The Double-Edged Effect of Knowledge Acquisition: How Contracts Safeguard Pre-existing Resources

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Giorgio Zanarone
Assistant Professor of Business Economics
Colegio Universitario de Estudios Financieros
Address: C/ Ayala 76, apt. 4C 20118 Madrid, Spain
(+34) 650 284 191
gzanarone@cunef.edu.

Desmond (Ho-Fu) Lo
Assistant Professor
Marketing Department,
Leavey School of Business
Santa Clara University
500 El Camino Real
Santa Clara, CA 95050
408-554-4716; fax: 408-554-5206
hlow@scu.edu

Tammy L. Madsen
Associate Professor of Strategy
Management Department,
Leavey School of Business
Santa Clara University
500 El Camino Real
Santa Clara, CA 95050
408-551-7165; fax: 408-554-2331
tmadsen@scu.edu

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Research Summary: Acquiring knowledge on a partner's pre-existing resources plays an important yet ambiguous role in collaborative relationships. We formally model how contracts trade off productive and destructive uses of knowledge in a buyer-supplier relationship. We show that, when the buyer's pre-existing resources are vulnerable to the revelation of sensitive knowledge, the supplier overinvests in knowledge acquisition as it expects to use the knowledge as a threat in price negotiations. A non-renegotiable closed-price contract prevents such overinvestment and reduces the supplier's ability to expropriate the buyer ex post. Our results extend to the cases of renegotiable closed-price contracts, repeat interactions between a buyer and a supplier, and the use of non-disclosure policies. We draw theoretical, empirical, and managerial implications from our model.

Managerial Summary: This study yields new insights regarding the use of contract design in protecting pre-existing, non-relationship specific assets in buyer-supplier arrangements. Anecdotal examples illustrate the "dark side" of these arrangements where opportunistic suppliers exploit knowledge of buyers' pre-existing resources to seek rent and appropriate value. When a supplier is likely to act harmfully, a closed-price contract that specifies the price of the supplier's component upfront may reduce the supplier's incentives to overinvest in acquiring and exploiting knowledge of the buyer's pre-existing resources. As such, when a buyer's pre-existing resources are highly valuable, and thus more vulnerable to use by the supplier outside of the arrangement, a non-renegotiable closed-price contract is more efficient. Additionally, limited disclosure policies and informal agreements based on repeated interactions complement indirect governance via price contracts.

INTRODUCTION

Inter-firm collaboration is often motivated by a partner's intent to make productive use of a focal firm's pre-existing, knowledge-based resources and capabilities (e.g., Dussauge, Garrette, and Mitchell, 2000; Khanna, Gulati, and Nohria, 1998; Mowry, Oxley, and Silverman, 1996). Hence, activities related to acquiring knowledge are an important form of engagement in contractual relationships (Kogut 1988; Powell, Koput, and Smith-Doerr, 1996). This engagement, however, has a less-studied destructive or "dark side" where a focal firm's *pre-existing*, non-relationship specific resources emerge as potential hazards, exposing the firm to the partner's rent-seeking threats and harm. For instance, anecdotal evidence suggests that suppliers spend extraordinary effort to acquire sensitive and strategic knowledge, skills, and technologies *beyond* the formal agreement established with their clients (Hamel, Doz, and Prahalad, 1989) and subsequently, directly compete with them (Arora and Merges, 2004; Arruñada and Vázquez, 2006; Mohr and Sengupta, 2002; Rosetti and Choi, 2005; The Economist, 2012). Systematic evidence also illustrates how telecom contract manufacturers evolve into branded producers through active learning about their downstream partners and markets (Alcacer and Oxley, 2014).

Many studies examine the role of contractual provisions in safeguarding relationship-specific assets *developed within* a collaborative arrangement (e.g., Oxley, 1997; Poppo and Zenger, 2002; Reuer and Arino, 2007) and how contracts govern collaboration in general (e.g., Argyres, Bercovitz, and Mayer, 2007; Ghosh and John, 2005; Lo, Frias, and Ghosh, 2012). However, we lack studies analyzing how firms structure these arrangements to trade off the potentially productive and destructive effects associated with knowledge acquired from their *pre-existing* resources and capabilities. We argue that the vulnerability of the pre-existing resources and capabilities a firm brings to an exchange – namely, non-relationship-specific factors that are mobile (e.g. company documents) or imperfectly mobile (e.g., innovation capabilities) – affects the contractual terms adopted and through that channel, the extent of a partner's investment to acquire knowledge about such resources.

To explore these ideas, we develop a formal theory of how contracts can be used to govern the "double-edged-sword" nature of knowledge acquisition investments in buyer-supplier relationships. We model two contractual scenarios where a buyer (such as an Original Equipment Manufacturer, or OEM) brings vulnerable, pre-existing resources and capabilities to a relationship, and a supplier (such as a component manufacturer) chooses the level of its investment in knowledge acquisition. In the first scenario, the parties leave the price open and negotiate it ex post—after the supplier's knowledge investment is sunk. In this case, if price negotiations fail, no transaction occurs and the supplier "retaliates" against the buyer by using its acquired knowledge to harm the latter's pre-existing resources. This ability to threaten the buyer may induce the supplier to seek rent by overinvesting in efforts to acquire knowledge of the buyer's pre-existing resources. In the second scenario, the buyer and the supplier agree on a "closed-price contract" that specifies the price upfront. As such, the supplier can no longer threaten to harm the buyer to seek rents, so it may have lower incentives to acquire knowledge from the buyer. Hence, we propose that a contract may be used to discourage investment rather than encourage it, a departure from the standard holdup problem analyzed by work on transaction cost economics (Williamson, 1979) and incomplete contracting (Grossman and Hart, 1986; Hart and Moore, 1988).

The study proceeds as follows. We first review the key concepts that inform our research question. Next, we present our model and propositions, as well as extensions of the baseline model. The extensions consider alternative scenarios that include repeat engagements between a supplier and a buyer and a buyer's internal policies to limit information disclosure to the supplier. The study concludes with implications for theory and practice.

CONCEPTUAL BACKGROUND

Pre-existing resources and knowledge acquisition

Firms are heterogeneous and thus enter collaborative arrangements with different resources and capabilities (Argyres and Zenger, 2012; Barney, 1989, 1991; Das and Teng, 2000; Rumelt, 1984). These pre-existing endowments include factors that are observable and tradable in a market such as company documents (e.g., engineering drawings, documented software code), content captured or shared in interactions or communications between a buyer and supplier (e.g., product design architecture, plant layouts), and knowledge held by employees (Grant, 1996), as well as resources such as brand, organizational architecture, and customer base that are unique to a firm and less accessible via simple market transactions (Barney, 1991; Dierickx and Cool, 1989; Peteraf, 1993). Since preferential access to unique resources underlies competitive advantage (Barney, 1991; Peteraf, 1993), the resources and capabilities that a buyer owns may be a target for knowledge acquisition by its supplier(s) (Alcacer and Oxley 2014; Arora and Merges, 2004; Arruñada and Vázquez, 2006; Hamel *et al.*, 1989). Resources that are observable and mobile tend to be easy to transfer. However, a buyer's imperfectly mobile resources may still afford opportunities for learning via voluntary or involuntary knowledge leakage or spillovers (Bonte, 2008; Harhoff, Henkel and von Hippel, 2003; Mansfield, 1985; Pisano, 1988).

The strategic motivations underlying suppliers' knowledge acquisition investment may depend on their valuations of a focal firm's pre-existing resources (Grant and Baden-Fuller, 2004). A supplier might pursue external knowledge to strengthen its ability to create value within a relationship or might exploit acquired knowledge to seek rent by threatening harm, or to actually expropriate the OEM's pre-existing resources. For example, the supplier could leverage knowledge acquired from a buyer to negotiate for concessions on price or other terms (Lyons *et al.*, 1990; Susarla, 2012), to shirk and shade quality (Anderson and Jap, 2005), or to generate new products or services with the intent of entering the buyer's industry as a competitor (Alcacer and Oxley, 2014; Arruñada and Vázquez, 2006; Rossetti and Choi, 2005). Thus, a firm's pre-existing resources may contribute to unbalanced outcomes in an exchange, where the partner benefits while the focal firm loses (Hamel *et al.* 1989).

Our study contributes to the literature on strategic knowledge acquisition in collaborative arrangements in two ways. First, we recognize that productive and opportunistic knowledge acquisition investments – often analyzed separately – are two facets of the same coin, and we analyze them jointly. Second, although prior work investigates governance mechanisms that safeguard relationship-specific assets from opportunistic behavior (see David and Han, 2004, and Tadelis and Williamson, 2013), it is silent on how firms should structure a collaborative arrangement to thwart the potential destructive effects associated with acquired knowledge on firm resources that *pre-exist* the relationship (Alcacer and Oxley, 2014; Ghosh and John, 1999). We fill this gap by showing that the susceptibility of a focal firm's pre-existing resources and capabilities to destructive use by its partners is an important determinant of governance structures.

Contract provisions

Contracts serve as a common governance tool for specifying terms of agreement that regulate collaborative arrangements. Many studies have examined contracts as a means for aligning expectations and instituting safeguards in collaborative arrangements (e.g., David and Han, 2004; Macher and Richman, 2008; Tadelis and Williamson, 2013). Economists have primarily focused on incentive and enforcement provisions (see Lafontaine and Slade, 2013, for a review), and strategy scholars have dedicated more attention to provisions promoting safeguarding, coordination, and adaptation (Oxley and Sampson, 2004; Poppo and Zenger, 2002; Reuer and Arino, 2007; Ryall and Sampson, 2009; Schepker *et al.*, 2014).

Although explicit, direct contractual provisions may inhibit the actions of parties in an exchange, they are limited in their ability to protect a buyer's non-contractible, knowledge-based resources from appropriation. Several scholars stress that non-compete clauses, intellectual property rights, trade secret protections, and firms' disclosure policies, are limited in their inter-firm application or judicial enforceability (Arora and Merges, 2004; Garmaise, 2009; Liebeskind 1996, 1997; Pooley, 1997). Other mechanisms such as forming cross-shareholding joint ventures (Oxley, 1999), reducing alliance scope (Oxley, 1997; Oxley and Sampson 2004), or complementing formal contracts with relational governance mechanisms (e.g., Ryall and Sampson, 2009; see also, Schepker *et al*., 2014) have their own limitations.

