples below hold true is straightforward and therefore omitted.

[46] Under slight abuse of notation, define $\hat{s}^e(q,a)$ and $\hat{\vartheta}^e(q,a)$ analogous to above. Given these definitions, the relevant treshold values obtain for $q = \overline{q}$, e.g., $v^3 \equiv 1 + \hat{\vartheta}^e(\overline{q}, a^*)$. The only exception is $t^5 \equiv -2 + \phi_a \left(a^S\right) + \hat{\vartheta}^e_a \left(q^M, a^S\right)$.

Example 1

(E1) Suppose that both the seller and the buyer experience negative spillovers. Then, for $|n_{aq}(0,0)|$ *sufficiently small, we have* $\Omega = \{B\}$*, and quantity contracts are irrelevant, i.e., it is strictly optimal for the parties to agree on* $q = 0$*.*[47]

(E2) Suppose that the buyer experiences positive spillovers while the opposite is true for the seller. Then, if $n_{aq}(0,0)$ *is positive but not too large, we have* $\Omega = \{B\}$*. While for small values of* $n_{aq}(0,0)$ *some* $\tilde{q} > 0$ *is optimal, trade contracts are irrelevant if* $n_{aq}(0,0)$ *is sufficiently large.*[48]

(E3) Contrary to (E2), suppose that the seller experiences positive spillovers while the opposite is true for the buyer. Then, if $n_{aq}(0,0)$ *is slightly negative, either* $\Omega = \{S\}$ *or* $\Omega = \{B\}$ *holds. While under these conditions the investment incentives of the seller are increasing in* q *when he owns the asset, only when the effect of* q *is strong enough we have* $\Omega = \{S\}$*. In this case, some* $\tilde{q} > 0$ *is optimal. If the effect of* q *is weak then* $\Omega = \{B\}$*, and the parties should not sign a quantity contract, i.e.,* $\tilde{q} = 0$*.*[49]

Example (E1) shows that if (i) for both parties the effects of a and q on the internal payoffs are relatively similar, and if (ii) for both parties internal trade makes the external use of the asset less profitable then the property-rights approach is well founded. Example (E2) shows that this is also possible if spillovers are asymmetric. While in the first two examples $\Omega = \{B\}$ even when trade is contractible, in Example (E3) the optimal organizational form is unique but it depends on the parameter values whether $\Omega = \{B\}$ or $\Omega = \{S\}$ holds.

7 Conclusion

In a symmetric information setting, we study how two incentive instruments, the organizational form and quantity contracts, are used to generate investment incentives. Our model nests standard property-rights and hold-up models as special cases. We admit

[47] Formally, $n_{aq}(0,0) \in (\hat{\theta}^e_{aq}(0,0), -\hat{s}^e_{aq}(0,0))$.

[48] Formally, $n_{aq}(0,0) \in (0, -\hat{s}^e_{aq}(0,0))$. $\tilde{q} = 0$ is only optimal if $n_{aq}(0,0) > \hat{\theta}^e_{aq}(0,0)$.

[49] Formally, $n_{aq}(0,0) \in (\max\{\hat{\theta}^e_{aq}(0,0), -\hat{s}^e_{aq}(0,0)\}, 0)$. If additionally $\hat{S}_a\left(S, \overline{q}, a^B(B,0)\right) > 1$ then $\Omega = \{S\}$ and some $\tilde{q} > 0$ is optimal. If $\hat{S}_a\left(S, \overline{q}, a^B(B,0)\right) < 1$ then $\Omega = \{B\}$ and $\tilde{q} = 0$ is optimal.

general message-dependent contracts but provide conditions under which non-contingent contracts are always optimal. First, we contribute to the foundation of the property-rights theory of the firm by characterizing when and when not the PRT makes correct predictions even when trade is contractible. We show under which circumstances only the right choice of a quantity contract, only the right choice of organizational form or both are important to reduce the hold-up problem. Second, while maintaining the symmetric information assumption of the PRT our model allows to study how the two incentive instruments interact depending on the environment . This is in the spirit of the multi-tasking literature which, however, focuses on environments of asymmetric information. We fully characterize optimal contracts, and we illustrate how our model may shed light on the classic Fisher-Body case. Third, even when the optimal organizational form is not unique our model imposes restrictions on observables, and hence provides some guidance for future empirical work on the property-rights theory.

