Fixed versus Open Prices: A Choice between Countering Opportunism and Creating Value

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Abstract

Based on observed features in many supplier-buyer relations, we develop a model where the parties spend effort to acquire knowledge on each other’s technology and know-how, and choose the degree of price openness to balance value-enhancing and opportunistic uses of such knowledge. We show that under minimum openness, akin to a fixed-price contract, the parties cannot threaten harmful uses of knowledge in order to renegotiate the price, so they have weaker incentives to acquire knowledge in the first place. This hampers the seller’s ability to supply a product that fits the buyer’s needs, but also reduces the chances that knowledge will be used opportunistically ex post. Our model predicts that fixed-price contracts prevail over open-price contracts when the parties are more opportunistic, when the assets they bring to the relationship are more vulnerable to harmful uses of knowledge, and when the good’s value is less responsive to acquired knowledge.

Keywords: Bargaining, Firm Capabilities, Knowledge, Opportunism, Pricing.

JEL codes: D23; L14; L22; M21; M31

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1. Introduction

A key feature in inter-firm contracts is the mechanisms governing the division of surplus. These can range from maximum openness, as in open-price contracts that let the price be entirely determined by future negotiations between the parties, to maximum rigidity, as in fixed-price contracts where the price is either fixed upfront or determined by verifiable formulae.¹ What drives the choice between open-price and fixed-price contracts?

An important insight from recent works on incomplete contracts is that fixing the price upfront may prevent inefficient behaviors that take place ex post, at the contract execution stage (Masten 1988, 2009; Hart and Moore 2008).² While the parties’ ability to engage in ex post inefficient behaviors is treated as independent from ex ante actions in these works, observers of inter-firm relations have noted that such ability may indeed originate from actions undertaken by the parties at an earlier stage, and that, in addition to enabling opportunistic behavior, these ex ante actions may also generate value. In this

¹ Our definition of fixed-price contracts differs from that in Bajari and Tadelis (2001). They define fixed-price contracts as those that allow for a single price, and compare them to cost-plus formulae. In contrast, we define fixed-price contracts as those that unambiguously specify price ex ante, either through a single price or through a precise formula. Hence, cost-plus contracts that do not allow for negotiation of the price premium would also be treated as fixed-price contracts according to our definition. We adopt this definition because our purpose is to compare contracts that pre-determine the price and contracts that leave price open for ex post negotiation.

² Masten (2009) argues that fixing the price upfront reduces wasteful rent-seeking when the parties expect to trade repeatedly. Hart and Moore (2008) argue that fixing the price upfront limits retaliation following disagreements on the appropriate division of surplus, at the cost of preventing efficient trade in some states.
paper, we investigate how the choice between fixed-price and open-price contracts trades off these two considerations.

To organize ideas, consider the relation between an equipment manufacturer (the buyer) and a component supplier (the seller). Both firms may bring complementary capabilities – brand strength, distribution channels, after-sales support, manufacturing processes, technological architecture, and the like – into their collaboration (Teece 1992). To create value – for instance, enhancing fit between the seller’s component and the buyer’s needs, or insuring just-in-time delivery of components – both parties must acquire knowledge on their partner’s capabilities that enables them to understand and productively utilize those capabilities (Teece 1981, 1992; Demsetz 1988; Zander and Kogut 1995). These efforts are costly, and probably hard to contract upon, because technological and managerial know-how is often tacit in nature and requires “intimate personal contact, demonstration, and involvement” (Teece 1981, p.86; see also Davis 1977).

In addition to using non-contractible knowledge to create value within the focal relationship, an opportunistic party may also take advantage of that knowledge to obtain private benefits that hamper the partner’s capabilities in future business relations. For instance, the seller may exploit its knowledge of the buyer’s quality-control procedures and its close relationship with the buyer’s staff to covertly cut costs and lower quality, thus harming the buyer’s brand equity (Anderson and Jap 2005). Also, the seller may

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4 This phenomenon is sometimes called the “dark side” of close relations in the management literature (Anderson and Jap 2005).
use his knowledge of the buyer’s technology and distribution channels to directly compete with him in the downstream market (Hamel et al. 1989; Arruñada and Vázquez 2006). Finally, both the buyer and the seller may threaten to use knowledge in harmful ways in order to favorably renegotiate price or other contract terms (Lyons et al 1990, p.4).

In principle, the parties could contract away opportunistic uses of knowledge – for instance, via non-compete agreements. In practice, however, this may be too costly given the multiple avenues for opportunistic behavior (Masten 1988), the tacitness of knowledge, and the presence of legal constraints on contracts. An alternative, indirect mechanism, which we explore here, is for the buyer and the seller to reduce their incentives to acquire knowledge by fixing the price upfront. Fixing the price helps because, by preventing future negotiations, it eliminates an incentive for the parties to possibly use their acquired knowledge as a bargaining chip in the future. The upshot is that, by reducing the ex ante acquisition of knowledge, fixed-price contracts also reduce the productive effects of knowledge on value-creation. Hence, the choice of fixed versus open prices can be seen as one between countering opportunism and creating value. Elaborating on this trade-off, we find that firms are more likely to adopt open-price contracts than fixed-price contracts when i) they are less opportunistic, ii) their capabilities are less vulnerable to opportunistic uses of knowledge, and iii) the value of trade is more responsive to acquired knowledge.

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5 For more examples on ex ante knowledge acquisition and ex post opportunism in various inter-firm relations, see Hamel et al, (1989), Lyons et al, (1990), Hamel (1991), Anderson and Jap (2005), Arruñada and Vázquez (2006), and Myers and Cheung (2008).

6 Masten (1988) forcefully describes the actions that creative transactors can threaten in order to force price renegotiations. While he does not mention knowledge, the examples he brings are not inconsistent with the idea that acquired knowledge can be a base for such threats.
Our predictions are broadly consistent with anecdotal observations and empirical findings in the contracting literature. The empirical literature suggests an inverse relation between rigid price terms and ex post opportunism, as implied by our model’s predictions i) and ii). For instance, Crocker and Reynolds (1993) find that price terms in air-force procurement contracts are more rigid when the engine manufacturer has a past record of judicial disputes and, therefore, is likely to be opportunistic. Kalnins and Mayer (2004) and Corts and Singh (2004) find – respectively, in the US information-technology (IT) and offshore drilling industries – that clients and contractors use cost-plus contracts when they have frequently worked together before, possibly due to increased trust.7 More recently, Lo et al. (2011) find that equipment manufacturers and component suppliers use more rigid price formats as their brand strength increases.8

Consistent with our prediction iii), there is also indirect evidence that fixed-price contracts reduce value-creation within the relationship. For instance, in the industrial-equipment manufacturing sector, Ghosh and John (2005, 2009) find that less open price formats are associated with compromised value creation as measured by lower product differentiation and lower synergy in design and engineering efforts between the manufacturer and the component supplier.

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7 Corts and Singh (2004) offer a different interpretation of their results. See the discussion in section 3 for more on this.
8 Interestingly, protecting pre-existing assets from ex post appropriation is also observed in marriage agreements. Mastron (1997, pp.891-892) observes that women bringing in high-value tangible assets and the parties who wish to protect their assets for their children from previous marriages are more likely to seek safeguards in the form of prenuptial agreements. Hamilton (1999, p.72) notes similar evidence in 19th-century Quebec where one in every six couples used prenuptial agreements. Using archival data, she finds that these “non-conventional” marriage agreements were more frequently used by men who had attractive outside options, e.g., the literate class and well-to-do merchants (p.89), and who married widows with children from their previous marriages.
We organize the rest of this paper as follows. Section 2 presents our model. Section 3 compares open-price and fixed-price contracts. Section 4 discusses the relation between our model and the existing literature. Section 5 concludes.

2. The Model

A buyer (B) and a seller (S), both risk-neutral, are about to start a contractual relation whereby S will produce an intermediate good for B. Both B and S bring to the relation their pre-existing capabilities. These capabilities, such as superior engineering design or constituent brand strength, are unique to the respective contracting party. However, they are not relationship-specific, since they can be used to produce goods outside the focal relationship, and the value of such goods is independent of whether they are produced by B and S together or by each with a third party. We denote the values of B’s and S’s pre-existing capabilities, net of the value produced within the relation between B and S, as $\omega_B$ and $\omega_S$ respectively. Given that the parties’ capabilities are unique and idiosyncratic, we assume $\omega_B$ and $\omega_S$ are both non-contractible.

