# Sourcing Innovation: When to Own and When to Control Your Supplier?

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*Problem definition.* Many firms rely on their suppliers as a major source of innovation, and they harness the innovation potential of their supplier base by organizing procurement (or innovation) contests. Most research on contests has assumed that suppliers compete "on even ground" in a procurement contest. In practice, however, such an assumption may not be true because suppliers can differ widely in one key aspect: whereas some suppliers are independent from the buying firm, others may be affiliated with or even controlled by the buyer. This paper seeks to understand how (varying degrees of) supplier ownership and supplier control affect the outcomes of a procurement contest in terms of the buying firm's profits and the level of product innovation. *Methodology/results.*We use a game-theoretic model to identify the mechanism by which supplier ownership and control effectuate results; we characterize when supplier ownership and control are (and are not) beneficial for a buying firm; and we study the cases where the goals of increasing profits and fostering innovation are (or are not) aligned. *Managerial implications.* Our analysis yields practicable insights on the optimal configuration of a buyer's supplier base structure, and it helps explain the rationale behind recent supplier base developments in many large industries. In particular, we demonstrate that highly profitable supplier base structures may severely undermine incentives for product innovation—a dilemma that can lead to severely negative long-term consequences for a buying firm's market competitiveness and thus may entice firms to sacrifice short-term profits in favor of long-term innovativeness.

*Key words*: innovation contest; industrial procurement; supplier management; supplier base; control rights

## 1. Introduction

In order to boost their innovativeness, many firms—especially those in industries characterized by increasing clock speed and skyrocketing research and development (R&D) costs—have decided to reach beyond their own boundaries: they actively tap their suppliers' innovation potential to yield innovative products (Chesbrough 2003, Cabral et al. 2006, Chen et al. 2022b). One of the most common and effective ways for a firm to foster and access innovation in its supplier base is by organizing procurement (or innovation) contests (see e.g. Dyer and Ouchi 1993, Mueller et al. 2016, Aoki and Wilhelm 2017). In a procurement contest, the buying firm confronts its suppliers with an innovation challenge and incentivizes them to invest in innovation efforts by offering an award (e.g., a valuable supply contract) for the winning supplier; after observing the suppliers' solutions, the buyer selects (and awards through a supply contract) the best innovation ex post. A procurement contest thus allows the buyer to shift a sizeable portion of the costs and risks inherent to many innovation initiatives onto its suppliers. To reap the full benefits of this contest format, scholars have devised helpful guidelines on how to optimally design and manage innovation contests (for excellent overviews, see Konrad 2009 and Ales et al. 2019). However, these guidelines can be at odds with the empirical reality of industrial procurement settings (for a thorough discussion of the issue, see Deng and Elmaghraby 2005, Chen et al. 2022b). For instance, research on contest theory has posited that all suppliers participating in a procurement contest are unaffiliated with the buyer (see e.g. Taylor 1995, Moldovanu and Sela 2001, Terwiesch and Xu 2008, Erat and Krishnan 2012, Ales et al. 2019, Bimpikis et al. 2019, Stouras et al. 2022). Yet in many industrial procurement settings, this assumption of independence is violated: buyers frequently hold a position in some of the competing suppliers. Of course, such (partial) ownership of a supplier allows the buyer (a) to appropriate additional rents from that supplier and, more importantly, (b) to exert influence on the supplier's (innovation) decisions. But does ownership or control of a supplier promote or hinder innovation? And does it increase the buyer's profits? We seek to understand how different supplier base structures—including (or not) affiliated suppliers and subsidiaries—affect the outcomes of procurement contests and, in turn, to understand how those structures end up affecting the innovativeness and profitability of a buyer.

The automotive industry exemplifies the significance of our research question. Consider the development of an anti-lock braking system (ABS) for the 1992 Cadillac Seville (Novak and Stern 2006). Cadillac was open to procuring the yet-to-be-developed, next-generation ABS system either from Bosch, an independent supplier, or from AC Delco, its internal brake division. It asked both firms to provide suggestions for how the challenge should be addressed. Bosch proposed an electronic ABS system, while AC Delco presented a mechanical solution. It turned out that Bosch's electronic system was notably superior to AC Delco's solution, which led Cadillac to award the supply contract to the independent supplier Bosch and to pass over their internal division (Mavrigian and Carley 1998). Another example is that of Continental (an independent supplier) and Denso (a Toyota-affiliated supplier), which were competing to win the supply contract for a cutting-edge crash prevention system for the 2015 Toyota Corolla. It came as a shock when Toyota awarded the supply contract to Continental (Kubota and Pfanner 2015), since Japanese car manufacturers tend to favor their own affiliated suppliers over independent competitors (Lincoln and Choi 2010, Ahmadjian and Oxley 2011). Finally, supplier base structures in the market for automotive battery cells (for electric vehicles) are shaping up in a similar fashion. When Chinese car manufacturer BAIC sourced the battery module for its luxury model ArcFox, for instance, it envisioned advanced features such as long-range capabilities and enhanced thermal management so as to support the car's luxury positioning (Anderson 2020, EVSpecifications 2020). In the procurement process for this novel battery module, a joint venture between BAIC and SK Innovation competed with several domestic Chinese battery manufacturers for the supply contract; the joint venture ultimately prevailed over the independent competitors (Kim 2020).

All these examples have a strong commonality: they demonstrate the effective use of procurement contests as a mechanism for sourcing innovative products. In particular, the procurement process always starts with the buyer drafting a rough specification of its needs and then inviting different suppliers—typically including independent and affiliated suppliers, subsidiaries, and even internal divisions—to develop and propose a customized solution. The candidate suppliers then carry out costly R&D activities and present their solutions to the buyer, usually in the form of working prototypes. The buyer evaluates the different solution alternatives and determines which supplier will be awarded the supply contract. Thus the procurement process closely follows the template of an innovation contest as described by, for instance, Taylor (1995) and Terwiesch and Xu (2008). Contests are an appealing procurement mechanism because they are informationally parsimonious, they provide ample innovation incentives for suppliers, and they give the buyer the flexibility to exploit the full innovation potential of its supplier base by choosing the winning supplier ex post—that is, after observing all solutions (Cabral et al. 2006). Not surprisingly, procurement contests have become ubiquitous in practice; they have been utilized not only in the automotive industry (e.g., Cooper and Slagmulder 1999, Langner and Seidel 2009, Mueller et al. 2016, Aoki and Wilhelm 2017, Calzolari et al. 2017) but also in the electronics (McIvor et al. 2006), information technology (Bristow and Dunaway 2011), and commercial aircraft industries (Paliwoda and Bonaccorsi 1994).

Their commonalities notwithstanding, the preceding examples differ markedly in one critical respect: the structure of the buying firm's supplier base. More specifically, suppliers vary greatly in terms of: (i) whether the buyer has financial stakes in and (partial) ownership of a supplier, and thus shares profits and losses with that supplier; and (ii) whether the buyer controls the supplier, thereby influencing (or not) its development decisions. So that we can better understand these differences, consider again the Cadillac ABS example. AC Delco was the *internal* braking division of Cadillac; Cadillac thus had full ownership of AC Delco and also exerted full control over their development decisions. In contrast, Bosch—AC Delco's primary competitor—was completely *independent* from Cadillac; Cadillac had no financial stake in Bosch, let alone any power to control that firm's innovation process. In the Toyota Corolla example, Denso was in between those two polar cases: Denso was one of Toyota's *affiliated* suppliers, with Toyota owning 24 percent of Denso. Although this minority stake rendered Toyota a potential financial beneficiary of Denso's success, Toyota honored the traditional Japanese Keiretsu system and did not intervene in Denso's development activities (Ahmadjian and Lincoln 2001, Lincoln and Choi 2010). Many other examples confirm the prevalence of such heterogeneous supplier base structures in practice (Kato et al. 2016, Dowlah 2018, Kosaka et al. 2020). Not only are some automotive suppliers owned by car OEMs in the United States (Liker et al. 1996), or in Japan through "vertical Keiretsu" (Dyer et al. 1998, Kato et al. 2016, Nikkei Asian Review 2016), but supplier ownership is prominent in the semiconductor (Naeher et al. 2011) and pharmaceutical industries (Krzeminska et al. 2013) as well.

Inspired by these commonly observed phenomena, we set out to answer the following question: How do different supplier base structures, defined by varying degrees of supplier ownership and control, affect the innovation and profitability outcomes of procurement contests? We first seek to understand the importance of *supplier ownership* by studying when the presence of an affiliated supplier in a procurement contest improves contest outcomes and when it does not. Second, we examine the impact of *supplier control*: When is it (and when is it not) beneficial for the buyer to not only (partially) own a competing supplier but also to exert control over that supplier's decisions? Taken together, our analysis compares different supplier base structures and assesses their potential contributions to innovation and profitability. Thus we (a) describe supplier base configurations for which innovative companies should strive and (b) also give a rationale for the emergence of different supplier base structures in practice.

To answer our research questions, we develop a game-theoretic model of a procurement contest with two (potentially) heterogeneous suppliers that each develop an innovative product and compete against one another to win a valuable supply contract. In our set-up, the buyer has varying levels of ownership of and control over one of the suppliers while the other supplier is fully independent from the buyer. We also incorporate different product and supplier base contingencies that bear on contest outcomes. With respect to *product* characteristics, we focus on the innovation potential of the product under development (i.e., is the product radically innovative and fraught with development uncertainties, or is it simply an incremental innovation), the value (or size) of the tendered supply contract, and the difficulty of development. In terms of *supplier base* characteristics, we investigate how the distribution of expertise between suppliers influences contest outcomes. In short, we establish a contingency theory about the desirability of supplier ownership and control for procurement contests aimed at fostering innovation.

Our analysis makes four main contributions. First, on a conceptual level, we identify and describe the mechanisms that determine how supplier ownership affects the innovation and profit outcomes of a procurement contest. Second, we characterize when ownership of a supplier is beneficial to a buyer and when it is detrimental; the outcome that prevails depends crucially on the procurement contest's extent of technological uncertainty and on the relative innovation potential of the affiliated and independent supplier. Third, we establish that the most profitable supplier base structure need not be the one that maximizes product innovation; our analysis here reveals when supplier ownership promotes (and when it hinders) innovation in the buyer's supplier base. Last, we show (rather surprisingly) that a buyer should not always seek control over its affiliated supplier because such control may reduce innovation and profitability both—even though the buyer can dictate all development decisions. Once again, the value of supplier control is determined by the level of technological uncertainty and by suppliers' relative innovation potential.

This study makes two overarching contributions to our understanding of supplier ownership and supplier control in practice. First, it gives senior management strategic guidance about the optimal structure of their supplier base. Should a buying firm own or control some of its suppliers so as to promote its supplier base's innovativeness and its own profitability? In answering this question, our paper sheds light on an important aspect that—together with other financial and strategic considerations that are outside the scope of this paper—should drive a firm's decision about whether to invest in its suppliers. Second, and on a more aggregate level, our analysis explains the evolution of ownership and control in larger supplier ecosystems; thus it helps explain the aggregation and disaggregation of entire industries.