While our model enriches the property-rights theory of the firm by introducing another incentive instrument which can (but no always does) substitute for outright ownership[50] we do not address some other criticisms which have been raised against the PRT, e.g., the sole focus on providing incentives for non-contractible investments, the owner-manager identity,[51] the ownership of asset by firms rather than individuals[52] and the embedding of the PRT in a market context.[53] Integrating all these important issues in a tractable, unified model of the boundaries of the firm awaits future research.

Appendix

A Proof of Proposition 1

Ad (vi): First, we prove part (vi) of the proposition where (C) is maximized subject to the constraint $q \equiv 0$. It follows from (2) and Assumption 4 that $\hat{S}_a(B, q = 0, a) < \hat{S}_a(X, q = 0, a) < \hat{S}_a(B, q = 0, a) < \phi(a)\ \forall a$ which in combination with Assumptions (1) and (3) implies $\hat{\sigma}((B, 0)) < \hat{\sigma}((X, 0)) < \hat{\sigma}((S, 0)) < \sigma^* = a^*$ because a^* is assumed to be

[50] This is in the spirit of Holmstrom and Milgrom (1994) and Holmstrom (1999).

[51] For a recent paper which explicitly models firm as hierarchies, see Hart and Holmstrom (2002).

[52] For a paper which addresses this issue, see Rajan and Zingales (1998).

[53] For this issue, see e.g., Hubbard (2001) or Gans (2001).

interior. For the proof of the remaining parts of the proposition, note that $\beta_a(O,q,a) - 1 \geq 0 \Leftrightarrow$

$$n_a(q,a) \geq 2\phi_a(a^*) - \phi_a(a) - [b_a(O,q,a) - b_a(X,q,a)] + [\beta_a(O,q,a) - \beta_a(X,q,a)] \; \forall O, q, a.$$

Ad (i): $\beta_a(X,\overline{q},a^*) - 1 < 0 \Rightarrow O$ is relevant, i.e., $\Omega = \{S\}$: note, that under a contract $(X,0)$ which forbids external trade as well as internal trade we have $\beta_a(X,0,a^*) - 1 < 0$. Given this observation, $\beta_a(X,\overline{q},a^*) - 1 < 0$ and Assumption 3 imply $\beta_a(X,q,a^*) - 1 < 0 \; \forall q$. Hence, (5) implies that for all contracts that specify $O \in \{B,X\}$ we face an underinvestment problem, and therefore it is strictly optimal to maximize investment incentives by specifying $O = S$. Given this ownership structure we show below that overinvestment by the seller can be avoided through the right choice of q. O is relevant $\Rightarrow$ $\beta_a(X,\overline{q},a^*) - 1 < 0$: When O is relevant X cannot be optimal. Hence, it must be true that for $O = X$ the first-best cannot be achieved. Therefore, we must have $\beta_a(X,\overline{q},a^*) - 1 < 0$: otherwise $\beta_a(X,0,a^*) - 1 < 0$ and the intermediate value theorem would imply that there exists a $\hat{q}$ such that a contract $(X,\hat{q})$ induces the first-best. We now turn to the optimal trade quantity. Ad $q = 0$: note, that $n_a(\overline{q},\sigma^{q=0}) < v^1 \Leftrightarrow \beta_a(S,\overline{q},\sigma^{q=0}) - 1 < 0$. Assumption 3 in combination with $\beta_a(S,\overline{q},\sigma^{q=0}) - 1 < 0$ implies $\beta_a(S,q,\sigma^{q=0}) - 1 < \beta_a(S,0,\sigma^{q=0}) - 1 = 0$ for all $q > 0$. Hence, (5) implies $\beta_a(O,q,\sigma^{q=0}) - 1 < 0$ for all $O \in \{B,X\}$ and q, which in combination with Assumption 2 implies that $\sigma(\beta = 0; (O,q)) < \sigma^{q=0} < \sigma^*$ for all $O \in \{B,X\}$ and q. Ad $q = \overline{q}$: $\beta_a(S,\overline{q},\sigma^{q=0}) - 1 > 0$ in combination with Assumption 3 implies that $\beta_a(S,\cdot)$ is increasing in q. This observation together with (5) implies $\beta_a(S,\overline{q},a) - 1 > \beta_a(S,q,a) - 1 > \beta_a(O,q,a) - 1 \; \forall a, \forall q < \overline{q}, \forall O \in \{B,X\}$. Hence, the contract $C = (S,\overline{q})$ maximizes investment incentives. Given $n_a(\overline{q},a^*) < v^2 \Leftrightarrow$ $\beta_a(S,\overline{q},a^*) - 1 < 0$ we face an underinvestment problem, and therefore the described contract is optimal. Ad $q = q^S$: Inequalities $\beta_a(S,\overline{q},a^*) - 1 \geq 0$, $\beta_a(S,0,a^*) - 1 < 0$ (see part (vi)) and the intermediate value theorem imply that there exists a $q^S \in]0,\overline{q}]$ (and generically $q^S < \overline{q}$) which satisfies $\beta_a(S,q^S,a^*) - 1 = 0$. Hence, the contract (S,q^S) induces the first-best. Moreover, note that $\beta_a(X,0,a^*) - 1 < 0$ which in combination with Assumption 3, $\beta_a(X,\overline{q},a^*) - 1 < 0$ and (5) implies that: $\beta_a(B,q,a^*) - 1 < \beta_a(X,q,a^*) - 1 < 0 \; \forall q$. Hence, under an arbitrary contract (O,q) with $O \in \{B,X\}$ the first-best cannot be achieved.