The relationship between B and S follows these stages:

1. **Contracting**: B and S decide whether to start a business relation. If they do so, they may sign a contract $(t, d, p)$, where $t \in \{0,1\}$ denotes the decision on whether to trade the good or not ($t = 1$ means trade), $d$ is a vector of contractible good’s
characteristics, and \( p \in \mathbb{R} \) denotes the price to be paid from B to S upon delivery. A typical element of \( d \) is \( d^f \in \{0,1\} \), where \( d^f = 1 \) means that the good possesses contractible feature \( f \). Denote the chosen contract as \( (t_c, d_c, p_c) \), the value of the contracted good to the buyer as \( V(d) \), and the seller’s cost of producing the contracted good as \( C(d) \). Firms can choose between two contractual forms: a fixed-price contract (FPC), which fixes the price upfront, and an open-price contract (OPC), which leaves the price open for negotiation at stage 4.\(^9\)

2. **Knowledge acquisition:** B and S meet before starting production and simultaneously choose the non-contractible knowledge-acquisition efforts \( a^e_B \in \mathbb{R}^+ \) and \( a^e_S \in \mathbb{R}^+ \).

   Party \( i \) incurs an immediate, non-contractible cost \( L_i(a_i) \) by spending effort \( a_i \).

   Examples of knowledge-acquisition efforts would be the time, personnel, and other resources devoted by one party to study and understand the other’s technology;

3. **State realization:** B and S observe a state of the world \( k \), drawn with probability \( q_k \) from the finite set \( K \). We follow the literature on incomplete contracts in assuming that \( k \) is non-contractible. As we will explain momentarily, state realizations mainly determine the parties’ opportunities to engage in harmful activities;

\(^9\) While we assume that \( V(d) \) and \( C(d) \) are certain, the model could be extended to the case where they are subject to random fluctuations. Then, contracts that define the price as a function of future realizations of verifiable variables such as the CPI, or certain types of cost-plus contracts that define price adjustments as a precise function of labor and materials costs, would fall into the FPC category. Conversely, price formulas and cost-plus contracts that explicitly allow for (partial or total) ex post negotiations of the price would fall into the OPC category.
4. **Decisions:** Since $t$ and $d$ are contractible, even when the stage-1 contract fixes $t = t_c$ and $d = d_c$, the parties may negotiate new trade and product characteristics decisions $t(k) \neq t_c$ and $d(k) \neq d_c$, and a new price $p(k)$. After that, $S$ chooses the contractible trade decision $t$ and the contractible vector of product characteristics $d$.\(^{10}\) Finally, $B$ and $S$ simultaneously choose the non-contractible vectors of harm decisions $h_B$ and $h_S$ with typical elements $h_B^m \in \{0,1\}$ and $h_S^m \in \{0,1\}$, where $h_i^m = 1$ means that party $i$ exploits opportunity $m$ to harm his counterpart;

5. **Payoffs:** The parties’ payoffs (gross of payments and effort costs) are realized as a function of stage-2 efforts, stage-3 states and stage-4 decisions, as follows: $B$ receives $t[V(d) + V(a_B, a_s)] + \pi_B(a_B, h_B, k) + [1 - \alpha_B(a_s, h_s, k)] \omega_B$, and $S$ receives $\pi_S(a_s, h_s, k) + [1 - \alpha_S(a_B, h_B, k)] \omega_S - t C(d)$, where $V(a_B, a_s)$ is the good’s added value due to knowledge-acquisition at stage 2, $\pi_i(a_i, h_i, k)$ is party $i$’s private benefit from harming party $j$, and $\alpha_j(a_i, h_i, k) \omega_j$ is the cost party $i$ inflicts on party $j$ by harming him, defined as a reduction $\alpha_j(a_i, h_i, k) \in [0,1]$ in the value $\omega_j$ of party $j$’s pre-existing capabilities. We assume that the outcomes of non-contractible actions, $V(a_B, a_s)$, $\pi(a_i, h_i, k)$ and $\alpha_j(a_i, h_i, k) \omega_j$, are also non-contractible. Moreover, we assume that $\pi_i(a_i, h_i, k)$ and $\alpha_j(a_i, h_i, k) \omega_j$ are

\(^{10}\) Even if $t$ and $d$ are fixed by contract, $S$ still has a choice between delivering $t$ and $d$ and breaching the contract. That is why we say that $S$ “chooses” the contractible decisions. However, that we assume throughout the model that remedies are strong enough to deter breach, so $S$ ends up choosing the contracted values of $t$ and $d$ in equilibrium.
increasing in $a_i$ and concave, $V(a_B, a_S)$ is increasing in $a_B$ and $a_S$ and its Hessian is negative definite, $L_i(a_i)$ is increasing in $a_i$ and convex,

$$
\pi_i(a_i = 0, h_i, k) = \pi_i(a_i, h_i = 0, k) = \frac{\partial \pi_i(a_i = 0, h_i, k)}{\partial a_i} = 0,
$$

$$
\alpha_i(a_j = 0, h_j, k) = \alpha_i(a_j, h_j = 0, k) = \frac{\partial \alpha_i(a_j = 0, h_j, k)}{\partial a_j} = 0, \lim_{a_j \to \infty} \alpha_i(a_j, h_j \neq 0, k) = 1,
$$

and $a_B$ and $a_S$ are weakly complementary, or $\frac{\partial^2 V(a_B, a_S)}{\partial a_i \partial a_j} \geq 0$. Finally, we assume harm is inefficient — that is, $\alpha_j(a_i, h_i \neq 0, k) > \pi_i(a_i, h_i \neq 0, k)$ for any $i, j$ and $k$;

6. **Litigation:** If $B$ and $S$ have not renegotiated a new contract in stage 4, the game ends. If $B$ and $S$ have renegotiated $t$ at stage 4 and $t(k) = t_\epsilon$, $d(k) = d_\epsilon$ but $p(k) \neq p_\epsilon$, the party who has lost from renegotiation may claim that the new price $p(k)$ has been extorted under duress and ask a judge to reinstate the stage-1 price $p_\epsilon$.

The timeline of the game is shown in Figure 1.
**Discussion**

In this model, both B and S know from the outset the value $V(d)$ and the cost $C(d)$ of a good with certain “hard”, standard characteristics $d$ – for instance, an aircraft engine with given size, power and fuel consumption rate. Hence, they can write a contract at stage 1, which specifies those desired good characteristics and the trading price. At the same time, B and S both understand that the value of the good may be increased by a deeper knowledge of the counterpart’s designs, specifications, and product samples through activities such as plant visits, training, and demonstrations. To continue with the previous example, for given size, power and fuel consumption rate, S may produce engines that better fit B’s aircrafts the greater his knowledge of B’s designs and customers. Similarly, B can better integrate other components and features in his own aircrafts with S’s engines the more she knows about S’s technology. Since
technological know-what and know-how are often tacit in nature (e.g., Teece 1981; Oxley 1997), we assume knowledge-acquisition efforts – and the product features derived from them – are non-contractible. The value added to the good due to knowledge acquisition is captured by the term $V(a_B, a_S)$ which is increasing in both $a_B$ and $a_S$. Given this interpretation of $V(a_B, a_S)$, it is also natural to think at $a_B$ and $a_S$ as complementary: one party’s effort to acquire knowledge on his counterpart’s technology increases the marginal ability of the other party to create value.

As we explained in the introduction, B and S may use the knowledge acquired at stage 2 not only to increase the good’s value, but also for inefficient, harmful purposes (the decision vectors $h_B$ and $h_S$) ex post. We assume the decision to engage in harmful activities is non-contractible because, again, knowledge underlying firms’ capabilities is often highly tacit, so illegitimate uses of knowledge may be hard to verify. The greater the ex ante efforts in knowledge acquisition, the more profitable (for the offender) and costly (for the victim) the ex post harm decisions may be. This is captured by assuming that $\pi_i(a_i, h_i, k)$ and $\alpha_j(a_j, h_i, k)\omega_j$ are both increasing in $a_i$.