Our study is informed by, and relates to, recent empirical and theoretical work on the *indirect*, incentive role of contractual forms. Empirical studies find that buyers and suppliers often employ indirect contract provisions in the form of alternative price formats to govern their relationships in industrial markets (Ghosh and John, 2005; Lo *et al*., 2012). These studies suggest that in buyer-supplier relationships, closed prices may protect a buyer's pre-existing resources and capabilities from opportunism and expropriation. Analytically, our approach relates to Hart and Moore (2008), who explore the role of price terms in mitigating opportunism in incomplete contracts. Like us, they argue that, when a partner in a collaborative relationship feels unsatisfied with the price that arises from bargaining, it retaliates by causing harm to its counterpart. An important difference is that in our model, "retaliation" power, namely the supplier's acquired knowledge, arises endogenously in the contractual relationship, and we study to what extent it is optimal to limit it via contract. Our model also relates to Crocker and Reynolds (1993) and Bajari and Tadelis (2001), who discuss how tight price terms may reduce opportunistic bargaining within a collaborative relationship. Unlike us, these two studies do not consider the effect of price terms on knowledge acquisition and on pre-existing resources.

In sum, our study contributes to the literature on contracts by providing a formal, internally consistent analysis of *how* closed price and open price contract terms, respectively, safeguard pre-existing resources and capabilities and incentivize value creation.

MODEL SETUP

A buyer (B) wants to buy an indivisible good from a seller (S). Both B and S are risk-neutral. S may immediately sell the good to B as a 'standard' product at the competitive market price $\underline{C}$ equal to its production cost, in which case B obtains value $\underline{V} > \underline{C}$. If instead S invests time and effort to acquire *tacit* knowledge about B (e.g., its business, technology, and customers) before trading, it may be able to improve the good so that its value to B increases by $v > 0$, and S's production cost decreases by $c > 0$. The probability to achieve this efficiency gain $(v + c)$ is given by $q(a)$, where $a \geq 0$ denotes both S's knowledge acquisition investment and the cost of such investment to S, and $q(\cdot)$ is increasing in a. For instance, if S is B's supplier, a may be the time, effort, and employees S involves to learn about B's technology and customer base, and $q(a)$ is the probability that S produces an intermediate good, such as a component, that better fits B's end product, as a result of such knowledge acquisition investment. We assume that $q(\cdot)$ is strictly concave, $q(0) = 0$, $\lim_{a\to\infty} q(a) = 1$.

In addition to using the acquired knowledge to improve the good, S may also disclose it in a way that reduces B's ability to create value outside the relationship – for instance, by revealing information on B's pre-existing technology or customers to its competitors. Formally, after the investment is sunk, S can take the hostile action $h \in \{0,1\}$. If S harms B ($h = 1$), the value of B's pre-existing resources outside the relationship with S (e.g, its brand, design architecture, technology, customer base, and other non-physical assets), denoted as ω, will be reduced by a factor $\alpha(a) \in [0,1]$. Since S's ability to harm depends on how much it knows about B, we assume that $\alpha(\cdot)$ is strictly increasing. We also assume $\alpha(\cdot)$ is concave, $\alpha(0) = 0$, and $\lim_{a\to\infty} \alpha(a) = 1$.

To insure that S chooses a positive investment level under all the contractual forms analyzed in the paper, we assume $q_a(0) > \max\left\{\frac{1}{c}, \frac{2-\alpha_a(0)\omega}{v+c}\right\}$.

In this and the next sections, we assume that if S uses its acquired knowledge to harm B, it does not obtain any *direct* benefit. This implies that S may use its knowledge as a credible threat to bargain with B over the good's price. We relax this assumption in a later section. In Appendix 1, we generalize the model to allow for more flexible functional forms on how the value of B's pre-existing resources interacts with the potential harm and efficiency gains, and, show that the model's results persist in the more general setting.

Timing. Figure 1 shows the timeline of events in our model. At stage 1, B and S choose the contract terms that will regulate their transaction, particularly, whether to specify the trading price or not. At stage 2, S chooses the knowledge investment a. At stage 3, B and S observe whether S's investment to acquire knowledge has made the efficiency gain possible. At stage 4, the chosen contract terms are executed, unless they are renegotiated. Moreover, S chooses whether to use the acquired knowledge to harm B (the action h). Finally, at stage 5, the payoffs are realized.

[INSERT FIGURE 1 HERE]

Assumptions. We make the following assumptions on the informational structure of the game and the way B and S negotiate at stage 4. We assume that the value of B's pre-contractual resources, ω, S's knowledge investment a, whether the investment results in an efficiency gain or a harm, the size of realized gains $(v + c)$ and harms $(\alpha(a)\omega)$, and whether S uses its acquired knowledge to harm B (the action h), are all observable to B and S but non-verifiable to courts. In contrast, we assume that whether B and S trade the good, and at what price, are verifiable.

As standard in contracting theory, we assume both parties form rational expectations on their counterpart's strategies — that is, on how contract terms affect knowledge acquisition investment, bargaining, and the decision to harm. This is reasonable in our context because empirical studies in industrial markets show that suppliers and their clients are often experienced in contracting practices (e.g., Ghosh and John, 2005; Lo *et al.*, 2012). Following the literature on contract theory, we also assume that negotiation results in the Nash bargaining solution: B and S trade, S does not harm B, and each party receives its disagreement payoff plus one half of the bargaining surplus (e.g., Hart and Moore, 1988). Moreover, we assume that, *in case of disagreement*, S strictly prefers to harm B ($h = 1$). This may result from the fact that, once knowledge is acquired, inflicting harm no longer generates direct costs for S. For instance, disclosing acquired knowledge on B's resources and capabilities would not require additional effort from S, as it can be a by-product of S's routine communications with firms operating in related businesses (Mansfield, 1985; Mintzberg, 1989: Chapter 1). Symmetrically, even though harm does not generate direct profits, S may derive some pleasure from harming B if B does not concede to its demands during bargaining (Hart and Moore, 2008). Theoretically, if the negotiation fails, B may also feel aggrieved and hence have a desire to harm S. However, B does not have an opportunity to harm S in our model, because only B owns pre-existing resources that are vulnerable to S's harmful actions, but not vice versa. As we formally show in the next section, these assumptions imply that, while harm does not occur in equilibrium, S can use its acquired knowledge of B as a credible threat to bargain over the price of the good.

Notice that our interpretation of harm as revelation of sensitive knowledge to B's competitors or potential partners does not contradict the assumption that knowledge is unverifiable by courts. As industry insiders, and being unconstrained by procedural formalities, competitors and partners may be in a better position than courts to investigate ex post whether S's revelations about B 'smell right'. To economize on notation and space, we do not explicitly model the cheap-talk game between S and B's competitors and partners.

GOVERNING KNOWLEDGE INVESTMENTS UNDER RENT SEEKING

In this section, we study how B and S can organize their contractual relationship to optimize the seller's knowledge investment, given that S can use the acquired knowledge both productively and as a rent-seeking threat in price negotiations. As a benchmark, we begin by analyzing the first-best case where, at stage 2, S chooses the level of its knowledge acquisition investment that maximizes the parties' total or joint surplus, $\mathrm{JS}(a) \equiv \underline{V} - \underline{C} + q(a)(v + c) - a$. The first-best investment is given by

$$a^{FB} \equiv \mathrm{argmax}_a\{\mathrm{JS}(a)\} > 0. \quad (1)$$

Knowledge investments with an open price

If they have not signed a contract specifying the price at stage 1, B and S will have to negotiate about trade and the price at stage 4, after the knowledge acquisition investment is sunk. We refer to this as the 'open- price' scenario. One may think at this case as one where, rather than signing a long-term contract ex ante, the parties negotiate a 'spot-market' contract ex post. The importance of open-price contracts is indirectly confirmed by the fact that the Uniform Commercial Code (UCC) has a section (2-204) that specifically deals with them (see also Crocker and Reynolds, 1993; Ghosh and John, 2005; Lo *et al.* 2012). Given Nash bargaining, B's and S's expected post-negotiation payoffs are

$$U_B^0 \equiv [1 - \alpha(a)]\omega + \frac{1}{2}[q(a)(v + c) + \alpha(a)\omega], \text{ and} \quad (2)$$

$$U_S^0 \equiv \frac{1}{2}[q(a)(v + c) + \alpha(a)\omega]. \quad (3)$$

In words, both parties threaten not to trade in case of disagreement and, *in addition*, S threatens to use its acquired knowledge to reduce the outside value of B's resources. Consequently, S's knowledge investment is

$$a^0 \equiv \mathrm{argmax}_a\{U_S^0(a) - a\} > 0. \quad (4)$$

By comparing the open-price and the first-best scenarios, we obtain the following result.

Proposition 1: In the open-price scenario, S overinvests in knowledge acquisition relative to the first best when B's pre-existing resources are highly valuable (large ω), and underinvests when those resources are not too valuable (small ω).

Proof: please refer to Appendix 2.

When B does not bring vulnerable pre-existing resources to the relationship ($\omega = 0$), S's investment does not have any potentially destructive effects. As a result, Proposition 1 above corresponds to the case analyzed in standard holdup models of contractual relationships (Grossman and Hart, 1986; Hart and Moore, 1988): the seller invests less than in the first best, because it expects that half of the efficiency gain will be appropriated by the buyer through bargaining.

In contrast, when B brings valuable pre-existing resources to the relationship ($\omega > 0$), S's knowledge acquisition investment becomes partially destructive, as it can be used to reduce the value of B's resources. While such harm does not occur in equilibrium, it improves S's bargaining position. As a result, when it chooses how much to invest in knowledge acquisition, S places half weight on the productive effect (rather than full weight, as in the first best) and half weight on the destructive effect (rather than zero weight, as in the first best), as illustrated by equations (3) and (4). When B's vulnerable pre-existing resources are not too valuable, the inefficiently low weight of the productive effect dominates, and the standard underinvestment result obtains. However, when B's vulnerable resources are sufficiently valuable, the inefficiently high weight of the destructive effect dominates, and S *overinvests*.

An implication of Proposition 1 is that in traditional holdup models, the parties always use contracts to encourage investment whereas in our model, they may sometimes use contracts to *discourage* it. In particular, we will see below whether, and to what extent, specifying the price in a contract can achieve this goal.

Knowledge investments with a closed-price contract

Suppose that, at stage 1, B and S agree on a simple contract that specifies ex ante a price $p \in [\underline{C}, \underline{V}]$ at which the parties will trade at stage 4. We refer to this as the 'closed-price' scenario to distinguish it from the 'open-price' case analyzed in the previous section. Since trade is contractible and strictly preferred by both parties, any renegotiation of a price between $\underline{V}$ and $\underline{C}$ will be purely redistributive. Nevertheless, S may successfully demand such a redistributive renegotiation, because it can use the knowledge acquired at stage 2 as a threat against B. To this respect, we distinguish between two types of closed-price contracts.