## 2. Related Literature

In this paper, we seek to understand how different supplier base structures—defined by varying degrees of ownership and control—affect the efficacy of a buyer's procurement process for innovative products. This focus naturally links our work to the extensive economics literature on vertical integration and the boundary of the firm. The stream most relevant to us draws on the theory of property rights and transaction costs to discuss the eminent "make or buy" decision (for excellent surveys of this literature, please refer to Segal and Whinston 2013 and Tadelis and Williamson 2013). However, that body of work focuses almost exclusively on how an appropriate allocation of ownership can prevent so-called hold-up problems between a buyer and a *single* supplier (for a detailed overview, see Bresnahan and Levin 2013). Hence this literature does not speak to our question of how supplier ownership (and supplier control) affects innovativeness in a *competitive* situation, which is much more likely to occur in practice.

More immediately, our paper is also part of the larger literature on procurement, which studies optimal sourcing practices from a variety of different angles. First of all, many authors have discussed the design of efficient procurement mechanisms with the aim of *minimizing sourcing costs* (Laffont and Tirole 1993, Elmaghraby 2000). Their studies have identified several factors that the buying firm can leverage to achieve cost efficiency (Beil 2010). These factors include, inter alia:

(a) active management of the supplier ecosystem by controlling the size of the supplier base (Li and Wan 2017, Li 2020), establishing a supplier qualification procedure (Wan and Beil 2009, Wan et al. 2012, Chen et al. 2018, Zhang et al. 2021), engaging with "preferred" suppliers (Burguet and Perry 2009, Loertscher and Riordan 2019) while maintaining supplier base competitiveness via recruitment of new suppliers (Beil et al. 2018), and installment of multi-sourcing channels (Li and Debo 2009, Chaturvedi et al. 2014); (b) an optimized design of the procurement process that accounts for multi-stage procurement processes (Elmaghraby 2003) and the value of information disclosure during the sourcing process (Kostamis et al. 2009); and (c) configuring products and production systems to promote cost reduction (Kim and Netessine 2013, Chen et al. 2022a) and combat cost uncertainty (Gur et al. 2017, Hu and Qi 2018). In the second place, the procurement literature has been extended beyond mere purchasing cost considerations to examine how a buying firm can improve its overall profitability by accounting for other factors such as product quality (Beil and Wein 2003) and supplier risk (Chaturvedi and Martínez-de-Albéniz 2011, Yang et al. 2012).

Yet among the wealth of topics that the procurement literature has addressed, there is one issue to which only scant attention has been paid despite its prevalence in actual practice: How can firms foster *innovation* in their supplier base? This particular oversight reflects a subtle modeling choice: nearly all the research that studies procurement formally relies on contracts or auctions as their modelling primitive. However, the use of these mechanisms implicitly assumes that the buyer can fully specify ex ante the product to be procured or at least devise verifiable performance metrics (Deng and Elmaghraby 2005, Fugger et al. 2019); for otherwise, a supplier could shirk by ex post redefining the product to suit its own preferences or deceiving the buyer about its performance. For products that are innovative, though, the procurement process violates both of those assumptions because—at the start of the process—the buyer can neither fully describe the innovation to be sourced nor define objective and verifiable performance metrics (Scotchmer 2004, Cabral et al. 2006). It follows that neither contracts nor auctions should be the mechanism of interest when modeling the procurement of innovative products. For such modeling, the most apt primitive is the contest format because contests offer strong innovation incentives even in the absence of verifiable metrics. This notion is lent credence by the widespread use of contests in the real-world practice of sourcing innovation (Cooper and Slagmulder 1999, Langner and Seidel 2009, Mueller et al. 2016).

There is a growing body of literature on contests that has identified effective design levers for a contest organizer seeking to improve outcomes (for comprehensive reviews, see Konrad 2009 and Ales et al. 2019). Those design levers include, among others, the number of participants allowed to enter the contest (Taylor 1995, Fullerton and McAfee 1999, Che and Gale 2003, Körpeoğlu and Cho 2017), the contest duration (Körpeoğlu et al. 2021), the distribution of contest prizes (Moldovanu and Sela 2001, Terwiesch and Xu 2008, Ales et al. 2017), the management of participation (Nittala et al. 2022, Stouras et al. 2022), the installation of handicaps to promote fair competition (Che and Gale 2003, Epstein et al. 2011, Franke et al. 2014), the possibility of team (rather than individual) submissions (Candoğan et al. 2021), the benefits of running parallel contests (Hu and Wang 2021, Stouras et al. 2021, Körpeoğlu et al. 2022), the appropriate scope of a contest (Erat and Krishnan 2012, Jiang et al. 2021), the provision of interim performance feedback (Aoyagi 2010, Bimpikis et al. 2019, Mihm and Schlapp 2019, Jiang et al. 2022), and the screening of contestants (Yücesan 2013, Khorasani et al. 2020).

It is noteworthy that much of the above cited work on contests has been inspired by crowdsourcing contexts, so the work in this field tends to focus on those aspects of contest design that are relevant to crowdsourcing settings. Questions of ownership and control are (by definition) largely absent in such settings. Yet contests are ubiquitous in industrial procurement, which differs in many constitutional aspects from crowdsourcing. For instance, supplier ownership and control strongly influence a buying firm's ability to extract rents from its affiliated suppliers, which endogenously handicaps independent suppliers in procurement contests. Yet, contrary to much of the crowdsourcing literature that posits a negative impact of exogenous handicaps (**?**), our analysis reveals that handicaps that emerge endogenously may actually induce better contest outcomes for the buying firm. There is a nascent literature on contests that concentrates on questions of industrial procurement (Deng and Elmaghraby 2005, Chen et al. 2022b), but the roles of supplier ownership and supplier control have not been analyzed.

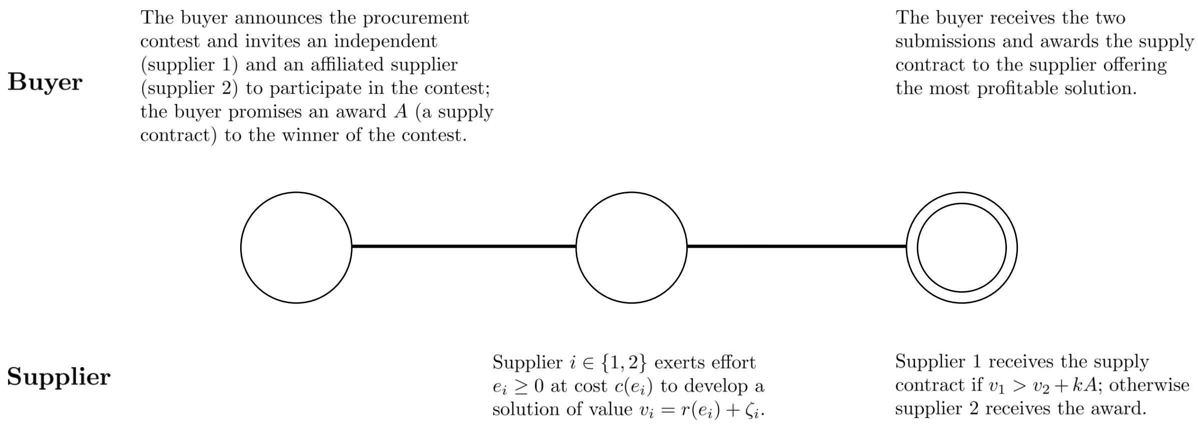
So even as the literature on procurement reflects many aspects of industrial sourcing but lacks the focus on innovative products, the contest literature accommodates research on innovation but lacks the focus on industrial procurement. Our study advances both the literatures on procurement and contest theory by studying how different ownership and control structures affect innovation in a buyer's supplier base.

## 3. The Model

Consider a firm (hereafter "the buyer") that organizes a procurement contest among two suppliers toward the end of acquiring an innovative product. At the start of the contest, the buyer promises an award to the winner; the award incentivizes the suppliers to invest in innovation efforts during the contest. In particular, each supplier exerts effort at its own expense to improve the value of its product. At the end of the contest, the buyer evaluates the performance of each supplier's product and then selects the winner according to its preferences.

We complement this typical contest structure by considering scenarios in which one of the competing suppliers is affiliated with the buyer; that is, we allow the buyer to share ownership in

**Figure 1 Sequence of Events**




and/or to exert control over that affiliated supplier. The presence of an affiliated supplier in a procurement contest has immediate implications for both the contest's competitiveness and the buyer's true procurement costs. In particular, a buyer that (partially) owns one of its suppliers can extract additional rents from it—a dynamic that will influence the buyer's decision about which supplier to select as the contest winner. Furthermore, a buyer that controls the affiliated supplier can directly steer that supplier's investment in innovation efforts, which affects not only the incurred development costs but also the supplier's competitive position in the contest.

In reality, the notions of ownership and control cannot always be fully separated. In many legal systems, for instance, a sufficiently high level of ownership in a supplier also transfers control rights to the buyer (see e.g. Fama and Jensen 1983, Leech and Leahy 1991, Claessens et al. 2000, Franks and Mayer 2001, Del Prete and Rungi 2017). Yet disentangling the different effects of supplier ownership and supplier control on the outcomes of a procurement contest requires that we analyze those two concepts individually. Therefore, we first concentrate our discussion on modeling and analyzing the implications of supplier ownership before introducing supplier control in Section 5.

### 3.1. The Procurement Contest

The procurement contest, as summarized in Figure 1, unfolds as follows. The buyer initiates the contest by asking both suppliers to submit a solution for the innovative product, and incentivizes them by promising an award $A > 0$ to the winner of the contest. In industrial procurement settings, the award typically takes the form of a supply contract. As is customary in the contest literature, we assume that $A$ is exogenous (Aoyagi 2010, Erat and Krishnan 2012, Körpeoğlu and Cho 2017, Körpeoğlu et al. 2022).

Each supplier $i \in \{1,2\}$ then decides whether (or not) to participate in the contest; not participating gives a supplier a utility of zero. If it participates, supplier $i$ expends an unobservable solution effort $e_i \geq 0$ to develop the product at private cost $c(e_i)$, where $c$ is a twice continuously differentiable, increasing, and strictly convex function with $c(0)=0$ and $c'(0)=0$. The performance of supplier $i$'s product is given by $v_i = r(e_i)+\zeta_i$, where $r$ captures the deterministic relationship between effort and performance and where $\zeta_i$ is a stochastic performance shock specific to supplier $i$. We assume that $r$ is a twice continuously differentiable, strictly increasing, and concave function with $r(0)=0$ and $\lim_{x\to\infty} c'(x)/r'(x)=\infty$. The realization of $\zeta_i$ is supplier $i$'s private information, and we assume that $\zeta_i$ is a random variable with probability density function $g_{\zeta_i}$ and support on $\mathbb{R}$. For conciseness, we define $\Delta\zeta=\zeta_1-\zeta_2$ as the difference between the performance shocks of supplier $i=1$ and supplier $i=2$. The probability density function of $\Delta\zeta$ is given by $g_{\Delta\zeta}(x)=\int_{-\infty}^{+\infty} g_{\zeta_1}(x+y)g_{\zeta_2}(y)\,dy$, and its cumulative distribution function is $G_{\Delta\zeta}(x)=\int_{-\infty}^{x} g_{\Delta\zeta}(y)\,dy$. We further assume $g_{\Delta\zeta}(x)$ to be continuously differentiable almost everywhere, and we denote its first-order derivative by $g'_{\Delta\zeta}(x)$. At points of non-differentiability, $g'_{\Delta\zeta}(x)$ denotes the right derivative: $g'_{\Delta\zeta}(x)=\lim_{y\to x^+} g'_{\Delta\zeta}(y)$.