Ad (ii)+(iii): the proof of the Ω-part is analogous to (i), and therefore omitted. $\Omega = \{B\}$, $\Omega = \{X,B\}$, $\Omega = \{X\}$ or $\Omega = \{S,B\}$ are not possible because it follows from the above discussion that $X \in \Omega$ implies $S \in \Omega$, and that $B \in \Omega$ implies $X, S \in \Omega$. If $\Omega \neq \{S\}$ if follows from the proof of part (i) that the first-best is achieved for all $O \in \Omega$, and hence an analogous intermediate value theorem argument as above implies that the optimal trade quantities are as given in the proposition.

Ad (iv)+(v): Follows directly from the proofs of the other parts of the proposition.

B Proof of Proposition 2

Ad (i): (5), (6), Assumption 1 and Assumption 4 imply that $a^* > a^j(j,0) \geq a^j(X,0) \geq a^j(i,0)$ for $j,i = B,S,\ j \neq i$. Hence, it follows from Assumption 1 that it depends on the relationship of $a^B(B)$ and $a^S(S)$ whether $\Omega = \{B\}$ or $\Omega = \{S\}$. Note, that $\widehat{S}_a\left(S,0,a^B(B,0)\right) - 1 = \widehat{s}^e\left(a^B(B,0)\right) - \widehat{\theta}^e\left(a^B(B,0)\right)$ from which the claim follows immediately.
To prove (ii)-(vii), we first characterize Ω. Note that

$$\begin{array}{l} \text{(a) } a^j(S,q) \geq (\leq) a^j(X,q) \geq (\leq) a^j(B,q)\ \forall q \text{ for } j = S\ (B) \\ \text{(b) } a^j(j,0) > a^i(j,0) \text{ for } i,j \in \{B,S\} \text{ and } i \neq j, \text{ and} \\ \text{(c) } a^S(X,0) = a^B(X,0), \end{array} \qquad (9)$$

where (a) follows from (5), (6) and Assumption 1. Note that the inequalities in (a) are strict whenever the respective left-hand side (right-hand side) is strictly positive. Claims (b) and (c) follow from $\widehat{S}_a(0,q,a) > \widehat{B}_a(O,q,a) \Leftrightarrow \widehat{s}_a(O,q,a) > \widehat{\theta}_a(O,q,a)\ \forall O,q,a$ and Assumption 1. If the first-best cannot be achieved the contract which maximizes investment incentives is optimal since generically only one party will invest in equilibrium. Moreover, if, for a given O, we have $\tilde{a}(O,q) \geq a^*$ for some q then the first-best can be achieved under organizational form O because $\tilde{a}(O,q)$ is continuous in q. Hence, $\tilde{a}(O,0) < a^*\ \forall O$ and the intermediate value theorem imply that there exists a $\hat{q}$ such that $\tilde{a}(O,\hat{q}) = a^*$. Hence, it is useful to denote the maximal total equilibrium investment which is sustainable under ownership structure O by $\tilde{a}^O \equiv \max_q \tilde{a}(O,q)$. We claim:

$$\begin{array}{l} \tilde{a}^B = \max\left\{a^B(B,\overline{q}), a^B(B,0), a^S(B,\overline{q})\right\}, \\ \tilde{a}^S = \max\left\{a^S(S,\overline{q}), a^S(S,0), a^B(S,\overline{q})\right\}, \text{ and} \\ \tilde{a}^X = \max\left\{a^S(X,\overline{q}), a^B(X,\overline{q})\right\}. \end{array}$$

Consider $\tilde{a}^B$: Assumption 3 implies that if $a^B(B,q)$ is increasing in q then $\tilde{a}^B = a^B(B,\overline{q})$. If $a^B(B,q)$ is decreasing in q then $\tilde{a}^B = \max\left\{a^B(B,0), a^S(B,\overline{q})\right\}$. Hence, $\tilde{a}^B$ is given by the above expression. The proof for $\tilde{a}^S$ is completely analogous. Assumption 3 and $a^S(X,0) = a^B(X,0)$ imply the solution for $\tilde{a}^X$.