If they use a *non-renegotiable* closed-price contract, B and S can commit at stage 1 not to renegotiate the price at stage 4. For instance, if S is one of B's many suppliers, it may be illegal for B to renegotiate S's standard-form contract without renegotiating with each of S's peers (Ben-Shahar and White, 2006; Zanarone 2013). If renegotiation is impossible for exogenous reasons, S will not feel angry toward B when the contracted price is enforced, and thus it will not retaliate by using its knowledge to harm B. In other words, we assume that, while S is willing to harm B out of spite if B refuses to renegotiate, S does not blame B if renegotiation is exogenously ruled out. This assumption is consistent with, and less stringent than, the notion of 'contracts as reference points' in Hart and Moore (2008).

Moreover, under U.S. law, redistributive price renegotiations can be sued under the doctrine of duress: if B cannot easily replace S ex post (for instance, due to 'temporal specificity'), and if there have been no material changes in the contractual description of S's good and in S's production costs, courts will presume a price increase to be extorted by S under duress, even though they cannot verify extortion directly (Schwartz, 1992). From a legal point of view, S extorting payment from B without renegotiating the contractual price would be problematic because B may sue S for restitution on the grounds that a payment without consideration is not a valid contract. Additionally, if S's threat to reveal knowledge is fleeting, for instance, because its acquired knowledge on product design has become public after B's product introduction to market, the law will make any renegotiation attempt—and any attempt of S to harm B—unsuccessful. This may happen as B can accept to change the price under S's threat, then wait until S's opportunity to retaliate elapses and sue S for reinstatement of the original price.

In contrast, under a *renegotiable* closed-price contract, redistributive price modifications are allowed, and like in an open-price contract, S may opportunistically use its acquired knowledge to increase its bargaining position. Unlike in an open-price contract, however, if the parties fail to modify a renegotiable closed price contract, the initially contracted price is enforced. This case may be relevant when the contract between B and S is purely bilateral and private, and hence more easily renegotiable, or when the costs of litigating in court are large, so that B and S may not find a reinstatement lawsuit worthwhile. We analyze the two kinds of closed-price contracts in turn below.

Case 1: A non-renegotiable closed-price contract

Knowing that renegotiation is not feasible, S will sell the good to B at stage 4, and B will pay the contracted price. Hence, when S invests at stage 2, it does not put any weight on the possibility to use knowledge as a threat in price negotiations. Formally, S's expected post-investment utility is

$$U_S^C(a) \equiv p - \underline{C} + q(a)c = p - \underline{C} + U_S^0(a) - \frac{1}{2}[q(a)(v-c) + \alpha(a)\omega], \tag{5}$$

and S's knowledge acquisition investment is

$$a^C \equiv \text{argmax}_a\{U_S^C(a) - a\}. \tag{6}$$

It follows from (5) and (1) and from concavity that $a^C < a^{FB}$ when $v > 0$ and $a^C = a^{FB}$ when $v = 0$. This proves the following:

Proposition 2: Under a non-renegotiable closed-price contract, S does not overinvest ($a^C \leq a^{FB}$).

Since S knows that under a closed-price contract, any attempt to renegotiate the price is bound to fail, it places zero weight on the threat effect when choosing its knowledge acquisition investment. Moreover, S places full weight on the potential cost reduction c, which benefits it directly, and zero weight on the potential value added v, which benefits B. Thus, if the value added v is negligible, a simple contract specifying the trading price will induce S to choose the first-best investment level. If instead the value added v is substantial, the contract will induce S to invest an amount that is less than that in the first-best scenario.

Given propositions 1 and 2, we can evaluate when a non-renegotiable closed-price contract increases or decreases S's knowledge acquisition investment, relative to the open-price scenario. It turns out that the answer crucially depends on the value of B's pre-existing resources. Let

$$\underline{\omega} \equiv \inf\{k \in R^+ | \frac{\partial}{\partial a}[q(a^C)(c-v) - \alpha(a^C)k \leq 0. \qquad (7)$$

Let us refer to an investment that benefits the counterpart more than the investing party as 'cooperative', and to an investment that benefits the investing party more than the counterpart as 'selfish', as in MacLeod and Malcomson (1993) and Che and Hausch (1999). When B's resources are valuable enough ($\omega > \underline{\omega}$), it follows from equation (4) and from concavity that $a^C < a^0$. The explanation is that S can inflict great harm on B by revealing its acquired knowledge. As a result, removing S's incentive to use acquired knowledge as a threat by contracting the price ex ante substantially reduces S's knowledge acquisition investment. The opposite is true when B's resources are not too valuable ($\omega < \underline{\omega}$). Note that, when S's knowledge acquisition investment is 'cooperative' (that is, it benefits B more than S, so that $v > c$), $\underline{\omega} = 0$, and a closed-price contract reduces S's incentive to invest irrespective of ω. These results are summarized by the following:

Proposition 3: A non-renegotiable closed-price contract reduces S's knowledge acquisition investment, relative to the open-price scenario, if, and only if, B's pre-existing resources are valuable enough ($\omega > \underline{\omega}$).

By affecting the relative knowledge acquisition investment levels in the non-renegotiable 'closed-price contract' and the 'open-price' scenarios, B's pre-existing resources indirectly affect the efficiency of these two contractual arrangements. We evaluate the effect of B's pre-existing resources on contract choice in the following:

Proposition 4: When the knowledge acquisition investment is 'cooperative' ($v > c$), a non-renegotiable closed-price contract is more efficient than an open price for high values of B's pre-existing resources (high ω), and less efficient for low values of B's pre-existing resources (low ω). When the investment is 'selfish' ($v < c$), a non-renegotiable closed-price contract is efficient for low and high values of B's pre-existing resources, but inefficient for intermediate values.

Proof: please refer to Appendix 2.

When B's pre-existing resources are not too valuable (low ω), S underinvests in knowledge acquisition both with and without a closed-price contract (propositions 1 and 2). In that case, the efficient governance is the one that maximizes S's investment – that is, an open-price contract when the investment is 'cooperative' ($v > c$), and a closed-price contract otherwise. As ω increases, S's incentive to acquire knowledge under an open-price contract also grows, because S can benefit more and more from using such knowledge as a threat in bargaining. For very large values of ω, S overinvests so much that the joint surplus under an open price contract falls below that under a closed-price contract. Consequently, the relationship between the efficiency of a non-renegotiable closed-price contract and the value of B's pre-existing capabilities is monotonic when $v > c$, and U-shaped when $v < c$.

Proposition 4 relates to recent empirical evidence by Lo *et al.* (2012), who investigate price formats between suppliers and buyers in technologically intensive industries. They find that in branded-component contracts, where a component is incorporated in, and co-branded with, the end-product, and when the OEM's customer strength (a proxy for ω) is high, the parties are more likely to specify the price ex ante than leave it open for ex post negotiation. This evidence holds after controlling for the parties' bargaining power, technological pace, and the complexity of the component-end-product interface. This finding cannot be easily explained by the transaction-cost view of contracts as a means to protect relationship-specific assets (e.g., Williamson, 1979), because the OEMs' pre-existing resources are *not* relationship-specific. That is, unless the supplier destroys the pre-existing resources through its harmful actions, or enriches them through its knowledge acquisition investment, they produce the same (or similar) value irrespective of whether the buyer buys from seller S or from an outside seller (Grossman and Hart, 1986; Williamson 1979). On the other hand, the evidence in Lo *et al.* (2012) seems consistent with our model: even if the OEMs' pre-existing resources are not relationship-specific, their value will diminish if the suppliers opportunistically disclose information on them. Hence, when the resources are highly valuable, contracting the price ex ante may be useful, as it reduces the suppliers' incentives to overinvest in knowledge acquisition in the hope to 'blackmail' the OEM later on.

Case 2: A renegotiable closed-price contract

We now consider the case where B and S cannot commit against redistributive renegotiations of the initially contracted price p. This scenario may arise because, for instance, the contract between B and S is private or the cost of judicially enforcing a fixed-price commitment is prohibitive. If the parties try to modify a renegotiable contract but fail to reach an agreement, the initially contracted price is enforced. Nevertheless, S may be able to force B to renegotiate the price by threatening to reveal its knowledge if B does not concede. Given Nash bargaining, B's and S's expected payoffs from such renegotiation are:

$$U_B^N \equiv \underline{V} - p + q(a)v + [1 - \alpha(a)]\omega + \frac{1}{2}\alpha(a)\omega, \text{ and} \tag{8}$$

$$U_S^N \equiv p - \underline{C} + q(a)c + \frac{1}{2}\alpha(a)\omega = U_S^0 + \frac{1}{2}q(a)(c - v). \tag{9}$$

Consequently, S's stage-2 knowledge investment is

$$a^N \equiv \text{argmax}_a\{U_S^N(a) - a\}, \tag{10}$$

where the superscript 'N' stands for 'closed-price contract and where the parties cannot commit against renegotiation. Given concavity, (3) and (9) imply the following

Proposition 5: A renegotiable closed-price contract decreases S's knowledge acquisition investment, relative to the open-price scenario, if, and only if the investment is cooperative ($v > c$).

When choosing how much to invest under a renegotiable closed-price contract, S places half weight on the harm it can cause to B by revealing its knowledge, as in the open-price scenario. The difference, relative to the open-price scenario, is that with a closed-price contract, S places more weight on the potential cost reduction c, and less weight on the value increase v. As a consequence, a contract will decrease S's incentive to invest in knowledge acquisition when $v > c$, and increase it when $v < c$.

Optimal contract design

Since renegotiable and non-renegotiable closed-price contracts induce different levels of knowledge investment, it is natural to ask which contracting mode is the most efficient one. It follows from (5) and (9) and from concavity that $a^N \geq a^C$, with $a^N = a^C$ for $\omega = 0$. This leads to our next proposition:

Proposition 6: Designing a closed-price contract in a way that prevents renegotiation is efficient when S's knowledge acquisition investment is, overall, not too productive (small $v + c$), and when the value ω of B's pre-existing resources is high enough.

Proof: please refer to Appendix 2.

If B and S choose to write a non-renegotiable closed-price contract ex ante, S will have no incentives to use knowledge as a threat in price negotiations. Therefore, S's knowledge acquisition investment would be smaller than if renegotiation were feasible. This is desirable when the loss from reducing S's knowledge acquisition investment (namely, a lower probability to achieve the efficiency gain $+c$) is not too large, and when the threatening potential of knowledge is strong (large ω), so that a renegotiable closed-price contract induces S to severely overinvest.