Finally, after receiving the suppliers' submissions, the buyer evaluates the performance of the different solutions and selects its preferred supplier. The buyer then announces the winner of the contest and awards $A$ accordingly.

Throughout the analysis, we assume that supplier $i=1$ is an independent supplier; that is, the buyer has no ownership in that supplier. In contrast, supplier $i=2$ may be (partially) owned by the buyer. More precisely, we assume that the buyer owns a fraction $k\in[0,1]$ of supplier 2's equity; that ownership allows the buyer to partake of supplier 2's profits. For future reference, and following common legal terminology, we designate supplier 2 as the buyer's *affiliated* supplier (Rossini 1998).

The buyer and also the suppliers are risk neutral and seek to maximize their expected profits. All primitives of the model are common knowledge, and we are interested in the pure-strategy Bayesian Nash equilibria (BNE) of the procurement contest. For such equilibria to exist, we require that the suppliers' performance uncertainty $\zeta_i$ be sufficiently large—a condition that is typically true of innovative products. A similar assumption is invoked throughout the entire literature on contests (see e.g. Lazear and Rosen 1981, Nalebuff and Stiglitz 1983, Aoyagi 2010, Ales et al. 2021).

### 3.2. Implications of Supplier Ownership

Each supplier $i\in\{1,2\}$ enjoys a profit of $A-c(e_i)$ from winning the contest or suffers a loss of $-c(e_i)$ from losing it. Since each supplier strives to maximize its expected profits $\pi_i$, it follows that supplier $i$ chooses its solution effort $e_i$ to maximize

$$\pi_i(e_i)=A\mathbb{P}(\{\text{supplier } i \text{ wins}\})-c(e_i). \tag{1}$$

The buyer likewise seeks to maximize its expected profits, which consist of (a) the value of the selected innovation $v_i$ less (b) the award payment $A$ to the winning supplier and (c) the retained share of the affiliated supplier's profits, since the buyer owns a fraction $k$ of that supplier's equity. The buyer's expected profits $\Pi$ can therefore be written as

$$\begin{aligned}\Pi &= \sum_{i=1}^{2} \mathbb{E}[v_i 1_{\{\text{supplier } i \text{ wins}\}}] - A + k\pi_2 \\ &= \mathbb{E}[\max\{v_1, v_2 + kA\}] - A - kc(e_2). \qquad (2)\end{aligned}$$

Several observations warrant further discussion at this point. First, because supplier $i = 2$ is an affiliated supplier, the buyer internalizes a fraction $k$ of that supplier's effort costs (i.e., $kc(e_2)$); however, the buyer also reaps a share of that supplier's revenues (i.e., $kA$) if it wins the procurement contest. It follows immediately that the buyer judges the performance of the independent and the affiliated supplier differently. When evaluating the performance of the independent supplier (i.e., supplier $i = 1$), the buyer is interested only in the value of the submitted solution $v_1$. In contrast, with respect to the affiliated supplier (i.e., supplier $i = 2$) the buyer not only reaps the benefits of the innovation, as given by $v_2$, but also extracts additional rents $kA$ from the affiliated supplier if it wins the contest. This asymmetry in evaluation has a bearing on how the buyer selects the winner of the contest: the buyer awards the supply contract $A$ to supplier $i = 1$ (the independent supplier) if and only if (iff) $v_1 > v_2 + kA$; in all other cases, the affiliated supplier receives the supply contract. Hence the independent supplier must overcome a handicap of $kA \geq 0$ to win the supply contract. In other words, it must provide a solution that is decidedly better than the solution provided by the affiliated supplier. The implication here is that the buyer will not always choose the product offering the best performance (i.e., if $v_2 < v_1 < v_2 + kA$). Instead, the buyer trades off product performance against the opportunity to extract additional rents from its affiliated supplier.[1]

Since the buyer selects supplier $i = 1$ as the contest winner iff $v_1 > v_2 + kA$, it follows that the two participating suppliers, upon participating in the contest, choose their equilibrium efforts to accord with the following set of optimization problems:

$$e_1^* \in \arg\max_{e_1 \geq 0} \pi_1(e_1; e_2^*) = A\mathbb{P}(v_1 > v_2 + kA) - c(e_1); \qquad (3)$$

$$e_2^* \in \arg\max_{e_2 \geq 0} \pi_2(e_2; e_1^*) = A\mathbb{P}(v_2 + kA \geq v_1) - c(e_2). \qquad (4)$$

Finally, we note that for all $i \in \{1, 2\}$, $\pi_i(0; e) > 0$ for all $e \geq 0$. That is, by choosing minimum effort (i.e., $e_i = 0$), each supplier $i$ can guarantee itself positive profits and hence always finds it worthwhile to participate in the procurement contest.

[1] The existence of such selection biases in the practice of procurement is well documented in the practitioner literature (Lincoln and Choi 2010, Ahmadjian and Oxley 2011). In the context of the Japanese Keiretsu system, for instance, Lincoln and Choi state that "[buyers] displayed a clear preference for intra-group partnerships over those with other groups or unaffiliated firms" (p. 15).

## 4. The Value of Supplier Ownership

In a procurement contest, the buyer's foremost interest is to promote supplier innovation; however, ownership in an affiliated supplier creates additional financial motives for the buyer that may interfere with the innovation motive. In particular, the opportunity for additional rent extraction induces the buyer to (implicitly) handicap the independent supplier. This behavior, naturally affects the behavior of each supplier in the procurement contest and thus also the buyer's profits and the level of product innovation. Our aim in this section is to pinpoint just how supplier ownership influences the outcomes of a procurement contest. Hence we identify when the presence of an affiliated supplier in a buyer's procurement contest promotes (or hinders) product innovation, as well as when it supports (or is inimical to) the buyer's profits. As noted before, in this section, we solely concentrate on supplier ownership, deferring until Section 5 our study of supplier control.

Our analysis proceeds in a step-by-step fashion to facilitate generating insights. We initiate the discussion by characterizing how various levels of supplier ownership—and thus differently sized handicaps—affect both the competitiveness of a procurement contest and the innovation efforts exerted by suppliers (Section 4.1). Those preparatory results then allow us to analyze the implications of supplier ownership on innovation outcomes (Section 4.2) and on the buyer's expected profits (Section 4.3). Finally, we spell out when the goals of spurring innovation and profits are aligned and when they are at odds (Section 4.4). We often complement the general findings with an illustrative example in order to build further intuition for our results. To streamline the presentation and maintain focus on the managerial implications of our analysis, we have relegated all mathematical derivations and formal proofs to the Appendix.

### 4.1. Impact of Supplier Ownership on Contest Competitiveness

As a starting point for the analysis, our first lemma characterizes the suppliers' equilibrium innovation efforts in the procurement contest as a function of the contest design parameters—most notably, our core concept of supplier ownership.

LEMMA 1. *Suppose the buyer does not control the affiliated supplier, and define* $\eta^{-1}(x) = c'(x)/r'(x)$*. Then, for any given* $k \in [0,1]$*, the unique pure-strategy BNE is symmetric with*

$$e^*(k) = \eta(Ag_{\Delta\zeta}(kA)). \tag{5}$$

*Furthermore,* $e^*(k)$ *increases with* $k$ *iff* $g'_{\Delta\zeta}(kA) \geq 0$*, and it increases with* $A$ *iff* $g_{\Delta\zeta}(kA) + kAg'_{\Delta\zeta}(kA) \geq 0$*.*

In line with previous work on innovation contests, Lemma 1 shows that supplier equilibrium efforts increase when the relative marginal return on effort, as measured by the increasing function $\eta$, increases (cf. Taylor 1995, Terwiesch and Xu 2008). Yet more important for our work is the influence of supplier ownership $k$ on equilibrium efforts, or the effect that ownership has on *contest competitiveness* as captured by $g_{\Delta\zeta}(kA)$. Because this term is central to our arguments throughout the paper, some diligence is warranted when interpreting $g_{\Delta\zeta}(kA)$. Note that suppliers perceive a contest to be competitive if they believe that their solutions will likely be of equaling value to the buyer—that is, if suppliers believe that $v_1 \approx v_2 + kA$ or (equivalently) $\Delta\zeta = v_1 - v_2 \approx kA$. Another way to say this is that the contest is competitive if there is a high chance that the difference in the suppliers' performance shocks $\Delta\zeta$ is approximately the size of the independent supplier's handicap $kA$, an event whose likelihood is measured by $g_{\Delta\zeta}(kA)$. Hence a contest is competitive if $g_{\Delta\zeta}(\cdot)$ has considerable probability mass around $kA$, which means that $g_{\Delta\zeta}(kA)$ is best interpreted as a measure of contest competitiveness.

It is well known in contest theory that the more competitive a contest, the more aggressively the contestants expend effort on finding a solution (Che and Gale 2003, Aoyagi 2010, Drugov and Ryvkin 2017, Mihm and Schlapp 2019). Lemma 1 confirms this fact: equilibrium efforts $e^*(k)$ increase with $g_{\Delta\zeta}(kA)$. But just when is a contest "more" or "less" competitive?—that is, when is $g_{\Delta\zeta}(kA)$ large and when is it small? Some important cases come to mind. First, $g_{\Delta\zeta}(\cdot)$ can be small over its *entire* domain, and thus trivially so at $kA$. In this case, $g_{\Delta\zeta}(\cdot)$ captures strong uncertainty about the suppliers' relative innovation performance. So in that case it is difficult to assess, ex ante, which supplier will provide the more innovative product. This is characteristic of many procurement contests involving radical innovation. Second, $g_{\Delta\zeta}(kA)$ must be small if $kA$ designates a point in the left- or right-hand tail of $g_{\Delta\zeta}(\cdot)$. In those cases, one of the suppliers has a substantially greater innovation potential than the other supplier and so the contest is de facto already decided. In contrast, if the suppliers' innovation potentials are similar and if incremental innovation is warranted, then $g_{\Delta\zeta}(kA)$ is likely to be high. Thus the magnitude of $g_{\Delta\zeta}(kA)$ is driven chiefly by two factors: (i) the aggregate technological uncertainty in the contest, and (ii) the difference in innovation potential between the two suppliers.

We are now ready to explain how supplier ownership influences innovation efforts. One might naïvely expect equilibrium efforts to decrease in the buyer's level of ownership because a higher $k$ leads to a larger selection bias in favor of the affiliated supplier, thereby potentially undermining effort incentives. However, this simple argument is not unequivocally correct because it disregards the asymmetry (measured by $g_{\Delta\zeta}$) in the suppliers' innovation potential. We can state the problem formally in this way: equilibrium efforts are increasing in $k$ iff the likelihood of close contest outcomes $g_{\Delta\zeta}(kA)$ is increasing in $k$, or iff $g'_{\Delta\zeta}(kA) \geq 0$. Put differently, a greater handicap leads to a more competitive contest if it "evens out" the competition, which occurs if (a) the affiliated supplier has a disadvantage and (b) the additional handicap on the independent supplier closes their expected performance gap. In contrast, if the affiliated supplier has an advantage then a greater handicap $kA$ for the independent supplier further biases the competition and therefore reduces effort incentives.