Ad (iv): In the following, we show that $\Omega = \{B\}$ iff (a) $\tilde{a}^B > \tilde{a}^S, \tilde{a}^X$ and (b) $a^* > \tilde{a}^S, \tilde{a}^X$. Ad (a): It follows from (9) that $\tilde{a}^B > \tilde{a}^S, \tilde{a}^X \Leftrightarrow \tilde{a}^B > \max\left\{\tilde{a}^S, \tilde{a}^X\right\} \Leftrightarrow \max\left\{a^B(B,\overline{q}), a^B(B,0)\right\} > a^S(S,\overline{q}) \Leftrightarrow 1 < \max_q \widehat{B}_a\left(B,q,a^S(S,\overline{q})\right)$. Ad (b): It follows from (9) and $a^S(S,0) < a^*$ that $a^* > \tilde{a}^S, \tilde{a}^X \Leftrightarrow a^* > \max\left\{a^S(S,\overline{q}), a^B(X,\overline{q})\right\} \Leftrightarrow \widehat{S}_a(S,\overline{q},a^*), \widehat{B}_a(X,\overline{q},a^*) < 1$. Now, we argue that $\widehat{B}_a\left(B,q^M,a^S\right) = \max_q \widehat{B}_a\left(B,q,a^S(S,\overline{q})\right) > 1 \Rightarrow \widehat{S}_a(S,\overline{q},a^*) < 1$. This claim holds true if $\widehat{B}_a\left(B,q^M,a^S\right) > 1$ implies $a^S < a^*$. If $q^M = 0$ this follows immediately because Proposition 2(i) implies $a^S < a^B(B,0) < a^*$. Now assume $\widehat{B}_a\left(B,\overline{q},a^S\right) > 1$ and suppose to the contrary that $a^S \geq a^*$ which implies $\widehat{S}_a(S,\overline{q},a^*) \geq 1$. Simply by substituting for the definitions, one can show that $\widehat{B}_a\left(B,\overline{q},a^S\right) > 1$ and $\widehat{S}_a(S,\overline{q},a^*) \geq 1$ are mutually compatible iff $\widehat{s}^e_a(a^*) + \widehat{\theta}^e_a(a^*) > 2\phi_a(a^*)$ which is impossible given Assumption 4. It follows from (1), (2) and (7) that conditions (a) and (b) are equivalent to the conditions which are stated in the proposition.

Ad (v): Analogous to (iv) and therefore omitted.

Ad (ii), (iii), (vi), (vii): First, note that $\tilde{a}^X > \tilde{a}^S, \tilde{a}^B$ cannot be true because this would imply $\max\{a^S(X,\overline{q}), a^B(X,\overline{q})\} > \max\{a^S(S,\overline{q}), a^B(B,\overline{q})\}$ which does not hold true because $a^S(X,\overline{q}) \le a^S(S,\overline{q})$ and $a^B(X,\overline{q}) \le a^B(B,\overline{q})$. Hence, either $\hat{a}^S > \hat{a}^X$ or $\hat{a}^B > \hat{a}^X$ holds. Hence, $X \in \Omega$ iff $\hat{a}^X = \max\{a^S(X,\overline{q}), a^B(X,\overline{q})\} \ge a^*$. Now, suppose $a^S(X,\overline{q}) \ge a^*$ which implies $a^B(X,\overline{q}) \le a^B(X,0) < a^*$ and $a^* \le \hat{a}^X = a^S(X,\overline{q}) < a^S(S,\overline{q}) \le \hat{a}^S$. Hence, $O = S$ is optimal as well. Moreover, $a^S(S,\overline{q}) > a^*$ implies $a^B(S,\overline{q}) \le a^S(S,0) < a^*$. Hence, $\hat{a}^S = a^S(S,\overline{q})$. Now, $\hat{a}^B \ge a^*$ holds iff $\max\{a^B(B,\overline{q}), a^S(B,\overline{q})\} \ge a^*$. Next, we show that given $a^S(X,\overline{q}) \ge a^*$ it is not possible that $a^B(B,\overline{q}) \ge a^*$: Suppose to the contrary that $a^B(B,\overline{q}), a^S(X,\overline{q}) \ge a^*$ which together with the above discussion implies $\hat{\vartheta}_a(B,\overline{q},a^*), \hat{\vartheta}_a(S,\overline{q},a^*) \ge 1$. Assumption 4 and $\hat{\vartheta}_a(S,\overline{q},a^*) \ge 1$ imply $2 + n_a(\overline{q},a^*) > 1 + \hat{\vartheta}^e_a(a^*) + n_a(\overline{q},a^*) \ge 2$ which implies $n_a(\overline{q},a^*) > 0$. Hence, $\hat{\vartheta}_a(B,\overline{q},a^*) = \phi_a(a^*) - n_a(\overline{q},a^*) + \hat{\vartheta}^e_a(a^*) < 1$ which is a contradiction to $a^B(B,\overline{q}) \ge a^*$. Hence, $\hat{a}^B \ge a^*$ iff $a^S(B,\overline{q}) \ge a^*$. To summarize: $\Omega = \{S, X\}$ iff $a^S(X,\overline{q}) \ge a^* > a^S(B,\overline{q})$, and $\Omega = \{B, S, X\}$ if $a^S(B,\overline{q}) \ge a^*$. In both cases the seller invests. Again, it follows from (1), (2) and (7) that these conditions are equivalent to the conditions which are stated in the proposition. The proof for the remaining case that $a^B(X,\overline{q}) \ge a^*$ is completely analogous and therefore omitted.