Proposition 6 provides a novel explanation, based on the trade-off between the productive and destructive effects of knowledge investment, for managerial practices that make contractual renegotiation difficult. For instance, if S is only one of B's similar suppliers or distributors, the price in its contract may be explicitly tied to the price applying to S's peers. Then revising S's price upwards would be prohibitively costly for B, as it would force B to simultaneously revise the price granted to S's peers. In fact, uniform and rigid contract terms have been observed in private procurement (Ben-Shahar and White, 2006). The same may occur if S is one of B's employees. In this case, S's salary may be explicitly tied to that of its peers through either formal compensation tiers (Milgrom and Roberts, 1988) or informal company-wide agreements (Levin, 2002).

Even when S's contractual position is unique – for instance, because it is the CEO of a company whose board B represents – B may commit not to raise S's compensation by making it explicit and public. Under these conditions, opportunistic renegotiation would be negatively interpreted by the firm's shareholders and other investors, and possibly punished through a no-confidence vote against B, or through a sale of shares.

We conclude this section by showing that the results obtained so far are qualitatively similar if we relax the assumption that B and S have equal bargaining power. To see this point in the starkest possible way, suppose that S has all the bargaining power, and thus it appropriates the entire surplus in case of negotiation. This may occur, for instance, if S relies on posted or take-it-or-leave-it prices, or if it monopolizes the manufacturing of a key component. Under an open-price contract, S would invest at the first-best level for $\omega = 0$, and overinvest for $\omega > 0$ (i.e., the overinvestment threshold ω^* in Proposition 1 would be 0) and S's investment would always be higher than under that of a closed-price contract (i.e., the overinvestment threshold $\underline{\omega}$ in Proposition 3 would also be 0). Moreover, the efficiency of a closed-price contract would monotonically increase in ω, irrespective of whether the investment is 'selfish' or 'cooperative' (first part of Proposition 4). In other words, provided that S has some bargaining power and that B brings vulnerable pre-existing resources to the relationship (that is, $\omega > 0$), our main finding that fixing the price ex ante is useful to prevent excess knowledge acquisition survives. In fact, this result is strengthened, when bargaining power is unevenly distributed.

GOVERNING KNOWLEDGE INVESTMENTS UNDER BOTH RENT-SEEKING AND EXPROPRIATION

We now extend our model to the case where, in addition to using its acquired knowledge as a threat in price negotiations, S may also use it to expropriate B's pre-existing resources. Formally, we assume that, in addition to the bargaining threat h at stage 4, S can take a second harmful action $m \in \{0,1\}$ at some stage after bargaining and before payoff realization. Action m is non-contractible and causes a loss $\beta(a)\omega$ to S. The key point is that, while action h does not benefit S directly, action m gives it a direct, private benefit $\pi(a)$. We assume $\beta(a)$ and $\pi(a)$ to be strictly increasing in S's knowledge acquisition investment and concave. In addition, to insure that S always chooses a positive investment level, we also assume: $q_a(0) > \max\left\{\frac{1}{c}, \frac{2-\alpha_a(0)\omega}{v+c}, \frac{1+\beta_a(0)\omega}{v+c}\right\}$. Note that, as for the efficiency gain probability $q(a)$ in the baseline model, we assume the private benefit from expropriation, $\pi(a)$, does not depend on the value of B's pre-existing resources, ω. We show in Appendix 1 that our results are robust when the former are allowed to interact with the latter.

Since action m is profitable for S and non-contractible, it cannot be used as a credible threat in bargaining – that is, S will always set $m = 1$ in equilibrium. As mentioned previously, an example of $m = 1$ could involve the seller exploiting its knowledge about the buyer's technology to compete with it in the downstream market (Arruñada and Vázquez, 2006; Alcacer and Oxley, 2014; Hamel *et al.*, 1989; The Economist, 2012), whereas examples of $h = 1$ would be the seller disclosing sensitive information on the buyer's technology and products to its competitors.

Given the possibility of expropriation, S's knowledge acquisition investment in the first best, an open-price contract, a non-renegotiable closed-price contract, and a renegotiable closed-price contract becomes, respectively:

$$a_{ex}^{FB} \equiv \text{argmax}_a\{q(a)(v+c) + \pi(a) - \beta(a) - a\}, \quad (11)$$

$$a_{ex}^{0} \equiv \text{argmax}_a\{U_S^0(a) + \pi(a) - a\}, \quad (12)$$

$$a_{ex}^{C} \equiv \text{argmax}_a\{U_S^C(a) + \pi(a) - a\}, \text{ and} \quad (13)$$

$$a_{ex}^{N} \equiv \text{argmax}_a\{U_S^N(a) + \pi(a) - a\}. \quad (14)$$

A few useful results follow from equations (11) through (14). First, the first-best investment decreases in ω, the value of B's pre-existing resources. Second, since the expropriation benefit $\pi(a)$ adds to S's rent-seeking utility under all contract forms, propositions 3, 4 and 5 continue to hold (although the critical thresholds for ω are not necessarily equal to those in the pure rent-seeking model). In particular, a closed-price contract reduces S's investment, relative to the open-price case, if and only if ω is large enough. Third, and in contrast with Proposition 2 in the rent-seeking model, S may overinvest, relative to the first best, even under a closed-price contract, provided that ω is large enough. That is because the closed-price investment does not depend on ω, while the first-best investment decreases in it. Given these results, our next proposition is:

Proposition 7: Relative to the open-price contract, a non-renegotiable closed-price contract reduces the expropriation caused by S's knowledge acquisition investment, if, and only if B's pre-existing resources are valuable enough (large enough ω). Relative to the open-price contract, a renegotiable closed-price contract reduces expropriation if, and only if S's knowledge investment is cooperative ($v > c$).

Proposition 7 suggests that S's ability to use the acquired knowledge to expropriate B's pre-existing resources is an additional determinant of whether B and S should sign a closed-price contract, and of how such contract on re-negotiability should be designed. Proposition 7 also offers testable predictions on how, by affecting knowledge acquisition investment, a chosen contractual form may affect frequently observed firms' behaviors, such as opportunistic movements up the value chain by contract manufacturers who rely on the technology gathered from their clients (Alcacer and Oxley 2014; Arruñada and Vázquez 2006).

EXTENSIONS TO THE BASELINE MODEL

Interaction between price terms and buyer's disclosure policy

In this section we explore the possibility that B may restrict S's knowledge acquisition investment directly, for instance, by limiting S's access to its own employees, materials and documents, or premises. To provide a comprehensive analysis, we allow harmful uses of knowledge by S to take the form of both rent-seeking and expropriation.

We begin by redefining the value and harm functions, respectively, as: $q(k)$, probability of within-relationship efficiency gain; $\pi(k)$, S's private expropriation benefit; $\alpha(k)\omega$, B's harm from S's rent-seeking; and $\beta(k)\omega$, B's harm from S's expropriation; where $k = \min\{a, b\}$ is S's acquired knowledge, a is S's knowledge acquisition investment, and b is the maximum amount of knowledge that B allows S to acquire as a result of its disclosure policies.

Importantly, we assume the productivity of B's knowledge investment is subject to an exogenous 'minimum learning constraint,' x, below which no ex post value creation or harm can arise:

$$q(k < x) = \alpha(k < x) = \beta(k < x) = \pi(k < x) = 0.$$

This assumption implies that if B's disclosure policy is $b < x$, then S's knowledge investment is unproductive, so S will choose $a = 0$, and the joint surplus will be $JS(0) = \underline{V} - \underline{C}$, under both a closed-price and an open-price contract. We further assume the minimum learning constraint is binding, in the sense that $\min\{JS(a^0), JS(a^C)\} > JS(0) = \underline{V} - \underline{C}$, so B would prefer not to use a disclosure policy at all than to completely hamper S's knowledge acquisition. This is the case if B's losses from ex post expropriation are not so severe as to make the joint gains from knowledge acquisition negative. Our approach is consistent with Hamel *et al*. (1989), Liebeskind (1996, 1997), and Arora and Merges (2004), among others, who have discussed the opportunity cost of non-disclosure in terms of forgone supplier's learning, or 'structural isolation' of sensitive information. The minimum learning constraint x is large, for instance, when S's component has a complex interface with B's end product. Under these conditions, to obtain a customized component, B must disclose at least some core information on its engineering designs, product drawings, and user preferences, to S as well as grant S's employees access to some of its own staff and premises.

To check the robustness of our analysis of price terms as a governance mechanism when non-disclosure is possible, we allow for maximum effectiveness of a disclosure policy by assuming b is contractible, so that B internalizes S's cost of investing in knowledge acquisition and would like to choose a jointly efficient disclosure level. In the same spirit, we assume the minimum learning constraint x is independent of ω, the value of B's pre-existing resources.[1] Finally, in studying knowledge disclosure and investment under open-price and closed-price contracts, and for brevity, we only consider the non-renegotiable closed-price contract case. Nonetheless, our analysis immediately extends to the case of a renegotiable contract.

Interaction between price terms and disclosure

A first issue we are interested in is whether the possibility to use a disclosure policy completely *substitutes* for a closed-price contract as a mechanism to govern S's knowledge acquisition, in the sense that it makes B switch from closed-price to open-price. A second and related issue is whether a disclosure policy can improve, if at all, upon the sole provision of incentives via open-price and closed-price contracts.

Let $JS^0 \equiv JS(a_{ex}^0)$ and $JS^C \equiv JS(a_{ex}^C)$ be, respectively, the open-price and closed-price joint surpluses in the absence of disclosure policy, and let $JS^{0D} \geq JS^0$ and $JS^{CD} \geq JS^C$ be the surpluses when a disclosure policy is feasible. Then, we have the following result.

Proposition 8: Assume that, if a disclosure policy is not feasible, the optimal mechanism to govern knowledge acquisition is the closed-price contract ($JS^C > JS^0$). Then, there exists a threshold $\underline{x} \geq 0$ such that, (i) when a disclosure policy is feasible, it completely substitutes the closed price contract if S's minimum learning constraint is small ($x < \underline{x}$), whereas it does not substitute it ($JS^{CD} > JS^{0D}$) if the minimum learning constraint is large

1. If instead x increased in ω (for instance, if more valuable buyer's resources were also more complex), disclosure policies aimed at reducing S's overinvestment would become less effective precisely when overinvestment is likely—that is, at high levels of ω.

($x > \underline{x}$). Moreover, there exists $\overline{x} > \underline{x}$ such that (ii) the possibility to impose a disclosure policy is not used by B ($JS^{CD} = JS^{C}$ and $JS^{0D} = JS^{0}$) if S's minimum learning constraint is very large ($x > \overline{x}$).

Proof: please refer to the Appendix 2.

