Second Sourcing vs. Sole Sourcing with Capacity Investment and Asymmetric Information

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We study the decision of a manufacturer (the buyer), expecting new sourcing opportunities in the future, in selecting between sole- and second-sourcing strategies for a noncommodity component. In a sole-sourcing strategy, the buyer commits to source from a single supplier (the incumbent) over the entire horizon. In a second-sourcing strategy, the buyer keeps the option open to source from a new supplier (the entrant) in the future. Supplier costs are private information, and the incumbent’s cost may change in the future due to learning. The buyer is relatively sure about current demand but uncertain about future demand. A supplier has to invest in capacity in order to produce the inputs for the buyer. With future private cost information, the incumbent earns rent in the future, and this prospective rent influences the incumbent’s decision early in the horizon. On one hand, a second-sourcing strategy allows the buyer to take advantage of alternative sourcing opportunities, lowering her future cost. This reduction of the future cost resulting from the option of using an alternative supplier is referred to as the option value of second sourcing. On the other hand, the future supplier competition in second-sourcing hurts the incumbent’s future profit. The expectation of a lower future profit in second sourcing (compared to sole sourcing) induces the incumbent to ask for a higher price at the beginning of the horizon. This causes more initial sourcing cost for the buyer in second sourcing than in sole sourcing. We refer to such increase of the initial cost due to the opportunity of introducing future supplier competition as the cost of future supplier competition of second sourcing.

The overall benefit of second sourcing relative to sole sourcing is influenced by the demand distribution and capacity cost. If the demand increases over time with positive probability, the incumbent’s initial capacity may not be able to cover all future demand. If the capacity is cheap, the entrant may serve as an exclusive supplier, ousting the incumbent. In this case, the option value of second sourcing is high. If the capacity is expensive, the entrant may serve as a supplementary supplier by receiving only the demand in excess of the incumbent’s installed capacity. In this case, the cost of future supplier competition is low while the option value is still significant. Thus second sourcing is better than sole sourcing not only when the capacity cost is low, but also when it is high (under the condition that demand increases over time with positive probability and the entrant’s cost is relatively low). For intermediate capacity cost, the cost of future supplier competition dominates the option value and hence, sole sourcing is preferred. We also find that second sourcing is more attractive when the buyer expects the demand to increase in the future, or expects the future demand to be more volatile. Finally, more initial capacity of the incumbent strengthens the incumbent’s competitiveness against the entrant, reducing the cost of future supplier competition. As a result, we find that second sourcing may lead to overinvestment of the initial capacity.
1 Introduction

Focusing on core competencies, companies are relying on external suppliers for activities with increasing complexity and strategic importance (Gottfredson et al., 2005; Maurer et al., 2004; Liker and Choi, 2004). In the automotive industry, suppliers provide not only small parts, but increasingly complex subsystems such as exhaust systems, cockpits, front ends, and integrated seats. As the modularization of vehicles continues, OEMs will expect suppliers to deliver entire roof systems, integrated interiors, complete doors, and trunk lids (Maurer et al., 2004). A similar trend is occurring in the electronics industry, where OEMs usually outsource most production or even entire system builds in order to focus on the functions of design and marketing (Barnes et al., 2000; Carbone, 2000).

Accompanying this trend of more complex sourcing activities are the dynamics of the supply market. The development of supply bases in low-cost countries brings new sourcing opportunities for OEMs, thanks to growing engineering and production capabilities and growth of the emerging economies in these areas (Balasubramanian and Padhi, 2005). At the same time faster development of new technology shortens the product life cycle and causes the emergence of new suppliers that embrace new technologies. As an example of supply base development, low quality of raw material and low productivity in developing countries had prevented more production in the automotive industry from going overseas. But as suppliers in China had become more competitive in quality and cost, in 2008 Ford was planning to double its purchasing of China-made parts and DaimlerChrysler expected to increase its purchasing of parts in China to more than $840 million compared with $100 million in 2006 (Bloomberg News, 2006). As an example of technology development, Fujitsu Ltd. became a competitive newcomer to the electronics manufacturing industry by adopting advanced technologies that allow them to process silicon wafers that are 300 mm in diameter with circuit lines as narrow as 90 nm. This motivated Lattice Semiconductor Corp. to migrate business from a Taiwanese supplier to Fujitsu (Einhorn, 2004).

With potential new supply opportunities in the future, a key question for a manufacturer is what relationship to build with a supplier. We observe different choices made by companies in industry. Japanese companies are known for *keiretsu*, which features interlocking long-term relationships between companies. In such relationships, the length of trading is projected to continue beyond the duration of a current contract. For example, a typical contract of JJ Electric with a supplier is valid for a year but is very likely to be automatically renewed every year unless either party objects (Sako, 1992). However, the Japanese companies also lamented the difficulties they had
in breaking up existing relationships with suppliers to switch to new suppliers (Sako, 1992). In contrast, GM actively moved away from partnership relationships with its suppliers. The average length of contracts GM offered fell about 40% from 1.8 years in 1989 to just over one year in 1993. GM also set up a system of worldwide competitive bidding, saving an estimated $4 billion a year in the prices it paid for parts between 1992 and 1994 (Fine et al., 1996).

However, recent years have witnessed a growing trend of companies consolidating their supply base and forming long-term relationships with their key suppliers (Maurer et al., 2004; Pyke and Johnson, 2003). For example, Chrysler’s average contract length nearly doubled from 1989 to 1994 (Helper, 1991; Dyer, 1996). Chrysler gives oral guarantees to more than 90% of its suppliers that they will have the business for the life of the model they are supplying and beyond (Dyer, 2000). GB Electronics attempt to forge closer relationships with fewer suppliers with their Preferred Supplier Policy. Different from Chrysler, they consider giving out three-year contracts with either a fixed-price schedule or the right of price renegotiation every year (Sako, 1992). Ford planned to cut by more than half the number of suppliers from whom it bought 20 key parts by offering larger, long-term contracts on models built in 2008–2009 and beyond to a smaller group of suppliers (Mccracken, 2005). In fact, Ford purchases more than 90% of Land Rover’s components from single suppliers (Lester, 2002).

In the electronics industry, most telephone handset vendors rely on one main source for certain key components, but Apple has sourced its iPhone touchscreen display from four suppliers, who bid each time Apple releases a factory order. By pitting suppliers against each other, Apple maintains the upper hand and keeps its costs low (Carson, 2007). In another example, although Microsoft initially obtained some key components for its Xbox 360 game console systems from a single source, they indicated that they had kept alternative sourcing options open: “we are under no obligation to exclusively source components from these vendors in the future” (Microsoft Annual Report, 2005).

The variety of strategies followed by companies indicates that the supplier relationship choice for sourcing arrangements warrants further study. Based on the above observations, we identify several important issues to be considered in supplier relationship decisions.

**Capacity investment:** In order to provide complex customized products, a supplier is usually required to invest in specific capacity, such as workers with special skills, specific machines or tools, or facilities set up alongside the OEM’s site. The capacity cost is typically higher for components with a lower level of standardization or higher degree of supplier–buyer interdependence (Dyer, 2000). While a new supplier may be more efficient than the incumbent
supplier, the specific capacity investment, which is a sunk cost for the incumbent supplier, imposes extra cost for the new supplier. On the other hand, since the volume received by a supplier depends on the supplier relationship, the supplier relationship choice also leads to different capacity investment decisions.

**Demand uncertainty:** For a supplier that provides critical and customized components, the demand closely depends on, and hence is susceptible to, the variation of the final product demand. In the automotive industry, unstable and uncertain domestic volume of individual models is cited as one of the biggest challenges faced by manufacturers due to increased consumer choices (Andersson, 2006). The consumer electronics industry is notorious for risk stemming from short product life cycles and high demand uncertainty (Carbone, 2005). Furthermore, there is typically more uncertainty about the future demand than about the current demand. This demand uncertainty adds another source of future uncertainty, besides possible supplier switching (in a short-term relationship), that influences the decision of initial capacity investment.

**Information asymmetry:** Because suppliers tend to understand the technical processes better than the purchasing company, they are better positioned to identify areas of savings: reducing the number of components by combining separate parts, applying advanced fabrication techniques to reduce subsequent steps, changing part geometries and increasing machining tolerances, alternating materials that can reduce cost of noncritical components, etc. (Ulrich and Eppinger, 2004). This knowledge allows a supplier to hold private information of production costs. For technologically complex products, there is generally substantial private information about productivity or technologies of a supplier (Lyon, 2006). With private information, a supplier can extract significantly more profits than would otherwise be possible.

**Supplier learning:** Production processes for complex components may require ill-defined steps. This leaves open room for a supplier to improve efficiency over time by further optimizing the production processes. In general, OEMs’ shifting of more development and engineering work, which require complex tasks and customized products, to their suppliers implies a significant potential for a supplier to accumulate knowledge and experience from learning, thus reducing costs over time (Monczka et al., 2005; Gray et al., 2005; Lewis and Yildirim, 2002). This dynamic change of supply costs affects the negotiation of sourcing contracts (Monczka et al., 2005; Yelle, 1979).
Before selecting between long-term and short-term relationships, a buyer (manufacturer) needs to carefully design the sourcing strategy with each relationship and evaluate the profits by considering the above factors. We study two sourcing strategies, sole sourcing and second sourcing, representing long-term and short-term relationships. In the sole-sourcing strategy, the buyer commits the current and future demand volume to a single current supplier. In the second-sourcing strategy, the buyer commits only the current volume to the current supplier, but keeps the option open to source from another supplier in the future. Our goal is to understand when one strategy is better for the buyer than the other.

In order to understand fundamental economic determinants of the sourcing-strategy choice, we analyze a model with a two-period horizon. During the first period, only one supplier (incumbent) is available. This supplier is then joined by a second potential supplier (entrant) in the second period. While the first-period market demand is known, the second-period demand is uncertain. A supplier has to invest in capacity in order to produce the inputs for the buyer. The suppliers’ production costs are private information in both periods. Due to learning, the incumbent’s second-period cost may be different from those of the first period. Under such circumstances, we compare sole-sourcing and second-sourcing strategies. We focus on the difference between the two strategies resulting from the decisions made by the buyer and suppliers in response to the relationship choice. External factors, such as the extra cost of dealing with multiple suppliers in a second-sourcing strategy, are neglected, but could be added on top of our model without changing the internal mechanics.