Ad (ix) Before we proceed to characterize the optimal trade quantities, we prove part (ix) of the proposition. Regarding the first-best: the if-part follows immediately from the discussion above. With respect to the only if-part: if $\Omega = \{B, S\}$ the first-best cannot be achieved: suppose to the contrary that $\hat{a}^B, \hat{a}^S \ge a^*$ which together with the fact that $X \notin \Omega$, i.e. $a^* > \hat{a}^X$, implies $\hat{a}^B = a^B(B,\overline{q})$ and $\hat{a}^S = a^S(S,\overline{q})$, and hence $a^B(B,\overline{q}), a^S(S,\overline{q}) \ge a^*$. However, it has been shown above that this is not possible. Hence, if $\Omega = \{B, S\}$ it has to be the case that $\hat{a}^S = a^S(S,\overline{q}) = \hat{a}^B = \max\{a^B(B,\overline{q}), a^B(B,0)\}$. Therefore, all combinations (β,σ) such that $\beta + \sigma = a^S(S,\overline{q})$ are consistent with equilibrium. The investment behavior in the cases where $\Omega \neq \{B, S\}$ follows directly from the characterization of Ω above.

Finally, we characterize the optimal trade quantities. Ad (ii), (iii), (vi), (vii): in these cases, part (ix) implies that the first-best is achieved, and that only the seller (buyer) invests in cases (vi) and (vii) ((ii) and (iii)). Hence, the results follow immediately from Assumption 4 and inequalities (5) and (6). Ad (iv), (v): a contract $(S, 0)$ cannot be optimal because this would contradict our assumption that $\Omega = \{B\}$ when trade is non-contractible. Hence, if $\Omega = \{S\}$ either the first-best is achieved or, if this is not possible, i.e., if $\hat{\vartheta}_a(S,\overline{q},a^*) \le 1$, it is optimal to maximize incentives by setting $\hat{q} = \overline{q}$. Note, that $\Omega = \{B\}$ implies $\hat{a}^B = \max\{a^B(B,\overline{q}), a^B(B,0), a^S(B,\overline{q})\} > \hat{a}^S \ge a^S(B,\overline{q})$. Moreover, if $\Omega = \{B\}$ then $\hat{q} = 0$ iff $\hat{a}^B = a^B(B,0)$. Hence, if $\Omega = \{B\}$ and if the first-best cannot be achieved, i.e., $n_a(\overline{q},a^*) > t^3$, the optimal quantity is given by $\hat{q} = \overline{q}$ ($\hat{q} = 0$) if $a^B(B,\overline{q}) > (<) a^B(B,0)$ which together with $a^B(B,0) > a^B(B,\overline{q}) \Leftrightarrow n_a(\overline{q}, a^B) > \phi_a(a^B) + \hat{\vartheta}^e_a(a^B) - 2 \equiv t^4$ implies the result. Ad (vii): The claim immediately follows from Assumptions 4 and 3.

The proof that the order of the threshold value is as shown in Figure 3 is straightforward, and therefore omitted.