An intuitive implication of Proposition 8 is that, as B needs to disclose more information to S to insure value creation (formally, as x grows), a disclosure policy becomes less and less binding, and hence a less useful tool to govern S's knowledge acquisition. One could test this prediction by collecting survey data on the use of disclosure policies by buyers, as well as on transaction characteristics that, as discussed earlier on, may raise the minimum learning constraint x—for instance, complexity of the interface between the buyer's end product and the supplier's components.

Governing knowledge investments under repeated interactions

So far we have focused on a formal, arm's length procurement contract. In this section, we extend our model to study the effect of suppliers' and buyers' concerns for future transactions on the use of price terms in governing the acquisition and use of knowledge.

In particular, we allow for *many* buyers and suppliers to interact over an infinite sequence of periods, each buyer being matched to one (potentially different) supplier in each period. We assume for simplicity that all buyers are identical, and likewise for the suppliers. To emphasize the importance of repeated interactions, we also assume that in any given period t, while a buyer does not observe its supplier's knowledge acquisition investment in previous relationships, it observes whether the supplier has used its knowledge through either bargaining or expropriation to harm its past clients. Moreover, we assume a supplier observes the history of its client's payments to previous suppliers (i.e., whether previous suppliers have been paid, and how much). We interpret observability of past actions as the product of communication back-channels between buyers and suppliers in the same industry.

Given repeated interactions with a supplier, a buyer can extend its formal price contract by adding an informal provision whereby the supplier promises not to engage in rent-seeking and expropriation, in exchange for a share of the increased joint profits. Specifically, we follow the convention in repeated-game models of relational contracts (e.g., Baker *et al*., 2002), and we allow, in any given period, for the buyer to make an advance informal payment τ to its supplier (for surplus-splitting purposes), followed by a price adjustment ρ, conditional on the efficiency gain $(v + c)$ being realized, and by a 'good standing' bonus λ, conditional on the supplier not using its knowledge to expropriate the buyer. All the informal monetary payments are unrestricted in sign—that is, they could as well be negative. Thus, in any given period, a buyer's payoff under the informal contract is $U_B^I(\rho) \equiv \underline{V} - \tau + q[a(\rho)](v - \rho) - \lambda$, and its supplier's payoff is $U_S^I(\rho) \equiv \tau - \underline{C} + q[a(\rho)](c + \rho) + \lambda - a(\rho)$, where $a(\rho) \equiv \text{argmax}_a\{q(a)(c + \rho) - a\}$ is the supplier's knowledge investment conditional on the promised price adjustment. Accordingly, the per period joint surplus is $\text{JS}^I(\rho) \equiv U_B^I(\rho) + U_S^I(\rho)$.

We analyze informal contracts as stationary, trigger-strategy equilibria of the infinitely repeated game: all parties keep cooperating until somebody reneges, in which case cooperation stops forever after—that is, the buyer (supplier) stops honoring its informal contract with the reneging supplier (buyer), and it also warns the other buyers (suppliers) not to enter informal contracts with him in the future. As standard (e.g., Baker *et al*., 1994), we assume the relationship between a reneging party and its future counterparts will be governed by an optimal arm's length formal contract (either open-price or closed-price), as defined in previous sections. We denote a supplier's per period payoff under the optimal formal contract as U_S^F, a buyer's payoff as U_B^F, and the joint surplus as $\mathrm{JS}^F \equiv U_B^F + U_S^F$.

We now turn to analyze the interaction between formal open-price and closed-price contracts and the informal contract described above. Our analysis follows the spirit of many recent studies that emphasize the interaction between formal and informal contracts (e.g., Baker *et al.*, 1994, 2011; Corts and Singh, 2004; Klein, 2000; Poppo and Zenger, 2002; Ryall and Sampson, 2009; for recent reviews see Cao and Lumineau, 2014 and Gil and Zanarone, 2015).

For an informal contract to be self-enforcing, the buyer and the supplier must be willing to pay and accept the informal price adjustment instead of bargaining (if the formal contract is open price) or enforcing the formally agreed price (if the formal contract is closed price), and to pay and accept the end-of-period bonus instead of facing expropriation. Let $\overline{p}(\rho) \equiv \frac{1}{2}\{\underline{V} + \underline{C} + v - c + \alpha[a(\rho)]\omega\}$ and $\underline{p}(\rho) \equiv \frac{1}{2}\{\underline{V} + \underline{C} + \alpha[a(\rho)]\omega\}$ be the Nash bargaining prices when the efficiency gain is and is not realized, respectively. Let $p^C \in [\underline{C}, \underline{V}]$ be the price specified in a formal closed price contract. Finally, let r be the rate at which the buyer and supplier discount future payoffs—for instance, based on how soon they expect to exit the market. Then, we prove in Appendix 2 that informal contracts backed by a formal open price and by a closed-price term are self-enforcing, respectively, if, and only if:

$$\pi[a(\rho)] - \beta[a(\rho)]\omega + max\left\{\rho - \overline{p}(\rho); \overline{p}(\rho) - \rho; \underline{p}(\rho)\right\} \leq \frac{1}{r}[\mathrm{JS}^I(\rho) - \mathrm{JS}^F], \text{ and} \quad (\mathrm{SE^{OP}})$$

$$\pi[a(p)] - \beta[a(p)]\omega + \max\{\rho - p^C; p^C - \rho; p^C\} \leq \frac{1}{r}[\mathrm{JS}^I(\rho) - \mathrm{JS}^F]. \quad (\mathrm{SE^{CP}})$$

In words, the buyer's and supplier's discounted expected future gains from honoring the informal contract (the right-hand side) must exceed their present temptation to renege (the left-hand side). Given the above conditions, the buyer will choose an informal price adjustment ρ that induces its supplier to choose the level of knowledge investment that maximizes the joint surplus

$\mathrm{JS}^{I}(\rho)$, subject to self-enforcement constraint ($\mathrm{SE}^{\mathrm{OP}}$) when the underlying formal contract is open price, and to constraint ($\mathrm{SE}^{\mathrm{CP}}$) when the formal contract is closed price. We denote the surpluses under such optimal contracts as JS^{I0} and JS^{IC}, respectively.

Notice that the buyer can make ($\mathrm{SE}^{\mathrm{CP}}$) looser than ($\mathrm{SE}^{\mathrm{OP}}$), without changing the supplier's incentives to acquire knowledge, by appropriately choosing p^{C}. We assume that, if an informal contract backed by an open-price contract and one backed by a closed-price contract yields the same surplus, a buyer prefers the open-price contract—for instance, because it allows him to avoid contractual formalities. Then, we have the following result:

Proposition 9: When the buyers' and suppliers' concern for future engagements is strong (low r), an informal contract always achieves the first best ($\mathrm{JS}^{I0} = \mathrm{JS}^{IC} = \mathrm{JS}(a_{ex}^{FB})$), so a formal closed-price contract is not necessary. When the buyers' and suppliers' concern for future transactions is moderate (medium r), an informal contract improves on a purely formal one but does not achieve the first best ($\mathrm{JS}^{F} < \max\{\mathrm{JS}^{I0}, \mathrm{JS}^{IC}\} < \mathrm{JS}(a_{ex}^{FB})$), so a formal closed-price contract should be used to reduce the parties' reneging temptation. Finally, when the buyers' and suppliers' concerns for future transactions are weak (high r), the optimal contract is purely formal ($\mathrm{JS}^{F} > \max\{\mathrm{JS}^{I0}, \mathrm{JS}^{IC}\}$), and it includes a closed-price contract if, and only if $\mathrm{JS}(a_{ex}^{C}) > \mathrm{JS}(a_{ex}^{0})$.

Proposition 9 suggests a non-monotonic relationship between repeated interactions and the use of formal price terms. Moving from a scenario where buyers and suppliers are mostly involved in arm's length relationships—and hence buyers must rely on formal price contracts to govern their suppliers—to one characterized by some degree of interconnection and repeated interaction, favors the use of informal pricing agreements that provide suppliers with superior incentives to acquire and use their clients' knowledge. In this context, it is advisable to use formal closed-price contracts to *complement* relational enforcement by reducing the parties' temptation to breach the informal pricing agreements and bargain opportunistically. When buyers and suppliers are strongly embedded in within-industry networks, the need to use formal price terms as a deterrent disappears, and buyers can entirely rely on repeated interactions to prevent opportunism and govern knowledge transfers in their supply chains. Consistent with the literature on the interaction between formal and informal contracts, these results confirm the importance of formal closed-price contracts as tools to govern the acquisition and use of knowledge in supply chains, even in the presence of repeated interactions.

Proposition 9 is potentially testable, as its predictions only require to observe formal price contracts—something that existing studies have been able to measure (e.g., Crocker and Reynolds, 1993; Ghosh and John, 2005; Lo *et al*., 2012) — and the degree to which buyers and suppliers care about future transactions (i.e., their discount rates). The latter empirical requirement is more challenging, but empirical studies have developed plausible strategies to satisfy it (see Gil and Zanarone, 2015 for a recent survey).

DISCUSSION

This paper investigates the role of contracts in managing knowledge acquisition within buyer-supplier relationships. Drawing on observed business practice, we argue that a supplier's investments to acquire knowledge on its buyer's pre-existing resources may be used ex post both productively, to create value and, destructively, to gain favors in price negotiations and to expropriate the buyer's resources. If the destructive effect dominates, the supplier may have an incentive to *overinvest* in knowledge acquisition. We show that a closed-price contract that specifies the price of the supplier's component upfront may *reduce* the supplier's incentives to both overinvest ex ante and expropriate ex post, especially if the contract is designed in a way that discourages renegotiation. We also demonstrate that a non-renegotiable closed-price contract is more efficient when the buyer's pre-existing resources are highly valuable, and hence more vulnerable to the revelation, or use, of sensitive knowledge by the supplier outside of the focal agreement. Finally, our analysis indicates that direct tools for governing knowledge acquisition, such as buyer's limited disclosure policies and informal agreements based on repeated interactions, may complement indirect governance via price terms.

Our paper yields new insights for theory on the role of contract design in managing knowledge acquisition and protecting non-relationship-specific resources in collaborative arrangements. Scholars have long emphasized how firms use knowledge acquired on their partners' pre-existing resources and capabilities to create value. However, supported by anecdotal evidence, studies have also noted a 'dark side' of knowledge acquisition, whereby a focal firm's pre-existing resources may emerge as potential hazards, being subject to a partner's rent-seeking threat and opportunistic appropriations. When the involved knowledge is tacit and the value of vulnerable pre-existing resources is hard to verify, explicit or direct safeguards may not be feasible. Under these circumstances, our model shows that specifying the price terms upfront reduces a supplier's incentive to over-invest in knowledge acquisition in the hope to use such knowledge as a bargaining chip, and through that channel, it also reduces the supplier's ability to expropriate its partner's resources ex post.