Two additional features of stage-4 harm decisions are worth noting. First, because harm decisions are non-contractible, parties will exploit (some of) them in equilibrium whenever profitable, that is, when $\arg\max_{h_i} \pi_i(a_i, h_i, k) > 0$. This creates a trade-off: on one hand, increasing B’s and S’s ex ante knowledge-acquisition efforts is value-

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11 It should be clear that the model would continue to be valid if we allowed some, but not all of the feasible harmful uses of knowledge to be contractible.
enhancing, because it allows S to produce a higher quality good. On the other hand, it is value-dissipating because it creates the ex post deadweight losses from opportunistic uses of knowledge. We model these losses as reductions in the values of the parties’ pre-existing capabilities $\omega_n$ and $\omega_s$ – for instance, a loss of brand equity. This seems the natural result of certain harmful uses of knowledge, such as disclosing a partner’s technology to competitors.

A second important feature of harm decisions is that, when they are not profitable – formally, when $\Delta \pi_i^m = \pi_i\left(a_i, h_i^m = 1, h_i^{-m}, k\right) - \pi_i\left(a_i, h_i^m = 0, h_i^{-m}, k\right) = 0$ for some $i$ and $m$ – parties may use them as bargaining chips to (re)negotiate the good’s price. The reason is that, when harm is unprofitable, parties are indifferent between harming and not harming, so they can credibly commit to harm if their counterpart does not accept to (re)negotiate the price. Because the loss $\alpha_j(\omega_j, a_i, h_i, k)$ suffered by a victim of harmful activities increases in the offender’s knowledge-acquisition effort $a_i$, this means that the possibility of stage-4 bargaining may increase the parties’ incentives to acquire knowledge at stage 2. As we shall see in section 3, this importantly affects the choice between fixing the good’s price at stage 1 and leaving it open for ex post negotiation.

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12 Lyons et al. (1990, p.4) report that General Motor’s component suppliers are seriously concerned that General Motors may acquire sensitive information about them for price concession purposes.

13 As in Hart and Moore (2008), the threat to carry harm opportunity $m$ may be credible also when $\Delta \pi_i^m$ is slightly positive or negative, as long as parties incur a private cost for punishing a counterpart who accepts to negotiate ($\Delta \pi_i^m$ slightly positive), or receive a private benefit from retaliating against a counterpart who refuses to negotiate ($\Delta \pi_i^m$ slightly negative). These private benefits and costs may be either psychological or reputational.
Finally, the law of contract modification (stage 6) plays an important role in our model. As reported, among others, by Aiviazian *et al.* (1984), Schwartz (1992), and Schwartz and Scott (2003), when two parties are “locked-in” ex post, courts presume that modifications of the initial price that are *not* accompanied by modifications in the nature of the good (redistributive modifications) are extorted under economic duress. As a consequence, courts are willing to reinstate the original price in the presence of redistributive renegotiations. To formalize lock-in, we assume that the good’s added value due to knowledge-acquisition, \( V(a_B, a_S) \), drops to zero if B and S do not trade at stage 4. This may be due to the fact that S’s product has been tailored to B’s needs, or to B’s difficulty to find an alternative supplier in a short time (Masten *et al.* 1991). The possibility to sue for contract reinstatement is important because it allows parties to indirectly commit not to renegotiate ex post by fixing the price ex ante.

The commitment role of FPCs crucially depends on the assumption that neither the trade decision \( t \) nor the good’s contractible characteristics \( d \) need to be modified at stage 4 – that is, \( t^{FB} \) and \( d^{FB} \) are not state-contingent – so any price modification will be perceived by courts as redistributive and unenforceable.\(^{14}\) When this is not the case (for instance, because the product must be adapted to unforeseeable circumstances, as in Bajari and Tadelis 2001), there will still be a trade-off between value-enhancing and opportunistic uses of acquired knowledge, but fixing the price ex ante would not affect the parties’ incentives to acquire knowledge for adaptation purposes. In that case, other

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\(^{14} \) This is obvious in our model, since \( V(d) \) and \( C(d) \) are state-invariant. However, it may also occur in a more general model where \( V(d, k) \) and \( C(d, k) \) are state-contingent, as long as

\[
 d^{FB} = \arg \max_d \{ V(d, k) - C(d, k) \}
\] is not.
contractual tools, such as shifts in asset ownership, may help solve the tradeoff. We leave the exploration of non-price mechanisms for future work.

The role of FPCs in our model also depends on the assumption (implicit in the timeline) that, while parties can harm each other out of spite if negotiation breaks down at stage 4, they cannot do so after the initial contract has been reinstated at stage 6. If that were possible, the threat of suing redistributive contractual modifications would not be credible, so specifying the price ex ante would not prevent renegotiation. We find this assumption plausible, for two reasons. First, the opportunities for harmful uses of acquired knowledge may be fleeting, so the threat to harm would no longer be credible at the end of a (possibly lengthy) reinstatement lawsuit. For instance, S cannot hurt B by sneaking his acquired knowledge on his new product lines to competitors once B has already introduced those product lines. Second, there are harmful activities whose effect may be severely diminished after a successful reinstatement lawsuit: for instance, it may be hard for B to badmouth S and be believed if the receivers of his messages (presumably S’s other clients) know that B just lost a lawsuit with S on contractual matters, and even more so if the lawsuit was about reinstatement, which signals buyer’s opportunism.
3. The choice of contract form

We now turn to study the benefits and costs of writing an OPC versus a FPC at stage 1.

Open-Price Contract (OPC)

Consider the case where B and S wait to contract till after the state is realized. For any given contract \( (t(k), d(k), p(k)) \) that B and S may negotiate at stage 4, no party can litigate it at stage 6 because there is no previous contract to reinstate. Hence, negotiation will occur at stage 4. Following Grossman and Hart (1986), we assume that B and S agree on the Nash Bargaining Solution for the contractible decisions \( t \) and \( d \).

This insures first-best decisions

\[
d(k) = \arg \max_d \left[ V(d) + V(a_B, a_S) - C(d) \right] = d^{FB}, \text{ and}
\]

\[
t(k) = \arg \max_i t \left[ V(d) + V(a_B, a_S) - C(d) \right] = t^{FB} = 1.15
\]

To analyze the choice of harm decisions \( h_B \) and \( h_S \), denote as \( h_{N_i}(k) \) the sub-vector of decisions such that \( \Delta \pi_i^m = 0 \) for every \( h_i^m \in h_{N_i}(k) \), and as \( h_{H_i}(k) \) the sub-vector of decisions such that \( \Delta \pi_i^m > 0 \) for every \( h_i^m \in h_{H_i}(k) \), where the subscripts “N” and “H” 15

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15 We are assuming that \( V(d^{FB}) > C(d^{FB}) \).
stand for “negotiation” and “harm”, respectively. Because the decisions in \( h_{H_i}(k) \) are privately profitable for the offender, B and S will choose

\[
h_{HB}^*(a_B,k) = \arg\max_{h_{HB}} \pi_{HB}(a_B, h_{HB}(k), h_{NB}(k), k) \quad \text{and} \quad h_{HS}^*(a_S,k) = \arg\max_{h_{HS}} \pi_{HS}(a_S, h_{HS}(k), h_{NS}(k), k).
\]

Since the first-best harm decisions are 0-vectors, \( h_{HB}^*(a_i,k) \) will be inefficient in any state \( k \). Moreover, because the decisions in \( h_{Ni}(k) \) yield zero profits to the offender \( i \) but impose a cost \( \alpha_j(a_i, h_{Hi}(a_i,k), h_{Ni}(k), k) \omega_j \) on the victim \( j \), B and S will use them as bargaining chips – that is, they will threaten to set \( h_{Ni}^*(k) = 1 \) in case the negotiation fails. Under Nash Bargaining, it is \( h_{Ni}(k) = 0 \) in equilibrium. However, the threat to set \( h_{Ni}^*(k) = 1 \) affects the bargaining price. To analyze bargaining, we make the simplifying assumption that \( h_{Hi}^*(a_i,k) = h_{Hi}^*(k) \) for any \( a_i > 0 \) and \( k \) – that is, the payoff functions are such that the ex post harm decisions are independent of the ex ante efforts, provided that a positive amount of knowledge has been gathered, so that the benefits from harm are non-zero. To simplify notation, we define

\[
V^* \equiv V(d^{Hi})
\]

\[
C^* \equiv C(d^{Hi})
\]

\[
\pi^*_i(a_i, k) \equiv \pi_i(a_i, h_{Hi}^*(k), h_{Ni}(k) = 1, k) = \pi_i(a_i, h_{Hi}^*(k), h_{Ni}(k) = 0, k), \quad 16
\]