A similar reasoning explains why equilibrium efforts may *decrease* with the award size $A$—a finding that runs counter to prior work on contests among independent suppliers (e.g., Terwiesch and Xu 2008, Ales et al. 2017). When there is an affiliated supplier in the contest, the otherwise positive effect of a larger award on suppliers' effort incentives may be reversed because a larger $A$ also increases the independent supplier's handicap, and an increased handicap $kA$ may render the contest less competitive. These circumstances arise whenever $g'_{\Delta\zeta}(kA)$ is sufficiently negative.

**A Normal Example.** Lemma 1 makes very few assumptions about $g_{\Delta\zeta}(\cdot)$; alas, the resulting generality comes at the expense of intuition and nuance. We therefore introduce an example that should enable a more intuitive grasp of Lemma 1's general results. Our example is based on the following parameter combinations: $r(x)=rx$, $c(x)=cx^2/2$, and $\Delta\zeta \sim N(\mu,\sigma^2)$ with $r,c,\sigma>0$ and $\mu\in\mathbb{R}$. In this framework, assuming that the shock difference $\Delta\zeta$ is normally distributed (as a result, e.g., of the normally distributed $\zeta_i$) allows for an easy interpretation of our results: the parameter $\mu$ reflects the difference in innovation potential between the two suppliers; thus if $\mu>0$ then the independent supplier has a systematic advantage over the affiliated supplier, and if $\mu<0$ then the inverse is true. The term $\sigma$ similarly captures the aggregate technological uncertainty of the suppliers' solutions, with high (resp. low) levels of $\sigma$ characterizing radical (resp. incremental) innovation. Finally, the unimodality of the normal distribution leads to another handy feature: the probability density function increases up to $\mu$ but decreases thereafter.

Corollary 1. *Suppose the buyer does not control the affiliated supplier, and let $r(x)=rx$, $c(x)=cx^2/2$, and $\Delta\zeta\sim N(\mu,\sigma^2)$. Let $\phi$ denote the probability density function of a standard normal random variable. Then*

$$e^*(k)=\frac{rA}{c\sigma}\phi\left(\frac{kA-\mu}{\sigma}\right) \tag{6}$$

*for any $k\in[0,1]$, and the following statements hold:*

(i) *$e^*(k)$ increases with $r$ and decreases with $c$;*

(ii) *$e^*(k)$ increases with $\mu$ iff $\mu<kA$, and it increases with $\sigma$ iff $\sigma\le|kA-\mu|$;*

(iii) *$e^*(k)$ increases with $k$ iff $kA\le\mu$, and it increases with $A$ iff $kA\le\left(\mu+\sqrt{\mu^2+4\sigma^2}\right)/2$.*

Corollary 1 mirrors the findings of Lemma 1. Clearly, as shown in part (i), the higher the marginal return $r$ on effort and the lower the marginal cost $c$ of effort, the higher the suppliers' equilibrium efforts. Moreover, our earlier interpretation of $g_{\Delta\zeta}(\cdot)$ is confirmed by equation (6) and part (ii) of the corollary: contest competitiveness is low—and thus equilibrium efforts are low—when radical innovation is required (i.e., high $\sigma$) or when one supplier has a pronounced advantage over the other supplier (i.e., high or low $\mu$). In contrast, contest competitiveness surges when incremental innovation is required (i.e., low $\sigma$) and the invoked handicap offsets any systematic advantage that the independent supplier might have (i.e., $\mu \approx kA$).

Part (iii) of Corollary 1 helps us build intuition for how supplier ownership influences contest competitiveness. In particular, an increase in supplier ownership $k$ always leads to a larger performance handicap for the independent supplier. If the independent supplier has a large expertise advantage (i.e., $\mu \geq kA$), then a higher $k$ levels the playing field and consequently renders the contest more competitive. But if $\mu < kA$, then any further handicapping of the independent supplier reduces the likelihood of close contest outcomes and hence reduces competition also.

At a more abstract level, Corollary 1 shows that changes in any of our contextual parameters (i.e., $k$, $A$, $\mu$, $\sigma$) can intensify or compromise contest competitiveness, thereby increasing or decreasing (respectively) equilibrium efforts. This outcome is unexpected, given the award $A$ and technological uncertainty $\sigma$, because extant work on contests has postulated a monotonic impact of those parameters on equilibrium efforts (Taylor 1995, Terwiesch and Xu 2008, Ales et al. 2021). Hence we conclude that supplier ownership subtly modulates the effects that contest design parameters typically have on contest outcomes.

### 4.2. Impact of Supplier Ownership on Innovation

Having established how the suppliers' equilibrium efforts change with the buyer's level $k$ of ownership in the affiliated supplier and the resulting handicap $kA$, we are now well equipped to examine—and to provide an intuitive explanation for—the effect of different levels of supplier ownership on contest outcomes. In this section, we concentrate on showing how supplier ownership affects the degree of *innovation* resulting from a procurement contest. In particular, we ask: When does the presence of an affiliated supplier promote innovation, and when does it hinder innovation?

The following argument is intuitive. If a higher level of ownership ($k$) leads to greater equilibrium efforts, then innovation outcomes should improve with $k$. However, this logic fails to account for the buyer's capacity to extract rents from the affiliated supplier, which inclines the buyer to let the affiliated supplier win the contest—and this inclination increases with $k$. Thus a higher $k$ makes it more likely that the buyer will select an inferior innovation for purely financial motives, thus reducing the selected solution's level of innovativeness.

To determine which effect is more pronounced, we compare the expected level of innovation emerging from different supplier base structures. As a natural benchmark, we use a supplier base with only independent suppliers (i.e., $k = 0$); in that case, contest competitiveness is given by $g_{\Delta\zeta}(0)$. In order to derive the (sub)optimality of such a supplier base structure, the next proposition investigates when a supplier base that includes an affiliated supplier (i.e., a supplier for which $k > 0$) either does or does not lead to more innovation.

PROPOSITION 1. *Suppose the buyer does not control the affiliated supplier, and let* $\psi(k;e_1,e_2)=\mathbb{E}[v_1+(v_2-v_1)1_{\{v_1\le v_2+kA\}}]$ *be the expected performance of the procured innovation. Then the following statements hold.*

(i) *A contest between an affiliated and an independent supplier maximizes the expected performance of the procured innovation if* $g'_{\Delta\zeta}(0)>0$.

(ii) *A contest between two independent suppliers (i.e.,* $k=0$*) maximizes the expected performance of the procured innovation if* $g'_{\Delta\zeta}(kA)\le 0$ *for all* $k\in[0,1]$.

The key finding of Proposition 1 is revelatory: for a wide range of parameters, higher effort does lead to more innovation. In other words, the bias in a buyer's selection rule does not have any unintended consequences for innovation. Therefore, an affiliated supplier promotes innovation whenever the handicap $kA$ increases contest competitiveness as compared with the case of independent suppliers—formally, when $g'_{\Delta\zeta}(0)>0$. In contrast, it follows from part (ii) of the proposition that if the presence of an affiliated supplier reduces the contest's competitiveness (i.e., if $g'_{\Delta\zeta}(kA)\le 0$ for all $k$) then that supplier will likewise reduce innovation. Here, a contest between independent suppliers leads to products that are more innovative. It is intriguing that these results are independent of the contest's level of technological uncertainty.

In sum, the combination of Lemma 1 and Proposition 1 establishes that the supplier base structure most conducive to innovation is the one that best promotes contest competitiveness and thus the highest equilibrium efforts.

### 4.3. Impact of Supplier Ownership on Profits

So far, we have shown that supplier ownership affects the level of product innovation in a procurement contest. Yet supplier ownership also introduces a rent extraction motive for the buyer, which is absent in procurement contests between independent suppliers. That is, the buyer partakes of the affiliated supplier's profits regardless of whether or not that supplier wins the contest. So when selecting a contest winner, the buyer must carefully weigh the benefits and costs of rent extraction against the opportunity for innovation. We now proceed to analyze this trade-off in more detail by characterizing the supplier base structure under which a buyer can optimally balance its supplier base's capacity to foster innovation with the opportunity to extract rents from the affiliated supplier.

PROPOSITION 2. *Suppose the buyer does not control the affiliated supplier. Define* $\pi_2^*(k)=AG_{\Delta\zeta}(kA)-c(\eta(Ag_{\Delta\zeta}(kA)))>0$ *and* $I(k)=r'(\eta(Ag_{\Delta\zeta}(kA)))\eta'(Ag_{\Delta\zeta}(kA))>0$*. Then:*

(i) *the buyer's expected profits are maximized by a contest between an affiliated and an independent supplier if*

$$g'_{\Delta\zeta}(0)>-\frac{\pi_2^*(0)}{A^2I(0)}; \tag{7}$$

(ii) *the buyer's expected profits are maximized by a contest between two independent suppliers* (*i.e.*, $k=0$) *if, for all* $k\in[0,1]$,

$$g'_{\Delta\zeta}(kA)<-\frac{\pi_2^*(k)}{A^2(1-G_{\Delta\zeta}(A)+G_{\Delta\zeta}(0))I(k)}. \tag{8}$$

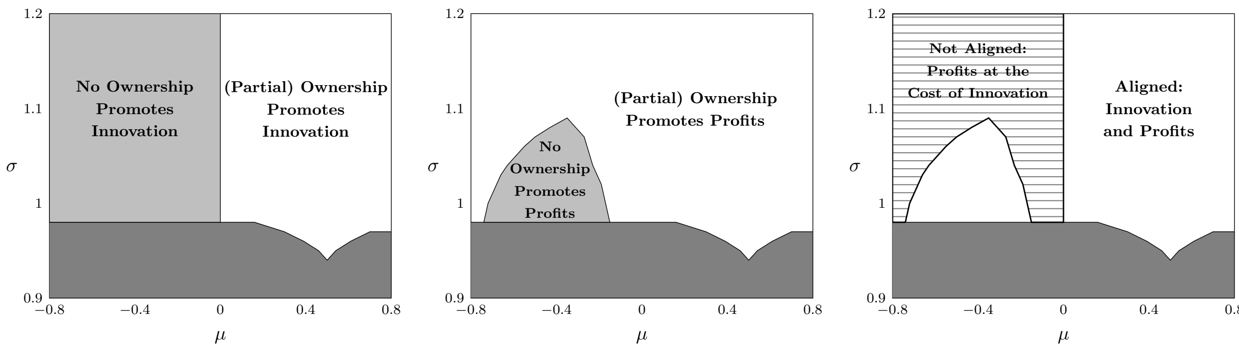
In brief, Proposition 2 indicates that the optimal supplier base structure depends mainly on two factors: the contest's competitiveness, and the *sensitivity* of contest competitiveness to supplier ownership. To be more specific, part (i) of the proposition establishes that the presence of an affiliated supplier is always in the buyer's best interest when the procurement contest is *not* very competitive. Recall from Section 4.1 that there could be two reasons why a contest may not be competitive: (i) the contest involves radical innovation (i.e., $g_{\Delta\zeta}(\cdot)$ is small over its entire domain); or (ii) the contest is de facto decided because one of the suppliers has a substantial advantage over the other (i.e., $g_{\Delta\zeta}(0)$ lies in a tail of the distribution). In those cases, supplier ownership has only a minor effect on contest competitiveness and thus also on equilibrium efforts (i.e., $|g'_{\Delta\zeta}(0)|\approx 0$); however, supplier ownership does allow for significant rent extraction. As a result, the buyer prioritizes rent extraction and thus prefers the presence of an affiliated supplier.