While the rich literature based on Transaction Cost Economics emphasizes the role of contracts in protecting relationship-specific assets from opportunism, prior work is relatively silent on the role of contracts in protecting non-specific resources and capabilities that firms bring to collaborative relationships. Our formal model fills this gap by showing that whether a closed-price contract is efficient, and whether it should be made renegotiable or not, depends on how vulnerable a buyer's pre-existing resources are to its supplier's opportunistic revelation or use of sensitive knowledge. Extending the transaction-cost perspective, our theory emphasizes the critical role that pre-existing, non-relationship specific assets play in determining contract terms, and in turn in creating and capturing value. Taken together, the results suggests that future studies of collaborative arrangements and the determinants of contract designs should consider the role of pre-existing resources, in addition to that of assets developed within the relationship.

Some of our results are consistent with observed practice. For instance, Lo *et al.* (2012) find that in branded-component contracts, where a component is incorporated in, and co-branded with, the end-product, and when the OEM's pre-existing customer strength is high, parties in an exchange are more likely to specify the price ex ante than leave it open for ex post negotiation. Most importantly, our theory is testable. Measures of the key variables are available or can be developed. For example, one can estimate the value of vulnerable, pre-existing resources from companies' cumulative experience in functional areas such as R&D or manufacturing (Leiblein and Madsen, 2009; Powell *et. al*., 1996), reputation scores from public documents (e.g., Fortune magazine's report of 'America's Most Admired Corporations'; Roberts and Dowling, 2002), intangible assets using Tobin'q (e.g., Villalonga, 2004), the extent of potential expropriation from the number of suppliers who later compete with their previous buyers and partners (Alcacer and Oxley, 2014), and a supplier's knowledge acquisition effort from the number of manhours, adjusted by the human capital stock of employees (e.g., experience, education, etc.), involved in collaborations with the buyer. Data on contractual price terms and the use of limited disclosure policies can be obtained by surveying buyers and suppliers (e.g., Crocker and Reynolds, 1993, Lo *et al*., 2012). While identification problems often arise in field data, these can be mitigated by including appropriate controls for unobserved heterogeneity—for instance, the buyer's and seller's bargaining power and the complexity of the buyer's technology (Lo *et al*., 2012) in tests of Proposition 4. Moreover, some of our predictions, such as those in Proposition 5 through 8, are inconsistent with holdup models that do not involve knowledge acquisition investments. As such, future empirical work that considers the role of knowledge acquisition investments may complement our findings as compared to those of traditional holdup models.

Similar to other studies, our model has its limitations. We discuss three of them below. First, we only consider knowledge acquisition investment by the supplier. It may be interesting to extend the model to the case where the buyer also invests in knowledge acquisition and has a chance to threaten or expropriate the supplier. In addition, our model directs attention to a buyer's bundle of pre-existing resources rather than examining a particular category of pre-existing resources. Future research might disaggregate the bundle to examine the conditions under which particular types of pre-existing resources have a larger influence on the likelihood and success of destructive and productive behaviour by a supplier. Finally, we focus on the case where the seller's good is valuable to the buyer even if it is not customized (although the good may become more valuable if the seller invests in knowledge acquisition). Extending our model to the case where the transaction may lose value in some states (for instance, due to an unexpected increase in the seller's production cost or a decrease in the demand for the buyer's end product) may generate interesting predictions about whether an optimal closed price contract should take the form of a fixed price (as in our model) or a price formula (see Bajari and Tadelis, 2001; Goldberg, 1985; Lafontaine and Masten, 2002; Masten, 2009). Nevertheless, several formal models show that, in some environments where the optimal level of trade is uncertain, simple contracts like the ones we model may be preferable to complex formulae (e.g., Edlin and Richelstein, 1996; MacLeod and Malcomson, 1993; Maskin and Tirole, 1999).

In sum, our paper provides a novel theory of how price terms can optimally balance the productive and destructive effects of knowledge acquisition investment in collaborative relationships, thus safeguarding the partners' pre-existing resources and capabilities. Our theoretical results are consistent with observed practice, are amenable to further empirical testing, and offer new insight for managers on how contracts should be designed when collaborative relationships require parties to acquire sensitive knowledge on their partners. Further explorations of how formal price and other contractual terms, in combination with disclosure policies and informal agreements govern knowledge investments under different firm boundaries, constitute important research opportunities that we hope to pursue in the future.

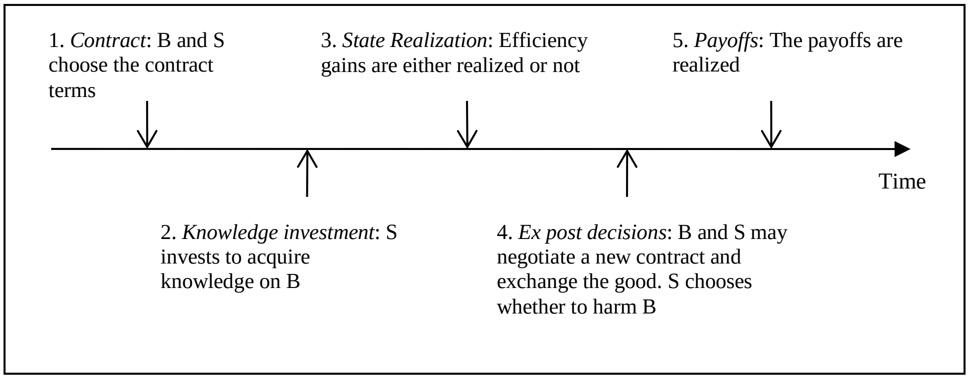

Figure 1. Timeline of events

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REFERENCES

Alcacer J, Oxley J. 2014. Learning by Supplying. *Strategic Management Journal* **35**: 204-223.

Anderson E, Jap S. 2005. The Dark Side of Close Relationships. *MIT Sloan Management Review* **46**: 74–82.

Argyres N, Bercovitz J, Mayer KJ. 2007. Complementarity and evolution of contractual provisions: an empirical study of IT services contracts. *Organization Science* **18**: 3-19.

Argyres N, Zenger T. 2012. Capabilities, transaction costs and firm boundaries. *Organization Science*, **23**: 1643-1667.

Arora A, Merges R. 2004. Specialized Supply Firms, Property Rights and Firm Boundaries. *Industrial and Corporate Change* **13**: 451-475.

Arruñada B, Vazquez XH. 2006. When Your Contract Manufacturer Becomes Your Competitor. *Harvard Business Review* September.

Baker G, Gibbons R, Murphy K. 1994. Subjective Performance Measures in Optimal Incentive Contracts. *Quarterly Journal of Economics* **109**: 1125-56.

Baker G, Gibbons R, and Murphy K. 2002. Relational Contracts And The Theory Of The Firm. *Quarterly Journal of Economics* **117**: 39-84.

Bajari P, Tadelis S. 2001. Incentives versus Transaction Costs: A Theory of Procurement Contracts. *RAND Journal of Economics* **32**: 387–407.

Barney JB 1989. Asset Stocks and Sustained Competitive Advantage - a Comment. *Management Science* **35:** 1511-1513.

Barney JB. 1991. Firm resources and sustained competitive advantage. *Journal of Management* **17**, 99-120.

Ben-Shahar O, White J. 2006. Boilerplate and Economic Power in Auto Manufacturing Contracts. *Michigan Law Review* **104**: 953–982.

Bonte W. 2008. Interfirm Trust in Buyer-Supplier Relations: Are Knowledge Spillovers and Geographic Proximity Relevant? *Journal of Economic Behavior and Organization* **67**: 855-870.

Cao Z, Lumineau F. 2014. Revisiting the Interplay Between Contractual an Relational Governance: a Qualitative and Meta-Analytic Investigation. Forthcoming in *Journal of Operations Management*.

Che Y, Hausch D. 1999. Cooperative Investments and the Value of Contracting. *American Economic Review* **89**: 125–147.

Corts K, Singh J. 2004. The Effect of Repeated Interaction on Contract Choice: Evidence from Offshore Drilling. *Journal of Law, Economics and Organization* **20**: 230-260.

Crocker K, Reynolds K. 1993. The Efficiency of Incomplete Contracts: An Empirical Analysis of Air-Force Engine Procurement. *RAND Journal of Economics* **24**: 126–146.

Das T, Teng B. 1998. A Resource-based Theory of Strategic Alliances. *Journal of Management* **26**: 31-61.

David R, Han S. 2004. A systematic assessment of the empirical support for transaction cost economics. *Strategic Management Journal,* **25**: 39-58.

Dierickx I, Cool K. 1989. Asset Stock Accumulation and Sustainability of Competitive Advantage. *Management Science.* **35:** 1504-1514.

Dussauge P, Garrett B, Mitchell, W. 2000. Learning from Competing Partners: Outcomes and Durations of Scale and Link Alliances in Europe, North America and Asia. *Strategic Management Journal* **21**: 99-126.

Edlin A, Reichelstein S. 1996. Holdups, Standard Breach Remedies, and Optimal Investment. *American Economic Review* **86**: 478–501.

Garmaise M. 2009. Ties that Truly Bind: Noncompetition Agreements, Executive Compensation, and Firm Investment. *Journal of Law, Economics and Organization* **27**: 376-425.

Ghosh M, John G. 1999. Governance Value Analysis and Marketing Strategy. *Journal of Marketing* **63**: 131–145.

Ghosh M, John G. 2005. Strategic Fit in Industrial Alliances: An Empirical Test of Governance Value Analysis. *Journal of Marketing Research* **42**(3): 346–357.

Gil R, Zanarone G. 2015. On the Determinants and Consequences of Informal Contracting. Working paper, Johns Hopkins University.

Goldberg V. 1985. Price Adjustment in Long-Term Contracts. *Wisconsin Law Review* 527–543.

Grant R. 1996. Toward a Knowledge-Based Theory of the Firm. *Strategic Management Journal* **17**: 109–122.

Grant R, Baden-Fuller C. 2004. A Knowledge Accessing Theory of Strategic Alliances. *Journal of Management Studies* **41:** 61-84.

Grossman S, Hart O. 1986. The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration. *Journal of Political Economy* **94**: 691–719.

Hamel G, Doz Y, Prahalad CK. 1989. Collaborate with Your Competitors – and Win. *Harvard Business Review* Jan.–Feb.: 133–139.

Harhoff D, Henkel J, von Hippel, E. 2003. Profiting from voluntary information spillovers: how users benefit from freely revealing their innovations. *Research Policy* **32**: 1753-1769.

Hart O, Moore J. 1988. Incomplete Contracts and Renegotiation. *Econometrica* **56**: 755–785.

Hart O, Moore J. 2008. Contracts as Reference Points. *Quarterly Journal of Economics*, **123**: 1–48.