The fundamental driver of relationship selection in our model is the following. With the option of alternative sourcing open, a second-sourcing strategy allows the buyer an opportunity to reduce her cost in the second period by switching to the entrant. Therefore, a second-sourcing strategy provides the option value, which is referred to as the reduction of the second period cost resulting from the opportunity of using an alternative supplier. With second-period private information, the incumbent earns rent in the second period. In the second period of a second-sourcing strategy, since the incumbent faces the competition from the entrant, he earns less rent than in the second period of a sole sourcing strategy. Therefore, the incumbent expects a lower second-period profit in a second-sourcing than in a sole-sourcing strategy. Since the buyer and incumbent care about the profits over the entire horizon, the second-period outcome has an impact on the first-period decisions. Particularly, expecting a lower profit in the second period, the incumbent will ask for a higher price in the first period of a second-sourcing strategy than in a sole-sourcing strategy. Therefore, the second-sourcing opportunity causes more first-period cost for the buyer. Such increase of the first-
period cost due to the second-period opportunity of introducing supplier competition is referred to as the cost of future supplier competition of second sourcing for the buyer.

The overall benefit of second sourcing relative to sole sourcing is influenced by the demand distribution and capacity cost. If the demand increases over time with positive probability, the incumbent’s initial capacity may not be able to cover all future demand. When capacity is cheap, the incumbent has weak first-mover capacity advantage over the entrant, and the entrant may serve as an exclusive supplier, ousting the incumbent. In this situation, second sourcing has high option value, and is thus superior to sole sourcing. When capacity becomes more expensive, the cost of future competition dominates the option value of second sourcing, resulting in sole sourcing preferred to second sourcing. Finally, when capacity is even more expensive, an interesting reversal occurs: The position of the entrant is then weakened in competition for the demand covered by the incumbent’s installed capacity, but the entrant may still serve as a supplementary supplier by receiving only the demand in excess of the incumbent’s installed capacity. This mitigates the cost of future supplier competition while delivering option value of second sourcing. As a result, second sourcing might be preferred by the buyer even if capacity is expensive (provided that demand increases over time with positive probability and the entrant’s cost is relatively low).

We show that more uncertainty of the future demand makes second sourcing more attractive. The reason is that more demand uncertainty reduces the incumbent’s first-mover capacity advantage in the competition with the entrant, increasing the option value more than the cost of future supplier competition of second sourcing. While the operations literature has studied multisourcing assuming no information asymmetry, our paper considers suppliers’ strategic behavior in a dynamic setting in the presence of suppliers’ private information, providing a different explanation for the value of sourcing from multiple suppliers in a volatile environment.

If the buyer can commit to sole sourcing, as assumed in our model, investing in more capacity than the demand in the first period will not occur in the optimal sourcing strategy choice. But if a sole-sourcing commitment is not credible and only second sourcing is feasible, our analysis shows that the incumbent may be induced to invest in excess capacity at the beginning of the horizon. This is because capacity investment of the incumbent can be used as a leverage to influence supplier competition. In that case, capacity is used as a substitute for commitment.

2 Literature review

There is a body of literature in economics and operations management that provides us with theory and insights in procurement. We refer readers to Elmaghraby (2000) for a general overview of the
literature and to Laffont and Tirole (1993) for theories of procurement. In the rest of this section, our review focuses on the papers that consider multiperiod supplier selection or capacity investment with uncertain demand.

In a multiperiod setting, multiple suppliers may be adopted earlier or later in the time horizon. When supplier competition is introduced at the beginning, a general insight is that investing in or sourcing from multiple suppliers at the beginning, even though not efficient, may benefit the buyer in the future. This benefit can be due to better information on suppliers’ quality (Deng and Elmaghraby, 2005) or bidding parity between suppliers (Dasgupta, 1990; Riordan, 1996; Klotz and Chatterjee, 1995; Lewis and Yildirim, 2002) resulting from the multisourcing stage. Different from these papers, in our model, supplier competition appears later following a single-sourcing stage (in the second-sourcing strategy). In this situation, the supplier competition influences the preceding decision of the buyer and supplier in the single-sourcing stage.

A stream of papers study the situation in which supplier competition is introduced later in the horizon. These papers usually consider actions of the buyer or supplier in the first single-sourcing stage that directly influence the incumbent’s production cost in the second multisourcing stage. The actions may include the buyer’s sourcing quantity decision (Anton and Yao, 1987; Rob, 1986) or the supplier’s cost-reduction efforts (Rob, 1986; Stole, 1994; Laffont and Tirole, 1988). They focus on how the future competition influences and is influenced by the action(s) in the first stage. While we analyze similar dynamics in the second-sourcing strategy, we consider a different type of action—capacity investment—in the first stage. Capacity investment indirectly influences the supplier’s overall cost (without changing the unit production cost) and plays a role in volume allocation between suppliers. Therefore, in our model, the initial investment influences the future competition in a different way.

The buyer may have the freedom to choose when to introduce supplier competition. Gray et al. (2005) analyze the dynamic make-or-buy decision with the buyer considering herself as an internal supplier besides an external supplier. Assuming complete information, they reveal that different sourcing structures may appear, depending on the negotiation power structure and pace of learning. We consider incomplete information and the buyer as the negotiation leader. Therefore, the sources of profits and costs for the buyer and supplier are different, implying different dynamics in the system.

All the above-mentioned papers assume that the buyer has access to multiple suppliers. We analyze whether or not the buyer should allow herself such access by comparing sole sourcing with second sourcing. In this direction, several papers compare sourcing strategies that involve
different levels of commitment. Considering suppliers’ learning-by-doing, Elmaghraby and Oh (2004) compare the buyer’s profits from auctioning off a long-term contract with an eroding price and from conducting sequential independent auctions. While the two strategies exhibit the features of long-term and short-term relationships, they are different from the sole- and second-sourcing strategies considered in our paper. As a result, they find that the latter strategy often leads to more profits for the buyer, while we reveal that sole sourcing can be better than second sourcing under some conditions. Swinney and Netessine (2007) study a buyer’s choice between long-term and short-term contracts offered to a supplier, considering the supplier default risk. Assuming no information asymmetry, they show that the possibility of supplier default offers a reason for a buyer to prefer long-term contracts to short-term contracts. Our model considers a supplier with private information, with sole sourcing driven by a different reason: Sole sourcing induces the incumbent, who has guaranteed future business, to accept a low initial price. This reason is the same as in Riordan and Sappington (1989), who assume constant (unit) demand in the context of the defense industry. We consider a situation concerning uncertain demand and capacity investment, motivated by the manufacturing industry, and thus deliver new insights regarding the influence of product demand and capacity cost on relationship choice.

Several papers study procurement problems considering uncertain demand and capacity investment. Cachon and Zhang (2007) examine demand allocation in a multisourcing mechanism, assuming complete information of suppliers’ costs. Cachon and Zhang (2006) and Chen (2001) study single-sourcing strategies with incomplete cost information. In all these papers, the set of suppliers is static and the buyer and suppliers interact only once to determine the winner and the contract. We consider a dynamic situation in which a supplier may face competition from a new supplier in the future. Thus, in our paper, capacity investment has a new role—it shapes the future supplier competition (in a second-sourcing strategy). Taylor and Plambeck (2007) analyze repeated interaction between a single buyer and single supplier without considering the availability of a second supplier. Therefore, the incentive of supplier capacity investment in their model is different from ours.

Finally, there is a stream of literature that considers sourcing a commodity available in a spot market. They typically address the issue of how to combine long-term contracts and spot purchases in the presence of uncertain demand (Serel et al., 2001), uncertain market price (Wu et al., 2002), or both (Seifert et al., 2004). As no specific investment is required for the supplier, the competition between the supplier and spot market is completely determined by the contract price and the market price. We consider sourcing a customized product for which a supplier has to invest in
specific capacity; therefore, a spot market does not exist. In our model, the capacity cost and demand uncertainty together play an important role in the relationship choice.

3 The Model

3.1 Model Description

The final product: A downstream firm (buyer) has exclusive access to a final product market that lasts for two periods, \( t \in \{1, 2\} \). In each period, the firm sells the product at a unit price \( r \). The firm knows the demand in the first period. However, due to the long duration of the period (for example, a contract in the automotive industry typically lasts for a few years), the firm in the first period does not know the demand in the second period. In other words, the second-period demand remains uncertain until the beginning of the second period. To this end, let the first-period demand be \( x_1 \), and the second-period demand be \( X_2 \), drawn from a probability distribution \( G(\cdot) \) with density \( g(\cdot) \) and mean \( x_2 \). Define \( S(Q) = E[\min(X_2, Q)] \) as the expected demand covered by capacity \( Q \) in the second period. The production of the final product requires an essential input that the buyer sources from an external supplier. The in-house cost of the other inputs of the firm is normalized to zero.

The capacity investment: A supplier has to invest in capacity in order to produce inputs for the buyer. The capacity limits the quantity that the supplier can produce in a period. The capacity is acquired from a competitive market at a constant cost of \( k \) per unit. We assume existing capacity can be expanded at the same unit cost, and the value of unused capacity in the outside market is normalized to zero. We also assume the lead time of capacity investment is negligible compared to the length of a horizon, and hence in each period capacity is invested after the demand is observed. Nevertheless, capacity investment is still not a trivial decision: The supplier’s capacity invested in the first period influences his cost of satisfying demand and the result of supplier competition in the second period. Therefore, the first-period investment has to take into consideration the uncertainty of supplier competition and demand in the second period. In addition, we assume capacity is contractible, i.e. buyer and supplier can enter a court-enforceable agreement on the amount of capacity to install. This is reasonable when capacity can be observed and verified. In fact, in the automotive industry, the OEM often has control over specific capital investment (Dyer, 1997), or is given the opportunity to audit the amount spent by the supplier on capital investment used exclusively for the OEM and reimburses that cost (Visteon, 2003). (In Section 6, we relax this assumption by considering the situation when the capacity cannot be specified by the buyer.)
Since the buyer and suppliers are risk-neutral, we assume without loss of generality that the buyer pays the supplier the capacity cost separate from the unit price for the input.

The upstream market: Only a limited set of suppliers have the capability of deploying the capacity to produce the essential input for the buyer. A spot market does not exist because the input is a noncommodity and specific capacity investment is required for the production. To capture that over time new suppliers become available, we consider in Period 1 one supplier (the incumbent) and in Period 2 two suppliers (the incumbent from Period 1 and the entrant).