But what is the optimal supplier base structure for more competitive contests that involve incremental innovation and where none of the suppliers enjoys a clear advantage? In this scenario, the answer depends on how precisely supplier ownership affects the contest's competitiveness. So if an affiliated supplier renders the competition more intense than a contest with only independent suppliers (i.e., $g'_{\Delta\zeta}(0)>0$) then, by Proposition 2(i), supplier ownership always benefits the buyer. This situation occurs when the independent supplier has a minor advantage over the affiliated supplier—one that can be (at least partially) offset by introducing the handicap $kA$. The handicap thus renders the contest more competitive and leads to more innovation while also strengthening the buyer's ability to extract rents from the affiliated supplier. In contrast, if the affiliated supplier has even a minor advantage over the independent supplier then further handicapping the independent supplier could severely diminish the contest's competitiveness; the handicap may lower innovation incentives enough to make any rent extraction gains moot (i.e., if $g'_{\Delta\zeta}(kA)$ is sufficiently negative, as in part (ii) of Proposition 2). In such a case, it is in the buyer's best interest to forgo any rent extraction and instead host a contest with only independent suppliers.

**A Normal Example (continued).** To make the findings of Proposition 1 and 2 more accessible, we return to the illustrative example introduced in Section 4.1. Figure 2 illustrates our takeaways from the next corollary.

COROLLARY 2. *Suppose the buyer does not control the affiliated supplier, and let* $r(x)=rx$, $c(x)=cx^2/2$, *and* $\Delta\zeta\sim N(\mu,\sigma^2)$. *Then the following statements hold.*

**Figure 2 Impact of Supplier Ownership on Innovation and Profits**




*Note.* The graphs show the impact of supplier ownership on the level of innovation (left panel), the buyer's profits (middle panel), and the (mis)alignment between the buyer's interests in innovation and profits (right panel) as a function of the expected difference in innovation potential between suppliers ($\mu$) and the extent of technical uncertainty ($\sigma$). No pure-strategy equilibrium exists in the dark gray area. The parameters used here are $A=1$, $r(x)=2x$, $c(x)=x^2/2$, and $\Delta\zeta \sim N(\mu,\sigma^2)$.

(i) *An affiliated supplier improves the expected performance of the procured innovation iff* $\mu > 0$.

(ii) *There exist thresholds* $\gamma > 0$, $-\infty < \underline{\mu} < \overline{\mu} < 0$, *and* $0 < \overline{\sigma} < \infty$ *such that the buyer prefers a contest between an affiliated and an independent supplier if any of the following conditions is satisfied:* (a) $\mu > \overline{\mu}$ *or* $\mu < \underline{\mu}$; (b) $\sigma > \overline{\sigma}$; *or* (c) $Ar^2/c < \gamma$.

(iii) *There exist cases with* $\underline{\mu} < \mu < \overline{\mu}$, $\sigma < \overline{\sigma}$, *and* $Ar^2/c > \gamma$ *such that the buyer prefers a contest between two independent suppliers.*

The left panel of Figure 2 depicts the findings of Corollary 2(i): it clearly shows that supplier ownership promotes innovation iff the independent supplier has an expertise advantage over the affiliated supplier (i.e., $\mu > 0$). In that case—and only in that case—the presence of an affiliated supplier increases contest competitiveness, boosting equilibrium efforts and ultimately improving product innovation.

The middle panel of Figure 2 graphs the outcomes from parts (ii) and (iii) of Corollary 2, which perfectly mirror the results of Proposition 2. When the buyer seeks not only to promote innovation but also to extract rent from the affiliated supplier, having such a supplier benefits the buyer if the contest involves radical innovation or if there is a large difference in innovation potential between the suppliers. However, the buyer prefers to engage only independent suppliers when its affiliated supplier is marginally more advanced than the independent supplier *and* the contest involves incremental innovation.

## 4.4. Innovation versus Profitability

Comparing Propositions 1 and 2 leads to another interesting conclusion: the supplier base structure that maximizes a firm's expected profits is not necessarily the one that maximizes product innovation. The reason for this divergence is rooted in the buyer's preference structure, as formalized in equation (2). On the one hand, the buyer wishes to source an innovative product; on the other hand, the buyer also wants to maximize its rent extraction from the affiliated supplier. As discussed in Section 3.2, these two goals are not always aligned. In particular, they are misaligned if the presence of an affiliated supplier mildly reduces contest competitiveness and thereby reduces innovation—although this negative effect is offset by the much improved rent extraction opportunities. In contrast, if the presence of an affiliated supplier increases contest competitiveness then the buyer simultaneously maximizes product innovation and profitability when holding a procurement contest that includes an affiliated supplier. The next proposition formalizes those insights, and the right panel of Figure 2 presents the findings for our illustrative example. That figure reveals most notably that, for a wide range of parameter values (shaded region), the buyer is indeed willing to sacrifice product innovation in order to extract additional rents from its affiliated supplier.

PROPOSITION 3. *Suppose the buyer does not control the affiliated supplier.*

(i) *If* $g'_{\Delta\zeta}(0) > 0$, *then a contest between an affiliated and an independent supplier simultaneously maximizes the expected performance of the procured innovation and the buyer's expected profits.*

(ii) *If* $-\pi_2^*(0)/(A^2 I(0)) < g'_{\Delta\zeta}(kA) < 0$ *for all* $k \in [0,1]$, *then a contest between an affiliated and an independent supplier maximizes the buyer's expected profits but does not maximize the procured innovation's expected performance.*

(iii) *If* $g'_{\Delta\zeta}(kA) < -\pi_2^*(k)/(A^2(1 - G_{\Delta\zeta}(A) + G_{\Delta\zeta}(0))I(k))$ *for all* $k \in [0,1]$, *then a contest between independent suppliers simultaneously maximizes the expected performance of the procured innovation and the buyer's expected profits.*

From a managerial perspective, our preceding analysis has yielded three important insights. First, on a conceptual level, we have identified the mechanism by which supplier ownership affects the outcomes of a procurement contest. When taking ownership in a supplier, a buyer must balance innovation incentives with the opportunity for rent extraction. Ownership implies that the buyer shares the supplier's profits and thus extracts rents. Yet ownership implies also that the buyer handicaps the independent supplier and, in so doing, changes the effort incentives of all involved suppliers. One can hardly doubt that those altered effort incentives have a sizeable effect on the level of product innovation and, ultimately, on buyer profits.

Second, we have characterized the situations in which a buyer benefits from a supplier base structure that does (or does not) include an affiliated supplier. Most importantly, we have established that the value of affiliated supplier participation in a procurement contest depends critically on the contest's competitiveness and on the sensitivity of that competitiveness to supplier ownership.

A clear understanding of those two factors can help managers recognize the optimal structure for their supplier base—and help them build one that converges (in the long term) to an optimal structure.

Third, we have shown that firms, in their endeavor to maximize profits, might be tempted to sacrifice innovation and instead prioritize financial gains from rent extraction. Such a focus on short-term profits can have material long-term consequences: innovation is often path dependent, with new innovation building on past innovation (see, e.g., Schilling 2017). Therefore, a firm that chokes off innovation today may well prevent innovation in the future.

## 5. The Value of Supplier Control

In this section, we consider the possibility that the buyer not only owns (a portion of) the affiliated supplier but also *controls* that supplier. We ask: When does exercising control over an affiliated supplier improve contest outcomes for the buyer, and when does it worsen those outcomes?

One might prematurely jump to the conclusion that a buyer can always improve contest outcomes if it controls the affiliated supplier because, intuitively, exercising control allows the buyer to dictate all the supplier's decisions to its own liking. We shall explore when this intuitive reasoning is correct as well as, and perhaps more interestingly, when it fails to hold. In order to study the implications of supplier control, we must first slightly alter the base model (Section 5.1). We then study the impact of supplier control on the contest's competitiveness and on the suppliers' equilibrium effort provision (Section 5.2). Finally, we derive a contingency plan for establishing when the buyer does (or does not) benefit from controlling an affiliated supplier (Section 5.3).

Before delving into our analysis, it is worthwhile to clarify the relationship between supplier ownership and supplier control. Many legal jurisdictions stipulate a close bond between ownership and control, with pre-specified ownership levels in a supplier automatically implying control for the buyer (Franks and Mayer 2001, Del Prete and Rungi 2017). However, the ties between ownership and control are oftentimes more subtle. On the one hand, there are buyers that wield considerable influence on their affiliated suppliers even in the absence of substantial ownership (Liu 2017); on the other hand, there are buyers that actually forgo the opportunity to exert control over their suppliers despite having every legal right to control them (Riordan 1991, Hunold and Stahl 2017). We incorporate these various factual ownership and control structures into our model by assessing the value of supplier control for *any* given positive level of ownership. That is, we do not assume that a given ownership level $k$ automatically confers (or precludes) control.

### 5.1. A Model of Supplier Control

Our assumption that the buyer controls its affiliated supplier immediately implies that the latter no longer maximizes its own expected utility $\pi_2$ when choosing its solution effort $e_2$. Instead, it is now the buyer that decides on supplier 2's level of effort, and the buyer selects $e_2$ so as to maximize its own expected profits $\Pi$. At the same time, the independent supplier (i.e., supplier $i=1$) still chooses $e_1$ to maximize its expected utility $\pi_1$. So under supplier control, equilibrium efforts are the result of the following optimization problems:

$$e_1^c \in \arg\max_{e_1 \geq 0} \pi_1(e_1; e_2^c) = A\mathbb{P}(v_1 > v_2 + kA) - c(e_1); \tag{9}$$

$$e_2^c \in \arg\max_{e_2 \geq 0} \Pi(e_2; e_1^c) = \mathbb{E}[\max\{v_1, v_2 + kA\}] - A - kc(e_2). \tag{10}$$

In order for this problem to be meaningful, we must assume that the buyer cannot control the affiliated supplier if it has *no* ownership in that supplier; otherwise, the buyer could simply exploit the affiliated supplier at no cost. From now on we shall therefore focus on cases with $k > 0$.

It is also worth noting that control of an affiliated supplier (or the lack thereof) does not affect the *magnitude* of the rents that a buyer can extract from that supplier—the ability to extract rents is determined solely by $k$, the level of ownership. That is, supplier control just enables the buyer to influence a supplier's effort provision; by extension, however, that control affects the contest's competitiveness, the suppliers' chances of winning, and the level of product innovation.

## 5.2. Exercising Control and Contest Competitiveness

The following lemma characterizes the suppliers' equilibrium efforts when the buyer controls the affiliated supplier. It also compares those efforts to the equilibrium efforts without control (as presented in Lemma 1).