Khanna T, Gulati R, Nohria N. 1998. The dynamics of learning alliances: competition, cooperation, and relative scope. *Strategic Management Journal* **19**:193–210.

Klein B. 2000. The Role of Incomplete Contracts in Self-Enforcing Relationships. *Revue d'Economie Industrielle* **92:** 67-80.

Kogut B. 1988. Joint ventures: theoretical and empirical perspectives. *Strategic Management Journal* **9**: 319–32.

Lafontaine, F, Masten S. 2002. Contracting in the Absence of Specific Investments and Moral Hazard: Understanding Carrier-Driver Relations in U.S. Trucking. NEBR working paper #8859, National Bureau of Economic Research, Cambridge, MA. Available at: http://www.nber.org/papers/w8859.

Lafontaine F, Slade M. 2013. Inter-Firm Contracts. In *The Handbook of Organizational Economics*, Gibbons R, J. (eds). Princeton University Press: Princeton, NJ; 958–1013.

Leiblein MJ, Madsen TL. 2009. Unbundling Competitive Heterogeneity: Incentive Structures and Capability Influences on Technological Innovation. *Strategic Management Journal* **30**: 711-735.

Levin J. 2002. Multilateral Contracts and the Employment Relationship. *Quarterly Journal of Economics* **117**: 1075–1103.

Liebeskind J. 1996. Knowledge, Strategy and the Theory of the Firm. *Strategic Management Journal* **17**: 93-107.

Liebeskind J. 1997. Keeping Organizational Secrets: Protective Institutional Mechanisms and their Costs. *Industrial and Corporate Change* **6**: 623-663.

Lo D, Frias K, Ghosh M. 2012. Pricing Formats for Branded Components in Industrial Markets: An Integration of Transaction Cost Economics and the Resource-Based View. *Organization Science* **23**: 1282–1297.

Lyons T, Krachenberg A, Henke J. 1990. Mixed Motive Marriages: What's Next for Buyer-Suppler Relations? *MIT Sloan Management Review* **31**: 29–36.

Macher J, Richman B. 2008. Transaction Cost Economics: An Assessment of empirical research in the social sciences. *Business and Politics* **10**: 1-63.

MacLeod B, Malcomson J. 1993. Investments, Holdup, and the Form of Market Contracts. *American Economic Review* **83**: 811–837.

Mansfield E. 1985. How Rapidly Does New Industrial Technology Leak Out? *Journal of Industrial Economics* **34**: 217-223.

Maskin E, Tirole J. 1999. Unforeseen Contingencies and Incomplete Contracts. *Review of Economic Studies* **66**: 83–114.

Masten S. 2009. Long-Term Contracts and Short-Term Commitment: Price Determination for Heterogeneous Freight Transactions. *American Law and Economics Review* **11**: 79–111.

Milgrom P, Roberts J. 1988. An Economic Approach to Influence Activities in Organizations. *American Journal of Sociology* **94**: 154–179.

Mintzberg H. 1989. *Mintzberg on Management: Inside Our Strange World of Organizations.* The Free Press: New York, NY.

Mohr J, Sengupta, S. 2002. Managing the Paradox of Inter-Firm Learning: the Role of Governance Mechanisms. *Journal of Business and Industrial Marketing* **17**: 282-301.

Mowry D, Oxley J, Silverman B. 1996. Strategic Alliances and Interfirm Knowledge Transfers. *Strategic Management Journal* **17**: 77-91.

Oxley J. 1997. Appropriability Hazards and Governance in Strategic Alliances: A Transaction Cost Approach. *Journal of Law, Economics and Organization* **13**: 387–409.

Oxley J. 1999. *Governance of International Strategic Alliances: Technology and Transaction Costs.* Harwood Academic Publishers: Amsterdam.

Oxley J, Sampson R. 2004. The scope and governance of international R&D alliances. *Strategic Management Journal* **25**:723-749.

Peteraf M. 1993. The Cornerstone of Competitive Advantage: A Resource-Based View. *Strategic Management Journal* **14**: 179–191.

Pisano G. 1988. Innovation through market hierarchies, and joint ventures: Technology, strategy and collaborative arrangements in the biotechnology industry. Unpublished PhD dissertation, University of California, Berkeley.

Pooley J. 1997. The Top Ten Issues in Trade Secrets Law. *Temple Law Review* **70**: 1181-1190.

Poppo L, Zenger, T. 2002. Do formal contracts and relational governance function as substitutes or complements? *Strategic Management Journal* **23**: 707-725.

Powell W, Koput K, Smith-Doerr L. 1996. Interorganizational collaboration and the locus of innovation: networks of learning in biotechnology. *Administrative Science Quarterly* **41**: 116–145.

Reuer J, Arino A. 2007. Strategic Alliance Contracts: Dimensions and determinants of contractual complexity. *Strategic Management Journal* **28**: 313-330.

Roberts PW, Dowling GR. 2002. Corporate reputation and sustained superior financial performance. *Strategic management journal **23***: 1077-1093.

Ryall M, Sampson R. 2009. Formal Contracts in the Presence of Relational Enforcement Mechanisms: Evidence from Technology Development Projects. *Management Science* **55**: 906-925.

Rosetti C, Choi TY. 2005. On the dark side of strategic sourcing: Experiences from the aerospace industry. *Academy of Management Executive* **19**: 46-60.

Rumelt R. 1984. Toward a Strategic Theory of the Firm. In *Competitive Strategic Management*, Lamb, R. (ed.). Prentice-Hall: Englewood Cliffs, New Jersey; 556-570.

Schepker D, Oh W, Martynov A, Poppo L. 2014. The Many Futures of Contracts: Moving Beyond Structure and Safeguarding to Coordination and Adaptation. *Journal of Management* **40**: 193-225.

Schwartz, A. 1992. Relational Contracts in the Courts: An Analysis of Incomplete Agreements and Judicial Strategies. *Journal of Legal Studies* **21**: 271–318.

Susarla A. 2012. Contract Flexibility, Rent Seeking, and Renegotiation Design: An Empirical Analysis of Information Technology Outsourcing Contracts. *Management Science* **58**: 1388–1407.

Tadelis S, Williamson O. 2013. Transaction Cost Economics. In *The Handbook of Organizational Economics*, Gibbons, R., and J. Roberts (eds.). Princeton University Press: Princeton, New Jersey; 159-189.

The Economist. 2012. Apple v Samsung: Swipe, Pinch and Zoom to the Courtroom. 1 September: 61–62.

Villalonga B. 2004. Intangibles Resources, Tobin's *q*, and the Sustainability of Performance Differences. *Journal of Economic Behavior and Organization* **54**: 205–231.

Williamson O. 1979. Transaction-Cost Economics: The Governance of Contractual Relations. *Journal of Law and Economics* **22**: 233–261.

Zanarone G. 2013. Contract Adaptation under Legal Constraints. *Journal of Law, Economics and Organization* **29**: 799-834.

Appendix 1. A general model with flexible functional forms

In this appendix, we allow more functional flexibility in our model. To illustrate, we use the version of our model that includes both rent-seeking and expropriation. We redefine the efficiency gain from S's knowledge investment as $q(a,\omega)[v(\omega)+c(\omega)]$, the rent-seeking harm as $\alpha(a,\omega)d(\omega)$, and the net expropriation harm as $\beta(a,\omega)d(\omega)-\pi(a,\omega)$, where $v_\omega \geq 0$, $c_\omega \geq 0$, and $d_\omega > 0$. We subsequently evaluate the relationship between B's choice of contractual price form and the value of its pre-existing resources, ω. We interpret $q(a,\omega)$, $\alpha(a,\omega)$ and $\beta(a,\omega)$, respectively, as the value-creation, rent-seeking, and expropriation potentials enabled by S's knowledge acquisition, and $v(\omega)+c(\omega)$ and $d(\omega)$, respectively, as potential efficiency gains and B's losses.

As a first step, we analyze the relationship between ω and S's overinvestment under an open price (Proposition 1 in the baseline model). Recall that

$$U_S^0 \equiv \frac{1}{2}[q(a)(v+c)+\alpha(a)\omega] \text{ and}$$

$$JS = q(a)(v+c)+\pi(a)-\beta(a)\omega-a.$$

Given definitions (11) through (13), overinvestment occurs if, and only if

$$\partial[U_S^0(a_{ex}^{FB})+\pi(a_{ex}^{FB})-a_{ex}^{FB}]/\partial a > \partial[U_S^0(a_{ex}^{0})+\pi(a_{ex}^{0})-a_{ex}^{0}]/\partial a = 0.$$

After substituting the generalized harm and value functions, and dropping all the functional arguments for notational simplicity, we rewrite this condition as

$$JS_a+\beta_a d-\frac{1}{2}q_a(v+c)+\frac{1}{2}\alpha_a d > 0.$$

Since $JS_a(a_{ex}^{FB})=0$ by definition of the first best, we further rewrite the above equation as

$$\Delta \equiv (\alpha_a+2\beta_a)d-q_a(v+c) > 0. \tag{A1}$$

The likelihood of overinvestment increases in ω if $\Delta_\omega > 0$, or

$$[(\alpha_{a\omega} + 2\beta_{a\omega})d - q_{a\omega}(v + c)] + [(\alpha_a + 2\beta_a)d_\omega - q_a(v + c)(v_\omega + c_\omega)] + \frac{\partial a^{FB}}{\partial \omega}[(\alpha_{aa} + 2\beta_{aa})d - q_{aa}(v + c)] > 0. \quad \text{(A2)}$$

Moreover, the first-order condition of the first-best program (1) implies

$$\frac{\partial a_{ex}^{FB}}{\partial \omega} \equiv \frac{(\beta_{a\omega}d - \pi_{a\omega}) + \beta_a d_\omega - q_{a\omega}(v+c) - q_a(v_\omega + c_\omega)}{q_{aa}(v+c) - (\beta_{aa} - \pi_{aa})}. \quad \text{(A3)}$$

Conditions (A2) and (A3) say that the likelihood of overinvestment increases in ω if S's ability to cause harm using its knowledge is potentially broader than its ability to create value—formally, if $\alpha_{a\omega}$ and $\beta_{a\omega}$ are large relative to $q_{a\omega}$ and $\pi_{a\omega}$, or α_a and β_a are large relative to q_a, or d_ω is large relative to $v_\omega + c_\omega$, or α_{aa} and β_{aa} are large relative to q_{aa} and π_{aa}. We interpret these conditions empirically toward the end of the Appendix.