The supplier capability: A supplier incurs a cost of producing the input for the buyer that is specific to the supplier. In the first period, the incumbent’s cost, $c_1$, is drawn from probability distribution $F_1(c_1)$ (density $f_1(c_1)$), $c_1 \in [c_1, \bar{c}_1]$. Due to learning, the incumbent’s cost in the second period changes from the first period. Let the incumbent’s second-period cost be $c_I$, drawn from probability distribution $F_I(c_I)$ (density $f_I(c_I)$), $c_I \in [c_I, \bar{c}_I]$. We assume that $c_I$ and $c_1$ are independent. This assumption is reasonable when the duration of a period is long; this condition allows many random shocks to happen in a period that make the state of the cost one period later irrelevant to the one before. This assumption may also be reasonable when the shocks are tied to changes in, e.g., labor and subcontractor management, scrap rates, materials management, inbound and outbound logistics, etc., that can happen quickly and frequently; this condition implies short interval times between shocks. (In Section 6, we extend the analysis to the situation with correlated types across periods based on a simplified model and discuss the impact of cost correlation.) We also assume $F_I(\cdot)$ is exogenously given. While this distribution may be influenced by endogenous learning activities, exogenous learning is commonly observed in practice and widely considered in the literature. For example, Klotz and Chatterjee (1995) study sourcing with exogenous learning and see Yelle (1979) for a review of the learning literature. (In Section 6, we extend the analysis to situations with endogenous learning.) The entrant’s cost $c_E$ is drawn from a distribution $F_E(\cdot)$ (density $f_E(\cdot)$), $c_E \in [c_E, \bar{c}_E]$.

All supplier costs, including $c_1$, $c_I$ and $c_E$, are private information although their distributions, $F_1(c_1)$, $F_I(c_I)$ and $F_E(c_E)$, are common knowledge. In line with the mechanism design literature, we assume these distributions are log-concave; i.e., $F_1(\cdot)/f_1(\cdot)$, $F_I(\cdot)/f_I(\cdot)$ and $F_E(\cdot)/f_E(\cdot)$ are increasing functions. This condition is satisfied by a wide variety of commonly used distributions, including uniform and normal, and with some restrictions including beta, gamma and Weibull (Rosling, 2002; Bagnoli and Bergstrom, 2005). Define $J_1(c_1) = c_1 + F_1(c_1)/f_1(c_1)$, $J_I(c_I) = c_I + F_I(c_I)/f_I(c_I)$ and $J_E(c_E) = c_E + F_E(c_I)/f_E(c_I)$, which can be referred to as the suppliers’ virtual unit production costs for the buyer when the suppliers hold private cost information. Throughout
the analysis, we assume the revenue is large enough to cover the unit capacity cost and virtual cost in each period. This assumption ensures that it is always profitable for the buyer to source from a supplier rather than leaving demand unsatisfied in each period, even without knowing the actual supply costs.

**Assumption 1** \( r > k + \max(J_1(c_1), J_I(c_I), J_E(c_E)) \).

**Sourcing strategies:** The buyer may commit to sourcing from the only incumbent supplier over two periods. We refer to this strategy as *sole sourcing*. The commitment to sole sourcing may be implemented by a formal or informal contract. With a formal contract, a high penalty fee may be charged if the commitment is breached. With an informal contract (relational contract), breaking the commitment destroys the trust between the buyer and supplier, resulting in long-term losses (Taylor and Plambeck, 2007). In our paper, we assume that such commitment is credible, except in Section 5.4, where we discuss capacity investment when such commitment is infeasible. Alternatively, without making such commitment, the buyer can source a fraction or all of her needs in the second period from the entrant. We refer to this strategy as *second sourcing*. We assume the entrant is guaranteed to arrive in the second period. The case that the entrant does not appear can be captured by making the entrant’s cost very high, which reduces second sourcing to sole sourcing.

### 3.2 Model Formulation

The sequences of events in sole sourcing and second sourcing are demonstrated in Figure 1.

![Figure 1](image-url)

Figure 1: Sequences of events in sole sourcing and second sourcing.

As the leader, the buyer designs the contracting mechanism. Based on the revelation principle (Myerson, 1981), we can restrict the consideration of the buyer’s optimal contracting mechanism to
direct mechanisms that are incentive compatible (IC) and individually rational (IR) in each period. In a direct mechanism, the buyer offers a menu of contracts parameterized by suppliers’ costs to each supplier. Suppliers then report their costs and are awarded contracts corresponding to their reported costs. A mechanism is incentive compatible if it is optimal for a supplier to report his true cost. A mechanism is individually rational if the expected profit of a supplier from participation, irrespective of his cost, is nonnegative. As notation, we use subscript $t = 1, 2$ to indicate notations for period $t$, $I$ for Incumbent, and $E$ for Entrant.

**Sole-sourcing strategy:** We start by formulating the contracting problem in the second period. The second-period mechanism is based on the first-period capacity investment, $Q_1$, and the second-period demand, $X_2$. For simplicity of exposition, we suppress from the notation the dependency of the menu of contracts and the supplier’s second-period profit on $Q_1$ and $X_2$. Denote by $T_2 \doteq (Q_2, p_2)$ a second-period contract of the supplier, where $Q_2$ is the supplier’s capacity and $p_2$ is the unit price paid by the buyer. As the capacity is specific, and hence once invested cannot be sold to other buyers, the second-period capacity can only be higher than that in the first period, $Q_2 \geq Q_1$. The menu of contracts provided by the buyer can be specified by $\{T_2(c_I) : c_I \in [c_I, \bar{c}_I]\}$. If the supplier’s production cost is $c_1$, then reporting a cost $\tilde{c}_I$ results in second-period profits for the supplier of

$$\hat{\Pi}_2^I(\tilde{c}_I, c_I) = (p_2(\tilde{c}_I) - c_I) \min(X_2, Q_2(\tilde{c}_I)).$$  \hspace{1cm} (1)

Given $Q_1$ and $X_2$, let $\Pi_2^I(c_I) \doteq \hat{\Pi}_2^I(c_I, c_I)$ be the supplier’s expected profits when he reports the cost truthfully. The optimal mechanism design problem in the second period can be formulated as:

$$\Pi_2(Q_1, X_2) = \max_{T_2(c_1)} \mathbb{E}_{c_1} \left[ (r - p_2(c_1)) \min(X_2, Q_2(c_1)) - k(Q_2(c_1) - Q_1) \right]$$

s.t. $\forall c_I \in [c_I, \bar{c}_I] : \begin{cases} \Pi_2^I(c_I) = \max_{\tilde{c}_I} \hat{\Pi}_2^I(\tilde{c}_I, c_I) \quad \text{(IC)} \\ \Pi_2^I(c_I) \geq 0 \quad \text{(IR)} \end{cases}$.

In the first period, denote by $T_1 \doteq (Q_1, p_1)$ a contract of the supplier, where $Q_1$ is the capacity and $p_1$ is the unit price. The menu of contracts can be specified by $\{T_1(c_1) : c_1 \in [c_1, \bar{c}_1]\}$. The supplier chooses a contract considering the total profits in the two periods. If the supplier’s production cost is $c_1$, then reporting a cost $\tilde{c}_1$ results in total profits for the supplier of

$$\hat{\Pi}^I(\tilde{c}_1, c_1) = (p_1(\tilde{c}_1) - c_1) \min(x_1, Q_1(\tilde{c}_1)) + \mathbb{E}_{c_1, x_2} [\Pi_2^I(c_I, \tilde{c}_1, X_2)].$$  \hspace{1cm} (2)

Let $\Pi^I(c_I) \doteq \hat{\Pi}^I(c_I, c_I)$ be the supplier’s total profits when he reports the cost truthfully. Taking the second-period mechanism design as an embedded decision, the first-period mechanism design
then by reporting $\hat{c}$, the incumbent and entrant depend on costs reported by both suppliers. The contract for the incumbent is thus a combination of the capacity $Q^I_2 \geq Q_1$, unit price $p^I_2$, and the demand volume $y^I \leq Q^I_2$; denote by $T^I_2 \equiv (Q^I_2, p^I_2, y^I)$ the incumbent’s contract. Similarly, let $T^E_2 \equiv (Q^E_2, p^E_2, y^E)$ be the entrant’s contract. The contracts awarded to the incumbent and entrant depend on costs reported by both suppliers. Thus, the buyer offers a menu of contracts $T^I_2 (c_I, c_E) : c_I \in [c_{I_L}, c_{I_R}], c_E \in [c_{E_L}, c_{E_R}]$ to the incumbent, and $T^E_2 (c_I, c_E) : c_I \in [c_{I_L}, c_{I_R}], c_E \in [c_{E_L}, c_{E_R}]$ to the entrant. If the entrant is truthful, then by reporting $\hat{c}_I$ the incumbent with cost $c_I$ receives profits of

$$\hat{\Pi}^I_2 (\hat{c}_I, c_I) = \mathbb{E}_{c_E} \left[ (p^I_2 (\hat{c}_I, c_E) - c_I) y^I (\hat{c}_I, c_E) \right]. \tag{3}$$

Similarly, if the incumbent is truthful, then by reporting $\hat{c}_E$, the entrant with cost $c_E$ receives profits of

$$\hat{\Pi}^E_2 (\hat{c}_E, c_E) = \mathbb{E}_{c_I} \left[ (p^E_2 (c_I, \hat{c}_E) - c_E) y^E (c_I, \hat{c}_E) \right]. \tag{4}$$

Let $\Pi^I_2 (c_I) \equiv \hat{\Pi}^I_2 (c_I, c_I)$ and $\Pi^E_2 (c_E) \equiv \hat{\Pi}^E_2 (c_E, c_E)$ be the incumbent’s and entrant’s expected profits when they both report costs truthfully.