Lemma 2. *Suppose the buyer controls the affiliated supplier. Then, for any given $k \in (0,1]$, any pure-strategy BNE solves*

$$e_1^c = \eta\big(Ag_{\Delta\zeta}(G_{\Delta\zeta}^{-1}(k\eta^{-1}(e_2^c)))\big) \quad \text{and} \tag{11}$$

$$e_2^c = \eta\left(\frac{G_{\Delta\zeta}\big(r(e_2^c) - r\big(\eta(Ag_{\Delta\zeta}(G_{\Delta\zeta}^{-1}(k\eta^{-1}(e_2^c))))\big) + kA\big)}{k}\right). \tag{12}$$

*Now define $\underline{\delta} = -r(c^{-1}(A)) + kA$ and $\overline{\delta} = r(\eta(1/k)) + kA$, and let $e^*(k)$ be given by equation (5). Then:*

(i) *$e_2^c > \max\{e_1^c, e^*(k)\}$ if $g_{\Delta\zeta}(x) < \varepsilon$ for all $x \in [\underline{\delta}, \overline{\delta}]$ with $\varepsilon > 0$ sufficiently small;*

(ii) *$e^*(k) > e_1^c > e_2^c$ if (a) $kAg_{\Delta\zeta}(x)/G_{\Delta\zeta}(x) > 1$ for all $x \in [\underline{\delta}, \overline{\delta}]$ and (b) $g'_{\Delta\zeta}(x) > 0$ for all $x \leq kA$.*

Lemma 2 establishes that controlling the affiliated supplier has nuanced effects on the competitiveness of the contest and thus on the suppliers' equilibrium efforts. First, unlike in a contest without control (cf. Lemma 1), the two suppliers expend asymmetric effort levels in equilibrium. Namely, the independent supplier fights to win the supply contract $A$ (as before), whereas the affiliated supplier now chooses its effort to maximize the buyer's profits and not its own utility. As a result, the affiliated supplier is no longer interested only in $A$ but also in the value of its own (and of the independent supplier's) innovation: $v_1$ and $v_2$, respectively.

Second, in comparing the equilibrium efforts of an affiliated supplier with and without control, Lemma 2 shows that two factors drive the buyer's setting (when it has control) of the effort level of its affiliated supplier: (i) technological uncertainty, and (ii) the relative innovation potential of the affiliated and independent suppliers. Lemma 2(i) shows that, when under the buyer's control, an affiliated supplier expends more effort if (a) the contest involves radical innovation or (b) the affiliated supplier has a strong advantage over the independent supplier. In both cases, the affiliated supplier has a significant likelihood of winning the contest, which implies that the buyer is substantially interested in improving the performance $v_2$ of the affiliated supplier's innovation—and clearly, more solution effort (stochastically) increases $v_2$. At the same time, the buyer need not bear the full costs of this increased effort because it can relegate parts of those costs to the affiliated supplier's outside shareholders. Therefore, a buyer that controls its affiliated supplier will choose a higher effort level than that supplier would itself choose in the absence of control.

However, part (ii) of the lemma describes situations in which exercising control leads to *reduced* effort provision. This rather surprising outcome occurs when technological uncertainty is relatively low and the independent supplier has a markedly better innovation potential than does the affiliated supplier. In that case, the independent supplier has de facto won the contest and so the buyer will most likely end up procuring the independent supplier's innovation. Hence the direct marginal effect of the affiliated supplier's effort on the procured innovation is negligible, although it still generates costs for the buyer. The buyer will naturally prefer to minimize those costs by reducing the affiliated supplier's solution efforts. The buyer thereby also undermines the independent supplier's effort incentives, but that effort reduction is (in equilibrium) smaller than the buyer's cost savings. It follows that the buyer accepts a reduction in innovation performance in order to realize material cost savings.

Perhaps the key insight from Lemma 2 is this: controlling the affiliated supplier can reduce supplier incentives to invest effort in the contest, which means that supplier control can actually choke off innovation. This dynamic applies especially to contests in which incremental innovation is involved and the affiliated supplier is less capable than the independent supplier.

### 5.3. To Control, or Not to Control?

Since supplier control has an immediate effect on the suppliers' innovation efforts, we are faced with the question of whether those changes have a positive or negative impact on the buyer's profits and on the level of innovation. One might reasonably assume that control over the affiliated supplier always benefits the buyer; the buyer should be able to manipulate efforts so that either product innovation improves, the affiliated supplier is more likely to win, or effort costs are much lower (or some combination thereof). In other words, supplier control should allow the buyer to maximize both product innovation and expected profits. Yet despite this argument holding in a monopolistic context, it disregards the influence of a procurement contest's competitive nature. In fact, our next proposition reveals that supplier control is not a universal means for improving contest outcomes.

PROPOSITION 4. *For any given* $k \in (0,1]$, *the following statements hold.*

(i) *Controlling the affiliated supplier improves both the expected performance of the procured innovation and the buyer's expected profits provided that* $g_{\Delta\zeta}(x) < \varepsilon$ *for all* $x \in [\underline{\delta}, \overline{\delta}]$ *with* $\varepsilon > 0$ *sufficiently small.*

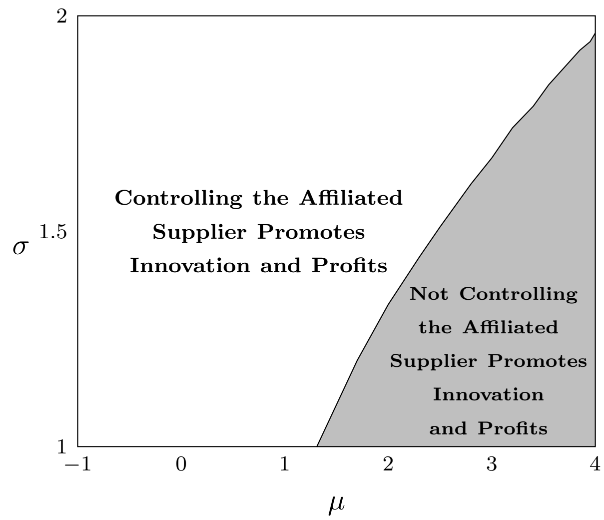
(ii) *Not controlling the affiliated supplier improves the expected performance of the procured innovation and the buyer's expected profits if* (a) $kAg_{\Delta\zeta}(x)/G_{\Delta\zeta}(x) > 1$ *for all* $x \in [\underline{\delta}, \overline{\delta}]$, (b) $g'_{\Delta\zeta}(x) > 0$ *for all* $x \leq kA$, *and* (c) $G_{\Delta\zeta}(kA) < \varepsilon$ *with* $\varepsilon > 0$ *sufficiently small.*

Proposition 4(i), which is closely aligned with Lemma 2(i), characterizes cases for which supplier control promotes innovation and profits: the buyer benefits from supplier control if the contest involves radical innovation or if the affiliated supplier has an advantage over the independent supplier. In those cases, according to part (i) of Lemma 2, we have $e_2^c > \max\{e_1^c, e^*(k)\}$; that is, with supplier control, the buyer entices the affiliated supplier to invest more effort. This increased effort boosts the buyer's expected profits for two reasons: first, a higher effort (stochastically) improves product innovation; and second, the odds of the affiliated supplier winning increase (because $e_2^c > e_1^c$), which in turn increases the buyer's expected rent extraction.

Part (ii) of Proposition 4 may well be the most surprising result: supplier control actually diminishes buyer profits, and the level of innovation, if the independent supplier is far more innovative (than its affiliated competitor) *and* innovation is expected to be incremental. We can understand this result by observing that, in this case, $e_2^c < e_1^c < e^*(k)$ by Lemma 2(ii). That is to say, supplier control reduces the innovativeness of the affiliated and independent supplier both. At the same time, the affiliated supplier lowers its efforts more than does the independent supplier, which leads to a lower chance of the former winning (and hence to less rent extraction by the buyer). Both of these effects are unquestionably detrimental to buyer profits, which explains why the buyer may prefer to forgo control over its affiliated supplier.

Overall, Proposition 4 allows us to draw an important conclusion about the repercussions of controlling a supplier: supplier control exhibits the same influence on product innovation as it does on a buyer's expected profits. So when control favors innovation, it also increases buyer profits; and when control squelches innovation, it also reduces buyer profits.

**Figure 3 Impact of Supplier Control on Innovation and Profits**




*Note.* The graph shows when supplier control does (and does not) promote innovation and buyer profits as a function of the expected difference in innovation potential between suppliers ($\mu$) and the extent of technical uncertainty ($\sigma$). The parameters used here are $A=1$, $k=1$, $r(x)=x$, $c(x)=x^2/2$, and $\Delta\zeta \sim N(\mu,\sigma^2)$.

**A Normal Example (continued).** As before, our illustrative example will reinforce the previous insights by making them more tangible.

Corollary 3. *Let $r(x)=rx$, $c(x)=cx^2/2$, and $\Delta\zeta \sim N(\mu,\sigma^2)$. Then, for any given $k \in (0,1]$, the following statements hold.*

(i) *There exist thresholds $-\infty < \underline{\mu} < 0$ and $0 < \overline{\sigma} < \infty$ such that controlling the affiliated supplier improves both the expected performance of the procured innovation and the buyer's expected profits if either of these conditions is satisfied:* (a) $\mu < \underline{\mu}$; *or* (b) $\sigma > \overline{\sigma}$.

(ii) *For sufficiently small $\sigma > 0$, there exists a threshold $kA < \overline{\mu} < \infty$ such that not controlling the affiliated supplier improves both the expected performance of the procured innovation and the buyer's expected profits if $\mu > \overline{\mu}$.*

Corollary 3 mirrors the results of Proposition 4. Part (i) of the corollary states that the buyer should prefer control over the affiliated supplier if (a) suppliers will be working on a radical innovation *or* (b) the affiliated supplier exhibits a higher level of expertise than does the independent supplier. Part (ii) shows that supplier control is detrimental to buyer profits if (a) only incremental innovation is involved *and* (b) the independent supplier has a considerable advantage in expertise over the affiliated supplier. Figure 3 illustrates these results.

In sum, our study of supplier control has yielded a fundamentally counterintuitive result: controlling a supplier can be detrimental to a buyer's profits. Of course, this claim would never be valid in a monopolistic setting. But as Proposition 4 shows, the competitive dynamics of a procurement contest can induce a buyer to make decisions that sacrifice product innovation and profits. Our analysis demonstrates why this managerial trap is most prominent when the contest involves incremental innovation and the independent supplier has a high innovation potential. In these circumstances, managers should resist the temptation to exert control over their affiliated suppliers.

## 6. Conclusions

How do different supplier base structures, as defined by varying degrees of supplier ownership and control, affect the outcomes of procurement contests? We answer this question by establishing when supplier ownership and control do (or do not) improve product innovation and the buying firm's profits. This paper's analyses thus contribute to our understanding of procurement processes—especially for innovative products.

This study deepens our knowledge of optimal supplier base structures for the procurement of innovative products by explicating how, exactly, technological uncertainty and the relative innovation potential of competing suppliers affect the value of supplier ownership and supplier control. For instance, we show that the buyer should (partially) own an affiliated supplier if radical innovation is sought or if there is a large difference in the suppliers' innovation potential. Yet for procurement contests that involve incremental innovation and suppliers of roughly equal innovation potential, the buyer may be best served by forgoing any ownership in its suppliers. It is likewise sometimes preferable for a buyer *not* to control its affiliated supplier because doing so may constrict both innovation and profits; this negative effect occurs when the independent supplier has much greater innovation potential (than does the affiliated supplier) and incremental innovation is needed. Finally, we also show that the firm's goal of fostering innovation may not always be aligned with its goal of achieving high profitability. In particular, if the contest involves radical innovation and if the affiliated supplier has an obvious advantage, then it may not be possible to achieve both of those goals.

Beyond merely offering managerial recommendations, we use the model developed here to gain perspective on the dynamics that drive our results; that is, we dissect the precise chain of causality that determines how supplier ownership and control each affect contest outcomes. We find that the presence of an affiliated supplier introduces—besides the classic innovation motive—a rent extraction motive that results in the buyer treating the affiliated supplier more favorably. In fact, that favoritism may then lead the buyer to procure the affiliated supplier's innovation even if it is inferior. It is precisely this bias in the buyer's selection process that has a strong bearing on supplier behavior and, eventually, on contest outcomes (in terms of both buyer profitability and product innovation).