C Numerical Example

This simple numerical example serves to illustrate Proposition 2. Suppose that the partial derivatives of the ex-post surplus and the threatpoint payoffs with respect to a are given by $\phi_a(a) \equiv \frac{3}{1+a}$, $\hat{S}_a(O,q,a) \equiv s \cdot q + I^S \cdot \frac{1}{1+a}$ and $\hat{B}_a(O,q,a) \equiv b \cdot q + I^B \cdot \frac{2}{1+a}$ respectively where I^S (I^B) is equal to 1 if $O = S$ ($O = B$) and 0 otherwise. Suppose that $\overline{q} = 1$, $s \geq 0$, $b \geq 0$, $s \neq b$ and $|s - b| < 2$. Given these payoff function, one obtains $a^* = 2$, $n_a(\overline{q}, a^*) = n_a\left(\overline{q}, a^B\right) = s - b$, $n_a\left(q^M, a^S\right) = \min\{s - b, 0\}$, $t^1 = -\frac{4}{3}$, $t^2 = -1$, $t^3 \equiv -\frac{1}{3}$, $t^4 \equiv 0$, $t^5 = \frac{2}{4} - \frac{5}{4}(s - b)$, $t^6 \equiv \frac{2}{3}$, $t^7 = 1$, $t^8 = \frac{5}{3}$. Note that, given these threshold values, $\left[n_a(\overline{q}, a^*) > t^2 \cap n_a\left(q^M, a^S\right) < t^5\right]$ is equivalent to $-1 < s - b < \frac{2}{5}$. Moreover, in cases (ii)-(iv) we have $q^O \equiv \left[\frac{1}{b-s}\right] \cdot (1 - \frac{2}{3}I^B + \frac{1}{3}I^S)$ while in cases (v)-(vii) we have $q^O \equiv \left[\frac{1}{s-b}\right] \cdot (1 - \frac{1}{3}I^S + \frac{2}{3}I^B)$.

D Proof of Proposition 3

For the purpose of the proof, consider the more general class of contracts $C'' = [p^B, p^S, p^X, q, t] : \Theta^2 \to [0,1]^3 \times [0, \overline{q}] \times \Re$ where $p^O\left(\theta^B, \theta^S\right) \leq 1\ \forall O$ denotes the probability with which ownership structure O is selected ex-post and where $\sum p^O\left(\theta^B, \theta^S\right) = 1\ \forall \theta^B, \theta^S$.[54] Since, without loss of generality, one can restrict attention to direct mechanisms which induce truth-telling on and off the equilibrium path the best-response investment functions of B, given this more general class of contracts, is defined by $\beta(\sigma; C'') \equiv \arg\max_{\hat{\beta}} \sum p^O(\hat{\beta}, \sigma) \cdot \hat{B}(O, q(\hat{\beta}, \sigma), a(\hat{\beta}, \sigma)) - \hat{\beta} - t(\hat{\beta}, \sigma)$ where $p^O(\theta) \equiv p^O(\theta, \theta)$ and $q(\theta) \equiv q(\theta, \theta)\ \forall O, \theta \in [0, \overline{\beta}] \times [0, \overline{\sigma}]$. The best-response function of S is defined analogously. For the moment, consider some message-independent decisions p^B, $p^S \in [0,1]$, $q \in [0, \overline{q}]$ and $t = 0$, and suppose that the equilibrium investments of both parties are interior, i.e., $0 < \hat{\beta}(C) < \overline{\beta}$ and $0 < \hat{\sigma}(C) < \overline{\sigma}$. Define $q^{\max} \equiv \arg\max_q \left\{\hat{S}_a(S, q, a)\right\}$ and $q^{\min} \equiv \arg\min_q \left\{\hat{B}_a(B, q, a)\right\}$. Note, that Assumption 3 implies that $q^{\max}$ and $q^{\min}$ are independent of a and $q^{\max}, q^{\min} \in \{0, \overline{q}\}$. Hence, it follows from (5) that

$$\hat{S}_a\left(B, q^{\min}, a\right) \leq \sum_O p^O \cdot \hat{S}_a(O, q, a) \leq \hat{S}_a(S, q^{\max}, a)\ \forall O, q, a. \tag{10}$$

Note, that the decision space $[0,1]^3 \times [0, \overline{q}]$ is compact and connected, and that the functions ϕ_a, $\hat{S}_a$ and $\hat{B}_a$ are continuously differentiable in all arguments except O (which, however, is not a decision variable given the larger class of contracts which we consider). Hence, Condition A of Segal and Whinston (2002) is satisfied in our framework. Inequality (10) implies that their Condition $H^{\pm}$ is satisfied as well. Our Assumption 2 is the analog to their Condition C. Hence, Segal and Whinston's (2002) Proposition 4 applies, i.e. if there is a message-dependent contract C'' which sustains an interior investment pair (β, σ) then there exists a non-contingent contract (p^B, p^S, p^X, q) for some $p^B, p^S, p^X \in [0,1]$, $q \in [o, \overline{q}]$ which also sustains (β, σ).