\[\text{Recall that by definition, for any } i \text{ and } j, \text{ decisions in the vector } h_{Ni} \text{ affect } \alpha_j(\cdot) \text{ but not } \pi_i(\cdot).\]
\[ \alpha^*_{ij} (a_j, k) \equiv \alpha_{ij} (a_j, \mathbf{h}_{ij}^0 (k), \mathbf{h}_{nj} (k) = 0, k) \quad \text{and} \]

\[ \alpha^0_{ij} (a_j, k) \equiv \alpha_{ij} (a_j, \mathbf{h}_{ij}^* (k), \mathbf{h}_{nj} (k) = 1, k), \]

where the superscript “O” in (5) stands for “Opportunistic”. The Nash-Bargaining price satisfies the following conditions:

\[
\begin{align*}
\nabla^* + V(a_B, a_s) + [1 - \alpha^*_B (a_B, k)] \omega_B - p(k) = [1 - \alpha^0_B (a_s, k)] \omega_B \\
+ \frac{1}{2} \left\{ \begin{array}{l}
\nabla^* + V(a_B, a_s) - C^* \\
+ \left( \alpha^0_B (a_s, k) - \alpha^*_B (a_s, k) \right) \omega_B \\
+ \left( \alpha^0_S (a_B, k) - \alpha^*_S (a_B, k) \right) \omega_S 
\end{array} \right. \quad \text{and} \\

p(k) - C^* + [1 - \alpha^*_S (a_B, k)] \omega_S = [1 - \alpha^0_S (a_B, k)] \omega_S \\
+ \frac{1}{2} \left\{ \begin{array}{l}
\nabla^* + V(a_B, a_s) - C^* \\
+ \left( \alpha^0_B (a_s, k) - \alpha^*_B (a_s, k) \right) \omega_B \\
+ \left( \alpha^0_S (a_B, k) - \alpha^*_S (a_B, k) \right) \omega_S 
\end{array} \right. \quad \text{17}
\end{align*}
\]

Solving for the price we obtain

\[
p(a_B, a_s, k) = \frac{1}{2} \left\{ \begin{array}{l}
\nabla^* + V(a_B, a_s) + C^* + \left[ \alpha^0_B (a_s, k) - \alpha^*_B (a_s, k) \right] \omega_B \\
- \left[ \alpha^0_S (a_B, k) - \alpha^*_S (a_B, k) \right] \omega_S 
\end{array} \right. \quad \text{18}
\]

Anticipating this outcome, B and S choose their knowledge-acquisition efforts at stage 2 to solve, respectively,

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17 The terms \( \pi_B (a_B, k) \) and \( \pi_S (a_s, k) \) are not displayed, as they appear on both sides of the bargaining equations and, therefore, cancel out.

18 We assume equal bargaining power between B and S because the parties’ relative bargaining power is not a parameter of interest in this model. Similar results obtain if we assume generic degrees of bargaining power – say, \( \gamma \) for the seller and \( 1 - \gamma \) for the buyer.
\[
\max_{a_b} E \left[ V^* + V\left(a_b, a_{s,b}^{op}\right) - p(a_b, a_{s,b}^{op}, k) + \pi_{b}^*\left(a_b, k\right) \right] - L_b\left(a_b\right) \quad \text{and} \quad (7)
\]

\[
\max_{a_s} E\left[ p(a_b^{op}, a_s, k) - C^* + \pi_{s}^*\left(a_s, k\right) + \left[ 1 - \alpha_{s}^*\left(a_b^{op}, k\right) \right] \omega_s \right] - L_s\left(a_s\right), \quad (8)
\]

where \( E[\cdot] = \sum_{k \in K} q_k [\cdot] \) is the expectation operator over states and the “OP” superscript stands for “open-price contract”. The payoff function of each party \( i \in \{B,S\} \) is continuous and concave in \( a_i \), so the first-order conditions are both necessary and sufficient for a maximum. After substituting (1) through (5) into \( p(a_b, a_s, k) \), we have the following first-order conditions for the buyer and the seller, respectively,

\[
\frac{1}{2} \frac{dV\left(a_b, a_s^{op}\right)}{da_b} + \frac{1}{2} E\left[ \frac{d\pi_{s}^*\left(a_s, k\right)}{da_s} - \frac{d\alpha_{s}^*\left(a_b^{op}, k\right)}{da_b} \right] \omega_s + E\left[ \frac{d\pi_{b}^*\left(a_b, k\right)}{da_b} \right] - \frac{dL_b\left(a_b\right)}{da_b} = 0 \quad (9)
\]

\[
\frac{1}{2} \frac{\partial V\left(a_b^{op}, a_s\right)}{\partial a_s} + \frac{1}{2} E\left[ \frac{d\pi_{b}^*\left(a_b, k\right)}{da_s} - \frac{d\alpha_{b}^*\left(a_s, k\right)}{da_s} \right] \omega_b + E\left[ \frac{d\pi_{s}^*\left(a_s, k\right)}{da_s} \right] - \frac{dL_s\left(a_s\right)}{da_s} = 0 \quad (10)
\]

We assume there is a unique intersection of (9) and (10), which defines the Nash-Equilibrium efforts. Note that, since the efforts are complementary in \( V(\cdot) \), party \( i \)’s best-response function \( a_i^{op}(a_j) \) is increasing in \( a_j \), for any \( i \) and \( j \). This property will play an important role in our analysis of optimal contract forms.
At stage 1, the expected joint surplus under an OPC is given by

\[ JS^{\text{OP}} = V^* + V\left(a_{B}^{\text{OP}}, a_{S}^{\text{OP}}\right) - C^* + \sum_{i} \left\{ E\left[ \pi_i^*(a_{i}^{\text{OP}}, k) + \left[ 1 - \alpha_i^*(a_{i}^{\text{OP}}, k) \right] \omega_i \right] - L_i\left(a_{i}^{\text{OP}}\right) \right\} \]

The above analysis can be summarized through the following proposition.

**Proposition 1**: Under an OPC, i) the ex post production and trade decisions \( d \) and \( t \) are efficient; ii) the parties’ ex ante knowledge-acquisition efforts \( a_{B}^{\text{OP}} \) and \( a_{S}^{\text{OP}} \) are, in general, inefficient; iii) the parties make inefficient harm decisions ex post; and iv) the aggregate level of ex post inefficiency in any state \( k \), measured by

\[ \sum_{i} \left[ \alpha_i^*(a_{i}^{\text{OP}}, k) \omega_i - \pi_i^*(a_{i}^{\text{OP}}, k) \right] \], is increasing in \( a_{B} \) and \( a_{S} \).

**Proof**: Results i) and iii) have been already proved. Result iv) follows from the assumption that \( \alpha_j^*(a_{i}, h_{i} \neq 0, k) \omega_j > \pi_j^*(a_{i}, h_{i} \neq 0, k) \). To prove result ii), note that the efficient level of party \( i \)’s knowledge-acquisition effort satisfies

\[ \frac{\partial V(a_{i}, a_{i})}{\partial a_{i}} - \frac{dL_{i}(a_{i})}{da_{i}} = 0 \], which is in general different from both (9) and (10). QED.

**Fixed-Price Contract (FPC)**

Consider now the case where, at stage 1, B and S agree on a FPC \( (t_{c} = 1, d_{c}, p_{c}) \). If parties renegotiate the price at stage 4, the outcome will be identical to that under an OPC. However, now the party who loses from renegotiation can sue the other at stage 6.
and ask the judge to reinstate the initial price $p_c$.\(^\text{19}\) Anticipating that, B and S do not even bother to bargain at stage 4, so S will deliver the product with contractible characteristics $d_s$, generating value $V(d_c) + V(a_B, a_S) = V^c + V(a_B, a_S)$ and production cost $C^c = C(d_c)$, and S will pay him the agreed-upon price $p_c$. Moreover, B and S will choose the privately optimal harm decisions $h_{NB}^*(k)$, $h_{NS}^*(k)$, and

$h_{NB}^*(k) = h_{NS}^*(k) = 0$, as before. Anticipating that, B and S will choose their knowledge-acquisition efforts at stage 2 to solve, respectively:

$$\max_{a_B} V^c + V(a_B, a_S^{FP}) + E \left[ \pi_B^*(a_B, k) + \left[ 1 - \alpha_B^*(a_S^{FP}, k) \right] \omega_B \right] - p_c - L_B(a_B)$$

and

$$p_c - C^c + E \left[ \pi_S^*(a_s, k) + \left[ 1 - \alpha_S^*(a_S^{FP}, k) \right] \omega_S \right] - L_S(a_s),$$

where the “FP” superscript stands for “fixed-price contract”.