Many practical examples mirror our theoretical predictions. In the introduction section, we used observations from the automotive industry to contextualize our research question; our results, in turn, prove helpful for understanding some empirical characteristics of supplier ecosystems in that industry. Note that an automobile consists of a large number of complex components, most of which evolve incrementally while some change radically from one generation to the next. Our findings predict that components that are susceptible to radical innovation—and hence usually require expertise beyond the typical knowledge of a car manufacturer (Kume 2020)—will likely be sourced from a supplier base that includes some affiliated suppliers. This prediction is surprisingly consistent with empirical reality in the automotive industry, and it is certainly true for what are currently the two most game-changing components: electronic driver assistance systems, and battery systems for electric vehicles. For the electronic driver assistance systems that some have argued will ultimately enable autonomous driving, purely independent suppliers (e.g., Waymo, MobilEye) are already competing with suppliers that are affiliated with specific car OEMs—such as Cruise with GM and Honda, ArgoAI with Ford and Volkswagen, and PonyAI with Toyota (Greenwood 2022). And for the battery system of electric vehicles, independent suppliers such as CATL or LG Chem are competing fiercely with the car OEMs and their affiliated suppliers for market share; examples include Volkswagen, which owns a share of the battery start-up Northvolt, and Tesla, which is engaged in a battery joint venture with Panasonic (Wilmot 2019).

For other components that demand less innovative solutions, our findings predict that the corresponding supplier ecosystems will consist solely (or nearly so) of independent suppliers. The reality of many such components supports this idea: tires are made by independent suppliers, as are lighting and suspension systems. In line with this prediction, our model also offers a plausible explanation for the vast wave of divestitures that occurred in more mature (i.e., less innovative) segments of the automotive industry at the end of the 1990s (Shirouzu 1999) and thereafter, as exemplified by the spin-outs of Delphi from GM, Visteon from Ford, and Faurecia from Peugeot.

Although these anecdotal examples are intriguing, they hardly constitute empirical verification of our model's predictions. It is nonetheless reassuring to see that real-world observations seem to be consistent with our findings. Furthermore, the idea that our model allows for predictions about the evolution of entire supplier ecosystems is enlightening in another respect. By broadening the lens and considering the supplier base as a whole, and not simply one buyer–supplier relation at a time, our paper allows for some overarching conclusions about the preferred shape of a buyer's supplier ecosystem. In many industries, the share of product innovation that is originally conceived by a buying firm's suppliers is steadily growing (a trend to which, e.g., the automotive and pharmaceutical industries are testament; Mueller et al. 2016, Crama et al. 2017). To remain competitive in these industries, it is thus a priority for senior management to unlock the full innovation potential of their supplier base. This study provides managers with some essential insights on how to achieve that goal (e.g., identifying classes of suppliers in which to invest and from which to divest). Our focus is on fostering innovation in a buyer's supplier base, but senior managers must in practice consider other factors as well—such as corporate finance, legal issues, anti-trust rules, and company valuation (Tirole 2006)—when deciding about any long-term investment in an affiliated supplier. That said, our paper offers clear guidelines about when affiliated suppliers can (or cannot) help a buyer with building an innovative supplier base.

In sum, we believe that this research has deepened our theoretical understanding of how best to source innovation and that it offers practical insights for senior managers on the most appropriate structure for their supplier base. Thus we hope to help answer some crucial strategic questions that should be addressed by senior operations executives.

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# Appendix to Sourcing Innovation: When to Own and When to Control Your Supplier?

## Appendix. Proofs.

*Proof of Lemma 1.* We derive the suppliers' equilibrium efforts by solving the optimization problems given in (3) and (4). Since each supplier's outside option is zero and $c(0)=0$, it follows immediately that both suppliers always participate in the contest (i.e., because for each $i\in\{1,2\}$, $\pi_i(0;e)>0$ for all $e\geq 0$). We can hence derive the BNE of the contest by investigating the suppliers' incentive compatibility conditions.

Our assumption that $\zeta_i$, $i\in\{1,2\}$, is sufficiently variable guarantees that there always exists a BNE in pure strategies. Thus, for any given $k\in[0,1]$, supplier $i$'s first-order optimality condition is given by

$$\frac{c'(e_i)}{r'(e_i)}=\eta^{-1}(e_i)=Ag_{\Delta\zeta}\left(r(e_2)-r(e_1)+kA\right), \tag{EC.1}$$

for all $i\in\{1,2\}$. Given our assumptions on $c$ and $r$, it follows readily that $\eta^{-1}$ is an increasing function, and equilibrium efforts are thus symmetric and unique; yielding $e^*(k)=\eta\left(Ag_{\Delta\zeta}(kA)\right)$. Straightforward differentiation of $e^*(k)$ with respect to $k$ and $A$, and noting that $\eta$ is an increasing function, concludes the proof.

*Proof of Corollary 1.* The equilibrium effort in (6) follows directly from inserting the given parametric assumptions in (5). Applying standard differentiation techniques to (6) proves the rest of the results.

(i) The claim follows immediately from the linearity of $e^*(k)$ in $r/c$ and the fact that $\phi(x)>0$ for all $x\in\mathbb{R}$.

(ii) By the properties of $\phi$, $e^*(k)$ increases in $\mu$ if and only if $(kA-\mu)/\sigma>0$, yielding the desired result. Note that $\partial e^*(k)/\partial\sigma=-rA\phi\left((kA-\mu)/\sigma\right)\left(\sigma^2-(kA-\mu)^2\right)/(c\sigma^4)$, and the result follows from requiring that $\sigma^2-(kA-\mu)^2\leq 0$.

(iii) By the properties of $\phi$, $e^*(k)$ increases in $k$ if and only if $(kA-\mu)/\sigma\leq 0$, yielding the desired result. To establish the sensitivity of $e^*(k)$ with respect to $A$, we will use the fact that $\phi'(x)=-x\phi(x)$ for all $x\in\mathbb{R}$. Differentiating (6) gives $\partial e^*(k)/\partial A=r\phi\left((kA-\mu)/\sigma\right)\left(-(kA)^2+\mu kA+\sigma^2\right)/(c\sigma^3)$, and the result follows from requiring that $-(kA)^2+\mu kA+\sigma^2\geq 0$.

*Proof of Proposition 1.* From the definition of $\psi(k;e_1,e_2)$, it follows that $\psi(k;e_1,e_2)=r(e_1)+\mathbb{E}[\zeta_1]-kAG_{\Delta\zeta}(r(e_2)-r(e_1)+kA)+\int_{-\infty}^{r(e_2)-r(e_1)+kA}G_{\Delta\zeta}(x)dx$. Hence, $\psi(k;e^*(k),e^*(k))=r(e^*(k))+\mathbb{E}[\zeta_1]-kAG_{\Delta\zeta}(kA)+\int_{-\infty}^{kA}G_{\Delta\zeta}(x)dx$, and taking the first-order derivative with respect to $k$ yields $d\psi(k;e^*(k),e^*(k))/dk=r'(e^*(k))\partial e^*(k)/\partial k-kA^2g_{\Delta\zeta}(kA)=A^2(I(k)g'_{\Delta\zeta}(kA)-kg_{\Delta\zeta}(kA))$. Here, $I(k)=r'(\eta(Ag_{\Delta\zeta}(kA)))\eta'(Ag_{\Delta\zeta}(kA))>0$ because $r$ and $\eta$ are increasing functions.

(i) A sufficient condition for $\arg\max_k\psi(k;e^*(k),e^*(k))>0$ to hold is $d\psi(0;e^*(0),e^*(0))/dk>0$, which is equivalent to $g'_{\Delta\zeta}(0)>0$.

(ii) A sufficient condition for $\arg\max_k\psi(k;e^*(k),e^*(k))=0$ to hold is $d\psi(k;e^*(k),e^*(k))/dk\leq 0$ for all $k\in[0,1]$. This condition is obviously satisfied if $g'_{\Delta\zeta}(kA)\leq 0$ for all $k\in[0,1]$.

*Proof of Proposition 2.* Given the suppliers' equilibrium effort $e^*(k)$ as defined in (5), the buyer's expected profit as a function of $k$ reads $\Pi^*(k) = r(e^*(k)) - kc(e^*(k)) + \mathbb{E}[\max\{\Delta\zeta, kA\}] + \mathbb{E}[\zeta_2] - A$. The first-order derivative of $\Pi^*(k)$ with respect to $k$ is hence:

$$\begin{aligned}\frac{d\Pi^*(k)}{dk} &= A^2 r'(\eta(Ag_{\Delta\zeta}(kA)))\eta'(Ag_{\Delta\zeta}(kA))\,(1 - kAg_{\Delta\zeta}(kA))\,g'_{\Delta\zeta}(kA) + AG_{\Delta\zeta}(kA) - c(\eta(Ag_{\Delta\zeta}(kA)))\\ &= A^2 I(k)\,(1 - kAg_{\Delta\zeta}(kA))\,g'_{\Delta\zeta}(kA) + \pi_2^*(k). \end{aligned} \tag{EC.2}$$

Note that $I(k) > 0$ because $r$ and $\eta$ are increasing functions. In addition, $\pi_2^*(k) > 0$ since in equilibrium, supplier 2 will always guarantee itself a strictly positive utility; for otherwise the supplier would find it profitable to exert zero effort, hence contradicting Lemma 1.

(i) A sufficient condition for the optimality of $k^* > 0$ is that $d\Pi^*(0)/dk > 0$, or equivalently, $A^2 I(0) g'_{\Delta\zeta}(0) + \pi_2^*(0) > 0$.

(ii) A sufficient condition for the optimality of $k^* = 0$ is that $d\Pi(k)^*/dk < 0$ for all $k \in [0,1]$, or equivalently, for all $k \in [0,1]$,

$$A^2 I(k)\,(1 - kAg_{\Delta\zeta}(kA))\,g'_{\Delta\zeta}(kA) + \pi_2^*(k) < 0. \tag{EC.3}$$

Note that for (EC.3) to hold, it is necessary that $w(k) = 1 - kAg_{\Delta\zeta}(kA) > 0$ for all $k \in [0,1]$. Suppose to the contrary that there exists $k_0 \in (0,1]$ such that $w(k_0) < 0$. Since $w(0) = 1 > 0$, it follows from the continuity of $w$ and the Intermediate Value Theorem that there exists $k_1 \in [0, k_0]$ such that $w(k_1) = 0$. However, since $\pi_2^*(k) > 0$, condition (EC.3) would then fail to hold at $k_1$.

The requirement that $w(k) > 0$ also implies that (EC.3) will not hold if $g'_{\Delta\zeta}(kA) \geq 0$ for some $k$. Now suppose that $g'_{\Delta\zeta}(kA) < 0$ for all $k \in [0,1]$. In this case, $w(k) > 1 - G_{\Delta\zeta}(A) + G_{\Delta\zeta}(0) > 0$ for all $k \in [0,1]$, and it follows that condition (EC.3) is satisfied if $g'_{\Delta\zeta}(kA) < -\pi_2^*(k)/(A^2(1 - G_{\Delta\zeta}(A) + G_{\Delta\zeta}(0))I(k)) < 0$ for all $k \in [0,1]$.