If only the seller invests, note that inequality (10) and Assumption 2 imply $\sum p^O \cdot$

[54] We assume that renegotiations occur after the realization of the randomly determined organizational form.

$\vartheta_a(O,q,a) \le \vartheta_a\left(S, q^{\max}, \sigma^S\right) \equiv 1\ \forall p^O, q$ and $a \ge \sigma^S$, where σ^S denotes the equilibrium investment level given the contract $(p^B, p^S, p^X, q) = (0,1,0,q^{\max})$. Note that $\sigma^S > 0$ due to Assumption 1. The above inequality implies that if $\sigma^S \le a^*$ than the contract $(0,1,0,q^{\max})$ is optimal. If $\sigma^S > a^*$ it follows from Assumption 4 that $q^{\max} = \overline{q}$. Hence, Assumption 2 implies $\vartheta_a(S,\overline{q},a^*) > 1 > \vartheta_a(S,0,a^*)$. Because ϑ_a is continuous in q the Intermediate Value Theorem implies that there exists a q^* such that $\vartheta_a(S,q^*,\sigma^*) = 1$. Hence, in this case the contract $(0,1,0,q^*)$ is optimal. Hence, the set of optimal contracts always contains a contract of the form (O,q) for some $O \in \{B,X,S\}$ and $q \in [0,\overline{q}]$.

Now, suppose that investments are transferable and consider an arbitrary contract of the form $\tilde{C} = \left(p^B, p^S, p^X, q\right)$. Under slight abuse of notation, define $a^S(\tilde{C}) \equiv \arg\max_a\{\sum p^O \cdot \vartheta(O,q,a) - 1\}$ and define $a^B(\tilde{C})$ analogously. Note, that the $a^j(\tilde{C})$'s, and hence $\hat{a}(\tilde{C})$ are not only continuous in q but in p^B, p^S and p^X as well. Suppose an arbitrary message-dependent contract $C'' = [p^B, p^S, p^X, q, t] : \Theta^2 \to [0,1]^3 \times [0,\overline{q}] \times \Re$ sustains an interior investment vector $(\tilde{\beta}, \tilde{\sigma})$ where $0 < \tilde{\beta} < \overline{\beta}$ and $0 < \tilde{\sigma} < \overline{\sigma}$. In this case, the first part of the proof implies that the restriction of attention to non-contingent contracts of the form (p^B, p^S, p^X, q) where $p^B, p^S, p^X \in [0,1]$, $q \in [o,\overline{q}]$ is possible. We now show that the same holds true if an arbitrary contract C'' sustains an investment vector $(\tilde{\beta}, 0)$ where $0 < \tilde{\beta} < \overline{\beta}$. The case $(0,\tilde{\sigma})$ where $0 < \tilde{\sigma} < \overline{\sigma}$ is completely analogous and therefore omitted. Since C'' sustains $(\tilde{\beta}, 0)$ an investment $\tilde{\beta} > 0$ by the buyer is a best-response to $\sigma = 0$. Now, consider the exactly same situation but assume that only the buyer has the *possibility* to invests, i.e., suppose it is exogenously given that $\sigma \equiv 0$. In this *corresponding one-sided investment problem* it is still a best-response to choose $\tilde{\beta}$ given the original contract C''. Because $0 < \tilde{\beta} < \overline{\beta}$, i.e., $\tilde{\beta}$ is interior, the first part of the proof implies that for this corresponding one-sided investment problem there exists a non-contingent contract $\tilde{C} = \left(p^B, p^S, p^X, q\right)$ which also sustains $\tilde{\beta}$. Hence, $\tilde{\beta} = a^B(\tilde{C})$. Now, let us return to the original two-sided problem: there it is still a best-response to choose $\tilde{\beta}$ given $\sigma = 0$ and $\tilde{C}$. The characterization of equilibrium investments in Section 3.2 implies that in the two-sided problem, given contract $\tilde{C}$, either $(\tilde{\beta}, 0)$ or (β, σ) where $\beta + \sigma \ge \tilde{\beta}$ emerges as investment equilibrium. If $\beta + \sigma \le \beta^* + \sigma^*$ contract $\tilde{C}$ leads to higher welfare than the initial contract C''. If $\beta + \sigma > \beta^* + \sigma^*$ then Assumption 4, the Intermediate Value Theorem and the observation that $\hat{a}(\cdot)$ is continuous in p^B, p^S and q implies that there exists a non-contingent contract $\overline{C}$ which induces the first-best $a^* = \beta^* + \sigma^*$. Hence, we have shown that, if an message-dependent contract C'' induces an investment pair $(\tilde{\beta}, 0)$ where $0 < \tilde{\beta} < \overline{\beta}$, then there always exists a non-contingent contract of the form (p^B, p^S, p^X, q) which leads to weakly higher welfare. In a next step, we show that the set of optimal contracts always contains a contract which assigns probability one to some O: consider a non-contingent contract $C' = \left(p^{B\prime}, p^{S\prime}, p^{X\prime}, q'\right)$ where $p^{O\prime} > 0$ for some $O' \in \{B,X,S\}$ which leads to an equilibrium total investment of $\hat{a}(C')$. Now, define $C^O = \left(p^O = 1, q\right)$ $\forall O \in \{B,S,X\}$. Without loss of generality, suppose that $\hat{a}(C^S) \ge \hat{a}(C^O)\ \forall O$ which implies that $\hat{a}(C^S) \ge \hat{a}(C')$. If $\hat{a}(C^S) \le \beta^* + \sigma^*$ then C^S leads to weakly higher welfare than C'. If $\hat{a}(C^S) > \beta^* + \sigma^*$ then, because $\hat{a}()$ is continuous in q, the Intermediate Value Theorem and $\hat{a}((S,0)) < \beta^* + \sigma^*$ imply that there exists a $\hat{q}$ such that $\hat{a}([S,\hat{q}]) = \beta^* + \sigma^*$ which concludes the proof.