The optimal mechanism is incentive compatible and individually rational for both the incumbent (ICI and IRI) and entrant (ICE and IRE). Let $c = (c_I, c_E)$ be the profile of suppliers’ costs. Then the optimal mechanism design problem in the second period can be formulated as

$$\Pi^I_2 (Q_1, X_2) = \max_{T^I(\cdot), T^E(\cdot)} \mathbb{E}_{c} \left[ r \min (X_2, y^I (c) + y^E (c)) - p^I_2 (c) y^I (c) - p^E_2 (c) y^E (c) - k (Q^I_2 (c) - Q_1 + Q^E_2 (c)) \right]$$

s.t. $\forall c_I \in [c_{I_L}, c_{I_R}]$

$$\begin{align*}
\Pi^I_2 (c_I) &= \max_{\hat{c}_I} \hat{\Pi}^I_2 (\hat{c}_I, c_I) \quad \text{(ICI)} \\
\Pi^E_2 (c_E) &= \max_{\hat{c}_E} \hat{\Pi}^E_2 (\hat{c}_E, c_E) \quad \text{(ICE)} \\
\Pi^I_2 (c_I) &\geq 0 \quad \text{(IRI)} \\
\Pi^E_2 (c_E) &\geq 0 \quad \text{(IRE)}
\end{align*}$$

The buyer’s first-period mechanism design problem is the same as in sole sourcing, except that different second-period profits of the buyer and incumbent are taken in the embedded decision.
From now on, we use subscript “S” to represent variables for second-sourcing strategies, which can be considered as Short-term relationships.

4 Design of Sourcing Strategies

4.1 Optimal sole-sourcing strategy

Lemma 1 characterizes the buyer’s optimal profit from sole sourcing.

Lemma 1 In the optimal sole-sourcing strategy, the buyer’s first-period profit is 

\[ \Pi_{L,1}(c_1, Q_L(c_1)) = (r - J_1(c_1)) \min(x_1, Q) - kQ + x_2 \mathbb{E}[J_I(c_I) - c_I], \]  

(5)

Incumbent’s 2nd-period rent

and the second-period profit is 

\[ \Pi_{L,2}(Q) = (r - \mathbb{E}[J_I(c_I)]) x_2 - k(x_2 - S(Q)), \]  

(6)

and \( Q_L(c_1) = x_1 \) for all \( c_1 \in [\underline{c}_1, \overline{c}_1] \) is the first-period capacity investment.

Let \( \Pi_L = \mathbb{E}_{c_1}[\Pi_{L,1}(c_1, Q_L(c_1)) + \Pi_{L,2}(Q_L(c_1))] \) be the buyer’s total profit from sole sourcing.

In the second period, as the buyer does not have complete information of the supplier’s cost, the supplier receives positive rents (profits); for the buyer, the supplier’s ex ante unit cost is the virtual cost \( J_1(c_1) \geq c_I \) (Equation 6). With the assumption that \( F_I(\cdot) \) is log-concave, \( J_1(c_1) \) increases with \( c_1 \).

Similarly, in the first period, the buyer pays rent for the supplier’s private information of \( c_1 \)—for the buyer, the supplier’s ex ante unit cost is \( J_I(c_I) \) (Equation 5).

While the buyer loses rent in the second period, this rent is captured in advance by the buyer in the first period of the optimal mechanism (see Equation 5). This is because any contract that leads to nonnegative total profits is acceptable for the supplier. Therefore, the positive profit flow in the future after the contract is awarded prompts the supplier to lower the acceptable price today. As a result, the supplier collects rents only for the first-period, but not for the second-period, private information. When the first-period cost uncertainty is low and hence the first-period rent is small, the first-period price may be even less than the supplier’s actual cost, resulting in a negative profit for the supplier in the first period.

4.2 Optimal second-sourcing strategy

In a second-sourcing strategy, the incumbent has to compete with the entrant in the second period. Define \( L[a|b] = \mathbb{E}[a|b] \Pr(b) \). The buyer’s optimal profit from a second-sourcing strategy is summarized in Lemma 2.
Lemma 2 In the optimal second-sourcing strategy, the buyer’s profit in the first period is $\mathbb{E}_{c_1} [\Pi_{S,1} (c_1, Q_S (c_1))]$ and in the second period is $\mathbb{E}_{c_1} [\Pi_{S,2} (Q_S (c_1))]$, where, for a given first-period capacity $Q$,

$$
\Pi_{S,1} (c_1, Q) = (r - J_1 (c_1)) \min (x_1, Q) - kQ + \left\{ \begin{array}{ll}
S (Q) \mathbb{L} [J_I (c_I) - c_I J_E (c_E) + k \geq J_I (c_I)] \\
+ (x_2 - S (Q)) \mathbb{L} [J_I (c_I) - c_I J_E (c_E) \geq J_I (c_I)]
\end{array} \right.
$$

Incumbent’s 2nd-period rent

$$
\Pi_{S,2}(Q) = rx_2 - S(Q) (S_c I_E (c_E) + k | J_E (c_E) + k < J_I (c_I)) + \mathbb{L} [J_I (c_I) | J_E (c_E) + k \geq J_I (c_I)]
$$

$$
- (x_2 - S(Q)) (S_c I_E (c_E) + k | J_E (c_E) < J_I (c_I)) + \mathbb{L} [J_I (c_I) + k | J_E (c_E) \geq J_I (c_I)],
$$

and $Q_S (c_1) = \arg \max_Q (\Pi_{S,1} (c_1, Q) + \Pi_{S,2} (Q))$ is the first-period capacity investment if the supplier’s first-period cost is $c_1$.

Let $\Pi_S = \mathbb{E}_{c_1} [\Pi_{S,1} (c_1, Q_S (c_1)) + \Pi_{S,2} (Q_S (c_1))]$ be the buyer’s total profit from second sourcing. In the second period with two suppliers available, the buyer determines the demand allocation by comparing the suppliers’ (ex ante) marginal costs, which include the virtual production cost and capacity cost. Sourcing from the entrant always incurs new capacity investment cost, but sourcing from the incumbent incurs capacity cost only for the quantity in excess of the incumbent’s installed capacity. Therefore, the entrant’s marginal cost is $J_E (c_E) + k$. For the incumbent, the marginal cost is $J_I (c_I)$ for the demand volume covered by the installed capacity $Q$ (covered demand, with volume $\min (X_2, Q)$ and expectation $S (Q)$), and is $J_I (c_I) + k$ for the demand volume in excess of the installed capacity $Q$ (excess demand, with the volume $(X_2 - Q)^+$ and expectation $x_2 - S (Q)$).

The buyer will source the covered demand from the entrant if and only if $J_E (c_E) + k \leq J_I (c_I)$, and source the excess demand from the entrant if and only if $J_E (c_E) \leq J_I (c_I)$. The demand allocation rule is summarized in Table 1.

<table>
<thead>
<tr>
<th>Demand volume</th>
<th>$J_E (c_E) &lt; J_I (c_I) - k$</th>
<th>$J_I (c_I) - k \leq J_E (c_E) &lt; J_I (c_I)$</th>
<th>$J_I (c_I) \leq J_E (c_E)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incumbent</td>
<td>$0$</td>
<td>$\min (X_2, Q)$</td>
<td>$X_2$</td>
</tr>
<tr>
<td>Entrant</td>
<td>$X_2$</td>
<td>$(X_2 - Q)^+$</td>
<td>$0$</td>
</tr>
</tbody>
</table>

Table 1: The demand allocation rule in second sourcing

Notice that in the second period, the incumbent receives lower volume and hence gains less rent in expectation in second sourcing than in sole sourcing. This will play an important role in the analysis to follow. Despite a lower second-period profit, the buyer can still offer a menu of contracts in the first period that captures the incumbent’s expected profit in the second period (see Equation 7).
Also note that the optimal capacity in the first period, $Q_S(c_1)$, is not necessarily equal to the demand $x_1$. This will be further discussed in Section 5.4.

To summarize, in the optimal mechanisms of both sole- and second-sourcing strategies, the suppliers’ virtual costs replace the true costs to determine the buyer’s profits. This is similar to Myerson (1981), who shows that in an optimal (forward) auction to sell a single object, the bidders should be only compared by their virtual values (the counterpart of virtual costs in a reverse auction) and the seller only loses the information rent. We apply this result to a two-period setting in which the first-period mechanism is designed expecting the optimal outcome in the second period. This allows us to compare sole and second sourcing and study the supplier relationship choice in a dynamic setting. Therefore, our focus is not on optimal mechanism design (as in Myerson, 1981), but on supplier relationship choice which contains optimal mechanism design as an embedded decision.

Although in our model, the incumbent may receive a negative profit in the first period for the expected second period rent captured in advance by the buyer, and receives a positive profit in the second period due to private information, this is not necessarily the only profit flow in an optimal result. Instead of pressing for a low price at the beginning, the buyer could demand price reduction in the future, which may leave positive profits in both periods for the incumbent. For risk-neutral players, these different flows can result in the same net profit for the buyer and the incumbent. In fact, price reduction is often required in the practice of long-term sourcing (Monczka et al., 2005). No matter which flow is realized, the essential point is that by choosing whether to commit to a single supplier, the buyer has different power in demanding a low price, whether now or in the future.

5 Comparison of sole and second-sourcing strategies

Based on the optimal sole- and second-sourcing strategies characterized in Lemmas 1 and 2, we now compare the two strategies and analyze the impact of various factors on the strategy selection.

5.1 Trade-off between sole sourcing and second sourcing

Based on Lemma 2, we can see that in the second period, under the condition $J_E(c_E) + k \leq J_I(c_I)$ the second sourcing option reduces the ex ante unit cost of sourcing covered demand from $J_I(c_I)$ to $J_E(c_E) + k$, generating cost savings of $J_I(c_I) - J_E(c_E) - k$, and under the condition $J_E(c_E) \leq J_I(c_I)$ reduces the cost of sourcing excess demand from $J_I(c_I) + k$ to $J_E(c_E) + k$, generating cost savings
of $J_I(c_I) - J_E(c_E)$. To this end, we define the expected unit cost saving in the second period brought by the second sourcing opportunity as the *option value* of second sourcing.

**Definition 1** The *option value* of second sourcing on covered demand is $O(k)$, and on excess demand is $O(0)$, where

$$O(\kappa) \doteq \mathbb{L}[J_I(c_I) - J_E(c_E) - \kappa|J_E(c_E) + \kappa \leq J_I(c_I)],$$

for $\kappa \in \{0, k\}$.

While the second sourcing opportunity lowers the buyer’s cost, it at the same time reduces the incumbent’s profit, in the second period. Since the buyer can capture in the first period the incumbent’s second-period rent, the second sourcing opportunity results in less profits for the buyer in the first period. In other words, expecting the future competition from a new supplier in a second-sourcing strategy, the incumbent will ask for a higher price in the first period. To this end, we define the incumbent’s decrease of profits in the second period, or equivalently the buyer’s increase of costs in the first period, resulting from the buyer’s second sourcing opportunity as the buyer’s *cost of future supplier competition* of second sourcing.