The necessary and sufficient first-order conditions for a Nash Equilibrium are

$$\frac{\partial V(a_B, a_S^{FP})}{\partial a_B} + E \left[ \frac{d\pi_B^*(a_B, k)}{da_B} \right] - \frac{dL_B(a_B)}{da_B} = 0$$

for the buyer, and

$$E \left[ \frac{d\pi_S^*(a_s, k)}{da} \right] - \frac{dL_S(a_s)}{da} = 0$$

for the seller.\(^\text{20}\)

---

\(^{19}\) For simplicity, we assume zero litigation costs. In general, the results will hold as long as these costs are not so high to always prevent litigation.

\(^{20}\) In this case, we need not assume a unique Nash equilibrium. It follows from (13) and (14) that $a_s^{FP}$ is independent of $a_B$ and positive, and $a_B^{FP}(a_s)$ is monotonically increasing in $a_s$, so a unique intersection of (13) and (14) exists.
Denote the solutions as \( a_{FB}^{FP} \) and \( a_{FS}^{FP} \), respectively. Given symmetric information, B and S will choose \( d_c \), at stage 1, to maximize the joint expected surplus

\[
V(d) + V(a_{FB}^{FP}, a_{FS}^{FP}) - C(d) + \sum_i \left\{ \mathbb{E} \left[ \pi_i^* \left( a_i^{FP}, k \right) + \left[ 1 - \alpha_i^* \left( a_j^{FP}, k \right) \right] \omega_i \right] - L_i \left( a_i^{FP} \right) \right\},
\]

and the price \( p_c \) to split the surplus. Consequently, B and S will agree on \( d_{FB}^{FP} \), and the expected joint surplus under a specific contract will be

\[
JS^{FP} = V^* + V(a_{FB}^{FP}, a_{FS}^{FP}) - C^* + \sum_i \left\{ \mathbb{E} \left[ \pi_i^* \left( a_i^{FP}, k \right) + \left[ 1 - \alpha_i^* \left( a_j^{FP}, k \right) \right] \omega_i \right] - L_i \left( a_i^{FP} \right) \right\}.
\]

We can now state the following

**Proposition 2**: Under a FPC, i) the ex post production and trade decisions \( d \) and \( t \) are efficient; ii) the parties’ ex ante knowledge-acquisition efforts \( a_{FB}^{FP} \) and \( a_{FS}^{FP} \) are, in general, inefficient; iii) the parties make inefficient harm decisions ex post; and iv) the aggregate level of ex post inefficiency in any state \( k \), measured by

\[
\sum_i \left[ \alpha_i^* \left( a_j^{FP}, k \right) - \pi_i^* \left( a_j^{FP}, k \right) \right],
\]

is increasing in \( a_B \) and \( a_S \).

**Proof**: It replicates that of proposition 1.

Since price cannot be renegotiated at stage 4 under a FPC, each party \( i \in \{B, S\} \) does not place weight on the threat to dilute party \( j \)’s capability – the term

\[
\mathbb{E} \left[ \frac{d \alpha_j^O (a, k)}{da_i} - \frac{d \alpha_j^* (a, k)}{da_i} \right] \omega_j \] in (9) and (10) – when choosing his own knowledge-acquisition effort. This tends to reduce both parties’ equilibrium efforts, relative to the case of an OPC. However, this effect is mitigated by the fact that, when choosing \( a_B \), B
places more weight on value-creation under a FPC (compare equations (9) and (13)) because he does not face the prospect of losing half of such value during ex post bargaining. The former negative effect of FPCs on knowledge-acquisition efforts dominates the positive one, provided that the marginal effect of B’s effort on his threatening capacity is large, relative to its effect on value-creation. We formalize this result through the following

**Proposition 3:** Suppose $\omega_s$ is large enough. Then, i) $a_{i}^{OP} > a_{i}^{FP}$, ii)

$$\sum_{i} [\alpha_i^*(a_{j}^{OP}, k) \omega_i - \pi_i^*(a_{j}^{OP}, k)] > \sum_{i} [\alpha_i^*(a_{j}^{FP}, k) \omega_i - \pi_i^*(a_{j}^{FP}, k)],$$

and iii)

$$V(a_{i}^{OP}, a_{j}^{OP}) > V(a_{i}^{FP}, a_{j}^{FP})$$

for any i, j and k.

**Proof:** in appendix.

The fact that $a_{s}^{OP} > a_{s}^{FP}$ is quite intuitive. When choosing his knowledge-acquisition effort, S expects the same direct benefit from using knowledge for harmful purposes, and faces the same cost of effort, under a FPC and an OPC. However, under the latter S receives two additional benefits from acquiring knowledge: first, he expects to reduce B’s outside option by threatening harm at the bargaining stage, which allows him to negotiate a more favorable price. Second, he appropriates through bargaining part of the value that knowledge-acquisition adds to the good. As a result, S has greater incentives to acquire knowledge under an OPC. To see the intuition behind the result that $a_{B}^{OP} > a_{B}^{FP}$, rewrite the threshold condition $\omega_s > \omega_s$ as
This means that the marginal increase in B’s incentives to acquire knowledge under an OPC evaluated at the point \((a_B^{FP}, a_S^{FP})\) (the left-hand side in (15)), more than compensates the marginal reduction in B’s incentives due to his lower stake in the transaction’s added value (the right-hand side in (15)). If that is the case, switching from a FPC to an OPC increases B’s overall incentives to acquire knowledge ex ante. Since sellers with valuable pre-existing capabilities are more exposed to B’s threats (\(\omega_S\) is large so (15) is likely to hold), proposition 3 implies that OPCs, which allow for ex post bargaining, increase the buyer’s effort to acquire knowledge when the seller’s capabilities are valuable – that is, when \(\omega_S > \omega_a\).

Because ex ante efforts produce both added value and ex post inefficiencies in the form of harmful uses of acquired knowledge (propositions 1 and 2), proposition 3 also implies that, under a FPC, both the added value and the aggregate level of ex post inefficiencies will be smaller than under an OPC. Ghosh and John (2005, 2009) find evidence consistent with this result in industrial-equipment manufacturing contracts. They find that, when contracts leave less scope to negotiate the price ex post, equipment manufacturers and their component suppliers spend less effort in creating fit in component design and engineering and, as a result, quality is compromised.

According to proposition 3, the optimal contract form must solve a trade-off between ex ante incentives, which are enhanced by OPCs, and ex post opportunism,
which is reduced by FPCs. In the next section, we investigate the determinants of contract choice in greater detail.

**Comparative analysis**

At stage 1, B and S compare their expected payoffs under a fixed-price versus an open-price contract. For simplicity, we assume \( \min \{ JS^{FP}, JS^{OP} \} > \sum_i \omega_i \), implying that B and S always generate more surplus together than separate. Given this assumption, B and S will choose a FPC if, and only if \( JS^{FP} > JS^{OP} \), and will use an upfront transfer to split the surplus, if necessary. After simplifying and rearranging, this boils down to

\[
\sum_i E \left[ (\alpha_i^* (a_{ij}^{OP}, k) - \alpha_i^* (a_{ij}^{FP}, k)) \omega_i - (\pi_i^* (a_{ij}^{OP}, k) - \pi_i^* (a_{ij}^{FP}, k)) \right] + \sum_i \left[ L_i (a_{ij}^{OP}) - L_i (a_{ij}^{FP}) \right] > V \left( a_{B_i}^{OP}, a_{S_i}^{OP} \right) - V \left( a_{B_i}^{FP}, a_{S_i}^{FP} \right)
\]

The implications of (16) for contract choice can be summarized through the following

**Proposition 4:** Assume \( \omega_s \) is large enough so Proposition 3 holds. Then a FPC will be chosen (and be efficient) when i) the increase in the aggregate cost of knowledge acquisition \( \sum_i \left[ L_i (a_{ij}^{OP}) - L_i (a_{ij}^{FP}) \right] \) is large; ii) the saving in aggregate ex post inefficiency \( \sum_i E \left[ (\alpha_i^* (a_{ij}^{OP}, k) - \alpha_i^* (a_{ij}^{FP}, k)) \omega_i - (\pi_i^* (a_{ij}^{OP}, k) - \pi_i^* (a_{ij}^{FP}, k)) \right] \) is large; and iii) the reduction in value-enhancement \( \Delta V^* = V \left( a_{B_i}^{OP}, a_{S_i}^{OP} \right) - V \left( a_{B_i}^{FP}, a_{S_i}^{FP} \right) \) due to reduced knowledge-acquisition efforts is small.