We now analyze the extent to which a closed price contract can be used to reduce S's overinvestment (Proposition 3 in the baseline model). Suppose that S's knowledge investment is "cooperative", in the sense that its main added value is to improve the quality of B's end product ($v(\omega) > c(\omega)$). Then, a closed-price contract reduces S's investment if, and only if $\partial[U_S^0(a_{ex}^C) + \pi(a_{ex}^C) - a_{ex}^C]/\partial a > \partial[U_S^0(a^0) + \pi(a_{ex}^0) - a_{ex}^0]/\partial a = 0$.

Recall that $U_S^C = q(a)c$ and that, by definition of closed price contract, it must be $\partial[U_S^C + \pi(a_{ex}^C) - a_{ex}^C]/\partial a = 0$. Suppressing the arguments, we thus rewrite the above condition as

$$\partial\left[U_S^C + \pi - a_{ex}^C + \tfrac{1}{2}q(v - c) + \tfrac{1}{2}\alpha d\right]/\partial a > 0, \text{ or}$$

$$\alpha_a d + q_a(v - c) > 0, \quad \text{(A4)}$$

which holds for all ω. Combining (A2) and (A4), we obtain the following result.

Generalized Proposition 4: Suppose (A2) holds. Then, when S's knowledge investment is "cooperative" ($v(\omega) > c(\omega)$), a non-renegotiable closed-price contract is more efficient than an open price for high values of B's pre-existing resources (high ω), and less efficient for low values of B's resources (low ω).

The above analysis shows that the positive association between buyer's pre-existing resources and the use of a closed-price contract obtained from our baseline model, where we assumed $v_\omega = c_\omega = \alpha_{a\omega} = \beta_{a\omega} = q_{a\omega} = \pi_{a\omega} = 0$ and $d_\omega = 1$, continues to hold in a more general setting provided that the potential harm from S's knowledge investment is broad relative to the potential efficiency gain (condition A2). This will be the case if B's technology (e.g., product concept and design) is applicable across product lines (broad potential damage), while the component S produces for B (e.g., a semiconductor chip) is specific to only a part of those products (concentrated gain), or if S can collect sensitive information on B's clients, product portfolio, and organization even without fully mastering B's production technology or product architecture. These conditions seem to fit many industrial equipment, IT, and biotech businesses. Consistent with that, Hamel *et al*. (1989) discuss how a Japanese product development engineer was able to take diligent notes on the partner's plant layout and assembly line, even though he was *not* a manufacturing person, and conclude that "[c]ollaboration doesn't always provide an opportunity to fully internalize a partner's skills. Yet just acquiring new and more precise benchmarks on a partner's performance can be of great value [in competing with the partner]" (p. 139). More generally, the idea that clever suppliers can collect potentially harmful information that does not necessarily have a direct relationship to the focal product or service they offer to their clients is emphasized by several case studies on contract manufacturers who become their clients' competitors (Arruñada and Vázquez 2006; Rossetti and Choi, 2005), and on suppliers who learn of loopholes in their clients' monitoring and control procedures and take advantage of it to shirk (Anderson and Jap, 2005).

Appendix 2. Mathematical proofs

Proof of Proposition 1: Given concavity, (1), (3) and (4) imply that a^0increases in ω and that $a^0 < a^{FB}$for $\omega = 0$. Hence, there must be a critical value $\omega^* > 0$ such that $a^0 < a^{FB}$for $\omega < \omega^*$and $a^0 > a^{FB}$for $\omega > \omega^*$. QED.

Proof of Proposition 4: A non-renegotiable closed-price contract is more efficient than an open-price one if, and only if $\text{JS}(a^C) > \text{JS}(a^0)$. Suppose $v > c$. Then, proposition 3 implies that $a^0 > a^C$ for any ω. Hence, it must be that $\text{JS}(a^0) > \text{JS}(a^C)$ in the underinvestment region ($\omega < \omega^*$), with $\text{JS}(a^0)$ approaching the first best as ω approaches ω^*. In the overinvestment region ($\omega > \omega^*$), $\text{JS}(a^0)$ starts decreasing in ω. Since a^C does not depend on ω, this implies that there must be a critical value $\bar{\omega}$ such that $\text{JS}(a^C) > \text{JS}(a^0)$ for $\omega > \bar{\omega}$. Suppose now that $< c$. Then, we know from Proposition 3 that $a^0 > a^C$if, and only if $\omega > \underline{\omega} > 0$. Hence, in the underinvestment region, $\text{JS}(a^C) > \text{JS}(a^0)$ for $\omega < \bar{\omega}$, whereas $\text{JS}(a^0) > \text{JS}(a^C)$ for $\omega > \bar{\omega}$. In the overinvestment region, by the same argument as before, there must be a critical value $\bar{\omega}'$ such that $\text{JS}(a^C) > \text{JS}(a^0)$ for $\omega > \bar{\omega}'$. Note that $\bar{\omega}' < \bar{\omega}$ because, when $< c$, a^C is strictly larger, and hence the underinvestment inefficiency from having a closed-price contract is smaller, than in the case where $v > c$. QED.

Proof of Proposition 6: Since open price is always an option, making a closed-price contract non-renegotiable is (weakly) efficient if, and only if $\text{JS}(a^C) > \text{JS}(a^N)$. This condition is more likely to hold the smaller the efficiency gain ($v + c$), because $\text{q}(a^N) > \text{q}(a^C)$. Moreover, since $\text{JS}(a^C) = \text{JS}(a^N)$ for $\omega = 0$, a^Nincreases in ω, and a^c is independent of it, it follows from the concavity of $\text{JS}(\cdot)$ that there must be $\overline{\omega}''$ such that $\text{JS}(a^C) < \text{JS}(a^N)$ for $\omega < \overline{\omega}''$ and $\text{JS}(a^C) > \text{JS}(a^N)$ for $\omega > \overline{\omega}''$. QED.

Proof of Proposition 8: Let ω^*_{ex}, ω^{**}_{ex} and $\underline{\omega}_{ex}$ be the levels of ω above which $a^0_{ex} > a^{FB}_{ex}$, $a^C_{ex} > a^{FB}_{ex}$ and $a^0_{ex} > a^C_{ex}$, respectively. Observe that $JS^C > JS^0$ only if either $\omega < \min\{\omega^*_{ex}, \underline{\omega}_{ex}\}$ or $\omega > max\{\omega^*_{ex}, \underline{\omega}_{ex}\}$. Part (i): Suppose $\omega < \min\{\omega^*_{ex}, \underline{\omega}_{ex}\}$. Then, a disclosure policy is useless under the open price contract, so $JS^{CD} \geq JS^C > JS^0 = JS^{0D}$ and $\underline{x} = 0$. Suppose now $\omega > max\{\omega^*_{ex}, \underline{\omega}_{ex}\}$. Then, for $\omega > \omega^{**}_{ex}$, $JS^{CD} = JS^C > JS^{0D} = JS(min\{x, a^0_{ex}\})$ if $x > a^C_{ex}$, and $JS^{CD} = JS^{0D} = JS(max\{x, a^{FB}_{ex}\})$ otherwise, so $\underline{x} = a^C_{ex}$. For $\omega < \omega^{**}_{ex}$, by continuity there must be $\underline{x} \in (a^{FB}_{ex}, a^0_{ex})$ such that $JS^{CD} = JS^C > JS^{0D} = JS(x)$ if $x > \underline{x}$ and $JS^{CD} < JS^{0D}$ otherwise. Part (ii): Suppose $\omega < \min\{\omega^*_{ex}, \underline{\omega}_{ex}\}$. Then, we know that $JS^{0D} = JS^0$ for any x. Moreover, for $\omega > \omega^{**}_{ex}$, $JS^{CD} = JS^C$ if, and only if $x > a^C_{ex}$, so $\overline{x} = a^C_{ex}$. For $\omega < \omega^{**}_{ex}$, $JS^{CD} = JS^C$ for any x, so $\overline{x} = 0$. Suppose now $\omega > max\{\omega^*_{ex}, \underline{\omega}_{ex}\}$. Then, $JS^{0D} = JS^0$ if, and only if $x > a^0_{ex}$ and $JS^{CD} = JS^C$ if, and only if $x > a^C_{ex}$. Since $a^0_{ex} > a^C_{ex}$, this implies that $\overline{x} = a^0_{ex}$. QED.

Proof that conditions (SE^{OP}) and (SE^{CP}) are necessary and sufficient for informal contracts to be self-enforcing: for an informal contract to be self-enforcing, both the buyer and the supplier must be willing to honor the advance payment and initiate the relationship (participation constraints):

$U^I_B(b) \geq U^F_B$ for the buyer, and (B1)

$U^I_S(b) \geq U^F_S$ for the supplier. (B2)

In addition, the buyer and the supplier must be willing to pay and accept the informal price adjustment instead of bargaining (the open-price case) or enforcing the formal fixed price (the closed-price case), and to pay and accept the end-of-period bonus instead of facing expropriation (incentive constraints). Let $o \in \{0,1\}$ be an indicator for whether the underlying formal contract is open price ($o = 1$) or closed price ($o = 0$). Then, the buyer's incentive constraints are:

$$-\rho - \lambda + \frac{1}{r} U_B^I(\rho) \geq -o\overline{p} - (1-o)p^C - \beta[a(\rho)]\omega + \frac{1}{r} U_B^F \text{ on rent-seeking, and} \qquad \text{(B3)}$$

$$-\lambda + \frac{1}{r} U_B^I(\rho) \geq -\beta[a(\rho)]\omega + \frac{1}{r} U_B^F \text{ on expropriation.} \qquad \text{(B4)}$$

The supplier's incentive constraints are:

$$\rho + \lambda + \frac{1}{r} U_S^I(\rho) \geq o\overline{p} + (1-o)p^C + \pi[a(\rho)] + \frac{1}{r} U_S^F \text{ and} \qquad \text{(B5)}$$

$$\lambda + \frac{1}{r} U_S^I(\rho) \geq o\underline{p} + (1-o)p^C + \pi[a(\rho)] + \frac{1}{r} U_S^F \text{ on rent-seeking, and} \qquad \text{(B6)}$$

$$\lambda + \frac{1}{r} U_S^I(\rho) \geq \pi[a(\rho)] + \frac{1}{r} U_S^F \text{ on expropriation.} \qquad \text{(B7)}$$

Note that the buyer has only one incentive constraint on rent-seeking because it is not tempted to bargain when the efficiency gain is not realized, and hence the informal price adjustment is zero. Summing up the binding incentive constraints for the buyer and the supplier, we obtain necessary condition (SE^{OP}) in the open price case, and (SE^{CP}) in the closed price case. In fact, these conditions are also sufficient for self-enforcement because, provided that they hold, the buyer and the supplier can adjust the advance payment τ to insure that all the participation and incentive constraints, (B1) through (B7), hold as well. QED.