**Definition 2** The *cost of future supplier competition* of second sourcing on covered demand is $A(k)$, and on excess demand is $A(0)$, where

$$A(\kappa) \doteq \mathbb{L}[J_I(c_I) - c_I|J_E(c_E) + \kappa \leq J_I(c_I)],$$

for $\kappa \in \{0, k\}$.

The difference between $O(\kappa)$ and $A(\kappa)$ characterizes the *marginal benefit* of second sourcing for the covered ($\kappa = k$) or excess ($\kappa = 0$) demand:

$$M(\kappa) \doteq O(\kappa) - A(\kappa) = \mathbb{L}[c_I - J_E(c_E) - \kappa|J_E(c_E) + \kappa \leq J_I(c_I)].$$

Let $\mu_E$ be the expected entrant’s cost, and $U(l, h)$ be the uniform distribution between $l$ and $h$. Figure 2 illustrates $O(\kappa)$, $A(\kappa)$ and $M(\kappa)$ as functions of $\mu_E$, assuming uniform distributions of $c_E$ and $c_I$ (they are independent of $c_1$).

As the entrant’s expected cost $\mu_E$ increases, the probability of switching $\Pr(J_E(c_E) + \kappa \leq J(c_I))$ is lower, resulting in both option value, $O(\kappa)$, and cost of future supplier competition, $A(\kappa)$, decreasing with increasing $\mu_E$. Note that conditional on switching, the option value $J_I(c_I) -$
Figure 2: $O(k)$, $A(k)$ and $M(k)$, $k = 0, k$, with changing $\mu_E$. $k = 0.3$, $c_I \sim U(0.3, 0.6)$, $c_E \sim U(\mu_E - 0.1, \mu_E + 0.1)$.

$J_E(c_E) - k$ decreases with $c_E$ while the cost of future supplier competition $J_I(c_I) - c_I$ is independent of $c_E$. Therefore, with $\mu_E$ increasing, $O(k)$ tends to decrease faster than $A(k)$ when $\mu_E$ is small, and the opposite when $\mu_E$ is large. As a result, $M(k)$ decreases to below zero when $\mu_E$ is small, and increases when $\mu_E$ is large. When $\mu_E$ is very high, the probability of switching is zero and, hence, $O(k)$, $A(k)$ and $M(k)$ all equal zero.

$M(k)$ and $M(0)$ follow the same shape as functions of $\mu_E$, with $M(k)$ equivalent to $M(0)$ shifted to the left by $k$. Therefore, depending on the values of $\mu_E$ and $k$, $M(k)$ and $M(0)$ can be both positive, both negative, or have opposite signs. Lemma 3 summarizes the features of $M(k)$.

**Lemma 3** Assume $c_I \sim U(\mu_I - \Delta_I, \mu_I + \Delta_I)$ and $c_E \sim U(\mu_E - \Delta_E, \mu_E + \Delta_E)$.

(i) $M(k)$ is a quasi-convex function of $\mu_E$, $M(k) = 0$ for $\mu_E - \Delta_E + k \geq J_I(\bar{\tau}_I)$.

(ii) There exists a unique $\hat{\theta} < J_I(\bar{\tau}_I) + \Delta_E$ such that $M(k) > 0$ for $\mu_E + k < \hat{\theta}$, $M(k) = 0$ for $\mu_E + k = \hat{\theta}$, and $M(k) < 0$ for $\hat{\theta} < \mu_E + k < J_I(\bar{\tau}_I) + \Delta_E$.

The features of $M(k)$ revealed in Lemma 3 drive the results of how $\mu_E$ and $k$ influence the comparison of sole-sourcing and second-sourcing profits. While Lemma 3 is based on uniform cost distributions, in the extension in Section 6, we examine $M(k)$ under general cost distributions and find that its shape remains similar for broad situations.

Besides the marginal benefits of second sourcing for the covered and excess demand, $M(k)$ and $M(0)$, the value of second sourcing also depends on the volumes of these two parts of demand. For given initial capacity $Q$, the expectation of covered demand is $S(Q)$, and the expectation of excess demand is $x_2 - S(Q)$. Therefore, the value of second sourcing relative to sole sourcing can be characterized as in Lemma 4.
Lemma 4 Define $\Pi_L (c_1, Q) = \Pi_{L,1} (c_1, Q) + \Pi_{L,2} (Q)$ and $\Pi_S (c_1, Q) = \Pi_{S,1} (c_1, Q) + \Pi_{S,2} (Q)$. Then

$$\Pi_S (c_1, Q) - \Pi_L (c_1, Q) = S(Q)M(k) + (x_2 - S(Q))M(0).$$

Although the optimal first-period capacity investment may differ in the two sourcing strategies, based on Lemma 4 we can conclude that second sourcing is better than sole sourcing if $M(k)$ and $M(0)$ are both positive, and the opposite if they are both negative. If $M(k)$ and $M(0)$ have opposite signs, then the relationship choice depends on the expected volumes of covered and excess demand, which are in turn impacted by the first-period capacity investment.

5.2 Comparing the profits in sole- and second-sourcing strategies

Lemma 4 allows us to provide sufficient conditions for comparing sole-sourcing and second sourcing profits based on the situations when $M(k)$ and $M(0)$ are both positive or negative. Following Lemma 3, these situations can be characterized by $\mu_E$ and $k$, and are summarized in Proposition 1. When $M(k)$ and $M(0)$ have opposite signs, comparing the profits is more difficult because then the first-period capacity investments in the two strategies play a role. We thus complete the picture with numerical study as shown in Figure 3.

Proposition 1 Assume $c_I \sim U (\underline{c}_I, \overline{c}_I)$ and $c_E \sim U (\mu_E - \Delta_E, \mu_E + \Delta_E)$. Then for all demand distributions of $X_2$ and given $\hat{\theta}$ as defined in Lemma 3,

(i) when $\mu_E - \Delta_E \geq J_I (\overline{c}_I)$, $\Pi_L = \Pi_S$,

(ii) when $\mu_E - \Delta_E < J_I (\overline{c}_I)$ and $\mu_E \geq \hat{\theta}$, $\Pi_L \geq \Pi_S$, and

(iii) when $\mu_E < \hat{\theta}$, $\Pi_S \geq \Pi_L$ if either $\mu_E + k \leq \hat{\theta}$ or $\mu_E - \Delta_E + k \geq J_I (\overline{c}_I)$.

Figure 3 demonstrates the regions of the entrant’s expected cost $\mu_E$ and capacity cost $k$ that lead to different comparison results between sole-sourcing and second-sourcing profits.

When $\mu_E$ is high ($\mu_E - \Delta_E \geq J_I (\overline{c}_I)$), second sourcing reduces to sole sourcing, as the entrant will never be able to win the competition with the incumbent. This is intuitive.

When $\mu_E$ is low ($\mu_E < \hat{\theta}$), second sourcing is better than sole sourcing when $k$ is both low ($\mu_E + k < \hat{\theta}$) and high ($\mu_E - \Delta_E + k > J_I (\overline{c}_I)$). With $\mu_E$ low, the marginal benefit of second sourcing for excess demand, $M(0)$, is positive. If in addition the capacity cost $k$ is also low ($\mu_E + k \leq \hat{\theta}$), the marginal benefit for covered demand, $M(k)$, is positive as well. Therefore, second sourcing is preferred to sole sourcing when both $\mu_E$ and $k$ are low. If $\mu_E$ is low but $k$ is high ($\mu_E - \Delta_E + k \geq J_I (\overline{c}_I)$), then the entrant is deterred from winning the covered demand, but
Figure 3: Breakeven curves of $\mu_E$ and $k$ values with respect to sole-sourcing and second-sourcing profits. $r = 3$, $\Delta_E = 0.1$, $x_1 = 0.5$, $X_2 \sim U(0.35, 0.65)$, $c_I \sim U(0.6, 0.9)$, $c_E \sim U(\mu_E - \Delta_E, \mu_E + \Delta_E)$. (The distribution of $c_1$ is irrelevant because it does not affect $\Pi_S - \Pi_L$, as will be discussed later.) Line (1) is $\mu_E + k = \hat{\theta}$. Line (2) is $\mu_E - \Delta_E + k = J_I(\bar{c}_I)$.

the buyer still benefits from the entrant winning the excess demand. Therefore, this situation also leads to the choice of second sourcing, for the benefit of using the entrant as only a supplementary supplier. If $\mu_E$ is low and $k$ is intermediate ($\mu_E + k > \hat{\theta}$ and $\mu_E - \Delta_E + k < J_I(\bar{c}_I)$), sole sourcing may or may not be better than second sourcing. In this situation, the marginal benefit of second sourcing is negative on the covered demand but positive on the excess demand. Thus the selection of the sourcing strategy depends on the expected volumes of excess and covered demand, which are determined by the initial capacity investment.

When $\mu_E$ is intermediate ($\mu_E - \Delta_E < J_I(\bar{c}_I)$ and $\mu_E > \hat{\theta}$), the marginal benefit of second sourcing is negative for excess demand and zero or negative for covered demand. Hence, in this situation second sourcing is inferior to sole sourcing.

Proposition 1 suggests that the buyer should leave the option of alternative sourcing open only if highly competitive new sources are expected to emerge ($\mu_E$ low), e.g., due to emerging suppliers in low-cost countries or new suppliers with better technologies. This is intuitive. However, the decision is more subtle when the supply capacity cost enters the picture. Second sourcing is favored when supply capacity investment is inexpensive, which can be the case when the buyer sources inputs with a high level of standardization or a low degree of supplier–buyer interdependence. But sourcing from the entrant can also be beneficial even when the inputs require costly specific capacity investment. The difference between the two cases is that in the former case, the buyer exclusively sources from
the incumbent or entrant, while in the latter case, the entrant will only be used as a supplementary supplier that provides quantity for the overflow demand in excess of the incumbent’s installed capacity.