One implication of result ii) is that contracts between opportunistic parties – in the sense of parties who are willing to set \( h_{hi}^* (a_i, k) = 1 \) in any state \( k \) – are more likely to
be governed by fixed price terms. To see why, note that, absent opportunism,

\[ h^*_i (a_j, k) \approx 0 \] for any \( i \) and \( k \), so

\[
\sum_i E \left[ \left( \alpha^*_i \left( a^*_j, k \right) - \alpha^*_i \left( a^*_{op}, k \right) \right) \omega_i - \left( \pi^*_i \left( a^*_i, k \right) - \pi^*_i \left( a^*_{op}, k \right) \right) \right] \approx 0 \] and the advantages of fixing the price ex ante are diminished. This is consistent with Crocker and Reynolds (1993), who find that the US Air Force used less flexible price formats in its contracts with engine suppliers when the degree of suppliers’ ex post opportunism, measured by their record of past judicial disputes with clients, was greater. In terms of our model, past judicial disputes may measure the likelihood that an engine supplier has harmed his previous clients (being sued in response) and, therefore, is an opportunistic type.

Result ii) also implies that, when knowledge-acquisition efforts have little marginal effect on the parties’ ability to harm each other ex post – for instance, because the parties have been working together for so long that they already know each other’s technology and product lines quite well – contracts are less likely to be governed by rigid price terms. This is because, if the parties know each other well, that is,

\[ \alpha^*_i (a_j, k) \approx \alpha^*_i (k) \] and \[ \pi^*_i (a_j, k) \approx \pi^*_i (k) \] for any \( i \) and \( k \), then

\[
\sum_i E \left[ \left( \alpha^*_i \left( a^*_j, k \right) - \alpha^*_i \left( a^*_{op}, k \right) \right) \omega_i - \left( \pi^*_i \left( a^*_i, k \right) - \pi^*_i \left( a^*_{op}, k \right) \right) \right] \approx 0 ; \] hence the advantages of fixing the price ex ante are diminished. This is consistent with Kalnins and Mayer (2004) and Corts and Singh (2004), who find – respectively, in the IT and offshore drilling industries – that clients and contractors use cost-plus contracts when they have
frequently worked together before. As explained in the introduction, purely formulaic cost-plus contracts would fall into our FPC category. However, in most cost-plus contract price adjustments are only partially formulaic, much of them being left to negotiations between the parties (Crocker and Reynolds 1993; Bajari and Tadelis 2001; Masten 2009; Lo et al. 2011). Note that both Kalnins and Mayer (2004) and Corts and Singh (2004) interpret past interactions as a proxy for future interactions and, therefore, take their evidence as supporting the idea that relational contracts sustained by the shadow of future transactions and open price terms are complementary governance tools. Our model provides an alternative explanation, which emphasizes the reduced need to safeguard against opportunistic uses of newly acquired knowledge via fixed price terms when the stock of accumulated knowledge is already large, due to past interactions. From (16), we can obtain additional testable predictions on the determinants of contract choice. Let $\tau$ be a parameter in the value-enhancement function such that $\frac{\partial V(a_i, a_j, \tau)}{\partial \tau} > 0$ and $\frac{\partial^2 V(a_i, a_j, \tau)}{\partial a_i \partial \tau} > 0$. Then, we can state the following

**Proposition 5:** Assume $\omega_i$ is large enough, so Proposition 3 holds. Then, for any $i, j \in \{B, S\}$, the likelihood that a FPC will be chosen over an OPC (and be efficient) i) increases in $\omega_i$ provided that the good’s value $V(\cdot)$ is not too responsive to the parties’

$^{21}$ In the Indian software industry, Banerjee and Duflo (2000) also find a negative – albeit not statistically significant – relation between past interactions and fixed-price contracts.

$^{22}$ As we explain below, one interpretation of $\tau$ is product complexity.
knowledge-acquisition efforts, and ii) decreases in $\tau$ provided that $V(\cdot)$ is relatively more responsive than the damage $\alpha_j(\cdot)$ to $i$’s knowledge-acquisition effort.

**Proof:** in appendix.

To understand the intuition behind result i), note that an increase in the value of party $i$’s pre-existing capabilities, $\omega_i$, generates two effects. First, it expands $i$’s losses from $j$’s ex post opportunism, since more valuable assets are exposed to misappropriation. This favors FPCs because the losses from ex post opportunism increase in party $j$’s knowledge-acquisition effort, and FPCs reduce such efforts (proposition 3). Second, an increase in $\omega_i$ increases $j$’s incentives to acquire knowledge under an OPC, as $j$ faces the prospect of using the acquired knowledge ex post as a threat to bargain over price. This further increases $i$’s losses from ex post harm, which favors FPC; but the increased knowledge also enhances the value of trade and thus favors OPCs. The latter “virtuous” effect of OPCs on value-creation is dominated by the compounded “perverse” effect on ex post harm as long as added value is not too responsive to $j$’s ex ante efforts. Result i) is consistent with the evidence in Lo *et al.* (2011), who find that in branded-component agreements, where a component is incorporated in and co-branded with the end-product\(^{23}\), the stronger the brand strength of the component-supplier or the market strength of the OEM is, the more rigid the price format that parties use.\(^{24}\)

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\(^{23}\) Examples of co-branding agreements are Dell Serve-Intel Xeon CPU and Nissan engine-Zenith fuel injection system.

\(^{24}\) Helper and Levin (1992) argue that Japanese automobile manufacturers used long-term informal contracts with suppliers – while their American counterparts used arm’s length formal contracts – because
Result ii) is also intuitive. On the one hand, an increase in $\tau$ favors OPCs because the added value $V(\cdot)$ increases more in $\tau$ at high levels of knowledge-acquisition efforts, and OPCs enhance those efforts. On the other hand, party i’s greater effort also increases the damage $\alpha_j(\cdot)\omega_j$ she expects to inflict ex post to party j through opportunistic behavior, and this favors FPCs. The former effect dominates the latter when value is relatively more responsive than harm capacity to the parties’ acquired knowledge – that is, when the value of the expression

$$\frac{\partial V(a_B^{op}, a_S^{op}, \tau)}{\partial a_i} - E \left[ \frac{\partial \alpha_j^o(a_i^{op}, k)}{\partial a_i} + \frac{\partial \alpha_j^*(a_i^{op}, k)}{\partial a_i} \right] \omega_j$$

is large. A natural interpretation for $\tau$ is in terms of technological complexity. The more responsive the good’s added value to the parties’ ex ante knowledge acquisition efforts, the less standardized and more idiosyncratic – and, therefore, more technologically complex – the good. Under this interpretation, Proposition 5 predicts that increases in the value of the parties’ pre-existing capabilities favor FPCs when technological complexity is modest. This is consistent, again, with the evidence on co-branding agreements in Lo et al. 2011: they find that the positive effect of component-suppliers’ brand strength and of equipment manufacturers’ brand strength on the use of rigid price formats diminishes when the interface between the good produced by the contractor and the client’s equipment is technically complex.

US manufacturers enjoyed large economic rents, relative to Japanese manufacturers, in the 1910-29 period and in the 1950s (pp.575-7). Insofar as informal contracts are more open to ex post negotiation than formal ones, the argument in Helper and Levin (1992) seems consistent with proposition 5 (i) in our model.
4. Relation to the literature

As explained in the introduction, the primary contribution of our paper is applied-theoretical. We build a model of the choice between fixed and open-price contracts, which captures features of inter-firm relations described in the empirical literature but absent in previous works on this topic – namely, the tradeoff between efficient and opportunistic uses of previously acquired knowledge – and yields predictions that are consistent with the existing evidence.\(^{25}\) In addition, our paper offers a methodological contribution to the literature on incomplete contracts by studying the interaction between ex ante and ex post inefficiencies and their effect on contract design. We discuss the latter contribution in section 4.1, and the relation of our paper to previous works on price terms and ex post inefficiencies in section 4.2.