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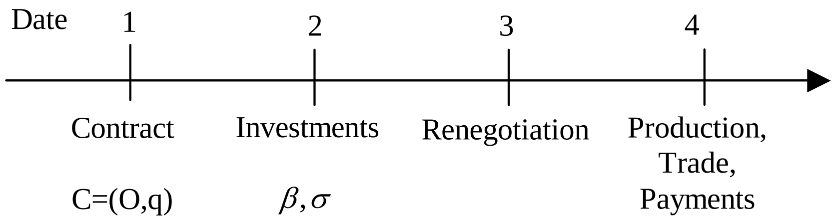

Figure 1: The sequence of events

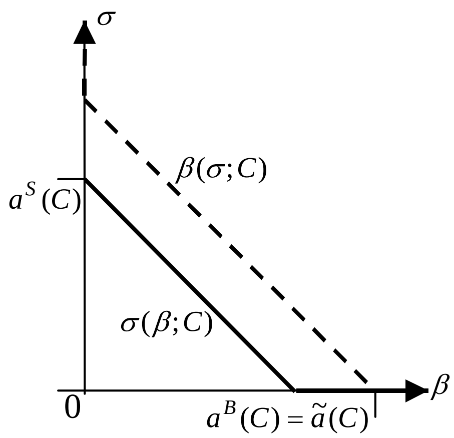

Figure 2: Transferable investments

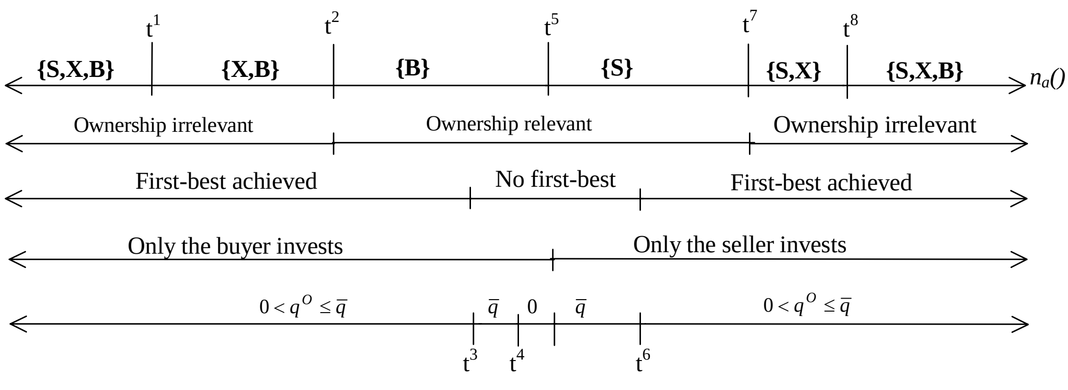

Figure 3: Properties of optimal contracts