If a supplier’s cost $c_1$, $c_I$ or $c_E$ were public information, then $J_1(c_1)$, $J_I(c_I)$ or $J_E(c_E)$ would be replaced by $c_1$, $c_I$ or $c_E$ in the optimal results characterized in Lemmas 1 and 2, and so in $O(\kappa)$, $A(\kappa)$ and $M(\kappa)$. Particularly, if $c_I$ were public information, the marginal benefit of second sourcing would be $M(\kappa) = \mathbb{L}[c_I - J_E(c_E) - \kappa|J_E(c_E) + \kappa \leq c_I]$, which is always nonnegative. Therefore, *second sourcing is always better than sole sourcing when the incumbent’s second-period cost is public information*. An intuitive explanation follows. When $c_I$ is public information, the incumbent does not expect any profit in the second period of either strategy. Therefore, the relationship choice does not make a difference in the second period for the incumbent and, thus, does not influence the first-period price. This means the cost of future supplier competition of second sourcing is zero. Then with the benefit of the option value, second sourcing can only be better than sole sourcing. This result implies that the trade-off between the option value and cost of future supplier competition is driven by the information asymmetry on $c_I$ alone. Information asymmetry on either $c_1$ or $c_E$ does not play an essential role. Information asymmetry of $c_1$ results in the information rent paid for the quantity sourced from the incumbent in the first period. Given that the same quantity $x_1$ is sourced in the first period of both strategies, the information asymmetry or distribution of $c_1$ does not influence the profit difference between the two strategies. Information asymmetry on $c_E$ results in information rent for the quantity sourced from the entrant, and thus weakens the entrant’s competitiveness in a second-sourcing strategy. But this does not qualitatively change the influence of $\mu_E$ or $k$ on the relative performance of the two strategies.

Note, if the demand is constant, $x_1 = X_2 = x$, then any initial capacity $Q \geq x_1$ covers all demand in the second period, leaving zero excess demand. In this case, the profit difference characterized in Lemma 4 reduces to $\Pi_S(c_1, Q) - \Pi_L(c_1, Q) = xM(k)$, and the relationship choice depends only on the sign of $M(k)$. The result is that second sourcing is preferred only when $k$ is low. This result is intuitive because given that the incumbent has the first-mover capacity advantage, the benefit of switching is lower if the capacity is more expensive. This result can also be easily derived by adapting the model of Riordan and Sappington (1989), which considers constant (unit) demand. It is by considering a more general demand pattern that we reveal the unintuitive result that second sourcing is also preferred when $k$ is high (given $\mu_E$ is low). If the second-period demand is possibly larger than the first-period demand, then there is positive probability that the incumbent’s initial capacity is too low to cover the second-period demand, resulting in positive excess demand. This
allows the buyer to benefit from second sourcing with the entrant only supplying excess demand, which is the case with \( \mu_E \) low and \( k \) high. In the following Section 5.3, we further analyze the impact of the demand distribution on supplier-relationship selection.

### 5.3 Impact of the demand distribution

As shown in Lemma 4, the comparison between sole and second sourcing depends not only on supplier costs and capacity costs, which determine the marginal benefits of second sourcing for covered and excess demands, but also on the demand distribution, which affects the volumes of covered and excess demands.

**Proposition 2** Assume \( c_I \sim \mathcal{U}(\underline{c}_I, \bar{c}_I) \) and \( c_E \sim \mathcal{U}(\underline{c}_E, \bar{c}_E) \). Given two distributions for the second-period demand \( G_1 \) and \( G_2 \), where \( G_2 \) is greater than \( G_1 \) in the increasing convex order, changing the demand distribution from \( G_1 \) to \( G_2 \) can only turn the preferred strategy from sole sourcing to second sourcing, but not the opposite.

Proposition 2 shows that when the mean or variability of future demand is higher (which results in dominance in the increasing convex order), second sourcing may become more favorable than sole sourcing but not the other way around. Consistent with Proposition 2, Figure 4 demonstrates the regions of \( \mu_E \) and \( k \) values for which a second-sourcing strategy is preferred. The left panel changes the mean of demand but keeps the variance at zero. The right panel varies the demand uncertainty but keeps the mean constant.

The intuition for the result of Proposition 2 can be understood from Lemma 4. For given first-period capacity, a greater second-period demand level or variability increases the expected excess demand but not the covered demand (the covered demand decreases when demand variability is higher). When the buyer is indifferent between sole and second sourcing, it can easily be proved that second sourcing brings positive marginal benefit on excess demand but negative on covered demand. In this situation, increasing the expected excess demand, with the expected covered demand decreasing or unchanged, increases the benefits of second sourcing over sole sourcing.

Proposition 2 implies that although the alternative sourcing option is a tool to counter uncertainty in the supply market, the value of such option is enhanced with more uncertainty on the demand. Thus, the supply-cost uncertainty and demand uncertainty complement each other. The operations literature has studied dual sourcing problems in which a second source is used to mitigate the demand or supply risk, assuming no information asymmetry. We reach a consistent result that second sourcing is more valuable when demand uncertainty is higher. But our reason for
second sourcing is different: It is to lower total procurement costs considering strategic suppliers with private information in a dynamic setting.

Proposition 2 suggests that second sourcing becomes better if the buyer faces more market demand in the future. Therefore, second sourcing may be favorably considered for a new product with a growing market. But for a mature product with stable or declining demand, sourcing from a single supplier over time may be better. This seems to be consistent with the result revealed in the survey by Birou et al. (1997) that competitive bidding and dual/multiple sourcing should be used in the growth stage and single sourcing in the maturity stage of a product life cycle.

5.4 Impact of the initial capacity investment

We now turn to the first-period capacity decision. The second-period competition in a second-sourcing strategy is shaped by the incumbent’s first-period capacity investment. In expectation, a greater first-period capacity results in more covered demand and less excess demand in the second period. Therefore, the difference of the margin of initial capacity investment between second and sole sourcing can be characterized by the difference between the marginal benefits of second sourcing on covered and on excess demand.

Lemma 5 \[
\frac{d}{dQ} \Pi_S (c_1, Q) - \frac{d}{dQ} \Pi_L (c_1, Q) = \overline{G}(Q) (M(k) - M(0)),
\] where $\Pi_S$ and $\Pi_L$ denote the profits under sole sourcing and second sourcing, respectively, $G(Q) = M(k) - M(0)$ is the difference of the marginal benefits on covered and excess demand, and $\overline{G}(Q)$ is the expected value of $G(Q)$ under the demand distribution.
Recall from Lemma 3 that $M(\kappa)$ increases with $\mu_E$ when $\mu_E$ is large. Therefore, $M(k)$ may be greater than $M(0)$ when $\mu_E$ is large, as $M(k)$ is equivalent to $M(0)$ with $\mu_E$ increased by $k$. Given Lemma 5, this suggests that second sourcing may induce a higher first-period capacity investment than sole sourcing, although the second-period return of capacity investment is lower in the former strategy (as the buyer may fully switch to the entrant).

**Proposition 3** Assume $c_I \sim U(c_I, \bar{c}_I)$ and $c_E \sim U(c_E, \bar{c}_E)$, and $G(x_1)$ is sufficiently low. Then $Q_L < Q_S$ when $\mu_E - \Delta_E < J_I(\bar{c}_I)$ and $\mu_E + k$ is high enough, and $Q_L < Q_S$ is accompanied by $\Pi_L > \Pi_S$.

Recall $Q_L = x_1$ from Lemma 1. Proposition 3 shows that when the alternative sourcing opportunity has limited advantage against the incumbent supplier ($\mu_E + k$ is high), it is in the interest of the buyer to invest in more capacity upfront for the incumbent than she would with a sole-sourcing commitment, thereby resulting in excess capacity in the first period of second-sourcing. This is surprising at first sight as the first-period demand is deterministic and yet more capacity than demand may be invested. The reason is that more capacity increases the incumbent’s first-mover advantage in the supplier competition, thus reducing the cost of future supplier competition of second sourcing. Although more initial capacity also results in less option value, given that the option value is negligible with $\mu_E + k$ high, the saving on the cost of future supplier competition can be dominant. The condition of $G(x_1)$ being sufficiently low ensures that the capacity needed to cover the first-period demand is low enough to allow the investment in redundant capacity, while $\mu_E - \Delta_E < J_I(\bar{c}_I)$ ensures a positive probability of sourcing from the entrant in the second-sourcing strategy.

Note from Proposition 3 that the capacity overinvestment in second sourcing happens only when second sourcing is worse than sole sourcing. Therefore, if the buyer can credibly commit to sole sourcing, overinvestment will never occur in the optimal choice of supplier relationship (under the conditions of Proposition 3). However, if such commitment is desirable ($\Pi_L > \Pi_S$) but not credible (i.e., the buyer cannot commit to sole sourcing), then overinvestment of the upfront capacity may be necessary. This overinvestment can be regarded as a soft substitute of commitment, as a large investment credibly deters the buyer from sourcing from the entrant.

Our result is similar to that in Spence (1977), who shows that redundant capacity may be invested by the incumbent before entering the competition with an entrant. In their model, overinvestment allows the incumbent to reduce the market price through production expansion, which
drives a negative profit of the entrant if he enters. Therefore, such overinvestment serves as a credible threat made by the incumbent to the entrant, which deters the latter’s entry and in turn benefits the incumbent. Our result of overinvestment is caused by the buyer, not the equilibrium outcome of a duopoly model. It is used, without a sole-sourcing commitment, to induce the incumbent to accept a lower price in the first period, which benefits the buyer. Based on Proposition 3, the buyer would prefer sole-sourcing commitment, if it is feasible, to overinvestment in second sourcing.

By studying the decision of pre-qualifying multiple suppliers who compete for a procurement contract, Riordan (1996) also shows a result of overinvestment—the buyer may invest in full capacity for two suppliers but award production to only one supplier. The reason for this investment in redundant capacity is that it induces supplier competition (by developing more than one capable supplier) and hence reduces information rent in a later stage. In our model, overinvestment can be beneficial because it increases the incumbent’s future rent, which is captured by the buyer early in the horizon.

The existing insights in the procurement literature have shown that when the incumbent has advantage over an entrant due to existing investment or learning, it may be beneficial for the buyer to weaken the incumbent’s competitiveness by intentionally lowering the investment (Dasgupta, 1990) or sourcing from the less efficient entrant (Deng and Elmaghraby, 2005; Klotz and Chatterjee, 1995; Lewis and Yildirim, 2002). Our result complements this insight, showing that when the buyer is able to capture the incumbent’s future rent, the buyer may actually want to improve the incumbent’s competitiveness by investing in more initial capacity. This allows the buyer to press for a lower initial price, at the cost of possibly missing an efficient entrant in the future.