*Proof of Corollary 2.* (i) By Proposition 1(i), $k^* > 0$ if $\phi'(0) > 0$, which is true if $\mu > 0$. Similarly, by Proposition 1(ii), $k^* = 0$ if $\phi'(kA) \leq 0$ for all $k \in [0,1]$, which is true if $\mu \leq 0$.

(ii) Under the given parametric assumptions, condition (7) implies that the buyer prefers an affiliated supplier in the contest if

$$L = \phi\left(\frac{\mu}{\sigma}\right)\left(\frac{2\mu}{\sigma} - \phi\left(\frac{\mu}{\sigma}\right)\right) > -\frac{2c\sigma^2}{Ar^2}\left(1 - \Phi\left(\frac{\mu}{\sigma}\right)\right) = R. \tag{EC.4}$$

We now derive conditions for this inequality to be true:

(a) For $\mu \geq 0$, we have $L > -\phi(\mu/\sigma)^2 > R$ by the fact that $u_2^* > 0$ in equilibrium. Also, $\lim_{\mu\to-\infty} L = 0 > -2c\sigma^2/(Ar^2) = \lim_{\mu\to-\infty} R$. It follows from the continuity of $L$ and $R$, and the Intermediate Value Theorem that there exist thresholds $-\infty < \underline{\mu} < \overline{\mu} < 0$ such that (EC.4) holds for all $\mu > \overline{\mu}$ and all $\mu < \underline{\mu}$.

(b) Note that $\lim_{\sigma\to\infty} L = -1/(2\pi) > -\infty = \lim_{\sigma\to\infty} R$. By continuity of $L$ and $R$, and the Intermediate Value Theorem, there exists a threshold $0 < \overline{\sigma} < \infty$ such that (EC.4) holds for all $\sigma > \overline{\sigma}$.

(c) For any given $\mu \in \mathbb{R}$ and $\sigma > 0$, $L$ is finite, whereas $\lim_{Ar^2/c\to 0} R = -\infty$. It follows from the continuity of $L$ and $R$, and the Intermediate Value Theorem that there exists a threshold $\gamma > 0$ such that (EC.4) holds for all $Ar^2/c < \gamma$.

(ii) The result follows directly from part (i) together with the observation that $k^* = 0$ maximizes (2) if $A = r^2/(4c) = \sigma$ and $\mu/\sigma \in [-0.72, -0.17]$.

*Proof of Proposition 3.* The results follow directly from comparing the findings of Proposition 1 and 2.

*Proof of Lemma 2.* We derive the suppliers' equilibrium efforts by solving the optimization problems given in (9) and (10). By the same arguments as in the proof of Lemma 1, for any given $k>0$, there always exists a pure-strategy BNE, and such a BNE must satisfy the following first-order optimality conditions:

$$e_1^c = \eta\left(Ag_{\Delta\zeta}\left(r(e_2^c) - r(e_1^c) + kA\right)\right) \tag{EC.5}$$

$$e_2^c = \eta\left(\frac{G_{\Delta\zeta}\left(r(e_2^c) - r(e_1^c) + kA\right)}{k}\right). \tag{EC.6}$$

Noting that $r(e_2^c) - r(e_1^c) + kA = G_{\Delta\zeta}^{-1}\left(k\eta^{-1}\left(e_2^c\right)\right)$, and substituting $e_1^c$ into (EC.6), leads to (11) and (12).

We next demonstrate how, for any given $k>0$, the equilibrium efforts under control (i.e., $e_1^c$ and $e_2^c$) compare to the equilibrium efforts without control (i.e., $e^*(k)$ as given in (5)).

(i) In equilibrium, $e_1^c \le c^{-1}(A)$ and $e_2^c \le \eta(1/k)$, and thus $r(e_2^c) - r(e_1^c) + kA \in [\underline{\delta}, \overline{\delta}]$. Now suppose that $g(x) < \varepsilon$ for all $x \in [\underline{\delta}, \overline{\delta}]$. Then, $e_1^c < \eta(A\varepsilon)$ and $e^*(k) < \eta(A\varepsilon)$, and hence $\lim_{\varepsilon\to 0} e_1^c = \lim_{\varepsilon\to 0} e^*(k) = 0$. Moreover, $e_2^c > \eta\left(G_{\Delta\zeta}(\underline{\delta})/k\right) > 0$. The result follows by continuity of equilibrium efforts and the Intermediate Value Theorem.

(ii) Suppose that $kAg_{\Delta\zeta}(x)/G_{\Delta\zeta}(x) > 1$ for all $x \in [\underline{\delta}, \overline{\delta}]$. Then, by (EC.5) and (EC.6), $e_1^c > e_2^c$ because $\eta$ is an increasing function. This also implies that $r(e_2^c) - r(e_1^c) + kA < kA$; and since $g'(x) > 0$ for all $x \le kA$, $e^*(k) = \eta\left(Ag_{\Delta\zeta}\left(kA\right)\right) > \eta\left(Ag_{\Delta\zeta}\left(r(e_2^c) - r(e_1^c) + kA\right)\right) = e_1^c$.

*Proof of Proposition 4.* For any given $k>0$, the difference between the buyer's expected profits with and without control is given by $\Delta\Pi(e_1^c, e_2^c, e^*(k)) = \Pi(e_1^c, e_2^c) - \Pi(e^*(k), e^*(k))$, where $\Pi(e_1, e_2)$ is given in (2) and the equilibrium efforts are as defined in Lemma 1 and 2. Furthermore, for any given $k>0$, denote the difference between the expected performance of the procured innovation with and without supplier control as $\Delta\psi(k; e_1^c, e_2^c, e^*(k)) = \psi(k; e_1^c, e_2^c) - \psi(k; e^*(k), e^*(k))$.

(i) Suppose that $e^*(k) = 0$, $e_1^c = 0$, but $e_2^c > 0$. Then, $\Delta\Pi(e_1^c, e_2^c, e^*(k)) > 0$ because, by optimality, $e_2^c$ maximizes $\Pi(0, e_2^c)$, and thus $\Pi(0, e_2^c) > \Pi(0,0)$. Moreover, recall from the proof of Lemma 2(i) that $\lim_{\varepsilon\to 0} e^*(k) = \lim_{\varepsilon\to 0} e_1^c = 0$, but $\lim_{\varepsilon\to 0} e_2^c > 0$. Using those results, we have $\lim_{\varepsilon\to 0} \Delta\psi(k; e_1^c, e_2^c, e^*(k)) = \int_{kA}^{r(e_2^c)+kA} G_{\Delta\zeta}(x)dx > 0$. The result now follows directly from the limit properties of the equilibrium efforts derived in the proof of Lemma 2(i), the continuity of $\Delta\Pi(e_1^c, e_2^c, e^*(k))$ and $\Delta\psi(k; e_1^c, e_2^c, e^*(k))$, and the Intermediate Value Theorem.

(ii) Recall from the proof of Lemma 2(ii) that, if $kAg_{\Delta\zeta}(x)/G_{\Delta\zeta}(x) > 1$ for all $x \in [\underline{\delta}, \overline{\delta}]$ and $g'(x) > 0$ for all $x \le kA$, we have $e^* > e_1^c > e_2^c$. Under those assumptions, it then follows that $\Delta\psi(k; e_1^c, e_2^c, e^*(k)) > r(e^*) - r(e_1^c) - kA(G_{\Delta\zeta}(kA) - G_{\Delta\zeta}(r(e_2^c) - r(e_1^c) + kA))$, and clearly, $\Delta\psi(k; e_1^c, e_2^c, e^*(k)) > 0$ if $G_{\Delta\zeta}(kA) < \epsilon$, for sufficiently small $\epsilon > 0$. Moreover, we have $\lim_{\epsilon\to 0} e_2^c = 0$, and from the fact that, in equilibrium, the independent supplier must have a positive expected utility, it follows that $\lim_{\epsilon\to 0} c(e^*) < \rho$, for any arbitrarily small $\rho > 0$. As a result, $\lim_{\epsilon\to 0} \Delta\Pi(e_1^c, e_2^c, e^*(k)) = \lim_{\epsilon\to 0}(\mathbb{E}[\max\{r(e_1^c)+\zeta_1, r(e_2^c)+\zeta_2+kA\}] - \mathbb{E}[\max\{r(e^*)+\zeta_1, r(e^*)+\zeta_2+kA\}] + kc(e^*) - kc(e_2^c)) < -(r(e^*) - r(e_1^c)) + k\rho < 0$. The result is then a consequence of the continuity of $\Delta\Pi(e_1^c, e_2^c, e^*(k))$ and $\Delta\psi(k; e_1^c, e_2^c, e^*(k))$, and the Intermediate Value Theorem.

*Proof of Corollary 3.* Under the given parametric assumptions and with $\Phi$ denoting the cumulative distribution function of a standard normal random variable, the equilibrium conditions of Proposition 2 can be simplified as follows:

$$e_1^c = \frac{rA}{c\sigma}\phi\left(\frac{re_2^c - re_1^c + kA - \mu}{\sigma}\right) \tag{EC.7}$$

$$e_2^c = \frac{r}{ck}\Phi\left(\frac{re_2^c - re_1^c + kA - \mu}{\sigma}\right), \tag{EC.8}$$

and the equilibrium efforts without control $e^*(k)$ are given by (6).

(i) Note that (a) $\lim_{\mu\to-\infty} e_1^c = \lim_{\mu\to-\infty} e^*(k) = 0$ whereas $\lim_{\mu\to-\infty} e_2^c = r/(ck) > 0$; and (b) $\lim_{\sigma\to\infty} e_1^c = \lim_{\sigma\to\infty} e^*(k) = 0$ whereas $\lim_{\sigma\to\infty} e_2^c = r/(2ck) > 0$. By continuity of the equilibrium efforts and the Intermediate Value Theorem, it follows that there exist thresholds $-\infty < \underline{\mu} < 0$ and $0 < \overline{\sigma} < \infty$ such that $e_2^c > \max\{e_1^c, e^*(k)\}$ if either (a) $\mu < \underline{\mu}$, or (b) $\sigma > \overline{\sigma}$. The result now follows directly from Proposition 4(i), the properties of $\Delta\Pi(e_1^c, e_2^c, e^*(k))$ and $\Delta\psi(k; e_1^c, e_2^c, e^*(k))$, and the Intermediate Value Theorem.

(ii) If $e_1^c > e_2^c$ and $\mu > kA$, it is true that $e^*(k) = rA\phi((kA-\mu)/\sigma)/(c\sigma) > rA\phi((re_2^c - re_1^c + kA - \mu)/\sigma)/(c\sigma) = e_1^c$. Moreover, $\lim_{\mu\to\infty} e_1^c/e_2^c = \infty$ by the properties of the inverse Mill's ratio (i.e., $\phi(x)/\Phi(x)$) for the standard Normal distribution. It follows that by continuity of the equilibrium efforts and the Intermediate Value Theorem, there exists a threshold $kA < \overline{\mu} < \infty$ such that $e^*(k) > e_1^c > e_2^c$ for all $\mu > \overline{\mu}$. The result now follows directly from Proposition 4(ii), the properties of $\Delta\Pi(e_1^c, e_2^c, e^*(k))$ and $\Delta\psi(k; e_1^c, e_2^c, e^*(k))$, and the Intermediate Value Theorem.