4.1. Interaction between ex ante and ex post inefficiencies

The literature on incomplete contracts initiated by Grossman and Hart (1986) and Hart and Moore (1988) (hereafter GHM) has abstracted from ex post inefficiencies and focused on ex ante inefficiencies, by assuming that ex post decisions are contractible while ex ante decisions are not. Another stream of literature, inspired by Simon (1951) and Williamson (1975), has abstracted from ex ante inefficiencies and focused on ex

\(^{25}\) Recently, Hellmann and Thiele (2011) study how assigning rights to the proceedings of an innovative idea at the foundation stage of a venture may prevent, ex post, opportunistic appropriations of the idea by founders. They differ from us in that they do not study the choice between fixed-price and open-price contracts. More substantially, they take ideas as exogenous, so they do not study the tradeoff between efficient and inefficient uses of idea-generating knowledge, and the role of contract design in solving the tradeoff.
post inefficiencies, by assuming that ex post decisions are non-contractible (Gibbons 2005, Hart and Moore 2008, Hart and Holmstrom 2010, Baker et al. 2011) or contracted under asymmetric information (Bajari and Tadelis 2001, Matouschek 2004, Chakravarty and MacLeod 2009), and that ex ante decisions do not affect ex post ones – for instance, because they are contractible, or even immaterial. Here, we present a model where both the parties’ ex ante decisions (namely, their knowledge-acquisition efforts) and certain ex post decisions (namely, each party’s decision to harm the other) are non-contractible and the level of ex post inefficiency depends on the ex ante decisions. In such a model, the equilibrium decisions under a given contractual form, as well as the optimal contractual form itself, differ, in general, from the case where the ex ante and the ex post decisions do not interact with each other. To see this point, note that fixing the price upfront would be always inefficient in our model if either the ex ante knowledge-acquisition efforts or the ex post harm decisions were immaterial or contractible, or if the level of ex post harm did not depend on the ex ante efforts, because the only reason for fixing the price here is to reduce the parties’ incentives to acquire non-contractible knowledge ex ante and, through that channel, their ability to engage in non-contractible opportunistic behavior ex post.

26 A different example of interaction between ex ante and ex post decisions is Aghion and Tirole’s (1997) model of delegation, where a boss’ and a subordinate’s search efforts affect which decisions are proposed by the subordinate, and approved by the boss, ex post.

27 In their theory of procurement contracts, Bajari and Tadelis (2001) model ex ante non-contractible decisions (the seller’s cost-cutting effort) and ex post decisions that are negotiated under asymmetric information (project modifications), and find that fixed-price (cost-plus) contracts increase (decrease) both the seller’s ex ante incentives and the likelihood of ex post negotiation failures. An important difference from our model is that, in Bajari and Tadelis (2001), the level of ex post inefficiency (namely, the loss of trade opportunities due to negotiation failures) does not depend on the ex ante effort. Hence, the tradeoff between ex ante and ex post inefficiencies arises because fixed price contracts happen to increase both the seller’s ex ante incentives to spend effort and the buyer’s and seller’s ex post incentives to negotiate aggressively, albeit for unrelated reasons.
4.2. *Ex post inefficiencies and price terms*

Our paper complements previous models of the relation between price terms and ex post inefficiencies, in particular those of Masten (1988, 2009), Bajari and Tadelis (2001), and Hart and Moore (2008). Bajari and Tadelis (2001) model ex post inefficiencies arising from negotiation breakdowns, whereas we model hostile, opportunistic behaviors as described by Goldberg (1985) and Masten (1988), and in the management literature (see Introduction). Moreover, Bajari and Tadelis (2001) focus on a volatile environment where the nature of the good changes over time, so the law does not prevent renegotiation even in the presence of a fixed price, whereas we model a static environment where FPCs serve as a commitment device against renegotiation when the nature of the product remains unchanged ex post. Last, and related, Bajari and Tadelis (2001) do not study the choice between fixed and open price terms but, rather, the choice between fixed-price contracts and cost-plus formulae, both of which would fall under the FPC category in our model.

Masten (1988, 2009) is closer to us, in the sense that he models how fixed-price contracts constrain ex post opportunism. He defines opportunism as costly rent-seeking activities that occur in equilibrium, thus producing a deadweight loss. We distinguish between rent-seeking opportunism, which affects the distribution of surplus but does not occur in equilibrium, and a moral-hazard type of opportunism, which occurs in equilibrium and generates a deadweight loss. An advantage of our approach with respect to pure rent-seeking models is that, because equilibrium opportunistic decisions
are both non-contractible and ex post profitable, parties cannot contract around them by “rushing” to seal an agreement immediately after uncertainty over the state of the world is resolved.\textsuperscript{28}

Finally, our paper relates to Hart and Moore (2008), who model opportunism as the withdrawal of non-contractible performance (shading) that arises when parties are unhappy with the outcome of ex post bargaining. They argue that fixing the price ex ante reduces shading because parties do not feel like they are entitled to modify such price through ex post bargaining – that is, the initial price acts as a reference point for the parties. In addition to linking ex ante and ex post inefficiencies (see section 4.1), our model complements Hart and Moore (2008) in two other respects. First, we model opportunism as hostile decisions that reduce the value of a counterpart’s pre-contractual assets, rather than shading on performance. This allows us to derive comparative-static results on the effect of pre-existing assets on contract form, which are consistent with observed practices. Second, the trade-off between fixed and open prices in our model does not depend on the behavioral assumption that contracts are reference points. Rather, it depends on the fact that ex ante knowledge-acquisition fosters ex post opportunism, and fixed-price contracts discourage knowledge-acquisition – and, therefore, reduce opportunism – by eliminating the possibility to use the acquired knowledge as a threat to renegotiate price.

\textsuperscript{28} See Hart and Moore (2008) for a detailed discussion of this limitation of rent-seeking models.
5. Conclusion

We develop a model of price terms in close inter-firm relations where the contracting parties bring in pre-existing capabilities to produce an intermediate good. Drawing on real-world descriptions, we model a two-stage process in which the parties’ efforts to acquire knowledge ex ante can be used, ex post, to both enhance value of the intermediate good and harm their counterparts’ capabilities. Our main result is that, by eliminating the possibility to use knowledge as a threat to renegotiate price, a fixed-price contract reduces the parties’ incentives to acquire knowledge ex ante. This limits opportunistic uses of knowledge ex post, but may also result in low product enhancement. An implication of this result is that parties will protect pre-existing capabilities that are vulnerable to ex post expropriation by specifying the price ex ante.

Our model complements previous works on incomplete contracts, which focused on either ex ante or ex post inefficiencies in isolation, by showing that ex ante and ex post inefficiencies may interact with each other in driving contract choice. Our model also extends the Transaction Cost Economics rationale for contracts as a means to protect post-contractual, relationship-specific investments, by showing that fixed-price contracts may also protect firms’ pre-existing investments in general-purpose, non-specific capabilities.

While we focus on the trade-off between fixed and open price terms in inter-firm contracts, our model may also be extended to derive a theory of firm boundaries, in at
least three ways. First, parties may shift asset ownership to determine the outcome of ex post bargaining and, through that channel, their own ex ante incentives to acquire knowledge, as in Grossman and Hart (1986). The novel implication of our model would be that, by affecting ex ante incentives, asset ownership would also affect ex post inefficiencies, given by the parties’ opportunistic uses of knowledge. Second, shifting firms’ boundaries may limit a party’s ability to engage in opportunistic uses of knowledge ex post by excluding her from the use of key physical assets once the relationship is terminated (Klein and Murphy 1997, van den Steen 2010). For instance, it may be difficult for the manager of the component division of an original equipment manufacturer, relative to an independent contractor, to use his knowledge of the manufacturer’s technology and processes in order to directly compete with him, because the manager-employee does not own physical assets that can be redeployed to produce both components and original equipment. Finally, bringing both the buyer and the seller within a unified firm may help replicate the outcome of a fixed-price contract when court-enforcement is imperfect. While we have assumed, consistent with legal practice, that in the presence of redistributive contract modifications, courts will reinstate the initially fixed price, matters become complicated when contractible characteristics of the good to be traded (d in our model) are ex ante uncertain, as in Bajari and Tadelis (2001). In such an environment, courts may be unable to distinguish redistributive renegotiations from efficiency-enhancing ones and refuse to reinstate the initial price. One way to insure reinstatement, and hence to reduce ex ante knowledge-acquisition and ex post opportunism, is to bring the transaction within a unified firm, where disputes over transfer prices are resolved by (presumably better informed)
internal hierarchies, rather than courts (Williamson 1991, Hansmann 2010, Kornhauser and Macleod 2010). While a thorough exploration of the implications of our model for firms’ boundaries is beyond the scope of this paper, we hope to pursue it in future work.