6 Extensions

In this section, we consider several extensions and summarize the results. For detailed analysis and formal results of the extensions, please see Appendix B.

6.1 Correlated types

In the model we have assumed that the incumbent’s second-period cost is independent of his first-period cost. In this section we relax this assumption by considering correlation of the incumbent’s costs across periods. Following Laffont and Tirole (1993, Chap. 9.4), we analyze for tractability a two-type model in which the incumbent and entrant have their costs drawn from two possible values: \( c \) and \( \bar{c} \), \( \bar{c} > c \). Since the information asymmetry on \( c_E \) does not change the results qualitatively,
we assume the entrant’s cost is public information in this extension. All results are based on the assumption that \( r \) is large enough.

In order to provide a benchmark, we first analyze this two-type model assuming there is no cost correlation. Let the incumbent’s cost, \( c_t \), in period \( t \) be \( c \) (\( \overline{c} \)) with probability \( p_t \) (1 – \( p_t \)), \( t = 1, 2 \). With discrete types, the incumbent’s expected second-period demand in the second-sourcing strategy increases discontinuously with the capacity cost, \( k \). Specifically, there are two critical values \( k^0_1 \) and \( k^0_2 \), \( k^0_1 < k^0_2 \), such that the incumbent’s expected volume strictly increases with \( k \) only at \( k = k^0_1 \) or \( k^0_2 \); otherwise this volume does not change with \( k \). Let \( \Pi^0_L \) and \( \Pi^0_S \) be the buyer’s optimal profits from sole and second sourcing without cost correlation.

**Proposition 4**

(i) With \( k \) increasing, \( \Pi^0_S - \Pi^0_L \) increases at \( k = k^0_1 \) or \( k^0_2 \), otherwise \( \Pi^0_S - \Pi^0_L \) decreases. (ii) \( \Pi^0_S - \Pi^0_L \) is independent of \( p_1 \).

The first result of Proposition 4 suggests that the trade-off between the option value and cost of future supplier competition remains in this two-type situation. If increasing \( k \) does not change the incumbent’s future quantity (and hence the cost of future supplier competition), the relative performance of second sourcing is worse because of the decreasing option value resulting from increasing \( k \). But if increasing \( k \) causes more future volume sourced from the incumbent, then that change enhances the relative performance of second sourcing, as it reduces the cost of future supplier competition (without changing the option value at \( k = k^0_1 \) or \( k^0_2 \)).

The second result of Proposition 4 shows that the first-period cost uncertainty, characterized by \( p_1 \), does not influence the relative performance of sole and second sourcing when supplier costs are independent across periods. The reason is that with no cost correlation, only the first-period purchasing quantity accrues information rent caused by information asymmetry on \( c_1 \), and the same first-period quantity is purchased from the incumbent in the two strategies.

With cost correlation, we assume that the incumbent is efficient with probability \( p < 1 \) in the first period, and in the second period, the first-period efficient type remains efficient while the first-period inefficient type becomes efficient with probability \( q < 1 \). When there is cost correlation, the incumbent’s future cost information can be inferred from the initial cost. This gives rise to the *ratchet effect*: If an efficient type reveals his true type in the first period, he would receive a low price in the second period if the costs across periods are positively correlated. Thus he is reluctant to reveal his efficiency early in the relationship unless enough incentive is provided. The revelation principle (Myerson, 1981) cannot be applied to this situation with correlated types across periods. We consider (pure strategy) separating and pooling equilibria in which full information
and no information is learned about the incumbent’s type in the first period. We find that in both strategies the pooling equilibrium generates higher profits for the buyer than the separating equilibrium. (This result is consistent with Laffont and Tirole (1993, Chap. 9.4).)

**Proposition 5** The pooling profit is higher than the separating profit in both sole-sourcing (under the condition $x_1 - (1 - q) x_2 > 0$) and second-sourcing strategies.

We compare sole sourcing and second sourcing based on the pooling equilibrium. Let $\Pi^p_L$ and $\Pi^p_S$ be their profits. Similar to the situation without cost correlation, there are also two critical capacity cost values $k^p_1$ and $k^p_2$, $k^p_1 < k^p_2$, such that the incumbent’s expected second-period volume strictly increases with $k$ when $k$ is equal to $k^p_1$ or $k^p_2$. The first result of Proposition 6 characterizes the impact of $k$. It is similar to the impact characterized in Proposition 4, showing that cost correlation does not essentially change the influence of capacity cost on the relative performance of the sole- and second-sourcing strategies. In order to study the impact of cost correlation, we compare the profit difference between sole and second sourcing as a function of the first-period probability of an efficient incumbent, $p_1$, keeping the ex ante probability of an efficient incumbent in the second period, $p_2$, fixed. This is done by selecting $p = p_1$ and $q = \frac{p_2 - p_1}{1 - p_1}$. The second result in Proposition 6 is different from that in Proposition 4.

**Proposition 6** (i) With $k$ increasing, $\Pi^0_S - \Pi^0_L$ increases at $k = k^p_1$ or $k^p_2$, otherwise $\Pi^0_S - \Pi^0_L$ decreases. (ii) $\Pi^0_S - \Pi^0_L$ increases with $p_1$.

The reason that higher $p_1$ improves the relative performance of second sourcing in the presence of cost correlation can be explained as follows. When there is cost correlation, the incumbent’s first-period action influences not only his first-period profit, but also his second-period profit. As a result, the incumbent’s first-period private information incurs information rent not only on the first-period quantity, but also on the second-period quantity sourced from the supplier. But since the incumbent provides more quantity in the second period of sole sourcing than in second sourcing, the total quantity of this rent is higher in sole sourcing than in second sourcing. In other words, when the incumbent’s costs are correlated across periods, the first-period private information is more expensive in sole sourcing than in second sourcing. When $p_1$ increases, more rent is paid for each unit sourced from the inefficient type. Therefore, higher $p_1$ only weakens the performance of sole sourcing relative to second sourcing.
6.2 Endogenous learning

We have assumed that the incumbent’s second-period cost distribution is exogenously given. In this extension, we consider the situation when the incumbent’s second-period cost is affected by endogenous learning. To make the comparison tractable, we introduce information asymmetry on the incumbent’s second-period cost only. We further assume constant demand $x$ in each period, which implies that there is no excess demand and hence simultaneously sourcing from the incumbent and entrant is no longer possible in the second period. Two causes of endogenous learning are considered: 1) The buyer pushes the incumbent’s progress on the learning curve by purchasing more quantity than demand from the supplier, and 2) the incumbent invests cost-reduction efforts. The incumbent achieves random cost reduction in the second period, with the maximum cost reduction $a$ determined by the endogenous learning effort (in the form of either the buyer’s purchasing volume or the supplier’s investment in efforts). Therefore the distribution of $c_I$ depends on $a$. We assume $a$ is bounded by the incumbent’s first-period cost. All analysis is based on uniform cost distributions.

For given $a$, the difference of profits between sole and second sourcing can still be characterized by the marginal benefit $M$, which now depends on $a$: $\Pi_S(a) - \Pi_L(a) = xM(k,a)$. Increasing $a$ improves the incumbent’s second-period profit and thus reduces the cost of future supplier competition of second sourcing. Greater $a$ also results in less option value of second sourcing because it makes the incumbent more efficient. Lemma 6 shows that the impact of $a$ on the option value is more than that on the cost of future supplier competition.

**Lemma 6** Assume $c_I \sim U(c-a,c)$ and $c_E \sim U(c_E, \bar{c}_E)$. $M(k,a)$ decreases with $a$.

Given that the marginal benefit of second sourcing depends on $a$, endogenous learning complicates the comparison of sole sourcing and second sourcing because they may lead to different learning efforts, which result in different $a$ values. Therefore, we focus our analysis on the extreme situations when the two strategies generate the same learning efforts and complete the picture for general situations by numerical study.

6.2.1 Endogenous volume

When supplier cost reduction is determined by the first-period production quantity, the buyer decides the optimal $a$ in sole- and second-sourcing strategies, which may lead to purchasing more than the demand $x$ in the first period. More quantity has to be purchased in order to induce larger $a$. Let $Y(a, \gamma) = x + Y_0(a)/\gamma$ be the quantity that corresponds to $a$, where $Y_0(a)$ is an increasing convex function of $a$ with $Y_0(0) = 0$, and with the quantity required to achieve $a$ decreasing with
\( \gamma \geq 0, \gamma \) representing the pace of learning. Based on Lemma 6, the buyer has less incentive to induce supplier learning through purchasing in second sourcing than in sole sourcing. This result is summarized in the first point in Proposition 7.

The comparison of the buyer’s profits in the two strategies depends on the optimal first-period purchasing quantity, which again depends on the pace of learning. If learning is slow (\( \gamma \) low), there is no overpurchasing in either strategy. If learning is fast (\( \gamma \) high), both strategies will result in the largest possible purchasing quantity, which leads to \( a = c \). In both situations, the two strategies lead to the same first-period purchasing quantity and, hence, the same \( a \). When the pace of learning shifts from being very fast to very slow, the purchasing quantity decreases in both strategies. Based on Lemma 6, this improves the marginal benefit of second sourcing. Therefore, this change can only enhance the relative advantage of second sourcing but not the opposite. This result is summarized in the second point in Proposition 7. Based on the extreme conditions of very fast or very slow supplier learning, this reveals that second sourcing is preferred when learning is slow. Numerical experiments show that this result may be extended to general situations with intermediate learning paces (see Appendix B, Section 2.1).

**Proposition 7** Assume \( c_I \sim U(c - a, c) \) and \( c_E \sim U(c_E, \bar{c}_E) \).

(i) The buyer purchases less quantity in the first period of second sourcing than sole sourcing.

(ii) For fixed \( \mu_E \) and \( k \), it is only possible that \( \Pi_S < \Pi_L \) when \( \gamma \) is large enough and the opposite when \( \gamma \) is small enough, but not the other way around.

### 6.2.2 Supplier investment

When endogenous learning is caused by the incumbent’s investment in cost-reduction efforts, the incumbent determines \( a \) based on the return in the second period. Let \( \Lambda(a) = \theta \Lambda_0(a) \) be the cost of efforts to achieve \( a \), where \( \Lambda_0(a) \) is an increasing convex function of \( a \) and \( \theta > 0 \) characterizes the magnitude of investment cost. It can be shown that the incumbent’s marginal return of investing efforts is higher in a sole-sourcing than in a second-sourcing strategy. This is intuitive because the incumbent is guaranteed more business in sole sourcing than in second sourcing. Therefore the investment in a second-sourcing strategy can only be less than in a sole-sourcing strategy, as is summarized in the first point of Proposition 8.