References


Appendix: mathematical proofs

Proof of proposition 3: i) Compare first $a_s^{op}$ and $a_s^{fp}$. From (10) and (14) it follows that $a_s^{op} (a_b = 0) > a_s^{fp}$. Since S’s best-response function $a_s^{op} (a_b)$ is increasing in $a_b$ due to complementarity, it must be that $a_s^{op} (a_b^{op}) \geq a_s^{op} (a_b = 0) > a_s^{fp}$. Compare now $a_b^{op}$ and $a_b^{fp}$. To prove that $a_b^{op} \geq a_b^{fp}$ when $\omega_s$ is large enough, suppose

\[
\frac{\partial V(a_b^{fp}, a_s^{fp})}{\partial a_b} > \frac{\partial V(a_b^{fp}, a_s^{fp})}{\partial a_b} \equiv \omega_s.
\]  

(A1)

Rewriting (13), we have

\[
\frac{1}{2} \frac{\partial V(a_b^{fp}, a_s^{fp})}{\partial a_b} + \frac{1}{2} \frac{\partial V(a_b^{fp}, a_s^{fp})}{\partial a_b} + E \left[ \frac{\partial \alpha_s^{op} (a_b^{fp}, k)}{\partial a_b} - \frac{\partial \alpha_s^{fp} (a_b^{fp}, k)}{\partial a_b} \right] - \frac{dL_B(a_b^{fp})}{da_b} = 0.
\]  

(A2)

Rewriting (A1), we have

\[
\frac{1}{2} E \left[ \frac{\partial \alpha_s^{op} (a_b^{fp}, k)}{\partial a_b} - \frac{\partial \alpha_s^{fp} (a_b^{fp}, k)}{\partial a_b} \right] \omega_s > \frac{1}{2} \frac{\partial V(a_b^{fp}, a_s^{fp})}{\partial a_b}.
\]  

(A3)

From (A2) and (A3), it follows that
\[
\frac{1}{2} \frac{\partial V(a_B^{FP}, a_S^{FP})}{\partial a_B} + \frac{1}{2} \mathbb{E} \left[ \frac{\partial \alpha_S^O(a_B^{FP}, k)}{\partial a_B} - \frac{\partial \alpha_S^*(a_B^{FP}, k)}{\partial a_B} \right] \omega_S \\
+ \mathbb{E} \left[ \frac{\partial \pi_B^*(a_B^{FP}, k)}{\partial a_B} \right] - \frac{dL_B(a_B^{FP})}{da_B} > 0.
\]

(A4)

Denote the left-hand side in (A4) as \( B \left( a_B^{FP}, a_S^{FP} \right) \). We know from (9) that

\( B \left( a_B^{OP}, a_S^{SP} \right) = 0 \). Since the function \( B \left( a_B, a_S^{FP} \right) \) decreases in \( a_B \), this implies that

\( a_B^{OP} \left( a_S^{FP} \right) > a_B^{FP} \). Further, since \( a_B^{OP} \left( a_S \right) \) increases in \( a_S \) due to complementarity and

\( a_S^{OP} > a_S^{FP} \), this implies that \( a_B^{OP} \left( a_S^{OP} \right) > a_B^{OP} \left( a_S^{FP} \right) > a_B^{FP} \). This completes the proof of result i). Because \( \alpha_i^* \left( a_i, k \right) \omega_i > \pi_i^* \left( a_i, k \right) \) and the functions \( \alpha_i^* \left( a_j, k \right) \omega_i - \pi_i^* \left( a_i, k \right) \) and \( V \left( a_i, a_j \right) \) are increasing in \( a_i \) and \( a_j \) for any \( i, j \) and \( k \), result i) also implies results ii) and iii). QED.

**Proof of proposition 5**: Denote B’s and S’s expected payoffs under an OPC from (7) and (8), evaluated at \( \left( a_B^{OP}, a_S^{OP} \right) \), as \( \Pi_B^{OP} \) and \( \Pi_S^{OP} \), respectively. Similarly, denote B’s and S’s expected payoffs under a FPC from (11) and (12), evaluated at \( \left( a_B^{FP}, a_S^{FP} \right) \), as \( \Pi_B^{FP} \) and \( \Pi_S^{FP} \). From the envelope theorem, it follows that, for any \( i, j \in \{ B, S \} \),
\[
\frac{d(JS_{FP} - JS_{OP})}{d\omega_i} = \sum_{i,j} \left[ \frac{\partial \Pi_{i,FP}^{OP}}{\partial \omega_i} + \frac{\partial \Pi_{i,FP}^{OP}}{\partial a_j} \frac{\partial a_{i,FP}^{OP}}{\partial \omega_i} - \frac{\partial \Pi_{i,OP}^{OP}}{\partial \omega_i} - \frac{\partial \Pi_{i,OP}^{OP}}{\partial a_j} \frac{\partial a_{i,OP}^{OP}}{\partial \omega_i} \right] \\
= E\left[ \alpha_i^* (a_{i,OP}^{OP}, k) - \alpha_i (a_{i,FP}^{FP}, k) \right] + \frac{1}{2} E \left[ \frac{\partial \alpha_i^* (a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}})}{\partial a_j} + \frac{\partial \alpha_i^* (a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}})}{\partial a_j} \right] \frac{\partial a_{i,OP}^{OP}}{\partial \omega_i} \\
+ \frac{1}{2} E \left[ \frac{\partial \alpha_j^* (a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}})}{\partial a_i} + \frac{\partial \alpha_j^* (a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}})}{\partial a_i} \right] \frac{\partial a_{i,OP}^{OP}}{\partial \omega_i}, \\
- \frac{1}{2} E \left[ \frac{\partial V(a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}, \tau})}{\partial \omega_i} + \frac{\partial V(a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}, \tau})}{\partial \omega_i} \right] \frac{\partial a_{i,OP}^{OP}}{\partial \omega_i}
\]

From the implicit function theorem applied to (9) and (10), it follows that that

\[
\frac{\partial a_{k,OP}}{\partial \omega_i} > 0 \quad \text{for any } i, k \in \{B, S\}, \quad \text{so the above expression is positive when } \frac{\partial V(a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}})}{\partial a_j}
\]

and \( \frac{\partial V(a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}})}{\partial a_i} \) are small – that is, when \( V(\cdot) \) is not responsive to the parties’ knowledge-acquisition efforts. Also,

\[
\frac{d(JS_{FP} - JS_{OP})}{d\tau} = \sum_{i,j} \left[ \frac{\partial \Pi_{i,FP}^{OP}}{\partial \tau} + \frac{\partial \Pi_{i,FP}^{OP}}{\partial a_j} \frac{\partial a_{i,FP}^{OP}}{\partial \tau} - \frac{\partial \Pi_{i,OP}^{OP}}{\partial \tau} - \frac{\partial \Pi_{i,OP}^{OP}}{\partial a_j} \frac{\partial a_{i,OP}^{OP}}{\partial \tau} \right] \\
= - \left[ \frac{\partial V(a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}, \tau})}{\partial \tau} - \frac{\partial V(a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}, \tau})}{\partial \tau} \right] \frac{\partial a_{B_{FP}^{OP}}}{\partial \tau} \frac{\partial a_{B_{FP}^{OP}}}{\partial \tau}, \\
\quad - \frac{1}{2} \sum_i \left[ \frac{\partial V(a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}, \tau})}{\partial \omega_i} - \frac{\partial V(a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}, \tau})}{\partial \omega_i} \right] \frac{\partial a_{i,OP}^{OP}}{\partial \omega_i} \frac{\partial a_{i,OP}^{OP}}{\partial \omega_i}
\]

which is negative when \( \frac{\partial V(a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}, \tau})}{\partial a_i} - \frac{\partial V(a_{B_{FP}^{OP}, a_{S_{FP}^{OP}}, \tau})}{\partial a_i} \) \( \omega_j \) is large – that is, when the good’s value \( V(\cdot) \) is more responsive than j’s damage \( \alpha_j(\cdot) \) to i’s ex ante knowledge-acquisition effort. QED.