The comparison of the buyer’s profits in the two strategies depends on the incumbent’s efforts, which again are based on how costly the investment is. If investment is expensive, both strategies will result in zero investment. If investment is cheap, both strategies will result in the largest possible investment, which leads to \( a = c \). In both situations, the two strategies result in the same effort
and, hence, the same \( a \). When the investment shifts from being very cheap to very expensive, the effort changes from being very large to very small. Based on Lemma 6, this improves the marginal benefit of second sourcing. Therefore, this change can only enhance the relative advantage of second sourcing, but not the opposite. This result is summarized in the second point of Proposition 8. Based on the extreme conditions of very cheap or very expensive investment costs, this suggests that second sourcing is more favorable when the cost-reduction effort is expensive. Numerical experiments show that this result may be extended to general situations with intermediate investment costs (see Appendix B, Section 2.2).

**Proposition 8** Assume \( c_I \sim U(c - a, c) \) and \( c_E \sim U(\bar{c}_E, c_E) \).

(i) The incumbent invests less effort in the second sourcing than in the sole-sourcing strategy.

(ii) For fixed \( \mu_E \) and \( k \), it is only possible that \( \Pi_S < \Pi_L \) when \( \theta \) is small enough and the opposite when \( \theta \) is large enough, but not the other way around.

To summarize, endogenous learning complicates the comparison of profits from sole sourcing and second sourcing because these two strategies result in different learning efforts. Whether the learning is caused by the buyer endogenizing the purchasing quantity or the incumbent investing cost-reduction efforts, we find that second sourcing induces less learning efforts than sole sourcing, and tends to be more attractive when learning becomes more expensive.

### 6.3 Noncontractible capacity

In this extension, we examine the situation where the capacity is not contractible and hence a supplier decides the capacity. Since the information asymmetry on the incumbent’s first-period cost or on the entrant’s cost does not qualitatively change the results, we assume they are public information. Although the incumbent can improve his competitive position in a second-sourcing strategy by investing in more capacity, we find that the incumbent will never invest in more capacity than the buyer’s demand. This result is because the incumbent’s marginal return of overinvestment is less than the marginal cost of capacity \( k \). To see this, note that the incumbent exclusively serves the buyer or does not supply at all if his cost is very low or high relative to the entrant’s. In both of these situations, the incumbent’s future volume does not depend on his initial capacity. Therefore, only when the incumbent’s cost is intermediate—in which case the incumbent supplies up to his capacity and the entrant receives the excess demand—does more initial capacity increase the incumbent’s future volume. Therefore the marginal return of overinvestment is equal to the expectation of the incumbent’s information rent generated under the condition of dual sourcing.
This expectation is small because in the condition of dual sourcing the incumbent’s virtual cost is bounded by the entrant’s cost plus the capacity cost (see Table 1). As a result, it can be shown that the marginal return is always lower than \( k \) (for general cost distributions that are log-concave and general demand distributions).

The result that the incumbent will not voluntarily overinvest contrasts to the result in Spence (1977). In Spence the incumbent and entrant compete in a duopoly model in which the market price is determined by the total production quantity of the two suppliers. The installed capacity reduces the incumbent’s marginal cost, allowing him to produce at a level that makes production unprofitable for the entrant. In our model the buyer regulates the outcome of supplier competition. The price is determined by the information rent of suppliers but not by the total quantity. Therefore, higher existing capacity of the incumbent only improves his quantity (under the condition of dual sourcing) but cannot deter the entry of the entrant. Due to the different competition model, it may be considered that overinvestment has a lower return for the supplier in our case than in Spence (1977). This explains why overinvestment does not occur in our model but does occur in Spence (1977).

This result suggests that the incumbent will not voluntarily overinvest and overinvestment is only possible if induced by the buyer. With a supplier’s capacity noncontractible, the buyer can influence the supplier’s capacity decision by specifying an order quantity that the supplier must deliver. However, because the cost of inducing capacity investment is higher when contracting the order quantity than when contracting the capacity, we find that the buyer will never order more than what is demanded. Hence, overinvestment of capacity does not occur any more if capacity is noncontractible (assuming uniform cost distributions). Despite this difference with respect to capacity investment, we find that the comparison of profits between sole and second sourcing does not change qualitatively.

### 6.4 General cost distributions

The results stated in Propositions 1, 2, 3 and Lemma 3 are based on a uniform cost distribution. In this extension, we relax the assumption of a uniform cost distribution by considering general cost distributions. In this extension we continue to assume no information information asymmetry of the incumbent’s first-period cost and of the entrant’s cost. In fact, the result that second sourcing may cause overinvestment (Proposition 3) does not depend on the assumption of uniform distributions and so can be extended to general cost distributions. The results on the profit comparison (Propositions 1 and 2) rely on the shape of \( M(\kappa) \) as characterized in Lemma 3. Therefore, we examine the
shape of $M(\kappa)$ based on general cost distributions. We find that the features of $M(\kappa)$ for $\mu_E$ very high ($M(\kappa) \leq 0$ and increasing with $\mu_E$ up to 0) or low ($M(\kappa) \geq 0$ and decreasing with $\mu_E$) do not depend on uniform cost distributions. For general $\mu_E$ values, by numerical examinations, we find that the shape of $M(\kappa)$ remains similar in broad situations with general cost distributions. Therefore, our results may be extended to more general situations without the assumption of uniform cost distributions.

7 Conclusion and discussion

Manufacturers increasingly rely on suppliers to create more added value by purchasing from them more complex components or systems. The set of potential suppliers may undergo dynamic changes; for example, new suppliers with low costs may emerge as a result of supply base development in emerging economies or technology development. The dynamics of supply market bring buyers a critical decision: Should a long-term or short-term relationship to be built with a supplier? For a buyer that sources critical noncommodity inputs, the important factors to take into consideration include supplier capacity investment, demand uncertainty, information asymmetry on suppliers’ costs and supplier learning. We develop an analytical model that helps to understand how to select between sole sourcing (committing to source from a single supplier over time) and second sourcing (keeping open the option of sourcing from a future entrant supplier).

We find that both low and high capacity costs make second sourcing favorable (under the condition that the demand increases over time with positive probability and the entrant’s cost is relatively low): When the capacity cost is low, the buyer exclusively sources from the incumbent or entrant; when the capacity cost is high, the entrant is used as a supplementary supplier by receiving only the demand in excess of the incumbent’s existing capacity (referred to as excess demand). We find that more volatility or a higher level of the future demand favors second sourcing. This result is reached by considering strategic suppliers with private information in a dynamic setting. It provides a new explanation for using a second source under demand uncertainty—for sourcing excess demand at a lower overall cost. We also show that the incumbent supplier may invest in excess capacity in a second-sourcing strategy but not in a sole-sourcing strategy, and that overinvestment occurs only when sole sourcing dominates second sourcing for the buyer. This result reveals a new role of capacity in supply chain management—it shapes the future supplier competition, which influences the current price negotiation.

Our results imply that nonstrategic inputs with few customized features and a low degree of supplier–buyer interdependence are good choices for a second-sourcing strategy. The reason is that
the capacity for these items can be easily obtained from other buyers or installed at a low cost, which usually leads to low unit capacity costs. However, depending on the future product demand, it may also be significantly beneficial to leave the second sourcing option open for highly strategic inputs with high unit capacity costs. In that situation, the entrant supplier should only be used to supply the demand exceeding the incumbent’s installed capacity. In addition, allowing the option of alternate sourcing, a means countering uncertainty on the supply market, is more valuable for the buyer when facing more uncertainty in the demand.

Our model develops optimal sourcing strategies over the long run. As supplier competition reduces the procurement cost, it may be tempting for managers to create a competitive supplier portfolio in the future, ignoring the effects this creates on the current contracts. A supplier facing more competition in the future will press for a higher price, increasing the buyer’s cost in the short term. Therefore, to balance long-term and short-term profits, a manager should be proactive in shaping the future competition of suppliers. Investing in more capacity improves the incumbent’s position in the competition, while committing to a single supplier further eliminates the competition faced by the incumbent. Therefore, when committing to a single supplier is not credible, high capacity investment, even overinvestment, can be used as a soft and imperfect substitute for commitment to shape the future supplier competition.

Our results may be linked to the cyclic pattern of relationship types over time as observed in the automotive industry (Dyer, 2000). For example, Chrysler transitioned from multisource competitive purchasing in the 1980s to a collaborative approach (long-term relationships) during the 1990s. However, after the Daimler merger in 2000, the organization reverted to a more competitive multisupplier sourcing network. Ford had taken a multisourcing position until they started to cut the number of suppliers and form long-term relationships with some suppliers for key components in the 2000s (Dyer, 2000). Our result can be related to this phenomenon by linking information asymmetry and learning to new technologies. When a new technology is employed, there is usually great potential for the supplier to reduce costs, whose value is hard to estimate for the buyer. In this situation, sole sourcing may be selected by the buyer in order to capture high future rent. But after the technology becomes mature, the potential of supplier learning or the advantage of know-how is limited. In this case, the buyer may want to switch to second sourcing in order to take advantage of supplier competition and alternative sourcing opportunities. Therefore, over a horizon with repeated technology innovation, the buyer may alternate between sole and second sourcing, exhibiting a cyclic pattern.

In the end, we discuss the impact of several modeling assumptions. We assume the buyer is
the Stackelberg leader in the contracting mechanism by offering the suppliers menus of contracts, and a supplier will accept a contract if it generates him a profit no less than zero. This assumption is appropriate when the buyer leads the supply chain—for example, due to a technology or scale advantage over the suppliers—and hence has more bargaining power over the supplier. The situation where a supplier has more bargaining power and demands more profit (e.g., due to outside options) could be modeled with a positive reserve profit of a supplier in each period. This change would reduce the buyer’s profits while raising the supplier’s in both strategies, without altering the qualitative nature of the results.

We have ignored the time discount factor in the model. A discount factor would decrease the relative contribution of the future profit to the total expected profit for both the buyer and supplier, and, hence, lower the profit difference between sole sourcing and second sourcing. However, since a discount factor would not change the second-period mechanism in either relationship, the selection between the sole sourcing and second sourcing would remain the same.

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